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Walailak University, Thailand

*CORRESPONDENCE
Iddisah Alhassan
✉ alhassaniddisah@gmail.com

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Examining effects of climate information utilization by climate-vulnerability groups in the northern region of Ghana

Iddisah Alhassan[1]*, Philip Antwi-Agyei[2], William Adzawla[3], Mihaela Sima[4], Alexander Siegmund[5,6] and Emmanuel Eze[5,6,7]

[1]West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL) Doctoral Research Program, University of The Gambia, Banjul, Gambia, [2]Department of Environmental Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, [3]International Fertiliser Development Centre, Accra, Ghana, [4]Institute of Geography, Romanian Academy, Bucharest, Romania, [5]Institute of Geography and Heidelberg Centre for the Environment (HCE), University of Heidelberg, Heidelberg, Germany, [6]Department of Geography – Research Group for Earth Observation (ʳgeo), UNESCO Chair on Observation and Education of World Heritage and Biosphere Reserve, Heidelberg University of Education, Heidelberg, Germany, [7]Geographical and Environmental Education Unit, Department of Social Science Education, University of Nigeria, Nsukka, Nigeria

Impacts of climate change on climate-vulnerable populations receive little attention in the literature compared to the general population across the globe, including Ghana's Northern Region, than it has on the availability, sources, and kinds of climate services. Understanding the level of effects of utilizing climate information on farmers' livelihoods is important for climate policy evaluation. Therefore, this study investigates how farmers in three climate-vulnerable groups in Ghana's Northern Region make adaptation decisions based on climate information. Using a concurrent nested mixed research (quantitative and qualitative) approach, we collected data from 384 sampled farm household respondents, focus group discussions, and experts' (Key-informants) opinions on climate change in the region. We analyze the data using descriptive statistics and a probit model. The results of mean statistics indicate that whereas farmers across climate-vulnerability groups perceived climate change and variability, the less climate-vulnerable group utilized more climate information for adaptation 7.1 than their counterparts, 5.2 and 3.3 for moderate to high vulnerability, respectively. Also, the probit model result reveals that farmers in the three climate-vulnerable groups are negatively associated with utilizing climate information in their adoption of adaptation strategies for floods and droughts, but they are positively and significantly influenced by climate information in their decision to implement early planting and pest/disease control. Furthermore, although the results show that using climate information boosts farmers' chances of getting credit by 102.5%, there is no significant chance that farmers would be able to get credit without climate information. The study concludes that, to a greater extent, climate information significantly influences farmers' decisions regarding adaptation strategies in the region.

KEYWORDS

climate change, climate vulnerability, climate information, adaptive capacity, northern Ghana

Introduction

Climate change is anticipated to impact food production, resulting in global food insecurity (Kopainsky and Potthoff, 2022). According to Dawson et al. (2016), projections indicate that 31% of the world's population, approximately 2.5 billion, could face starvation by 2050 if there is no adaptation or technological advancements in the agricultural sector, and an additional 21%, approximately 1.7 billion, could face malnourishment due to climate change unless they fully adapt. Existing literature on climate change across many disciplines spelt out the effects of climate change on livelihoods across the globe among advanced economies, middle-income nations and the least developed countries (LDCs). It is perceived that advanced countries are better equipped to contain the effects of climate change, areas such as cities along the coast and agriculture are bound to suffer from the effects of climate change. The IPCC (2021) reported that North America and Europe are increasingly faced with climate-driven wildfires, droughts and floods, affecting important areas such as tourism, agriculture and infrastructure. On the other hand, Middle-Income Countries which are dependent on natural resources are particularly vulnerable. Research has shown that Mexico and Brazil recently faced droughts and unpredictable seasons, which impacted crops such as coffee, staples and maize which are crucial for the economies of these nations (Arora, 2019). Countries in Asia are experiencing destructive typhoons, droughts, landslides and floods never seen before affecting infrastructure and agriculture, which poses serious consequences on the livelihoods and the economies of these countries. Least Developed Countries, though, least contributors to the global total emission footprint are the most vulnerable to the effects of climate change due to limited resources for climate adaptation. Huq et al. (2019) observed that Bangladesh is increasingly faced with salinity and sea-level rise affecting agricultural productivity and displacing communities and social structure.

The effects of climate change continue to threaten the livelihood of many rural households that heavily depend on agro-based sustenance throughout sub-Saharan Africa (SSA), leading to increasing food insecurity (Kopainsky and Potthoff, 2022; Niang et al., 2018). In the agricultural sector, such effects include increased pests and diseases, drought, floods, and changes in rainfall patterns, which influence farm production (Alidu et al., 2022; Blazquez-Soriano and Ramos-sandoval, 2022; Pathak et al., 2021). The UNFCCC stated that rural communities whose livelihoods are anchored on rain-fed agriculture are affected by the effects of climate change and climate variability leading to food insecurity, climate refugees and loss of income (UNFCCC, 2018). The persistence of these effects will certainly directly affect the attainment of the United Nations Sustainable Development Goals (SDGs), particularly goals 1 (no poverty) and 2 (zero hunger). This will increase the perpetual instability on the African continent, such as tribal conflicts.

EU SCAR (2012) defines Agricultural Knowledge and Information System (AKAS), as a system of knowledge flows that comprises several establishments within a division, and provides access to farming information. As climate change continues to affect crop productivity, the only option left is to adapt. Several researchers, including Huang and Sim (2021), Khanal et al. (2021), and Turner-Walker et al. (2021) have suggested climate change adaptation as one of the options to reduce the unavoidable effects of climate change. The success level of adaptation needs many stakeholders' contributions in addition to farmers, non-governmental organizations (NGOs), policymakers, extension agents, community leaders, and researchers (Below et al., 2010; Bryan et al., 2009, 2013).

Studies revealed that information transfer aids farmers, especially small-scale farmers to transform and adapt to their situation (Ramos-Sandoval et al., 2016). Climate information consisting of agro-climatic information on smart agriculture, improved seed varieties, climatic and weather forecasting, agricultural advice, and other relevant information plays a vital role in adaptation. Baffour-Ata et al. (2024); McKune et al. (2018) and Antwi-Agyei et al. (2021a,b,c) stated that farmers in Africa make use of climatic information such as long-term and short-term climatic impacts in their decision-making during the clearing of land for farming, planting, and the use of different crop varieties. Other studies by Gebrehiwot and van der Veen (2013), Mulwa et al. (2017), and Ponce (2020). Blazquez-Soriano and Ramos-sandoval (2022) and Kumar et al. (2021) stated that farmers can achieve their intended goal of adaptation by using climate information to strengthen their resilience in the agricultural sectors.

IPCC (2022, p. 2902) defined climate information as "information about the past, current or future state of the climate system that is relevant for mitigation, adaptation and risk management. It may be tailored or "co-produced" for specific contexts, taking into account users' needs and values." According to earlier research (Antwi-Agyei et al., 2021a,b,c; Diouf et al., 2019; Ogunbode et al., 2019), climate information services (CIS) that offer climate information are essential in helping African farmers more effectively in addressing current risks and preparing them for future climate risks. Nonetheless, Africa is home to just 10% of the 1,017 ground-based weather observatory systems worldwide, and 54% of these stations have difficulty gathering accurate data (IPCC, 2022). As a result, there are numerous obstacles to obtaining trustworthy climatic information about climate change in Africa (Hansen et al., 2019). These obstacles include information uncertainty, signal complexity, and the potential cost of using technology.

Existing studies revealed that Ghana is prone to negative effects of climate change (Amuakwa-Mensah, 2015), as a result of its rain-fed agrarian dependency and over-reliance on natural resources. Ghana is also projected to experience higher temperatures with erratic rainfall variability and intense drought affecting agricultural activities (Christensen and Christensen, 2007). According to projections by Asante and Amuakwa-mensah (2015) and World Bank Group (2021), the Guinea-Savannah zone in Ghana's northern part, which is prone to droughts and floods, will experience a decrease in mean annual rainfall of about −7.8% and an increase in temperature of about 2.5°C. This decrease in precipitation and an increase in temperature will have repercussions on the livelihoods and well-being of the people who are predominantly small-scale farmers.

Climate information utilization among climate-vulnerable groups in the northern region of Ghana is faced with a complex web of environmental, socio-economic and data factors. Climate information plays a critical role in adaptation and resilience-building, especially among vulnerable people who are mainly dependent on crop production (Adger et al., 2009). The reliance on agriculture, which is faced with unpredictable rainfall patterns and unprecedented climate variability in the northern region of Ghana, amplifies the importance of timely, accessible and accurate climate information. Notwithstanding this, substantial barriers militate the real utilization of climate information.

One of the most notable barriers to climate information utilization in the northern region is accessibility and the ability of farmers to understand climate information. The majority of farmers in the region lack access to important and timely climate information due to inadequate infrastructure. Such infrastructural deficiencies include electricity and communication networks which play a crucial role in the dissemination of climate information across the country (Antwi-Agyei et al., 2021a,b,c). In many instances where the information is accessible, the methodical nature of the information and language barriers lead to poor comprehension of the information without the involvement of extension personnel and proper training (Antwi-Agyei et al., 2021a,b,c). Furthermore, socio-cultural barriers hinder the effective application of climate information among climate-vulnerable groups in the northern region of Ghana. Most of the time, indigenous practices battle with the systematically derivative climate information resulting in the hesitant of farmers to adopt such practices which may lead to it being branded as unreliable (Antwi-Agyei et al., 2021a,b,c; Nyadzi et al., 2019), hence limiting its adaptation.

IPCC (2014, p. 128) defines vulnerability as "the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt." The Northern Region of Ghana, which is characterized by semi-arid conditions with the majority of the inhabitants into small-scale farming, is disproportionately vulnerable to climate change effects exacerbated by low access to resources and technology (Aryal et al., 2020; Fosu-Mensah et al., 2012). Poor roads, hospitals, schools, housing, industries, and clean drinking water exacerbate this vulnerability compared to the southern parts (Ghana Statistical Service, 2018; World Bank Group, 2020). This situation calls for strategies that will increase farmers' resilience to climate change, which ultimately will raise crop productivity, leading to an increase in food security in the region. Climate information plays an important role in regions like the northern region of Ghana where limited education, poverty and infrastructural gaps worsen the inhabitants' vulnerability to climate change and climate variability (Yaro, 2013). Vulnerable groups, comprising women, smallholder farmers and low-income people are unduly affected by climate change as a result of limited adaptive capacity (IPCC, 2014). In light of this, climate information comes in to guide farming activities, such as the timing of rain, sources of inputs and farm management practices which have the potential to reduce the effects of climate change on crop productivity and increase yield (Partey et al., 2018).

Both print and electronic media, including television TV, radio sets, and newspapers, disseminate climate information in Ghana (Abdul-Razak and Kruse, 2017; Alidu et al., 2022; Antwi-Agyei et al., 2021a,b,c; Baffour-Ata et al., 2022; Owusu et al., 2021; Sarku et al., 2022). The findings of Alliagbor et al. (2020) and Waaswa et al. (2021) revealed that sharing information on climate-smart agriculture through various platforms such as TV, radio, print media, friends, and extension services leads to better adaptation strategies. Furthermore, farmers who practice climate-smart agriculture stand a better chance to increase their resilience and resist climatic effects, thereby increasing farm productivity (Martey et al., 2021). Factors such as access to climate information, rain duration, input sources, effective timing, improved crop varieties, and access to credit are reported to influence farmers' decisions to effectively adapt to climate change (Asrat et al., 2018; Mihiretu et al., 2020; Nyang'au et al., 2021).

Climate information utilization is greatly influenced by the socio-economic context of the northern region. Recommendations that can help farmers adapt to climate change are largely restricted by low-income levels of farmers. For example, financial constraints can restrict farmers' ability to access drought-tolerant crop varieties or engage in dry-season farming using irrigation systems (Partey et al., 2018). Additionally, low access to financial systems limits farmers' capacities to access credit facilities that could enable them to adapt to climate change (Antwi-Agyei et al., 2021a,b,c).

Studies such as Klemm and McPherson (2017), a comprehensive review on climate forecasting for agricultural producers, concentrated on the general population without mentioning the impacts on climate-vulnerable populations. Furthermore, Tarchiani et al. (2020), generalized their findings on the entire population without considering the needs of the most vulnerable population. Similarly, the majority of literature on climate services in Ghana, particularly in the Northern Region, focused on smallholder farmers' sources of climate information, availability, types, and barriers to access, with little research on how access impacts farmers' climate adaptation strategies. Furthermore, EPA (2020) 4th report to the UNFCCC, which classified the districts included in this study as climate change vulnerable, calls for more research into how and to what extent farmers' adaptation strategies in the area are impacted by the use of climate information. This will help improve the country's evaluation of climate policies.

Based on the above, this research is anchored on the Action Theory of Adaptation (Eisenack and Stecker, 2010). This theory holds the view that a potential stimulus with statistical changes in meteorological variables will lead to effects on an "exposure unit" affected by climate change and adaptation. The operator will then exercise adaptation. The operator has the means, resources, knowledge, and power that are passed on to the 'receptor of adaptation' who in this case are the household heads (Eisenack and Stecker, 2010). In this assumption, this research is of the view that the changes in meteorological variables, due to climate change, will affect the livelihoods of smallholder farmers, leading to stakeholders considering adaptation options.

To achieve the goal of this research, the specific research objectives of this paper are to: (1) determine the perception, and sources of climate information, and how farmers in climate-vulnerable groups in the Northern Region of Ghana utilize climate information for adaptation. (2) identify the barriers that affect the use of climate information among farmers in the climate-vulnerable groups, and (3) analyze the effects of utilizing climate information on the adoption of adaptation strategies among climate-vulnerable groups in the region. The findings of this study will add to the existing body of knowledge on the impacts of climate change information, highlighting the impact of climate information usage on adaptation among farmers in climate-vulnerable groups in Ghana. This will aid in guiding policy decisions related to climate adaptation, as well as determining which policies to disseminate to which climate-vulnerable groups for effective adaptation in the country.

A conceptual bivariate probit model

Several past literature modeled factors influencing socioeconomic variables of farmers' adoption decisions using logit or the probit models as in the case of Mittal and Mehar (2016) who modeled the socio-economic factors affecting the adoption of modern information and communication technology by farmers in India. Mudiwa (2011) also used the logit model to estimate factors determining the adoption of conserving farming by smallholder farmers in the Semi-Arid Areas of Zimbabwe. To understand the impact of modern agriculture technologies on farmers' welfare in Ethiopia and Tanzania, Asfaw et al. (2012) applied the probit model in their analysis. Furthermore, Owombo and Idumah (2015) modeled the determinants of land conservation technologies adoption among arable crop farmers using the probit approach in Edo State, Nigeria. They assumed that farmers' decisions are related to utility maximization. E.g., If climate information is defined as "CI" adaptation as "P" and *CI,* P is =1 for those who adopted and *CI**, *p* = 0 for those who did not adopt. The utility function of the *i*th farmer peculiar traits is assigned "$\int$" (e.g., information on rain duration, and access to farm credit) while the disturbance equals zero mean.

$U_{i1}(\int) = \beta_1 \int_i + \varepsilon_{i1}$ for adopters and $U_{i0}(\int) = \beta_0 \int_i + \varepsilon_{i0}$ for non-adopters.

Given that utilities are arbitrary, the *i*th farmer will opt for the next available "adoption" such that $U_{i1} > U_{i0}$.

Therefore, the likelihood of adoption for farmer *i,* is as follows:

$$Ą(1) = Ą(U_{i1} > U_{i0})$$

$$Ą(1) = Ą(\beta_1 \int_i + \varepsilon_{i1} > \beta_0 \int_i + \varepsilon_{i0})$$

$$Ą(1) = Ą(\varepsilon_{i0} - \varepsilon_{i1} < \beta_1 \int_i - \beta_0 \int_i)$$

$$Ą(1) = Ą(\varepsilon_{i1} < \beta \int_i)$$

$$Ą(1) = \emptyset(\beta \int_i)$$

$\varnothing$ represents the cumulative distribution function of ε. The working form of $\varnothing$ rest on the predictions assigned to ε. At this point by assuming the normal distribution for ε a probit model comes in. In this case, for a farmer "*i*," the chance of adopting climate information utilization or not, respectively, is given by:

$$\emptyset_{CI}(\beta \int_i) = \iint_{-\infty}^{\beta \int_i} \frac{1}{\sqrt{2\pi}} \exp\left(\frac{-t^2}{2}\right) bt$$

$$\emptyset_{p}(\beta \int_i) = \iint_{-\infty}^{\beta \int_i} \frac{1}{\sqrt{2\pi}} \exp\left(\frac{-t^2}{2}\right) bt$$

Researchers Nkamleu and Adesina (2000) argued that the probit method can estimate the two equations single-handedly, they however stated that this method is not enough since it eliminates the correlation and the disturbances associated with ε_{CI} and ε_P of the prevailing stochastic functions related to climate information utilization and climate adaptation strategies. We are using the bivariate probit model in this paper to address the deficiencies of the probit and or the logit model reported by (Brorsen et al., 1996) on the assumption of two normally distributed variables specified.

$$CI(CI,P) = \frac{1}{2_{\pi\delta_{CI}\delta_P}\sqrt{1-P^2}} e^{-\left(\varepsilon_{CI}^2 + \varepsilon_P^2 - 2p\varepsilon_{CI}\varepsilon_P\right)/\left(2\left(1-P^2\right)\right)}$$

$$\varepsilon_{CI} = \frac{e - \cap CI}{\delta_R}$$

$$\varepsilon_P = \frac{P - \cap P}{\delta_P}$$

P gives the correlation of *e* and p while the covariance is $\delta_{CIP} = p^{\delta} CI^{\delta} p. \underset{CI}{\cap}, \underset{P}{\cap}, {}^{\delta_{CI}}$ and δ_P.

CI and P represent the means and the marginal distributions, respectively. *p* = 0 if the distributions of *CI* and P are independent. We applied the "vce (robust)" command option in STATA to include the calculation of standard errors in the model for a full maximum likelihood.

The empirical model is given below:

$$\begin{aligned}
&Climate\ adaptation = \delta_0 Climate\ information \\
&+\delta_1 Access\ to\ credit + \delta_2 Rain\ duration \\
&+\delta_3\ Floods\ and\ drought + \delta_4\ Improve\ in\ income \\
&+\delta_5\ High\ productivity + \delta_6 Input_source \\
&+\delta_7 Pest\ /\ disease\ control + \delta_8\ Effective\ timing \\
&+\delta_9\ Soil\ /\ water\ conservation +, robust
\end{aligned}$$

The study adopted the probit model based on the following two factors. Firstly, the probit model can model the probability outcomes naturally ensuring valid distortions which are well-founded based on the assumption of normality. Furthermore, the model gives insights into the outcome of the results through marginal effects.

Research methods

Study area and context

The Northern Region of Ghana contains the study region (Figure 1). Small-scale farmers make up the majority of the population in the target region—up to 70% of the residents (MoFA, 2021) Approximately 58% of farmers focus on raising poultry, less than 2% practice forestry, and less than 1% are interested in aquaculture and beekeeping. Approximately 97% of farmers grow cereal crops (MoFA, 2021). Previous research has shown that this area is prone to recurrent bushfires, which pose a serious threat to farmers who primarily use primitive farming techniques (Alidu et al., 2022; Baffour-Ata et al., 2021; EPA, 2020). Furthermore, Ghana's Northern Region is known for its inadequate infrastructure and high rates of poverty (World Bank Group, 2020). Notwithstanding the accessibility of climate data, there has been scant research on the adaptation strategies employed by climate-vulnerable communities

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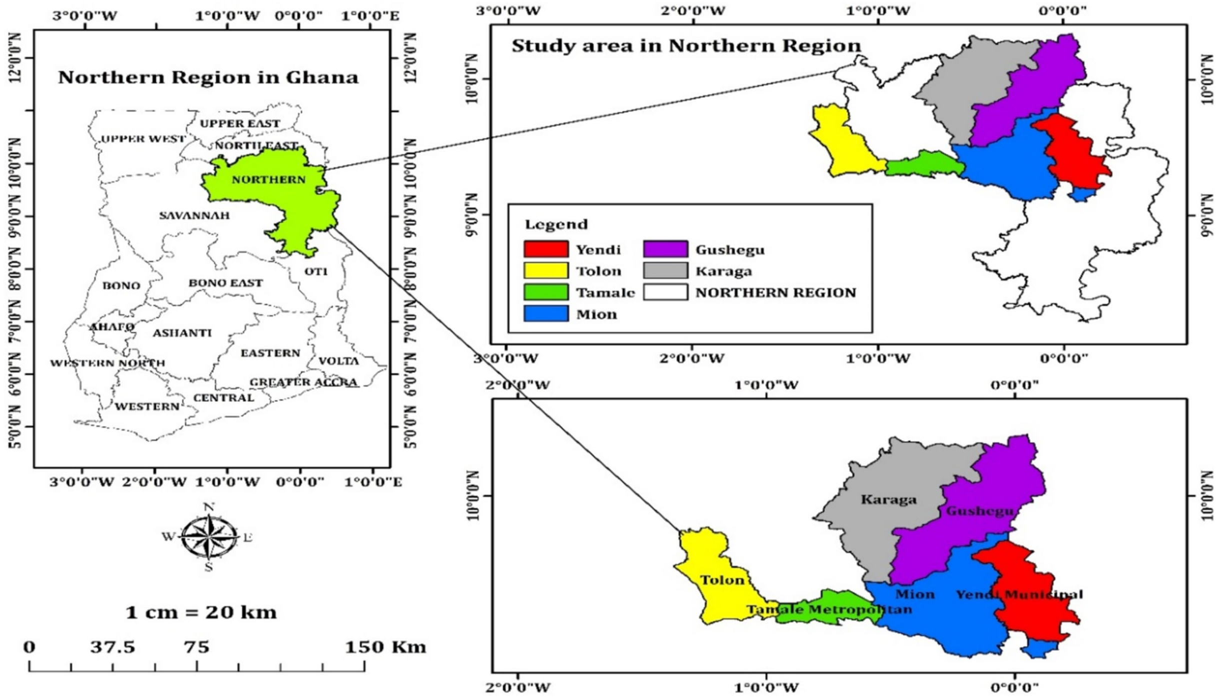

FIGURE 1
Study area map. Source: Authors.

in the region, particularly small-scale farmers, in response to climate change and their utilization of climate information to enhance their livelihoods. This study aims to address this knowledge gap by examining how three levels of climate-vulnerable groups (highly, moderately, and less vulnerable) in the northern region utilize climate information to enhance agricultural productivity and improve food security.

EPA (2020), calculated the categorization of vulnerability by grouping climate change exposure into current and expected future scenarios in Ghanaian districts. Exposure scores were calculated using 36 sub-parameters for medium-and long-term increases under two climate change scenarios (RCP 2.6 and RCP 8.5). The study assessed climate change sensitivity in the agricultural sector, focusing on the percentage of the population in each administrative region, as the sector is inherently climate-dependent and rain-fed, making it highly sensitive to climate changes. The study quantified the adaptive capacity in each region using seven parameters: economic activity, education, sanitation, rural water availability, health, security, governance effectiveness, and poverty. Districts received ranks for each parameter, but according to EPA (2020), no data was available to predict future capacity. District-specific exposure, sensitivity, and adaptive capacity were calculated as the sum of the ranks of parameters divided by the maximum, while district-specific CCV was calculated using the IPCC equation: Climate Change Vulnerability (CCV = (sensitivity exposure) − adaptive capacity. The EPA (2020) classified climate-vulnerable districts as highly vulnerable with a CCV) range exceeding 0.30, moderately vulnerable with a CCV range of 0.20–0.29, and less vulnerable from the range of 0.02–0.19. Based on the above three vulnerability groupings, we selected six districts, two from each of the 15 designated CCV districts. Table 1 below indicates the vulnerability level breakdown of each of the study districts selected and classified by the EPA (2020). Therefore, the vulnerability groupings of the EPA (2020) are considered reliable and scientifically valid for use in classifying the various districts that are closely investigated in this study.

Sample size, sample determination, and analytical method

The total household population of 2,275,197 in the region was obtained from Ghana Statistical Service (2021) population and housing census report. The sample size targeted crop farmers, more specifically farmers who are household heads, and resided in the community for at least 10 years, and have attained the age of 35 and above at the time of the sampling. We set the age cut-off point at 35 years because the questionnaire required farmers to provide their climate knowledge from the past 10 years, and we anticipated that farmers below this age bracket would struggle with this reference.

The sample size of 384 for the research was determined using the Raosoft formula.

$$X = Z\left(\frac{C}{100}\right)^2 r(100-r)\, n = Nx/((N-1)E^{2.}$$

$$E = Sqrt\left[(N-n)x/n(N-1)\right]$$

Where: N = Population size, r = responses, $Z\left(\frac{C}{100}\right)$ = critical value and C = confidence level.

TABLE 1 Climate change vulnerability index by district breakdown.

Vulnerability ranking	District	District CCV range	Sensitivity	Exposure	Adaptive capacity
Highly vulnerable	Mion	0.31+ highly vulnerable;	0.87	0.64	0.25
	Gushegu	0.31+ highly vulnerable;	0.87	0.70	0.29
Moderately vulnerable	Karaga	0.27–0.29 moderately vulnerable;	0.87	0.69	0.33
	Tolon	0.27–0.29 moderately vulnerable;	0.87	0.66	0.28
Less vulnerable	Tamale-metro	0.02–0.19 less vulnerable.	0.87	0.66	0.55
	Yendi	0.02–0.19 less vulnerable.	0.87	0.61	0.43

EPA (2020). 0.31–0.31 highly vulnerable; 0.27–0.29 moderately vulnerable and 0.02–0.19 less vulnerable.

For this study, we randomly selected 12 farming communities from the six districts using the lottery method, and interviewed 32 household heads in each community, resulting in a total of 384 smallholder farmers' household heads. In the selection of the two communities from each of the six selected districts, a sample frame was created by cataloging all the districts under the vulnerable categories (highly, moderately and less). The next stage was the cataloging of all communities under each district. For better identification, a unique ID was created for each district and community and grouped under each vulnerability category. Communities were then randomly selected using the clustering technique. This was achieved firstly, by stratifying the districts into climate vulnerability categories and then separating the sample frame by vulnerability groupings—highly, moderately and less. This was followed by grouping communities into categories by districts. After the stratifying stage, the districts were randomized to select two communities from each climate-vulnerability category group using STATA. The selection of the 32 household heads was done using a simple random selection method, where each household in the community stands the chance of being selected. This was achieved by randomly selecting household farmers within a distance apart keeping in mind the count until the required number is achieved. In addition to farmers from the communities in the study area, the research involved stakeholders such as government officials, district extension officers, assembly members, and non-governmental organizations working in the districts. Data was collected in three stages. In the first stage of the data collection, quantitative data was collected using a face-to-face administered survey questionnaire. The second stage was gathering qualitative data to complement and better explain the quantitative data.

Five focus groups were conducted in August 2023, from five of the six districts. Each focus group consisted of not less than eight farmers. The FGDs were conducted bearing in mind the need for homogeneity. This was achieved through the inclusion of the elderly (men and women), the youth and members who belong to farm-based organizations in communities where these organizations exist. The study conducted five FGDs, one each in Kpabia in the Mion district, Tolon in the Tolon district, Yendi municipality, Gushegu in the Gushegu district and Karaga in the Karaga district. Only five FGDs were conducted out of the four districts, one municipality and one sub-metropolis because, at the end of the fifth FGD it became apparent that responses from the five communities were almost the same and at a saturation point, thus; there was no need to continue. The conduction of the discussion was done in the local language (Dagbanli) since all the participants in the research communities were from the Mole Dagomba ethnic group who communicate in the Mole Dagbanli. The time for each FGD was limited to at least 60 min and at most 80 min.

TABLE 2 Sample determination by district.

Climate vulnerability Group	District	Household population	Sample
Highly vulnerable	Mion	94,838	65
	Gushegu	153,400	61
Moderately vulnerable	Karaga	113,668	66
	Tolon	115,712	61
Less vulnerable	Tamale South Metro	240,087	65
	Yendi	151,467	66
Total		869,172	384

Source: EPA (2020). vulnerability classifications by district; 0.31–0.31 highly vulnerable; 0.27–0.29 moderately vulnerable and 0.03–0.10 less vulnerable.

The third stage was Face-to-face interviews with five experts in the region. They were made up of 2 agricultural extension agents, a representative each from the Ministry of Food and Agriculture, the Presbyterian Agricultural Organization (NGO), and the Ghana Meteorological Agency respectively, were also contacted in September 2023. The study sampled these key informants Based on Palys (2008) stakeholders sampling approach, with the assumption that these respondents are important in the context of evaluating the responses from the administered questionnaires and the FGDs held earlier in this study. These respondents were considered because they are part of the institutions in the country that design, disseminate and educate farmers on the causes of climate change, its effects, and mitigation and adaptation strategies. The data was recorded and transcribed. We utilized a content analysis procedure to scrutinize the data, bolstering the quantitative results for a more profound comprehension of the investigated phenomenon (Table 2).

Validity and reliability of research instruments

The measurement of the accuracy of how a quantitative study is conducted is known as validity, and how quality is measured is referred to as reliability (Kimberlin and Winterstein, 2008). This was achieved through a well-designed questionnaire prepared and reviewed by three experts. One professor from the Kwame Nkrumah University of Science and Technology, Ghana; a senior researcher from the International Fertilizer Development Center, Ghana; and a senior academic from the Institute of Geography, Romanian Academy, Romania. Several recommendations were made, which were incorporated into the final version used in this study. Following approval, we uploaded the questionnaire into the Kobo Toolbox software for pilot testing on 10% of the total sample unit of 384, resulting in a total of 38 farmers who were interviewed in the selected districts for reliability testing. We conducted a test for internal consistency using the Cronbach alpha scale coefficient reliability, which yielded a result of 74%, surpassing the 50% rule of thumb considered acceptable by previous studies Bagozzi and Yi (1988), Cronbach (1951), and Cronbach and Shavelson (2004).

Data collection procedures

Farmers from six districts in the Northern Region of Ghana which are classified as vulnerable communities to climate change by EPA (2020) report to the UNFCCC were selected for this study, using a concurrent nested mixed research (quantitative and qualitative) approach. We conducted three stages of data collection. In the first stage, we administered a questionnaire to 384 small-scale farmers in selected districts to collect quantitative data. The questionnaire assessed farmers' perceptions of climate change, sources of climate information, the impact of climate information on farm productivity, factors preventing its utilization, and the types of climate adaptation practices influenced by it. The administering of the questionnaire was conducted between March 2023 and May 2023 during the off-farm period.

The second stage was the conducting of focus group discussions (FGD) for the qualitative data. Five focus group discussions were held with farmers in August 2023. One each from the Mion district the Yendi municipality, Tolon district, Gushegu and Karaga districts, respectively. They deliberated on their perceptions of climate change, sources of climate information, the effects of climate change on their livelihoods, challenges affecting their usage of climate information, and the adaptation practices practiced to cope with the effects of climate change. Data was recorded during the discussion processes and transcribed.

In-person interviews with local experts in September 2023 constituted the third phase of the data collection process. We spoke with two agricultural extension agents from the districts of Gushegu and Mion. We also conducted interviews with two agricultural experts' representatives from the Ministry of Food and Agriculture, and the Presbyterian Agricultural Office, a Tamale-based non-governmental organization (NGO). A member of the Ghana Meteorological Service in the Northern Region was also interviewed. They answered enquiries about their knowledge of climate change, their personal experiences with it in the area, their programs for farmers there, the kinds of climate information they give them, and some of the difficulties they encounter. We adhered to all established ethical guidelines and informed participants of their rights and data information anonymity.

Descriptive statistics was employed to analyze farmers' perceptions of climate change and their sources of information. Further descriptive analyses were done on the effects of climate adaptation on farm productivity, factors hindering climate information utilization, and the types of climate adaptation practices influenced by climate information utilization among the climate-vulnerability groups.

Results and discussion

Table 3 presents farmers' perceptions of climate change. Farmers agreed on changes in rainfall among climate-vulnerability groups, with some agreeing to decrease, increase, or remain constant. The results indicate that Farmers' perceptions of rainfall volume were high, with 78.6% of the most vulnerable groups reporting a decline in rainfall volume. On the other hand, 99.2% of the farmers in the less climate-vulnerable category reported a reduction in rainfall volume. These findings indicate that the majority of farmers in the study area are aware of changes in rain and are expected to take steps to mitigate their impact. The findings of Mihiretu et al. (2020) and Musafiri et al. (2022), stated that farmers who perceived climate change practiced adaptation. Other stakeholders also express their understanding of climate change, highlighting its impact on the agricultural sector in the region.

For example, a farmer in the Mion district which is classified as a highly climate-vulnerable district stated:

> *"How the rain used to rain is not the same […] and the time we used to farm is no longer the same. Some of the changes this brought about include delays in rainfall and low amounts of rainfall. Due to these changes, precise timing for farming has become difficult"* (FGD, farmer, Mion district, 2023).

These perceptions indicate that, through climate information, farmers in these climate-vulnerable communities may institute

TABLE 3 Perceptions of climate change and variability by climate-vulnerability groups.

Variable	Highly vulnerable (*n* = 126)			Moderately vulnerable (*n* = 127)			Less vulnerable (*n* = 131)		
	Decrease	Increase	No change	Decrease	Increase	No change	Decrease	Increase	No change
Rain volume	99 (78.6)	13 (10.3)	14 (11.1)	49 (38.6)	55 (43.3)	23 (18.1)	130 (99.2)	0 (0)	1 (0.8)
Rain duration	99 (78.6)	14 (11.1)	13 (10.3)	53 (41.7)	50 (39.4)	24 (18.9)	128 (97.7)	0 (0)	3 (2.3)
Rain onset	67 (53.2)	34 (27.0)	25 (19.8)	46 (36.2)	51 (40.2)	30 (23.6)	98 (74.8)	2 (1.5)	31 (23.7)
Storm	7 (5.6)	103 (81.8)	16 (12.7)	21 (16.5)	69 (54.3)	37 (29.1)	5 (3.8)	73 (55.7)	53 (40.5)
Drought	5 (4.0)	110 (87.7)	11 (8.7)	27 (21.3)	92 (72.4)	8 (6.3)	13 (10.0)	110 (84.0)	8 (6.0)
Floods	6 (4.8)	58 (46.0)	62 (49.2)	12 (9.5)	82 (64.5)	33 (26.0)	24 (18.0)	34 (26.0)	73 (56.0)

Source: Field Survey (2023). Numbers in parentheses indicate the percentage of households while those without are the frequencies. n = number of respondents.

measures that will lessen the effects of climate change on their livelihoods. Farmers' perceptions of rainfall volume in climate-vulnerable districts may change due to differences in geographical patterns and landscapes, as well as the farmers' gender, age, and education level. These places may have varying rainfall patterns and so be affected differently by different vulnerable groups. Mihiretu et al. (2020) claimed that based on disaggregation, farmers perceived distinct climate changes.

The term "rain duration" in this study refers to how long it rained during a production year. Farmers' perceptions of rain duration found that 78.6% of farmers in highly climate-vulnerable districts observed a drop in rain duration, compared to 97.7% of farmers in less climate-vulnerable districts. These discrepancies in perceptions of rainfall duration could be attributed to local climate variability. Climate variability can cause fluctuations in rainfall patterns at various sites. A farmer from the Gushegu district backed up this claim. Example:

> *"The duration of rainfall has reduced. The way it used to rain is no longer the same. The rain is fluctuating. Sometimes it will rain heavily for a longer period and at other times it will not rain like in previous years"* (Farmer, FGD, 2023).

According to farmers' perceptions of storm intensity in the research area, 81.8% of the highly climate-vulnerable groups said there were more storms than in previous years, whereas 54.3 and 55.7% of the moderately and highly vulnerable groups believed there were more storms. These findings corroborate Asare-Nuamah and Botchway (2019), which found that farmers in the Adansi north district of Ghana perceived an increased intensity of storms. In line with Derbile et al. (2022), who found that droughts commonly affect farmers in Africa, farmers' perceptions of drought showed that 87.7% of farmers in highly climate-vulnerable districts perceived an increase in drought, while 72.4 and 84% of farmers in moderately and less vulnerable groups perceived an increase in drought occurrence within the last 10 years. 64.5% of the moderately climate-vulnerable group reported feeling that the frequency of floods has decreased, and 56% of the less vulnerable group perceived no change.

Effects of climate information utilization on climate vulnerability-groups for adaptation

Level of climate adaptation by climate-vulnerability group

The results presented in Table 4 indicate that climate information utilization for adaptation among farmers living within climate-vulnerable districts is associated with the level of vulnerability (mean = 3.341, 5.259, and 7.160) for the highly, moderately, and less vulnerable groups, respectively. It indicates that farmers living in less vulnerable districts have utilized much of the information received for adaptation than farmers living in highly and moderately vulnerable districts.

This suggests that climate information has positively affected the livelihoods of the less vulnerable districts, elevating them to the level of less vulnerable status. Previous studies such as Antwi-Agyei et al. (2021a,b,c) and Vaughan and Dessai (2014) found that climate information helps reduce the effects of climate change on farmers' livelihoods. Furthermore, the classification of the study districts, as shown in Table 3, as highly, moderately, and less vulnerable to climate change by EPA (2020) report has been backed by the findings of this study, which revealed that the level of climate information utilization for adaptation reflected the status of climate vulnerability. The following statements suggested the importance of climate information to farmers in the area study area.

TABLE 4 Level of adaptation by categories of climate-vulnerable groups.

Climate vulnerable group	Climate adaptation rank	Climate information utilization
Less vulnerable	1	7.160
Moderately vulnerable	2	5.259
Highly vulnerable	3	3.341

Source: Field Survey (2023).

> *"Through climate information, we are introduced to a weedicide which we used to control a stubborn weed we were struggling to control on our soybean farm […] We also resorted to zero tillage farming which helps to minimize the effects of the Striga weed"* (Farmer, FGD, Mion district 2023).

This implies that making climate information available to farmers can increase their adaptive capacities, which can lead to the attainment of a non-climate vulnerability status in the region. It was further revealed that experts in the region are putting up their best by providing farmers with the needed support for adaptation. This was made known during a face-to-face interaction with the extension officers in the districts. For example:

> *"We are collaborating with some NGOs who are running projects and most of these projects are using climate adaptation techniques […] For example; the 'zipit' method and how to produce biochar as a fertilizer. […] And also, the introduction of climate-resilient crop varieties […]"* (Agriculture Extension Agents, Northern Region, 2023).

Climate adaptation practices influenced by climate information

To assess the influence of climate information on the adaptation strategies of farmers living within vulnerable districts in 2022, farmers are asked whether climate information played a key role in their adoption decision for such practices listed or not. Table 5 reveals that the majority of the adaptation strategies adopted in 2022 by the farmers were due to the effect of climate information, especially among the moderately and less climate-vulnerable groups. The majority of the response percentage scores came from the farmers living in less vulnerable districts, followed by the moderately and the least from the highly climate-vulnerable districts. Thus, the adaptation decisions by the less and moderately climate-vulnerable groups were more influenced by climate information, whereas the highly climate-vulnerable groups were less influenced by climate information.

The fact that the majority of farmers across the highly climate-vulnerable group in the research area did not use most of the adaptation techniques demonstrates their low adaptative capacity in the face of a changing climate.

Improving crop types and using drought-resistant cultivars are critical for farmers' adaptation to climate change in the fight against its effects. Farmers have recognized the importance of using drought-tolerant and high-yielding cultivars to combat the effects of climate change in all climate-vulnerable districts, with the majority coming from the less and moderately climate-vulnerable groups. The results indicate that the majority of farmers in the study area have resulted in using improved/drought-resistant crop varieties, pesticides, fertilizers and soil and water conservation. These findings are consistent with Tofu et al. (2022), who stated that farmers have resulted in the use of improved high-yielding and drought-resistant crop varieties for climate adaptation. Aside from the findings in Table 5. Farmers emphasized the need to employ improved crop varieties during one of the focus group talks. For example:

> *"We get better yields using the new crop varieties. We observed that if someone planted the local seed variety and applied fertilizer twice, and another person planted the improved seed variety and applied fertilizer once, the one who planted the improved variety would get more yield than the one who planted the local variety"* (Farmer, FGD, Gushegu district, 2023).

This statement serves as a testimony indicating that climate information plays a crucial role in farmers' decision-making on climate adaptation in the region.

Sources of climate information accessed by climate-vulnerable groups

The study identified several sources from which farmers get climate information. Table 6 indicates that radio and television sets

TABLE 5 Influence of climate information on adopted adaptation practices in 2022.

Variable	Highly vulnerable (n = 126)		Moderately vulnerable (n = 127)		Less vulnerable (n = 131)	
	Yes f (%)	No f (%)	Yes f (%)	No f (%)	Yes f (%)	No f (%)
Mulching	13 (10.3)	113 (89.68)	2 (1.6)	125 (98.4)	41 (31.3)	90 (68.7)
Minimum tillage	31 (24.6)	95 (75.4)	41 (32.3)	86 (67.7)	111 (84.7)	20 (15.3)
Improve crop varieties	75 (59.5)	51 (40.5)	96 (75.6)	31 (24.4)	124 (94.7)	7 (5.3)
Drought-resistant varieties	47 (37.3)	79 (62.7)	68 (53.5)	59 (46.5)	103 (78.6)	28 (21.4)
Use organic fertilizer	39 (30.9)	87 (69.1)	43 (33.9)	84 (66.1)	71 (54.2)	60 (45.8)
Use inorganic fertilizer	42 (33.3)	84 (66.7)	85 (66.9)	42 (33.1)	111 (84.7)	20 (15.3)
Pest/disease management	27 (21.4)	99 (78.6)	47 (37.0)	80 (63.0)	68 (51.9)	63 (48.1)
Crop rotation	25 (19.8)	101 (80.2)	89 (70.1)	38 (29.9)	74 (56.5)	57 (43.5)
Post-harvest management	25 (19.8)	101 (80.2)	38 (29.9)	89 (70.1)	84 (64.1)	47 (35.9)
Row planting	35 (27.8)	91 (72.2)	51 (40.2)	76 (59.8)	60 (45.8)	71 (54.2)
Change planting period	56 (44.4)	70 (55.6)	100 (78.7)	27 (21.3)	89 (67.9)	42 (32.1)
Farm insurance	6 (5.0)	120 (95.0)	8 (6.3)	119 (93.7)	2 (1.5)	129 (98.5)

Source: Field Survey (2023). Note: Numbers in parentheses indicate the percentage of households while those without are the frequencies. f = frequency, n = number of respondents.

TABLE 6 Farmers' source of climate information for adaptation.

Variables	Highly Vulnerable (n = 126)		Moderately vulnerable (n = 127)		Less vulnerable (n = 131)	
	Accessed	Not accessed	Accessed	Not accessed	Accessed	Not accessed
Television set	96 (76.2)	30 (23.8)	90 (70.9)	37 (29.1)	55 (42.0)	76 (58.0)
Radio set	50 (39.7)	76 (60.3)	115 (90.6)	12 (9.4)	127 (96.9)	4 (3.1)
Extension service	21 (16.7)	105 (83.3)	34 (26.8)	93 (73.2)	18 (13.7)	113 (86.3)
NGOs	2 (1.6)	124 (98.4)	9 (7.1)	118 (92.9)	2 (1.5)	129 (98.5)
Newspapers	1 (0.8)	125 (99.2)	1 (0.8)	126 (99.2)	0	131 (100)
Farm associations	3 (2.4)	123 (97.6)	10 (7.9)	117 (92.1)	8 (6.1)	123 (93.9)
Mobile text messaging	4 (3.2)	122 (96.8)	1 (0.8)	126 (99.2)	7 (5.3)	124 (94.7)
Social media	1 (0.8)	125 (99.2)	1 (0.8)	126 (99.2)	4 (3.1)	127 (96.9)
Personal reading	3 (2.4)	123 (97.6)	2 (1.6)	125 (98.4)	0 (0)	131 (100)
Meteorological services	2 (1.6)	124 (98.4)	2 (1.6)	125 (98.4)	1 (0.8)	130 (99.2)
Faith groups	1 (0.8)	125 (99.2)	8 (6.3)	119 (93.7)	8 (6.1)	123 (93.8)
Friends	20 (15.9)	106 (84.1)	47 (37.0)	80 (63.0)	44 (33.6)	87 (66.4)
Family members	11 (8.7)	115 (91.3)	37 (29.1)	90 (70.9)	57 (43.5)	74 (56.4)

Source: Field Survey (2023). Numbers in parentheses indicate the percentage of households while those without are the frequencies. n = number of respondents.

play an important role in disseminating climate information to farmers in the study area, with about 76.0, 70.9, and 42.0% of farmers in highly, moderately and less climate-vulnerable groups reported to have accessed climate information through television sets, respectively. On the other hand, a significant proportion, 90.6, and 96.9% of the farmers in the moderately and less vulnerable groups accessed climate information through radio sets while a negligible number 39.7% of farmers accessed climate information through radio sets. These findings confirmed Baffour-Ata et al. (2022) findings which reported that the majority of farmers in the northern region of Ghana accessed climate information through radio and television channels. It is also in line with Owusu et al. (2021) who found that farmers in the Upper West Region of Ghana used radio sets more for accessing climate information compared to other media due to their affordability, while Oyekale (2015) stated that radio sets were widely used in East and West Africa for accessing climate information and other government policies on climate due to its wider coverage area. Blazquez-Soriano and Ramos-sandoval (2022) also stated that television and radio are among the communication channels through which farmers receive climate information in Peru. However, the findings on the wide use of radio sets for accessing climate information contradicts Sarku et al. (2022) findings which stated that public radios are among the least sources from which farmers access weather and climate information in the Ada East district of Ghana. This scenario implies that farmers at different geographical locations in Ghana use different sources to access climate information for adaptation.

Extension services are one of the sources from where farmers have the advantage of face-to-face interactions with the information provider which can lead to immediate feedback. However, access to climate information through extension services was low for farmers in all climate-vulnerable districts. Specifically, only 16.7, 26.8, and 13.7% of farmers in highly, moderately and less vulnerable groups accessed climate information from the extension agents. It was further revealed during the FGDs that extension agents hardly pay visits to farmers for interaction. For example, a farmer in the Mion district stated:

> *"The agricultural extension officers don't come to this community for face-to-face discussions"* (Farmer, FGD, Mion district 2023).

Similar findings were made by Antwi-Agyei et al. (2021a,b,c) and Sarku et al. (2022) who reported low access and utilization of extension services in the Ada East and Upper East Regions of Ghana, respectively. This scenario paints a bad image of the extension-to-farmer ratio situation in the country, portraying a lack of commitment on the part of the government to solve the problem. Only a few (<10%) of the farmers from all vulnerable groups obtained climate information from other sources (newspapers, farm associations, mobile text messaging, social media, personal reading, faith groups, friends and family members).

Factors hindering farmers' access to climate information

Notwithstanding the benefits farmers stand to gain from climate information, several factors limit their use in the studied area. Results of this study show that the major factors that hinder the utilization of climate information by farmers in the study area are the source, cost, timing, and lack of incorporation of indigenous knowledge in available climate information (Table 7).

In addition to the survey findings in Table 7, one of the focus group respondents in this study confirms that:

> *"One of the challenges we faced has to do with resource constraints […] This is because by the time the information providers want you to use their information you may not have money to pay for the information or tractors will not be available to use"* (Farmer, FGD, Mion district, 2023).

The results in Table 5 revealed low utilization of climate information by the highly vulnerable group, and this could be due to certain impediments, such as illiteracy. The study by Changnon (2004), Ochieng et al. (2017), and Patt and Gwata (2002) stated that the majority of farmers in Africa are unable to use climate information due to illiteracy. This makes farmers lack the ability to decipher the meaning of the information provided since the majority of the language for reporting weather information services in the country by the meteorological service is English (Baffour-Ata et al., 2022). Also, the easy applicability of the technology could be another factor as stated by Savari et al. (2024). The following comments made in one of the focus group discussions by the farmers attested to this.

> *"The misalignment of the technology and indigenous knowledge ideas, financial constraints, and timing of the information prevents us from using the information sometimes. For example, the new rice variety they provided to us cannot be broadcasted unless you plant it. Furthermore, you cannot store the seeds to be used in the next planting season unless you buy them yearly"* (Famers, FGD, Yendi, Mino, and Gushegu districts, 2023).

The above statements imply that climate information, which Filho and Jacob (2020) argue is one of the indisputable ways to minimize the effects of climate change on farm productivity, may be threatened by resource constraints. In a nutshell, the findings show that climate-vulnerable groups in the research area experience a variety of impediments to fully utilizing climate information. Thus, while the

TABLE 7 Frequency distribution of factors hindering the use of climate information.

Variable	Highly vulnerable (n = 126) *f* (%)	Moderately vulnerable (n = 127) *f* (%)	Less vulnerable (n = 131) *f* (%)
Cost of the information	16 (12.7)	23 (18.1)	44 (33.6)
Lacks Indigenous knowledge idea	19 (15.2)	22 (16.3)	34 (26.0)
Source of the information	33 (26.2)	65 (51.0)	27 (20.6)
Timing of the information	58 (46.0)	17 (13.4)	26 (19.8)

Source: Field Survey (2023). Numbers in parentheses indicate the percentage of households while those without are the frequencies. f = frequency, n = number of respondents.

less climate-vulnerable groups encounter challenges relating to the cost of climate information, the moderately and highly climate-vulnerable groups regard the sources of the information and the timing of the information as barriers to utilizing climate information.

Figure 2 indicates that farmers' perception of the impact of climate information utilization on agricultural crop productivity within the climate-vulnerable districts is high among all three groups. These findings suggest that the majority of the farmers living within all the climate-vulnerable districts perceived utilizing climate information as a conduit for increasing crop productivity. These results support the findings of Nyadzi et al. (2019) who stated that effective utilization of climate information can lead to significant agricultural decision-making increasing yield. A similar finding by Tesfaye et al. (2020), revealed that the utilization of climate information enables farmers to adjust planting dates and appropriate selection of improved crop varieties which contributes to improved productivity.

The results further indicate that a significant number of 92.1, 86.6, and 93.9% of farmers across the climate-vulnerable districts perceived a positive impact of climate information on crop productivity. This could be a result of these farmers utilizing climate information which reduces the effects associated with climate change on their farm productivity. Antwi-Agyei et al. (2021a,b,c) suggested that reliable and accessible climate information can lessen the effects of climate change on regions with high extreme climate variability, which could result in increased food productivity. However, about 7.9, 13.4, and 6.1% of farmers within the highly, moderately and less climate-vulnerable districts still have reservations about the efficacy of any positive impact of climate information on crop productivity. Hansen et al. (2019), observed that factors such as the level of education, access to climate information and extension services can influence the effective utilization of climate information to achieve a positive outcome. In the absence of these factors, farmers are bound to underutilize this information, hence, less productivity. This could be among some of the reasons why some farmers still have doubts about the positive effects of climate information on farm crop productivity among climate-vulnerable groups in the region.

Effects of climate information utilization on climate adaptation

Table 8 describes the variables extracted from the questionnaire used for the probit analysis. Analysis of the effects of climate information on adaptation was done using a bivariate probit model to better understand the impacts of climate information on adaptation. A bivariate probit was used because the answers to closed-ended questions were dummy variables (yes or no). The summary model statistics for the bivariate regression model indicated a better-fit output for the model parameter estimates with a Prob>chi2 of 0.0000 < 0.05. The model also provides a better-fit result of (0.3) Pseudo R^2 for the study based on McFadden (1980) proposal, which states that a Pseudo R^2 value of 0.2–0.4 indicates a better fit for a probit model. We also used the "robust" command in STATA to handle issues of standard errors, and heteroskedasticity for any violations of standard error regression assumptions that may arise.

Table 9 presents the bivariate probit estimated results for the vulnerability groups, highlighting the effects of climate information on the adoption of adaptation measures. The results indicate that the availability of climate information has a positive and statistically significant effect at a 1% level on the determination of adoption of information on rainfall duration among farmers in the climate vulnerability groups, which supports the findings of Blazquez-Soriano and Ramos-sandoval (2022), Gebrehiwot and van der Veen (2013), Mulwa et al. (2017), and Ponce (2020), who stated that farmers use climatic information on long-time and short-time climatic impacts in their decision-making during the clearing of land for farming and planting. This indicates that understanding the commencement and secession of rain allows farmers to organize their agricultural activities effectively, including the use of early-maturing and late-maturing crop varieties. In this instance, information providers should use rainfall data as one of their adaptation techniques for the country's climate-vulnerable groups. Antwi-Agyei et al. (2021a,b,c) stated that farmers in north-eastern Ghana were using climate information for critical decision-making processes, such as the clearing of land

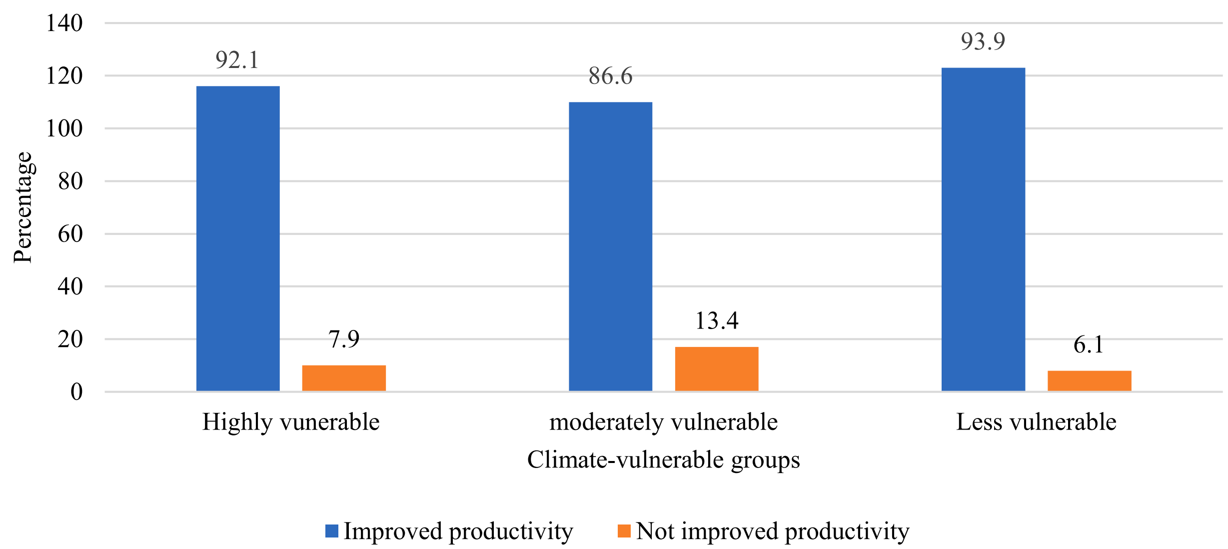

FIGURE 2
Farmers' perceptions of impacts of climate information on farm productivity.

TABLE 8 Descriptive statistics of the independent variables used in the analysis.

Variable	Description (1 = yes, 0 = no)	Categorical variables	
		Yes *f* (%)	No *f* (%)
Rain duration	If a farmer received rainfall duration	284 (74)	100 (26)
Input sources	If a farmer accesses farm input	239 (62.2)	145 (37.8)
Floods and drought	If a farmer benefited from information on floods and droughts	43 (11.2)	341 (88.8)
Improve in income	If farmer's crop production improves	349 (90.9)	35 (9.1)
High productivity	If a farmer had high returns	90 (23.4)	294 (76.6)
Effective timing	If a farmer can effectively plant on time	184 (47.9)	200 (52.1)
Pest/disease control	If a farmer benefited from information on pest/disease management	147 (38.3)	237 (61.2)
Soil/water conservation	If a farmer benefited from information on soil/water conservation	56 (14.6)	328 (85.4)
Access to credit	If a farmer accesses credit due to climate information	125 (32.6)	259 (67.6)

Source: Field Survey (2023). Numbers in parentheses indicate the percentage of households while those without are the frequencies f = frequency.

TABLE 9 Bivariate probit analysis of the effects of utilizing climate change information for adaptation.

Variables	Climate adaptation			Climate information utilization		
	Coefficient	Std. Err	P > |z|	Coefficient	Std. Err	P > |z|
Rain duration	1.113***	0.348	0.001	0.778***	0.248	0.002
Input sources	−1.126***	0.382	0.003	0.104	0.279	0.710
Floods and drought	−0.678*	0.318	0.033	−0.922***	−0.260	0.000
Improve in income	1.418***	0.401	0.000	0.292	0.198	0.141
High productivity	0.802*	0.396	0.043	0.008	0.179	0.963
Effective timing	1.691***	0.560	0.003	0.462**	0.186	0.012
Pest/disease control	5.816***	0.435	0.000	0.726**	0.324	0.025
Soil/water conservation	4.492***	0.732	0.000	−1.744***	0.545	0.001
Access to credit	0.442	0.337	0.191	1.025***	0.276	0.000
Constant	0.020	0.432	0.963	0.218	0.220	0.322
Athrho				0.163	0.169	0.334

Number of observations = 384; Walid chi2(18) = 704.49; Prob > chi2 = 0.0000; Log pseudolikelihood = −192.4733; Walid test of rho = 0; Chi2(1) = 0.93394; Prob > chi2 = 0.3338. Source: Field Survey (2023). *10%, ** = 5%, *** = 1%.

for farming, timing for planting, selection of crop varieties and changing crop patterns.

The results also indicate that utilizing climate information is negatively associated with farmers in vulnerable groups' decisions on the adoption of adaptation strategies for floods and drought in the study area. The reasons for this could be due to timing and accessibility of the information, reliability concerns, and lack of training. Antwi-Agyei et al. (2021a,b,c), found that farmers faced impediments including high illiteracy, methodical constraints and language barriers in utilizing climate information. The study by Musafiri et al. (2022), stated that the major barriers to utilizing climate information for adaptation are a lack of agricultural training and unpredictable weather patterns. This could be true because the prediction of extreme weather conditions in Africa such as heavy downpours resulting in floods and severe droughts is unreliable due to a lack of precise data gathering for predicting reliable climate information (IPCC, 2022), which could limit access and use of some vital climatic information among farmers.

The findings also show that, as an adaptive measure in the research area, farmers' decisions to use early planting and pest/disease control on their farms during agricultural seasons are strongly and favorably influenced by climate information. This result supports studies of Antwi-Agyei et al. (2021a,b,c) that found farmers' pest control adaption strategies were influenced by climate services. This means that farmers can use climate data to obtain information on more effective management strategies for pests and diseases like fall worms and locusts, which are a major source of problems for farmers across the nation.

Two additional intriguing findings from the study on agricultural credits and soil/water conservation are as follows: without access to climate information, farmers in climate-vulnerability groups are statistically and significantly more likely to practice soil/water conservation; however, once they have access to climate information, their likelihood of doing so is statistically and negatively correlated. Given that the bulk of these farmers lack literacy, this could be an obstacle. This confirms the findings of Baffour-Ata et al. (2022), who stated that because the meteorological agency in Ghana uses English for the majority of its reporting of weather information services, farmers are unable to understand the majority of the information available. Another major contributing element to farmers' failure in the study area to use specific adaptation methods is other cultural characteristics, such as the sort of technology. Antwi-Agyei et al. (2021a,b,c) also stated that due to illiteracy and the methodical nature of climate information presented, many farmers in Ghana are unable to successfully utilize it. Participants in the FGD disclosed this. For example:

> *"The misalignment of the technology and indigenous knowledge ideas, financial constraints, and timing of the information prevents us from using the information most of the time. For example, the new rice variety they provided to us cannot be broadcasted unless you plant it. Furthermore, you cannot store the seeds to be used in the next planting season unless you buy them yearly"* (Famers, FGD, Yendi, Mino, and Gushegu districts, 2023).

This statement reflects the challenges farmers faced in their attempts to apply the adaptation strategies introduced to them by information providers in the study area. Feleke (2015) mentioned that climate information policies that are user-friendly and reflect the Indigenous knowledge ideas of farmers yield better results. The study's findings on agricultural credit indicate that farmers have a low probability of obtaining credit for adaptation. Nonetheless, farmers in vulnerable groups after access to climate information have a statistically significant higher possibility of obtaining credit for adaptation—up to 102.5%—after receiving climate information on financing. This finding aligns with the findings of Maina et al. (2020) and Musafiri et al. (2022), who discovered that climate information services are crucial for farmers to obtain agricultural credits. Antwi-Agyei et al. (2021a,b,c) reported that the timelessness of climate information was a barrier to its utilization among farmers. The results indicate that the effective timing of farmers' access to climate information revealed a statistically significant association between climate information and farmers' probability of adopting climate adaptation strategies. These indicate that farmers who accessed climate information on a timely basis could plan when to start clearing their farms for plowing and also planting on time.

We computed the average marginal effects to gain a better understanding of the actual changes brought about by the predictor variable (climate information) on the response variables in Table 8. The results show that farmers in the vulnerable groups will be more likely to use rainfall duration as an adaptation strategy if they receive climate information about floods and droughts by 19%, while farmers who have access to climate information about floods and droughts are 19.8% more likely to not use the information. The same scenarios applied to the other response variables, which include improved crop production, effective timing, pest/disease control, and credit availability, indicating that farmers in the climate-vulnerable groups are more likely to use them after access to climate information (Table 10).

TABLE 10 Marginal effects of the variables on effects of climate information.

Variables	Average marginal effects		
	Coefficient	Std. Err	P > |z|
Rain duration	0.190***	0.052	0.000
Input sources	−0.028	0.059	0.627
Floods and drought	−0.198***	0.050	0.000
Improve crop production	0.114***	0.040	0.005
High productivity	0.035	0.378	0.347
Effective timing	0.157***	0.041	0.000
Pest/disease control	0.380***	0.081	0.000
Soil/water conservation	−0.132	0.120	0.272
Access to credit	0.208***	0.055	0.000

Source: Field Survey (2023). *** = 1%.

Conclusion

This study investigated the influence of climate information adoption on vulnerability classification based on EPA (2020) 4th report to the UNFCCC. The findings reveal varying levels of perception of climate change, sources of climate information and climate information utilization and adaptation practices across different vulnerability groups. The results indicate that less vulnerable groups are the highest users of climate information, suggesting that accessibility and efficient use of climate information can significantly enhance farmers' adaptive capacity, thereby reducing their vulnerability. Insights from the focus group discussions (FGDs) provide practical examples of how climate information—such as the introduction of effective weedicides and zero-tillage farming—has benefited farmers in less vulnerable districts, reinforcing the quantitative findings. The adoption of practices such as mulching, minimum tillage, and improved crop varieties is predominantly driven by climate information, with less vulnerable farmers showing the highest adoption rates. Thus, making climate information readily available is crucial for increasing adaptive capacities.

The bivariate probit analysis results highlight a positive and significant impact of climate information on variables such as rain duration, pest/disease control, timely release of climate information and access to credit, underscoring its critical role in enhancing adaptive practices. The findings further indicate that the availability of climate information has a positive and statistically significant effect on farmers' climate adaptation strategies within the climate-vulnerable districts. Farmers' decisions to use early planting and pest/disease control on their farms during agricultural seasons were found to be influenced by climate information. The findings show that the timely release of climate information can accelerate farmers' utilization of the information, hence improving crop productivity. However, the results indicate that input sources, flood and drought dynamics, and soil and water conservation practices exhibit an inverse relationship with climate information utilization among climate-vulnerable groups. This suggests that certain aspects of the climate information provided to farmers either fail to align with their specific needs or lack the integration of indigenous knowledge systems, thereby complicating the accessibility and practical application of such information.

This research will benefit the government and policymakers who are the custodians of climate information services and the providers of climate information such as the Ghana Meteorology (GMet), the Ministry of Environment, Science, Technology and Innovation (MESTI), the Ministry of Food and Agriculture (MoFA) and the Environmental Protection Agency (EPA). These bodies, through this research, henceforth ought to take into account the differential needs of the population including climate-vulnerable groups in the country when providing climate information for adaptation, since these individual groups have different impeding factors in the adoption of climate information for utilization. Both quantitative and qualitative responses identify several barriers to effective climate information utilization among highly vulnerable groups. These barriers include the cost of information, lack of incorporation of Indigenous knowledge, source reliability, and timing issues.

To address these challenges it is recommended that future climate information systems incorporate indigenous knowledge to enhance relevance and usability. The negative association with adaptation strategies for floods and droughts suggests a need for improved dissemination and application of climate information in these areas. Additionally, simplifying the presentation of climate information and implementing targeted educational and training programs for farmers could significantly improve their ability to understand and utilize this information effectively. The study further recommends that relevant authorities should consider providing irrigation facilities for farmers in the study area to engage in dry-season farming to counter the unpredictable rainfall patterns affecting conventional farming activities. This measure could increase climate-vulnerable communities' resilience to climate change and variability and consequently lead to food security in the region. Moreover, climate information providers ought to engage with farmers in their decision-making processes when developing climate utilization policies that impact farmers, as these climate-vulnerable groups face distinct primary barriers to utilizing climate information for adaptation.

This study contributes to the literature by highlighting the differential impact of climate information adoption on adaptation practices among farmers in various climate vulnerability groups in Ghana's Northern Region. It demonstrates that effective utilization of climate information can significantly reduce vulnerability. Policymakers and stakeholders in the Northern Region of Ghana and similar contexts must address the identified barriers to ensure the accessibility, relevance, applicability, and usability of climate information for all farmers. By doing so, they can reduce vulnerability and enhance the resilience of agricultural communities to climate change, ultimately contributing to sustainable development and food security in climate-vulnerable regions. Notwithstanding the contributions of this study to the body of knowledge and policy, its limitation emanates from the classifications of vulnerability based on districts rather than the individual farmers, given that, it is likely some farmers in most climate-vulnerable districts could be not or are less vulnerable to climate change. This study, therefore, suggests further research into individual farmers' level of vulnerability to climate change within climate-vulnerable districts in the northern region of Ghana.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the corresponding author, upon reasonable request.

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

IA: Conceptualization, Methodology, Investigation, Resources, Writing – original draft, Writing – review & editing. PA-A: Supervision, Writing – review & editing. MS: Supervision, Writing – review & editing. WA: Methodology, Supervision, Writing – review & editing. AS: Writing – review & editing. EE: Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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