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ORIGINAL ARTICLE

Farmers' perspectives on water availability in the lower Volta Delta region in Ghana

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Abstract

Smallholder farmers in the lower Volta Delta of Ghana operate in a risky and uncertain context due to water scarcity. However, the conventional analyses of water availability have mainly focused on drought, rainfall occurrence, and other climatic or weather elements, using secondary biophysical data with relatively little emphasis on farmers' perceptions and how socioeconomic factors contribute to the vulnerability of farming in the lower Volta Delta. This study examines farmers' perceptions of vulnerability to water availability to determine how perception is socially constructed and differentiated in various locations. The study was conducted using qualitative research methods in the Ada East, Ada West, South Tongu, and Anloga Districts in the lower Volta Delta of Ghana. Findings reveal that climate is not the only stressor on livelihoods in the area. Farmers perceive their livelihoods as vulnerable to socioeconomic stressors, including limited freshwater and groundwater resources. The perceived severity of water availability conditions determines farmers' response strategies, such as crop selection, planting dates, irrigation strategies, and other agronomic practices. These findings have important implications for researchers, agricultural extension agents, and policymakers to design appropriate measures and approaches to deal with water scarcity for farming in the region. The study also contributes valuable insights into the loss and damage incurred by farmers due to climate change and variability in the region.

Keywords Volta Delta · Farming · Water availability · Perception · Vulnerability · Decision response

Introduction

Food crop production is currently constrained by water scarcity, which can be attributed to climate change, variability in weather patterns, increased human demand, and overuse of water (Zougmoré et al. 2018). This is particularly relevant in West Africa, including Ghana, where evidence that water availability challenges food crop production is growing (Serdeczny et al. 2017; Nyadzi et al. 2018). Water scarcity is experienced in sensitive ecological zones such as the savanna regions, including the Volta Delta (Atta et al. 2015; Arto et al. 2019a, b). Over the years, the Volta Delta of Ghana, a predominantly agricultural area, has witnessed increased population growth and urbanisation coupled with agricultural expansion (Appeaning Addo 2015; Mul et al. 2015). The confluence of these factors places significant pressure on the existing water resources (Roest 2018) and heightens the susceptibility of farmers. This heightened vulnerability is primarily due to their heavy reliance on rainfall for food crop production (Antwi-Agyei et al. 2012; Iizumi and Ramankutty 2015; Abdul-Rahaman and Owusu-Sekyere 2017).

Farming in the lower Volta Delta basin has been documented as vulnerable to water scarcity (Ofori-Sarpong and Annor 2001; Teye and Owusu 2015; Amisigo et al. 2015; Gbangou et al. 2020a) due to several reasons, including dependence of farming on rainfall (Cazcarro et al. 2018; Addo et al. 2018), limited or no irrigation schemes (Sarku et al. 2020), and limited capacity or technology to cope

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with water scarcity (Adjei et al. 2018). Farmers' exposure to water scarcity affects household vulnerability, and their perceptions of water availability stressors potentially affect decision-making on how to respond to the situation. The response strategies adopted to deal with a particular stressor are defined by how people perceive vulnerability (Antwi-Agyei et al. 2013; Kumasi et al. 2019).

Water availability is influenced not only by the quantity and quality of water but also by various other factors, such as infrastructure, institutional, and socioeconomic conditions, which directly impact its demand and utilisation (Keshavarz and Karami 2014; Singh et al. 2016). Most studies conducted in the Volta Delta basin have primarily focused on climatic conditions, such as rainfall and temperature (see, for instance, Manzanas et al. 2014; Amekudzi et al. 2015; Baidu et al. 2017; Atiah et al. 2019; Gbangou et al. 2020a). Studies have applied secondary climatic data, primarily focusing on rainfall and temperature with limited analysis of the perceptions of farmers whose livelihoods are exposed to various water conditions (e.g. Amisigo et al. 2015; Amekudzi et al. 2015; Teye and Owusu 2015; Nyadzi et al. 2019; Gbangou et al. 2019, 2020a; Bessah et al. 2021). Additionally, studies have compared observed climatic trends and peoples' perceptions of climate variability in Ghana (see for instance Yaro 2013; Antwi-Agyei et al. 2017; Nyadzi et al. 2019). While the results from previous studies are informative for policy and practice, there exists a gap in knowledge regarding the construction of farmers' perceptions of water availability. There has been relatively little emphasis on how socioeconomic and cultural practices and memories influence people's construction of water availability phenomena in the lower Volta Delta.

This study aims to fill this knowledge gap by examining farmers' perceptions of the water availability situation in the lower Volta Delta and how these perceptions are socially constructed and differentiated in different locations. The study is guided by the following specific questions:

- What are the perceptions of farmers in the lower Volta Delta with regard to the stressors affecting their livelihoods?
- What are farmers' perceptions of the role of water availability in food crop production?

Literature review and conceptual framework

This section reviews the literature on vulnerability and risk perception to develop a holistic framework of farmers' vulnerability to water availability in the lower Volta Delta.

Vulnerability

Vulnerability is defined in various ways from disciplinary perspectives. In this paper, vulnerability refers to a food crop farming system's exposure to a *stressor*, such as drought conditions, and the system's sensitivity and adaptive capacity. *Vulnerability* encompasses several ideas, including sensitivity or susceptibility to harm and a lack of capacity to cope and adapt to exposure from a stressor (IPCC 2022). *Exposure* refers to a stressor's duration, frequency, and intensity, such as the late onset of rainfall or market forces acting upon a system, like food crop farming. It is conceptualised as an attribute of the relationship between the system and the perturbation rather than the system itself (Spence et al. 2011; Antwi-Agyei et al. 2017). Various natural and human stressors may act upon a crop farming system at any given time and contribute to its vulnerability (Ruiz-Agudelo et al. 2015; Laureta et al. 2021). Over time, biophysical stressors may change, such as an increase in global temperature due to greenhouse gas emissions, altering the vulnerability of a food crop farming system (IPCC 2022).

On the other hand, a system's *sensitivity* to *stressors* depends on how it can absorb impacts without suffering long-term harm or other significant states of change (Parker et al. 2019). The *exposure* and *sensitivity* are determined by the interactions between natural and human factors (Parker et al. 2019). They do not only change temporarily but also according to the type of hazard and the extent of the impact. Additionally, vulnerability is not simply a function of risks and shocks but also a result of a pre-existing socio-institutional context (Davies et al. 2013) and economic inequality (Osbahr et al. 2010; Mearns and Norton 2010; Miller et al. 2010).

Regardless of the nature of the external *stressor* or the *sensitivity* of the crop farming system, the ability to anticipate, cope with, resist, and recover from the impact of natural and human conditions defines the state of *vulnerability* for an individual or group (Bennett et al. 2016). This concept is included in the earlier definition to highlight the importance of capacity in vulnerable individuals. Therefore, *vulnerability* and *capacity* to respond (preventive, adaptive, and coping strategies) are contrary ideas (Hinkel 2011; Ruiz-Agudelo et al. 2015). Furthermore, vulnerability is socially differentiated, meaning it changes or is perceived differently by people over time (Thomas et al. 2019).

Defining perceptions

Perception is the judgments, beliefs, and attitudes that individuals form based on their experiences and cognitive processing of their environment (Shi-yan et al. 2018). *Experience*, *memory*, and *definition* shape perception (Dang et al. 2014). Personal value judgments, cultural beliefs (Tan et al. 2023), norms, and values (Martínez-García et al. 2013) contribute to the formation of *perception.*

In a food crop farming system context, *experience* can be defined as events, such as rainfall amounts, that occur during a farming season (Singh 2014). These events can be experienced directly or indirectly through historical accounts and differ among individuals based on their recollections (Osbahr et al. 2011).

Regarding *memory*, farmers may recall water availability events, such as droughts, as a part of their direct *experience* (Brown et al. 2017; Reyes et al. 2020). However, there is a tendency to exaggerate or forget certain events (e.g. drought) over time based on how a farmer is impacted, leading to varied definitions of experiences (Singh 2014).

Definition refers to social or natural criteria that people use to account for an event (Singh 2014). For instance, water shortage during farming can be used to classify a period as a 'drought season'. Memory and definition of rainfall amounts may overlap because what one remembers as rainfall amount is influenced by how one defines it.

Understanding *perceptions* of vulnerable people is crucial because individuals are motivated to respond when they perceive the need to do so (Singh et al. 2016). When farmers do not perceive any issue, they may not respond to an external stressor. In contrast, exaggerated *perceptions* of the risk of external stressors can lead to adopting maladaptation strategies. Thus, comprehending farmer perceptions and the factors shaping them is vital in developing adaptive decision strategies.

Study methods

Study context

The lower Volta Delta is a dynamic ecological region that offers multiple socioeconomic and environmental opportunities (Nicholls et al. 2020). Food crop farming is the primary economic activity, supplying neighbouring urban markets with foodstuffs such as maize, cassava, rice, and vegetables (Adjei et al. 2018). Other economic activities include fishing, tourism, artisanal and craftwork, and salt mining, with some individuals employed in the service sector. The region is flat and undulating, with an annual average rainfall of approximately 750–800mm. The delta is in the dry equatorial climatic zone with bimodal rainfall seasons.

I selected four districts—Ada East, Ada West, South Tongu, and Anloga (as shown in Fig. 1)—due to similarities in agroecological and climatic conditions in the area. The agricultural practices in these districts demonstrate the interface between vulnerable populations and various factors. The lower Volta Delta offers several socio-ecological

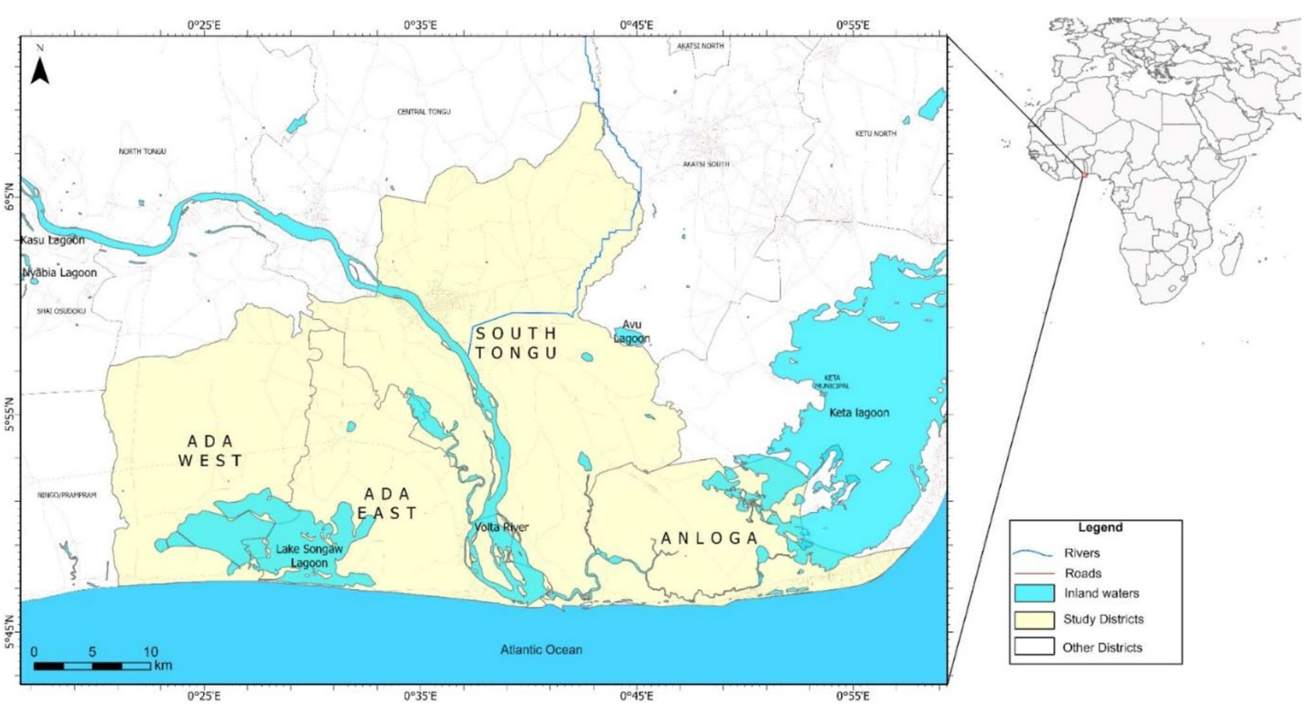

Fig. 1 Map showing study districts in the lower Volta Delta

and economic benefits (Appeaning Addo 2015). However, the area experiences changes in climatic and weather conditions (Gbangou et al. 2019, 2020a), coastal erosion, depletion of fresh water (Roest 2018), and groundwater resources. Furthermore, the construction of dams upstream of the Volta River has influenced water flow and distributary patterns that end in the sea at Ada Foah (Mul et al. 2015; Anthony et al. 2016). Fig. 1 provides an overview of the situation in the lower Volta Delta, where other water bodies, such as Songhor and Keta Lagoon, are saline and unsuitable for farming.

Meanwhile, studies have indicated that Ghana's lower Volta Delta receives the least rainfall (Ofori-Sarpong and Annor 2001; Owusu et al. 2008; Teye and Owusu 2015). Additionally, the selected districts cultivate vegetables for the urban market (Ayivor 2014; Addo et al. 2018; Adjei et al. 2018; Gbangou et al. 2020b). The significance of the study focuses on the vulnerability of farming within the framework of water availability conditions. The selected study districts are well suited for tackling the challenges that hinder the sustainable production of food.

Data collection procedure

I adopted a comparative case study approach (Bartlett and Vavrus 2017) to analyse and synthesise similarities, differences, and patterns of vulnerability in food crop farming and farmers' perceptions about water availability in the four study districts.

I conducted a reconnaissance study to identify agricultural extension agents in the operational areas of the districts. Initial conversations with the agricultural extension agents led to community visits and interactions with lead farmers to discuss farming practices, water availability conditions, and other socioeconomic factors affecting farming in the area. Subsequently, I selected certain communities within the districts to conduct the study based on information generated from agricultural extension agents and lead farmers. Additionally, I leveraged the knowledge acquired from previous research experiences I have undertaken in the area to select the study districts. My knowledge of the communities enabled me to conduct follow-up interviews to enhance the database of information generated for the study. The fieldwork took place over 4 months, from June to December 2021, and I employed various qualitative data collection methods, which are described below.

Semi-structured interviews

The unit of analysis for this study was a farming household. However, households are often divided along the lines of power, resource access, and gender and generational responsibilities. Therefore, I selected either a male or female household head or requested a younger member from a household unit (see Appendix 1). I conducted at least two interviews in each community. Overall, I conducted 35 semi-structured interviews in the Ada East District, specifically in Angorsekope, Kasseh-Kpodokope, Ada Foah, Kajanya, Toje, and Manaikpo. Similarly, in the Ada West District, I conducted 33 semi-structured interviews with farmers from Addokope, Korledor, Lihour-Salom, Matsekope-Toflokpo, Sege, and Fantivikope. In the South Tongu District, I conducted 25 semi-structured interviews in the Sogakope, Dordoekope, Dzitorkoe, Hikpo, and the Dabala-Agave areas. Furthermore, in the Anloga District, I conducted 25 semi-structured interviews with individuals from Agorve-Atsugbor, Torgorme, Veme, Dornogbor, and Xekpa.

The number of interviews conducted in each district was based on consideration of the following factors: availability and willingness of participants, duration of stay in the community, age, gender, education, years of farming experience, and type of farming practices. The interviews were conducted in the homes of interviewees, community centres, or farm fields using a semi-structured interview guide that included questions about demographic characteristics, stressors related to water availability, and perceptions of changes in water availability, among other issues. The semi-structured interviews were conducted in each community until no new information was identified. It is worth noting that in identifying potential interviewees for the study, some farmers preferred to abstain from participating in the research because they were of the view that they faced the same water availability situation described by initial interviewees in the community. Therefore, if one person (such as 'A') responds to the interview, it was considered applicable to other household members in a selected community. This experience was more common in small villages where initial interviewees were selected.

Focus group discussion

Two focus group discussions (FGDs) were conducted in each district, consisting of a mixed group of elderly men and women, and young men and women (see Appendix 2). During the discussions, some responses were ranked and scored; at times, a vote was cast to conclude diverging opinions on certain responses. This exercise pertained to questions on whether the *amount of rainfall* and the *length of rainfall* were increasing or decreasing during the main season, the start of the *main rainfall season*, and dates for the cessation of the farming season. Other issues that were ranked include *farmers' perceptions of stressors affecting livelihoods* and *perceptions of water availability in the districts*. The FGDs were conducted in the Angorsekope and Ada Foah communities in the Ada East District, Salom, and Lihour communities in the Ada West District, Dordoekope and Hikpo communities in the South Tongu District, and Xekpa and

Cape Coast road communities in the Anloga District. Focus group participants were drawn from various communities in the selected districts to generate in-depth information and corroborate preliminary findings from the semi-structured interviews.

Observation

I also visited some farms to gather first-hand information about the vulnerability of food crop farming. The field visits enabled me to connect social issues, policy, institutional, and market factors to the natural stressors contributing to the vulnerability of farming systems across the four districts, while taking records of water availability conditions and cultural practices. In the Ada Districts, I observed the use of groundwater and farmers' decision-making regarding saltwater intrusion due to over-withdrawal, especially during dry spells (drought conditions). However, there was no groundwater monitoring information system to test farmers' hypotheses in the study districts. Another observation was about the practice of carrying water to the farm and the depth of the wells. For instance, in the South Tongu District (Hikpo), I observed flooding of farms. On the other hand, in the Anloga District, I observed the depth of the wells during drought conditions and the sandy nature of the soil which reinforces constant irrigation during intense insolation. I took notes in a field notebook, and relevant pictures were taken to support the observations.

Meteorological data sources and analysis

Following field data collection, I gathered reports on daily historical observed rainfall data for two synoptic stations—Ada and Akatsi—from the Ghana Meteorological Agency (GMET) between 1981 and 2011. These weather stations are located in the coastal savanna region. The communities where the study was conducted lie within a 30-km range from the weather stations. These areas were selected for the analyses of rainfall and temperature data. The Akatsi station covers the Anloga District and some communities in the South Tongu District. While the Ada station also covers the Ada East and West, including parts of the South Tongu District. The datasets for the two stations were analysed separately. Since temperature does not vary significantly over small distances and is more a function of topography (Singh, 2014), I chose district-level average temperature for the analysis. I analysed district-level monthly data from the Ada and Akatsi stations separately. High temperatures can affect crop productivity, especially when such extremes coincide with critical crop-growing periods. Therefore, I considered averages of maximum and minimum temperature.

Due to missing precipitation data between 2013 and 2020, historical data was obtained from visual crossing weather to complement existing data. Rainfall data from the two weather stations, Ada and Akatsi, show differences in high variability in some years. I extracted the data pertinent to this study in Microsoft Excel and arranged the daily rainfall data for each station year-wise to create a graph depicting rainfall and temperature conditions in the study districts. The data obtained from the aforementioned sources for the two weather stations were processed using the Python programming language.

Data analysis

Initially, I transcribed audio recordings from the semi-structured interviews and FGDs into English. I synthesised information from the transcripts and field notes by reading, extracting, and integrating essential information. Subsequently, I analysed the field notes and transcripts to derive knowledge on initial themes and reviewed relevant literature to develop codes. With the aid of Atlas.ti software, I coded each transcript to generate sub-themes and codes and connected them to the broad themes of vulnerability and perception.

Results

Farmers' perceptions of stressors affecting livelihoods

Findings indicate that farmers were vulnerable to various socioeconomic stressors, such as 'decreased crop production', 'food insecurity', 'high input costs', and 'unavailability of labour', among other related stressors. Farmers ranked the aforementioned socio-economic stressors high in the 4 districts (see appendix 3). For example, farmers in the South Tongu District reported their inability to repay loans due to low crop yields and limited income from seasonal farming. Meanwhile, farmers in the Ada West District mentioned experiences of food insecurity during the dry season (November–April).

In the study districts, the application of fertilisers has become a necessity due to poor soil conditions resulting from overcropping. The rising costs of fertilisers and pesticides and poor seed quality were also perceived as stressors contributing to farmers' vulnerability. Additionally, farmers faced difficulties arranging money to purchase farm inputs like fertilisers and seeds. This situation is particularly common among 'poor' farmers who cannot afford the high cost of farm inputs. As a result, they often apply less fertilisers to their crops. Furthermore, farmers were forced to take loans from aggregators who later dictate the buying price of farm produce. The location of several farming communities and farmlands with limited access to transportation networks was also perceived as a stressor that reinforced farmers' vulnerability. This affected access to the market, ability to hire tractors and threshers, and access to agricultural extension services. In the study districts, the absence of proper roads led to high charges for tractors, labour, and hired vehicles, thereby inflating the total cost of production. Other conditions that contributed to farmers' vulnerability include a lack of storage facilities and irregular electricity supply. Irrigation farmers in the Ada East, South Tongu, and Anloga Districts also mentioned the high cost of electricity as a socioeconomic stressor.

In the four study districts, interviewees identified water scarcity and changing climatic conditions as the main environmental stressors that affect farming activities and limit food crop production. Water availability stressors mentioned by interviewees in the study districts include the amount of rainfall, level of water in wells and water bodies, and soil moisture availability. They also cited low soil water retention, soil nutrient loss due to over-cultivation, and soil erosion as stressors. However, interviewees' perceptions of their vulnerability to these stressors varied. In the South Tongu District, for example, farmers in rainfed communities ranked water scarcity as their primary concern. In contrast, those in the Hikpo community in the same district perceived that their croplands were exposed to too much water due to river overflow. Farmers located near the distributary of the lower Volta River in the same district mentioned limited water availability for farming. Meanwhile, in the Anloga District, farmers ranked water availability third due to the presence of groundwater in the area.

Farmers noted that soil types such as clayey soil lose water quickly after intense sunshine and exacerbate soil moisture availability for farming. In coastal areas in the Ada and Anloga Districts, sandy soil requires constant irrigation. Farmers also mentioned that certain crop varieties, such as tomato, watermelon, cucumber, and cassava, are sensitive to either 'too much' or 'too little water', and they struggle to find seed varieties that can withstand alternating environmental conditions.

Interviewees also shared stories about the emergence or persistence of various pests such as the fall armyworm, variegated grasshopper, white flies, stem borer, termites, and leaf beetles. Interviewees also mentioned disease conditions like late blight, tomato spotted wilt virus, fusarium wilt, leaf spot, and leaf curl, which were attributed to specific weather conditions. The incidences of pests and diseases were linked to stressors, such as the high cost of agrochemicals, poor seed quality, and limited access to agricultural extension services, which made farming systems vulnerable.

Farmers' perception of water availability for farming

Results on farmers' perception of water availability stressors affecting farming in the study districts indicate three primary conditions: (1) climatic and weather conditions, (2) groundwater situation, and (3) freshwater availability. Each stressor contributes to the sensitivity and vulnerability of farming and is analysed further in the following subsections.

Farmers' perception of climatic and weather conditions as stressors affecting food crop farming

Findings show that the *length of rainfall* is an exposure contributing to the intensity of water availability conditions in the study districts (see appendix 4). The rainfall duration affects water availability during the main farming season (referring to April–July), and it is perceived to have become shorter compared to 10–20 years ago. For instance, in the Ada West District, interviews revealed that farmers noticed a decrease in the number of rainy days. Farmers in the Ada East District reported that the length of the rainy season has been shorter or more variable over the past 5 years. This has increased the vulnerability of crops to water scarcity, especially in coastal and upland areas with limited soil moisture holding capacity. This situation exposes certain crops, such as maize and tomatoes, to adverse weather conditions, as rainfall usually stops suddenly during tasseling or flowering.

Farmers in the Ada East and West Districts have observed a reduction in the *amount of rainfall* during the main season (see appendix 5). Interviewees mentioned that rainfall is unpredictable in the South Tongu and Anloga Districts, with heavy rain for a few days in May and then it decreases in June and July. The variability in rainfall is a stressor for crops such as maize, tomato, and watermelon, which require consistent rain throughout the season.

Farmers perceived the *onset of the main rainfall season*, which occurs between March and April, as a significant stressor that contributes to the exposure and sensitivity of crop farming (see appendix 6). For some farmers, the onset of the rainy season depends on consistently receiving a substantial amount of rainfall for several days in March or April, which enables them to plough and sow. In the Ada East District, farmers mentioned that the water scarcity situation in the region has resulted in the need to consider any rainfall in a new year as the onset of the rainy season, as they use the initial rains to start ploughing and sowing watermelon seeds. According to interviewees from the Ada East District, the primary rainfall season, which used to commence in April or May over the past two decades, now starts earlier in January. While some farmers in the Ada West District instead mentioned a late onset in recent years (see appendix 6). However, some interviewees in the Anloga District and the coastal communities in the Ada East District perceived that the onset of rainfall is variable. At the same time, in the Ada West District, more responses indicate a later start of the onset of the farming season. Interviewees of the 30–40 age group in the four districts mentioned March or April as the months for the onset of rainfall in the past. The differences in interviewees' accounts can be attributed to the availability of freshwater or groundwater for irrigation in some districts. Additionally, age influenced memory, as farmers (30 years and above) narrated their experiences concerning onset dates, while younger people recounted those memories as if they owned them. However, they heard it from elderly people in the communities.

All the interviewees responded that the main rainy season now *ceases* earlier or is unpredictable compared to the past (see appendix 7). Interviewees described the current situation as an 'abrupt end', 'ending early', or 'ending early and abruptly'. During FGDs in the Anloga District, farmers noted that the cessation of the rainy season occurs by the end of June for the past 5 years. Interviewees who were 50 years and above in all the districts mentioned that the cessation of rainfall is unpredictable nowadays. Conversely, interviewees within the age group 40–49 years perceived that the main rainfall season ceased in July in the past. Additionally, farmers interviewed within the age group of 18–29 years mentioned July based on stories told by members of the farming community about past conditions.

Most interviewees indicated that the *minor rainfall season* traditionally starts in September and has remained unchanged. Farmers within the age group 40 years and above observed that August typically experiences limited rainfall, making it a dry month. This coincides with the onset of the minor season, which commences with occasional rain showers.

Farmers in the Ada East and West Districts have reported a trend of limited rainfall during minor seasons for the past decade until 2016. However, from 2017 to 2021, the situation changed as the rainfall started in August and continued until the end of the year. This phenomenon is supposed to be beneficial for farming; however, it has made crop farming in the study area more sensitive to different conditions, such as waterlogging or the emergence of pests and diseases, due to excessive rainfall. All farmers noted this trend, with one male watermelon farmer stating that 'it seems there is a switch between the seasons'. In the past, the minor season was perceived to end early, around October or November. However, farmers mentioned that in recent years (2017–2021), the minor season rains continue into the 'New Year'. Farmers in the district have to adapt their farming practices to account for these changes in weather patterns.

Interviewees provided a range of definitions for drought. Many farmers defined drought based on criteria, such as the number of days without rainfall. For example, a farmer in Ada West District stated that 'drought occurs when there is no rainfall for more than 21 days during the main season'. Other definitions mentioned include a month or more without rainfall, depleted soil moisture, and withering of crops. The perception of farmers regarding drought conditions indicates that crops were more exposed to water scarcity conditions in between farming seasons. Interviews conducted in communities in the Ada West District revealed that droughts have become more prolonged in between the main farming season, lasting for a month or more. Farmers in Anloga District perceived that drought conditions were not pronounced since they have a constant groundwater supply for irrigation. However, farmers aged 40 years and above acknowledged the occurrence of drought; yet, they perceived recent conditions as less severe due to their vivid memories of the acute situations experienced during the 1983 drought, which holds a significant place in the history of Ghana. Responses generated from farmers indicate that individuals anticipate encountering stressors of a specific magnitude and frequency before perceiving them as potential threats to their livelihoods. Regardless of the frequency and intensity of occurrence, drought conditions contribute to the sensitivity of crops to various conditions, like the occurrence of pests and diseases. Farmers' perceptions suggest that there have been fewer flood conditions in recent years compared to the past, except for the Hikpo community in the South Tongu District, where floods occurred due to river overflow during the rainy season.

Analysis of climate data from the Ada and Akatsi weather stations

The rainfall trend in the lower Volta delta The annual rainfall trend was examined by analysing the annual totals from 1980 to 2021 for the Ada and Akatsi weather stations, as shown in Fig. 2. The figure illustrates the observations of rainfall from the Ada weather station, which indicates an overall increase in rainfall over the years. However, the rainfall amounts exhibit fluctuations over time, with no apparent upward or downward trend. This result confirms some farmers' perceptions that rainfall amount and length have been variable. The years 1980, 1983, 1984, 1986, 1987, 2003, and 2018 recorded the lowest annual rainfall, with values ranging from 300 to 680 mm. Notably, the increase in rainfall amount in 2010–2021 coincides with farmer reports of 'very heavy rains'.

The annual rainfall data obtained from the Akatsi station also revealed significant variability in rainfall (see Fig. 2). The data analysed covers 36 years and provides insights into the rainfall patterns in the two districts (Anloga and South Tongu Districts). Upon analysing Fig. 2, it is evident that there is a substantial variation in the annual (mm) values from year to year. However, there is an overall increasing trend in the values over time, with some fluctuations and

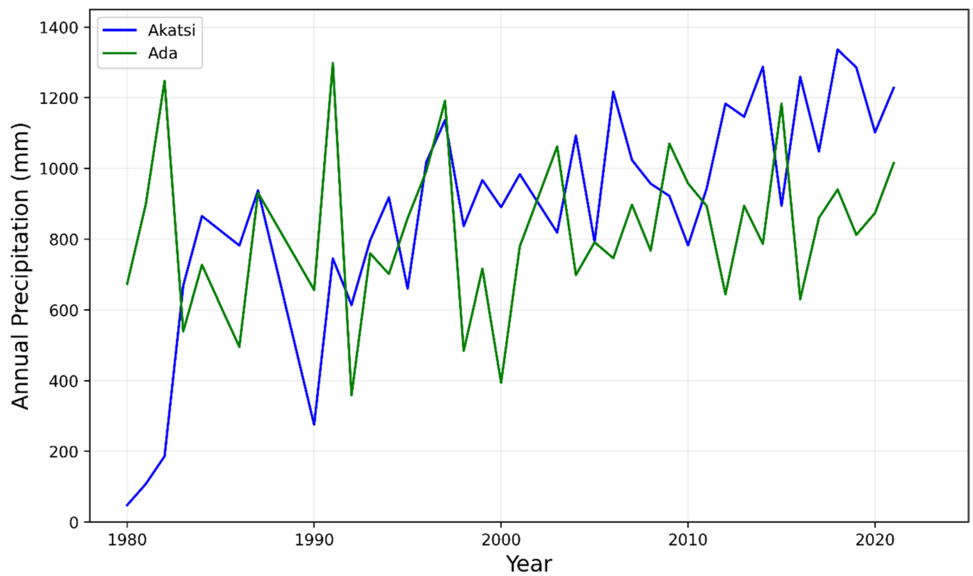

Fig. 2 Rainfall records for the Ada East, West, South Tongu, and Anloga Districts from 1980 to 2021 based on data from Ghana Meteorological Agency and Visual Crossing Weather

notable records of rainfall in the middle years (i.e. 1990, 1995, 1998, 2002, 2003, 2010, 2015, and 2019). The highest value was recorded in 1984, with a sharp increase from the previous year, while the lowest value occurred in 1991. Additionally, there were significant rainfall records in 1993 and 2006.

The average annual rainfall for the districts was 875.31 mm, with the minimum annual rainfall recorded being 47.8mm and the maximum being 1336.5 mm. The annual rainfall for each decade shows a continuously increasing trend as follows: 1980 (369.14 mm), 1990 (867.03 mm), 2000 (988.45 mm), 2010 (1142.67 mm), and 2020 (1303.45 mm). It can be observed that the rainfall has consistently increased over time, with the highest average rainfall occurring in the most recent decade (2010–2021) and the least recorded amount was in the 1980s.

Overall, Fig. 2 indicates a significant variation in annual (mm) values over time, suggesting that farmers in the Anloga and South Tongu Districts experience a highly variable rainfall pattern. These results confirm farmers' perception of the districts' total rainfall and rainfall pattern over the past three decades.

The annual rainfall totals in the entire dataset exhibited significant variability from the mean in different years. Ada exhibited a higher degree of inter-annual variability in rainfall amount, as indicated by a higher coefficient of variation in the mean rainfall data. The higher values may be attributed to abnormally high rainfall of 1380 mm and 1200 mm in 1990 and 2021, respectively. A similar trend was observed in the Akatsi data, where mean rainfall was also variable. However, the annual average rainfall from 1990 was above 600 mm and mostly fluctuated between 700 and 1000 mm, indicating an increase in rainfall amount over the years, especially in the last decades. This increase in rainfall in the two weather stations correlates with farmers' reports of increasing rainfall amount in recent years.

The temperature trend in the lower Volta Delta Interviewees noted changes in temperature conditions over the years. A farmer in the Ada West District mentioned that rainfall plays a critical role in regulating temperature, and its irregular occurrence has made crops more sensitive to increased insolation. Farmers in the Ada East District reported experiencing low temperatures between June and August, accompanied by overcast clouds. They were of the opinion that low-temperature conditions have made crops more sensitive, especially during the flowering and fruit formation stages. The responses from interviews and focus group discussions (FGDs) conducted in the four study districts corroborated findings indicating an increase in temperatures. Farmers mentioned 'intense insolation', 'heat in the air' (referring to warm air), and 'rapid evaporation of soil moisture after rainfall' as indicators.

To identify general trends in temperature, I plotted annual averages (Fig. 3). A simple linear trend line revealed a weak upward trend. Temperature affects crop yields positively or negatively, indirectly influencing the evaporation rate. Temperature variations can be observed during the analysed period (1980–2021). Fig. 3 shows that the maximum temperature at the Ada and Akatsi stations reached high records above 30 °C, with the highest annual maximum temperature of 34 °C in 2010.

High temperatures can affect crop productivity, while low maximum temperatures can also affect certain crops. Farmers report that temperature changes can impact crops differently depending on their growth stage, such as whether they are in the nursery or have reached the flowering or fruit formation stage. In general, the minimum annual temperature

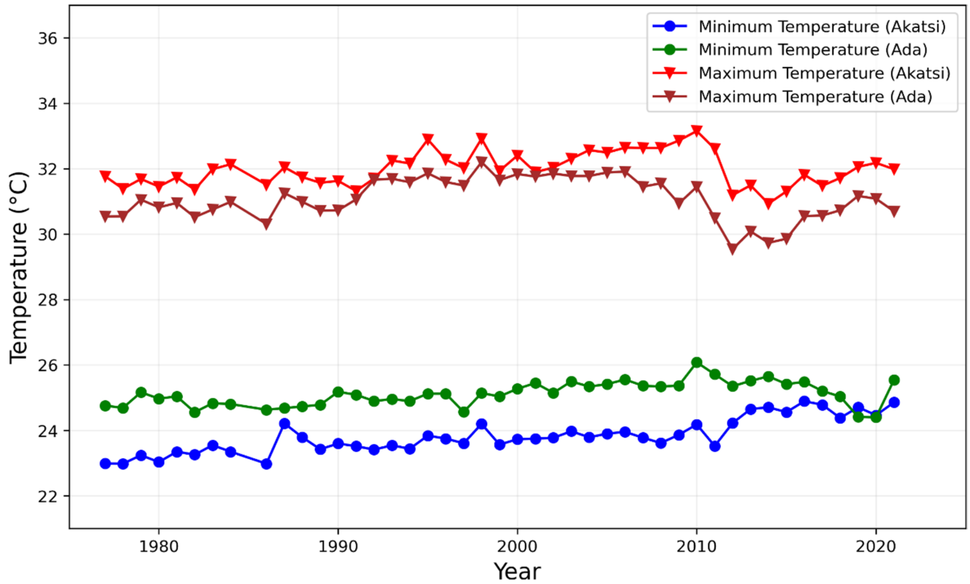

Fig. 3 Temperature records for the Ada East, West, South Tongu, and Anloga Districts from 1980 to 2021 based on data from Ghana Meteorological Agency and Visual Crossing Weather

has remained above 29 °C. However, farmer reports of 'higher temperatures' align with a discernible upward trend in annual maximum temperature. The increasing trend suggests that extreme temperatures may become more frequent.

Farmers' perception of the availability of groundwater for irrigation

In the inland section of Ada East and West Districts, groundwater is not easily accessible for farming, and wells tend to dry up due to over-withdrawal, particularly during the dry season. These conditions were significant stressors that affect water availability in the study districts.

In contrast to upland areas, coastal farming communities in the Ada East District have access to groundwater for year-round irrigation due to geological conditions. Based on field observations, each plot of land has a tubewell that runs on electricity. In wetland areas of the Anloga District, the high water table allows for easy withdrawal with a bucket to irrigate crops. However, tubewell irrigation techniques were employed in upland areas of the district.

Farmers in the coastal communities of Ada East and Anloga Districts have emphasised that groundwater plays a crucial role in reducing crop exposure to drought conditions and insolation during the day. This is particularly important in these areas as the sandy nature of the soil does not retain moisture. In the aforementioned areas, the availability of land is another stressor for farmers as most sharecrop on one to four plots of land. Hence, vegetables were intensively produced with groundwater. Farmers in the Anloga District have reported less water in the wells due to the rapid depletion of the water table.

In Ada East and Anloga District's coastal communities, crops were irrigated in the early morning and late afternoon. Sometimes, sprinklers were left running at night or during the day, depending on the evaporation rate, soil conditions, and crop maturity stage. In areas where groundwater irrigation was practised, farmers reported saltwater intrusion into the freshwater table and an erratic supply of electricity for irrigation as stressors contributing to water availability conditions. These issues become particularly pronounced during the dry season (November–March) and in between the main farming season, highlighting the excessive pressure on groundwater resources. These phenomena compound the sensitivity of crops to varied weather conditions. I observed that farmers' water requirements have increased due to the intensive cultivation of specific vegetables such as carrots, tomatoes, onions, chilli pepper, and other vegetables for the urban market. However, changes in cropping patterns and the intensive cultivation of crops with groundwater were rarely considered by farmers as factors contributing to the exposure and sensitivity of farming systems to water conditions.

Farmers' perception of riverine irrigation and availability of water for farming

Access to freshwater resources, such as streams and ponds, was crucial for farming in some areas in the study districts. In the Ada East and South Tongu Districts, communities located near the distributaries of the lower Volta River rely on irrigation farming. Two irrigation dams were present in the Angorsekope area in the Ada East District and the Dordoekope-Dzitorkoe area in the South Tongu District. Farmers in these areas use PVC pipelines to draw water from canals and irrigate their farmlands. The areas were mainly inhabited by wealthy farmers who cultivate larger tracts of land. During rainfall seasons, the water in the reservoir is sometimes rationed through unwritten norms shared in farming communities.

Despite the availability of water in the Angorsekope area (Ada East District) and the Dordoekope-Dzitorkoe area (South Tongu District), farmers under the riverine irrigation scheme also held the perception that their crops were vulnerable to water availability conditions. According to them, delivering water to farmlands through PVC pipelines and pumping machines requires fuel, which comes at a high cost. Farmers who do not own these resources borrow irrigation materials from other farmers and wait for their turn, exposing their crops to the weather, especially during droughts. Additionally, the location of farmlands in upland areas has repercussions on water withdrawal and contributes to the definition of water scarcity. Farmlands distant from water canals require several PVC pipelines to enable irrigation. 'Water doesn't reach our fields easily. We attach pipes, but they often break and waste a lot of water, so we have to borrow pipelines from other people to irrigate'.

The Hikpo community in the South Tongu District is prone to flooding due to the low-lying location of farmlands and the overflow of the river from upstream. Flooding occurred from January to March despite the absence of rainfall. This event is an example of an easily recalled recent experience. The area's recurrent flooding has constrained farmers to cultivate specific crops, such as okra, making it difficult to diversify their production to other crops.

Discussion

This study aimed to analyse farmers' perception of water availability in the lower Volta Delta and determine how perception is socially constructed and differentiated in various locations. The study's significance lies in demonstrating that food crop farming in the coastal savanna agroecological region is affected by climate and other external stressors, thereby providing knowledge on the loss and damage incurred in the area. Farmers' decision-making regarding different strategies is influenced by their perceived severity of water availability conditions. In this section, I highlight and discuss key themes that emerged from the findings of the study.

The findings indicate that farmers use various factors to define their vulnerability to water availability. The definitions pertain to (1) climatic and weather conditions, (2) groundwater situation, and (3) freshwater availability. Concerning findings on climatic and weather conditions, previous research has also highlighted similar results on rainfall and temperature conditions. For example, Gbangou et al. (2020a) observed that the rainy seasons in various regions in southern Ghana started earlier during 1986–2010. Similarly, Teye and Owusu's (2015) study in Matsekope in the Ada West District revealed changing rainfall patterns. Amisigo et al. (2015) reported that climate change and variability continuously affect rainfed farming in the lower Volta Delta. Other studies have also identified increasing or decreasing trends in the onset date, drought, and duration of the rainy seasons (see, for instance, Manzanas et al. 2014; Amekudzi et al. 2015; Gbangou et al. 2019; Nyadzi et al. 2019; Bessah et al. 2021). These studies support farmers' perceptions of the weather component of water availability. Nevertheless, it is crucial to conduct investigations to measure and map groundwater conditions, the salinity of water bodies, and soil moisture in the delta to verify farmers' perceptions.

The findings indicate that socioeconomic and cultural factors influence farmers' vulnerability. The result is consistent with earlier studies on the risk and exposure of livelihoods in the delta (for example, Cazcarro et al. 2018; Adjei et al. 2018; Appeaning-Addo et al. 2018). The IPCC (2022) report shows that various socioeconomic issues interact with biophysical stressors, exacerbating farmers' vulnerability in the lower Volta Delta. According to Teye and Owusu's (2015) study, declining rainfall contributes to seasonal migration as an adaptation response of farmers. Additionally, with various indirect stressors contributing to farmers' vulnerability, it can be inferred that biophysical conditions are not the only factors shaping perceptions. Government policies, economic changes, and infrastructure improvements, such as subsidised seeds, fertilisers, and agrochemicals, may intensify agricultural production. This finding reinforces Osbahr et al.'s (2011) idea that farmers may attribute water scarcity to a rainfall indicator, while it may be caused by other factors, such as intensive crop cultivation, to meet market demands, as identified in the study. This finding is relevant for planning water provisions for farming by considering how socioeconomic and cultural issues are linked to water availability. The study also provides valuable contextual knowledge and accounts for the dimensions of loss and damage farmers incur to climate change and variability in the area.

The role of memory and definition in recounting personal experiences is relevant when studying water availability stressors. These perception factors can lead to exaggeration or downplay of specific stressors. The varied experiences, memory, and definition of water availability stressors serve as reference points for farmers to compare past events with the present, leading to differences in perceptions. Age, income, and crop type also contributed to differences in perceptions. Similar findings on farmers' perceptions have been noted in other studies. For instance, Antwi-Adjei et al.'s (2017) study found that several non-climatic stressors, such as lack of money, high input costs, gender, market access, and lack of agricultural equipment, exacerbated farmers' vulnerability. Teye et al. (2015) also noted that people perceived the falling of trees for firewood and indiscriminate bush burning contribute to changes in climatic patterns alongside biophysical indicators. These findings highlight the importance of considering perceptions and local knowledge in assessing the vulnerability of farmers' livelihoods. It also serves as a pointer in designing criteria that can capture non-economic dimensions of loss and damages to water availability conditions in the areas.

Furthermore, researchers need to separate perceptions of the incidence of water availability stressors from the actual root causes of the problem when identifying conditions for planning purposes. Findings on irrigation in coastal communities indicated saline intrusion into the water table. The occurrence of saltwater intrusion in the coastal communities of Ada East and Anloga Districts was also identified to be a potent contributor to the decreased production of vegetables like carrots, onions, bell pepper (referred to as green pepper by farmers), and tomatoes since soil biogeochemistry can be changed by the saline water (Tully et al. 2019). Although farmers perceived the phenomenon as a result of overall water withdrawal due to intensive vegetable cultivation, variability in climate change could also contribute to groundwater salinity (Wang et al. 2013). Undoubtedly, adaptability to climate change and variability in the study area is cumulative to farmers' vulnerability to freshwater availability. Specifically, irrational land use patterns, crop arrangement issues, and a lack of policies regulating well and tubewell construction may be contributory factors. The study results highlight the need for participatory, comprehensive, and inclusive agricultural land use development planning taking into consideration, water resource management, and land use arrangements. Although significant progress has been made in streamlining climate change assessments and adaptation into the agricultural sector in Ghana, this research finding emphasises the need to enhance the implementation of institutions, policies, market guidelines, and techniques for research and development to support farmers' adaptive decision-making.

The perception and vulnerability of farming households to climate change have been areas of research focus in Ghana over the years. Studies have attempted to establish the correlation between farmers' perceptions and actual climatic data. However, the question remains, do farmers accurately perceive the trends of local climate variability? The analysis of climatic data, particularly the amount of rainfall, variability conditions, and increased rainfall amount in recent years, compared to farmers' perceptions, indicates a match. Even so, there were differences in data regarding temperature conditions. While farmers reported experiencing high temperatures in recent years, climatic data from the Ada and Akatsi weather stations indicate a steady trend of maximum and minimum average temperature in the study area. Similarities and disparities between farmer perception and climatic data regarding some parameters have been identified in other studies (Fosu-Mensah et al. 2012; Yaro 2013; Codjoe et al. 2014; Teye and Owusu 2015; Muita et al. 2016). For example, an analysis of farmers' perceptions and meteorological data in Myanmar (Hein et al. 2019) indicates that experiences of rainfall amounts during the early, mid, and late monsoon periods were highly accurate but less accurate for temperature.

This study's finding concerning how farmers in the lower Volta Delta perceive water availability, specifically climatic change, suggests the need to provide locally specific weather information and agricultural extension services. The perceived similarities and differences between farmers' knowledge and experience and climatic data can also affect smallholder farmers' climate-smart adaptation practices. Stakeholders need to identify how farmers' perceptions vary and develop training strategies on crop variety selection, planting dates, and other agronomic practices to meet farmers' needs and socioeconomic backgrounds. This is because memories and experiences can play a role in farmers' decision-making, which may result in maladaptation or negative coping strategies, eventually leading to food insecurity. For instance, selecting early maturing crops as a response strategy can be negatively affected by prolonged drought conditions and lead to crop failure. It can be capital intensive regarding the cost of seeds and fertilisers (Kihupi et al. 2015). Adopting intensification practices, especially artificial fertilisers, can contribute to greenhouse gas emissions and undermine sustainable development initiatives in the smallholder farming sector (Antwi-Adjei et al. 2018).

The results suggest geographical patterns of the vulnerability of food crop farming to water availability conditions in the lower Volta Delta since some districts have access to varied water resources for farming than other regions. In the Ada West, for instance, farming mainly depended on rainfall, while some farmers supported crop production with boreholes in upland areas with low water tables. The finding suggests an important observation which may need further empirical analysis. That is, communities in the Ada West and some parts of Ada East Districts have identified the need for boreholes for farming. However, the extent to which the water resource can be sustainably explored for farming is uncertain. Future research may apply practical and consensual monitoring tools such as models and participatory approaches to conduct vulnerability analysis to inform policy and stakeholders on integrated and coherent resilience indicators (e.g. warning, responses, and recovery) relevant to farming in the Volta Delta and similar regions.

Conclusion

The study's findings indicate that stakeholders in the climate-agricultural sector need to initiate research, including breeding programmes to help identify varieties/cultivars that suit abiotic and biotic stressors. The outcome of the study on farmers' vulnerability to water availability should be shared with farmers. The results also highlight the necessity of supplying farmers with crop varieties with traits such as drought tolerance, heat tolerance, resistance to viruses, and early maturation. Adopting this approach will help mitigate the risks farmers face in their agricultural activities. Also, improved crop varieties should be available at subsidised prices. Additionally, there is a need to train farmers and stakeholders like the agricultural extension agents to identify and use crop varieties that can respond to varied water availability conditions. The training programme should include building the capacity of farmers to select genetic diversities suitable for specific situations.

The findings also indicate the importance of early warning systems and their implementation at the community level through participatory approaches that involve stakeholders in the farming sector. The study's findings are relevant to the government's objective of providing irrigation facilities in major agricultural zones under the 'one-district-one-dam' programme. Additionally, the study offers valuable insights for water resource mapping in the area, which can inform effective irrigation options.

The promotion of sustainable water management practices is crucial to reducing the vulnerability of farming systems to water availability in the study districts. Farmers can undergo training to adapt to drought conditions and learn efficient water application techniques. Additionally, stakeholders should train farmers to implement rainwater harvesting interventions, including terracing and deep tillage, smart metering, leak detection systems for water distribution networks, and drip irrigation systems. Non-governmental organisations working with farmers can also incorporate water management strategies in their community interventions and educate them on using innovative technologies to support sustainable water management.

The response strategy of farmers should include mitigation efforts such as planting native trees on or around the farms to improve moisture levels, provide shade, and restore carbon. Soil moisture management techniques should also be implemented, and farmers can benefit from support and opportunities to grow nitrogen-fixing legumes to aid in soil management. The results of the study findings call for policy interventions on soil fertility and moisture mapping for farming and the provision of decision-support tools like soil maps to stakeholders in the area.

Additionally, policies should be formulated to guide groundwater extraction for irrigation purposes. For instance, stakeholders can establish a borehole or well scheme to enable individuals or farmer groups to access subsidised loans for digging wells. The study offers valuable knowledge for developing groundwater management and decision support strategies, including specifications on hand-dug wells, water column requirements for farmland irrigation, spacing between water wells, and regulation of water usage. Improving farmers' access to finance and insurance is also necessary for investing in water management technologies, such as crop insurance.

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