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Climate Information Services Available to Farming Households in Northern Region, Ghana

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ABSTRACT: Climate information services can build the resilience of African farmers to address the increasing threats associated with climate change. This study used household surveys with 200 farmers and focus group discussions to identify the types of climate information services available to farming households in two selected districts (Tolon and Nanton) in the Northern Region of Ghana. The study also identified the dissemination channels and the barriers faced by farmers in their access and use of climate information services for building climate resilience in Ghanaian farming systems. Multinomial logistic regression analysis was used to evaluate the determinants of farmers' access to climate information services. Results show that 70% of the surveyed farmers had access to varied forms of climate information services. The most prevalent meteorological variables accessible to them were rainfall, temperature, and windstorms in the form of daily and weekly weather forecasts, with only very limited availability and use of seasonal climate forecasts. Radio, television, and advice from extension agents were reported as the major dissemination channels by study respondents. A majority of the farmers reported lack of communication devices, mistrust in weather and climate forecasts, and lack of visual representations in the forecasts as major barriers to access and use of climate information services. The results highlight the importance of timely and reliable access to climate information services in enhancing farmers' decision-making capacities and the need for training and recruitment of more extension agents to work with farmers on linking climate information services to targeted actions on crop and land management.

KEYWORDS: Climate change; Climate services; Decision-making; Resilience

1. Introduction

Climate change is having significant adverse effects including flooding, erratic rainfall patterns, seal level rise, droughts, soil erosion, and lower crop productivity on the African continent (Dube et al. 2016; Coulibaly et al. 2020). These effects exacerbate food insecurity and poverty and threaten the livelihoods of millions of people across Africa (Atiah et al. 2022). This has necessitated the search for solutions to moderate the effects of climate change across Africa (Pachauri et al. 2014).

An important step toward improving the ability to manage climate-related hazards is the timely availability and usage of climate information services (Vaughan and Dessai 2014; Antwi-Agyei et al. 2021a,b). Climate information services are the ways in which climate information is made available to and useful for decision-makers across different sectors and at different scales (WMO 2018). Climate information services provide institutions and people with timely, contextualized climate information to lessen climate-related risks as well as protect lives, properties, and livelihoods (Vaughan and Dessai 2014; Nkiaka et al. 2019).

Such services include weather forecasts and climate predictions. Weather forecasts predict the state of the atmosphere over a short period of time and is dependent on the initial state of the atmosphere, while climate prediction or climate forecast is an attempt to produce a most likely description or estimate of the actual evolution of the climate in the future, for example, at seasonal, interannual, or decadal time scales (Infrastructure for the European Network for Earth System Modelling 2020). While seasonal forecasts are routinely issued in some regions, climate predictions at longer time scales are still at an early research stage. There are a number of sectors including the agriculture, marine, aviation, forestry, and utility companies with their own specific needs for weather and seasonal forecasts. For instance, farmers (the end users investigated in this study) make farm management decisions including irrigation, application of fertilizers and pesticides, and drying of crops based on weather and seasonal forecasts (Antwi-Agyei et al. 2021a).

Climate information services have received considerable research attention in the last few years particularly across the Sahel (e.g., Dayamba et al. 2018; Ouedraogo et al. 2018; Ouédraogo et al. 2018; Diouf et al. 2019). Dayamba et al. (2018) found that the "participatory integrated climate services for agriculture" approach enabled farmers in Mali and Senegal to make strategic plans long before the season, based on their improved knowledge of local climate features. Ouédraogo et al. (2018) reported that the majority of cowpea and sesame farmers in northern Burkina Faso are

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willing to pay for climate information services including decadal climate information, seasonal climate forecasts, daily climate information, and agroadvisories. The authors also found that several socioeconomic and motivational factors including age, gender, education, and the awareness of farmers to climate information had higher effect on their willingness to pay for climate information services. Similarly, Diouf et al. (2019) revealed that the main factors affecting gendered access to climate information services in Senegal include farmers' perceptions and use of climate information services, ethnicity, and area of residence.

Despite the impressive body of knowledge, climate information services are generally inadequate and infrequent in sub-Saharan Africa (SSA) because the telecommunication networks used by majority of the national meteorological and hydrological services (NMHS) are insufficient, ineffective, and outmoded and thus hinder the efficient delivery of observations and products, particularly to rural areas (Dorsouma 2015; Harvey et al. 2019). Inadequate infrastructure is also a factor restricting the ability of sub-Saharan African NMHS to take full advantage of advances in available science and technology (Dorsouma 2015; Harvey et al. 2019). Hence, evidence on mainstreaming climate information services in agricultural systems in SSA is limited (Vincent et al. 2017), despite its potential to promote adaptation to climate change (Vaughan et al. 2016).

Consequently, many smallholder farmers in SSA remain largely reliant on indigenous knowledge to adapt to the changes in climate (Mugambiwa 2018; Baffour-Ata et al. 2021a). In particular, farmers in northern Ghana, which has been identified to be extremely vulnerable to the threats of changing climate (Antwi-Agyei et al. 2012; Klutse et al. 2020), continuously rely on their indigenous agroecological knowledge to make crop and land management decisions in relation to climate change (Baffour-Ata et al. 2021a).

To date, there has only been limited research conducted on climate information services in Ghana especially in the northern part of the country (e.g., Nyantakyi-Frimpong 2019; Antwi-Agyei et al. 2020; Partey et al. 2020; Antwi-Agyei et al. 2021a). For instance, Nyantakyi-Frimpong (2019) reported on several structural barriers (e.g., gender norms, patriarchal values) to acquiring climate information services by smallholder farmers in the Upper West Region of Ghana. Antwi-Agyei et al. (2020) revealed that access and desire to pay for climate information services were influenced by both individual and environmental specific factors including drought experience, farming experience, food insecurity, incentives from the government and social group membership in the Upper East Region of Ghana. Nonetheless, current climate information services available to improve agricultural production as well as the barriers in accessing them by different socioeconomic groups particularly with reference to agrarian households in the Northern Region of Ghana have been less explored.

This study addresses this research gap by identifying climate information services available to farming households in two selected districts (Tolon and Nanton) in the Northern Region of Ghana where food security is threatened by climate change. Specifically, the study sought to 1) identify the kinds of climate information available to farming households in the selected districts; 2) determine the dissemination channels of climate information services accessible to the farmers in the study districts; 3) determine the factors influencing farmers' access to climate information services; and 4) identify the barriers confronting farmers in their access and use of climate information services. Findings of the study are expected to provide useful information to assist policy makers in devising appropriate policies and interventions to make climate information services available to farmers.

2. Materials and methods

a. Description of study communities

The Northern Region of Ghana is the largest region in the country, covering 70 384 km^2 (Ghana Statistical Service 2014). The vegetation in the region consists predominantly of grassland, especially savannah with clusters of drought-resistant trees such as baobabs (*Adansonia digitata*) and acacias (*Acacia nilotica*). For climatic conditions, average annual rainfall ranges between 750 and 1050 mm, while temperatures vary between 14°C at night and 40°C during the day (Ghana Statistical Service 2014). The region records very hot temperatures, low amounts of rainfall and high rainfall variability and suffers from perennial flooding when there are heavy downpours (Owusu et al. 2016; Klutse et al. 2020). Despite these challenges, the region is characterized by poorly developed weather and climate alert systems that can help farmers plan for crop seasons and adopt better farming practices (Antwi-Agyei et al. 2021a).

Two major crop farming districts in the region (i.e., Tolon and Nanton) (Fig. 1) were purposively selected for this study due to their perceived increased rainfall variation and rising temperature trends (Nantui et al. 2012; Musah et al. 2013). Prior research has also highlighted both districts to exhibit high rainfall variability and increasing temperature trends (Baffour-Ata et al. 2021b). About 92% and 89% of the households in Tolon and Nanton districts are engaged in agriculture (Ghana Statistical Service 2014). A majority of the farmers in both districts are involved in crop farming, cultivating predominantly rice, millet, sorghum, groundnut, and maize (Ghana Statistical Service 2014). These crops are used to meet the basic food requirement of majority of the Ghanaian population (Ministry of Food and Agriculture 2016). However, Baffour-Ata et al. (2021b) revealed that climate variability (in annual rainfall, onset, cessation, number of dry days and temperature) has substantially affected the yields of those food crops in both Nanton and Tolon districts thereby threatening food security in the districts. With technical advice from the Director of the Ministry of Food and Agriculture (MoFA) in Tamale as well as agricultural extension officers in the two districts, two communities from each district were selected for the study based on their intensive farming activities. These communities were Nyankpala and Kasuliyili (Tolon district) and Zieng and Tampion (Nanton district) (Table 1).

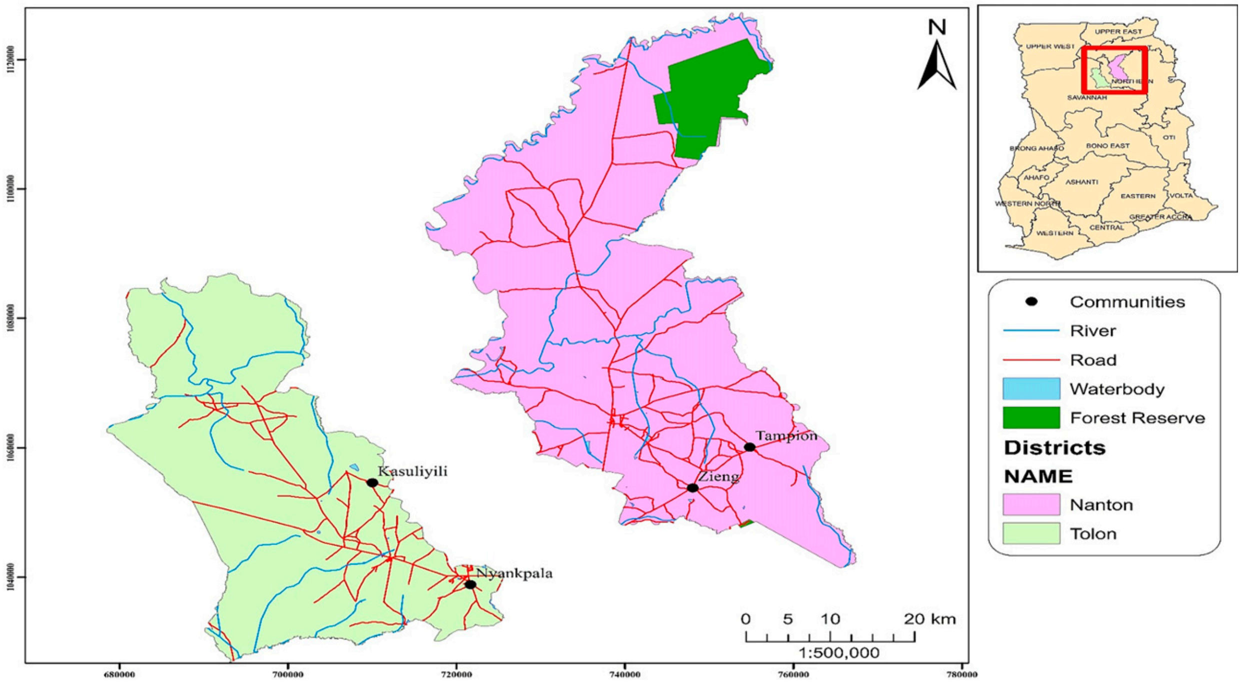

FIG. 1. Study districts showing the study communities.

b. Survey methods

Both qualitative and quantitative research methods comprising focus group discussions (FGD) and household surveys with 200 farming households were used in the four communities. For the household surveys, a set of closed-ended and open-ended questions were administered on a one-to-one basis to household heads (men or women) to determine the availability and their use of meteorological variables and climate information services. "Use" in this study was defined as a particular farm activity or operation driven by farmers' access to climate information services. Farmers were also asked about the dissemination channels for receiving climate information services and the barriers to their access and utilization. In each community, a maximum of 50 households were randomly selected using the fixed household method (Umulisa 2012). Fixed household method is a household sampling strategy where a predetermined number of households is selected from each sample community or village (Gambino and Nascimento Silva 2009). This was carried out to attain an expected sample size of 200 respondents. Using the lottery approach, each household in the community was assigned a number and later the numbers were drawn randomly from a box to select the samples. Questionnaires were administered in August 2019 in their local language (Dagbani). All respondents gave their informed consent for participating in the study.

One FGD was organized in each community to explore the meteorological variables, climate products and services

TABLE 1. Selected study districts in Northern Region. Source: Ghana Statistical Service (2014).

Feature	Tolon District	Nanton District
Selected communities	Nyankpala (9°23′32.19"N, 0°58′53.14"W); Kasuliyili (9°32′6.99"N, 1°5′11.91"W)	Zieng (9°31′33.76"N, 0°44′25.76"W); Tampion (9°34′57.23"N, 0°40′42.38"W)
No. of respondents	100	100
Climate	A single rainy season, starts in late April; dry season: November–March; daytime temperatures: 33°–39°C; mean annual rainfall: 950–1200 mm	Mean annual rainfall: 600–1000 mm; max temperature: As high as 42°C; min temperature: As low as 16°C
Agriculture	92.4% of households engaged in agriculture; 97.5% into crop farming; dominant crops: rice, maize, and groundnut; 74.1% are into livestock rearing	89.3% of households engaged in agriculture; 97.0% involved in crop farming; dominant crops: rice, groundnut, and maize; dominant animal reared in the district is poultry (chicken)
Economic activity status	80.5% of the population aged 15 years and older	77.6% of the population aged 15 years and older

available to the farmers, the dissemination channels of climate information services as well as the barriers to access and use of climate information services. About 10 participants were employed for the FGD and consisted of equivalent number of men and women in order to produce gender-specific information. In selecting the participants for the FGD, diverse socioeconomic groups and individuals who exhibited substantial awareness of the changing climate as well as a detailed agroecological comprehension of the farming communities were considered. The participants were encouraged to communicate diverse views yet also paying attention to other opinions. However, we ensured that all participants had equal opportunities for participation by promoting an open communication and a feedback system that facilitated constructive conversations.

c. Data analysis

Descriptive analyses were performed on the household survey data using Statistical Package for Social Sciences (SPSS) software, version 21 (Field 2013). Results were presented in a sex-disaggregated form due to the differential impacts of climate change on men and women. Another reason for presenting the results in a sex-disaggregated form instead of communities or districts was to avoid clustering effects that could have resulted in the loss of independence of observations. In this study, we categorized gender as men or women. The chi-square statistic was used to determine the association between gender and access to climate information. Qualitative data obtained from the FGDs were analyzed using thematic analysis (Castleberry and Nolen 2018). Multinomial logistic regression was used to assess the determinants of farmers' access to climate information services. This analytical tool is commonly used to explain the relationship between one nominal dependent variable and one or more independent variables (Starkweather and Moske 2011). Other authors have used this model to investigate the influence of socioeconomic factors on adaptation strategies (e.g., Legesse et al. 2013; Onubuogu and Esiobu 2014; Mugi-Ngenga et al. 2016). The model for this study is represented as

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_m X_m + \varepsilon, \qquad (1)$$

where Y is the dependent variable, β_0 is the coefficient of the constant term, β_1–β_m are the coefficients of the independent variables, X_1–X_m are the independent/explanatory variables, and ε is the error term.

The dependent variable in the model was access to climate information services. In agreement with previous studies (e.g., Ochieng et al. 2017; Muema et al. 2018; Antwi-Agyei et al. 2020) on determinants of access to climate information services, the explanatory variables included in the model were *farmer characteristics* (age of household head estimated in years, household size, that is, number of resident household members, highest education of household head, origin, that is, whether the farmer was an original inhabitant of the community or a migrant, farm income per season in Ghana cedis and farming experience defined as the practical knowledge, skill, or practice derived from participating in farming); *farm characteristics* (type of farmland tenure system); *institutional factors* (membership of an organization—equal to 1 if the household head belonged to a farmer group and 0 if otherwise; access to extension services—equal to 1 for farmers with access to extension services and 0 if otherwise); *household information devices* (access to radio—equals 1 if household head owned a radio and 0 if otherwise; access to television—equal to 1 if household head owned a television and 0 if otherwise; access to mobile telephone—equal to 1 if the household head owned a mobile telephone and 0 if otherwise). Thus, the independent or explanatory variables were age, household size, education, type of farmland tenure system, farming experience, access to extension services, access to household information devices (including radio, television, and mobile telephone), origin, farm income, and membership of an organization. In this study, we defined an extension service or agent as a person who offers technical advice on agriculture to farmers and also supplies them with the necessary inputs and services to support their agricultural production (FAO 1997). An extension agent provides information to farmers and passes to them new ideas developed by agricultural research stations (FAO 1997). Table 2 presents the variables included in the model and their hypothesized or expected signs.

Preceding the model evaluation, the independent variables were examined for multicollinearity, with the help of a contingency coefficient test to ascertain that two or more of the independent variables are not highly correlated with each other (Uddin et al. 2014).

3. Results

a. Socioeconomic characteristics of respondents

Women population constituted 42% of the respondents, with the rest being men (59%). In terms of age, majority of the respondents (62%) belonged to the age group of 21–40 years old, implying most of them were in the working age and hence fit for undertaking farming activities to make a living. About 69% of the respondents had nonformal education. A large number of the respondents (60%) were original inhabitants; people who had been born and lived in the selected communities up to the time of the surveys as opposed to the migrants who moved to the selected communities from other places in search of work or better living conditions. About 89% of the respondents owned farmlands, which most of them had acquired through inheritance (Table 3).

b. Farmers' access and use of climate information

Of the 200 respondents, about 70% of them had received information on meteorological variables (Table 4). For the purpose of this study, meteorological variables were discerned with regard to rainfall, temperature, windstorm, thunderstorm, and any other variable related to the climate. Of these variables, rainfall information was the most common (70%) followed by windstorm information (64%).

TABLE 2. Operational definition of variables. A plus sign indicates that independent variable may likely influence access and use of climate information services; a minus sign indicates the opposite.

	Measurement	Assumptions	Hypothesis
Dependent variable			
Access and use of climate information services			
Independent variables			
Age	Continuous (yr)	Young farmers would be more likely to access and use climate information services than older farmers because older farmers are less dependent on information and hence do not get in touch with innovations as immediate as their younger counterparts (Ouédraogo et al. 2018)	+
Household size	Continuous (no.)	Household size might not significantly influence farmers' access and use of climate information services	−
Education	Dummy (0 = no formal education; 1 = literate)	Education is anticipated to positively affect farmers' access to climate information; this is because more-educated farmers are able to amass knowledge and have better access to information	+
Type of farmland tenure system	Nominal	The type of farmland tenure system might not significantly influence farmers' access and use of climate information services	−
Farming experience	Categorical (yr)	Farming experience was likely to positively influence farmers' access to climate information services; this is because as farmers accumulate experience over time; they progressively switch from traditional agricultural technologies to improved technologies on the basis of observed performance and learning by doing (Ainembabazi and Mugisha 2014)	+
Access to extension services	Dummy (1 = if yes; 0 = otherwise)	Access to extension services is likely to positively influence farmers' access to climate information services; this is because farmers get better access to information from agricultural extension officers or agents (Antwi-Agyei and Stringer 2021)	+
Access to radio	Dummy (1 = if yes; 0 = otherwise)	It was hypothesized to positively affect farmers' access and use of climate information services; this is because farmers who own radios are knowledgeable and more aware of environmental issues and other factors that may affect their farming activities (Partey et al. 2020)	+
Access to mobile telephone	Dummy (1 = if yes; 0 = otherwise)	It was hypothesized to positively affect farmers' access and use of climate information services; this is because farmers who own mobile telephones are knowledgeable and more aware of environmental issues and other factors that may affect their farming activities (Partey et al. 2020)	+
Access to television	Dummy (1 = if yes; 0 = otherwise)	It was hypothesized to positively affect farmers' access and use of climate information services; this is because farmers who own televisions are knowledgeable and more aware of environmental issues and other factors that may affect their farming activities (Partey et al. 2020)	+
Origin	Dummy (1 = if original inhabitant; 0 = otherwise)	It was hypothesized to negatively affect access and use of climate information services; this is because original inhabitants are often less open to innovations and normally tend to rely on indigenous knowledge (Diouf et al. 2019)	−
Farm income	Continuous (Ghana cedis/year)	It was hypothesized to positively influence access and use of climate information services; this is because farm profit increases the probability of obtaining household information devices such as radio and television and that can increase the likelihood of access and use of climate information	+
Membership of an organization	Dummy (1 = if yes; 0 = otherwise)	It was anticipated to positively affect access and use of climate information services; this is because organized groups are likely to have technological innovations (Diouf et al. 2019)	+

TABLE 3. Sociodemographic characteristics of study respondents from the study districts.

Variables	Gender: Men (n = 117)	Gender: Women (n = 83)	Total (n = 200)
Age (yr)			
<20	2	0	2
21–40	68	55	123
41–60	39	21	60
>60	8	7	15
Education			
Nonformal education	70	68	138
Basic education	22	10	32
Secondary school	20	4	24
Tertiary education	5	1	6
Household size			
1–5 individuals	20	17	37
6–10 individuals	40	36	76
11–15 individuals	57	30	87
Origin			
Original inhabitant	87	33	120
Migrant	30	50	80
Type of farmland tenure system			
Rented	8	11	19
Owned	108	70	178
Buy	1	2	3
Farming experience (yr)			
<5	8	4	12
6–10	12	6	18
11–20	13	9	22
>20	84	64	148
Membership of an organization			
Yes	51	31	82
No	66	52	118
Access to radio			
Yes	84	48	132
No	33	35	68
Access to mobile telephone			
Yes	32	17	49
No	85	66	151
Access to television			
Yes	70	40	110
No	47	43	90
Farm income per season (GHS)			
<1000	102	80	182
Between 1000 and 2000	10	3	13
≥2000	5	0	5
Access to agricultural extension services			
Yes	79	52	131
No	38	31	69

Similarly, 59% of the respondents received temperature information.

The remaining farmers (30%) did not have access to meteorological variables but rather relied on indigenous to build their resilience and reduce their vulnerabilities to climate change. Some of the farmers talked about their personal experiences of handling the weather:

> I normally use the sun to predict whether it is going to rain or not. During very hot sunny days, I can easily predict that it is going to rain and normally my predictions do come true. I hardly listen to radio or watch television (TV) because they discuss unnecessary issues that will not benefit me. Hence, I always depend solely on the traditional knowledge I have acquired to determine the onset of the rains, the choice of crops to plant and the adaptation practices I must employ (Female farmer, Kasuliyili, August 2019).

> I have always consulted the fetish priest in my community to determine the nature of the season. I have absolute belief in him more than these forecasters who come on TV. I'm even not educated hence normally when the forecasters come on TV and speak their big English, I do not even understand (Male farmer, Tampion, August 2019).

> I have always used the appearance of some organisms such as the termites, scorpions, grasshoppers and army worms to predict the likelihood of the rains coming down. Sometimes, I even use the dominance of the birds in the sky to predict the onset of the rains. The appearance of the cattle egret and bee eater also tells me that, the rainfall season is very imminent (Male farmer, Zieng, August 2019).

Climate information products and services included daily, weekly, and monthly weather forecasts. Others included 10-day weather forecasts, seasonal forecasts, and weather warnings issued by the Ghana Meteorological Agency (GMet). About 51% of the respondents had access to weekly weather forecasts. This was closely followed by daily weather forecasts (49%). Thirty-seven percent of the respondents had access to seasonal forecasts. Similarly, about 37% of the respondents had access to weather warnings (Table 5).

Of the 140 respondents who received the products and services, the majority of them (65%) were satisfied, indicating they met their needs. Table 6 shows the focus group responses on how climate information services affect farming operations in the study communities. Some of the focus group participants reported these:

> I'm able to plan times for sowing, harvesting and other field activities based on the weekly weather forecasts I receive. As a result of this, I'm able to avoid negative effects of the weather and yield losses (Focus group participant, Nyankpala, August 2019).

> I can perform specific field operations such as determination of the right time to apply fertilizers on my farmland, irrigate as well as harvest due to the daily weather forecasts received via radio. Personally, I believe the daily weather forecasts meet my needs as a farmer. I listen to the radio every morning especially the news to know how the weather would be like before I leave for the farm (Focus group participant, Tampion, August 2019).

A small proportion of the respondents (6%) also reported that they did not meet their needs as farmers, although they

TABLE 4. Respondents' access to meteorological variables; χ^2 is the Pearson chi-square value.

Survey questions	Gender: Men (n = 117)	Women (n = 83)	Total (n = 200)	χ^2	p value
Do you receive rainfall information?					
Yes	85	54	139	0.632	0.426
Do you receive temperature information?					
Yes	71	46	117	0.167	0.683
Do you receive windstorm information?					
Yes	77	50	127	0.368	0.544
Do you receive thunderstorm information?					
Yes	64	45	109	1.529	0.216
Do you receive other information?					
Yes	4	1	5	0.755	0.385

received the climate information products and services. One of the focus group participants, for example, remarked:

> I normally receive the monthly weather forecasts but they do not come with any agro meteorological advisories hence I'm unable to provide myself with well-adapted guidance on the management of agro-climatic resources (Focus group participant, Zieng, August 2019).

c. *Farmers' sources of climate information services*

Farmers reported different channels for accessing climate information services including radio, television, mobile telephones, newspapers, short message service (SMS/text message), extension agents, community groups, and community leaders (Table 7). Majority of the respondents (66%) accessed the information through radio. This was followed by television (55%). About 52% of the respondents also accessed the information through extension agents. Moreover, about 12% of the respondents accessed the information through other means. For instance, two farmers reported:

> I also rely on other farmers and colleagues from different communities to get informed about how the weather would be like so as to help me prepare for the planting season or assist me in my farming decisions (Female farmer, Zieng, August 2019).

> Apart from community groups that mostly give me information about the weather or the climate, some of the non-governmental organizations (NGOs) through the organization of workshops and seminars do inform me about the onset date, cessation date and temperature forecast (Male farmer, Nyankpala, August 2019).

Gender and educational level of the farmers significantly influenced the farmers' sources of climate information services. For instance, gender affected farmers' access to climate information services through radio and newspaper ($p < 0.05$) (Table 7). A majority of the men (72%) accessed climate information services with radio as opposed to their female counterparts (58%). Similarly, more men (27%) used the newspaper to access climate information services relative to the women (10%). Educational level of the farmers affected farmers' access to climate information services via newspaper, television, and SMS significantly ($p < 0.05$) (Table 8).

TABLE 5. Respondents' access to climate information products and services; χ^2 is the Pearson chi-square value.

Survey questions	Gender: Men (n = 117)	Women (n = 83)	Total (n = 200)	χ^2	p value
Do you receive daily weather forecasts?					
Yes	55	42	97	2.979	0.084
Do you receive weekly weather forecasts?					
Yes	61	41	102	0.419	0.518
Do you receive monthly weather forecasts?					
Yes	24	12	36	0.561	0.454
Do you receive 10-day weather forecasts?					
Yes	11	6	17	0.168	0.682
Do you receive seasonal forecasts?					
Yes	50	23	73	3.213	0.073
Do you receive weather warnings?					
Yes	50	23	73	3.213	0.073
Are the products tailored to meet your needs?					
Yes	80	49	129	0.332	0.564

TABLE 6. Respondents' use of climate information services.

Examples of farm activities reported by the farmers	Meteorological variable used	Climate information products and services used
Timing of fertilizer application	Temperature, rainfall, and windstorms	Daily weather forecasts; weekly weather forecasts
Drying of crops	Temperature and humidity	Weekly weather forecasts; daily weather forecasts
Irrigation	Temperature and humidity	Daily weather forecasts
Preparation of farmland	Rainfall	Weekly weather forecasts; monthly weather forecasts
Harvesting of crops	Rainfall and temperature	Weekly weather forecasts; daily weather forecasts
Planting of crops	Temperature, rainfall, and thunderstorm	Weekly weather forecasts, seasonal forecasts, and monthly weather forecasts
Selection of crop varieties	Rainfall, temperature, and humidity	Seasonal forecasts; monthly weather forecasts
Adjusting planting dates	Rainfall and temperature	Seasonal forecasts; monthly weather forecasts
Pesticides application	Humidity, rainfall, temperature, and windstorms	Daily weather forecasts; weekly weather forecasts
Conserving water	Temperature, humidity, and rainfall	Monthly weather forecasts; 10-day weather forecasts
Protection of plants	Rainfall, thunderstorm, and windstorms	Weather warnings, daily weather forecasts, and weekly weather forecasts

d. Determinants of farmers' access to climate information services in the study communities

Regression results indicated that male farmers' access to climate information services were positively influenced by access to extension services ($B = 2.379$; $p = 0.000$), household information devices including radio ($B = 37.647$; $p = 0.000$) and mobile telephones ($B = 53.477$; $p = 0.002$). However, access to extension services ($B = 3.075$; $p = 0.000$) was the main determining factor in the female farmers' access to climate information services (Table 9).

e. Barriers to farmers' access and use of climate information services

Of the 200 respondents interviewed, a majority of the respondents (76%) reported lack of mobile telephones as the barrier in accessing climate information services (Table 10).

About 48% of the respondents bemoaned the lack of weather symbols or graphics in weather forecasts as a hindrance to their understanding of weather forecasts. This was also mentioned as a barrier in the FGDs. Furthermore, some of the respondents (35%) did not trust the weather or climate forecasts issued out by GMet. They asserted that sometimes they predict falsely and make it difficult to rely on the climate forecasts. About 32% of the respondents also stated that the climate information services received were too difficult for them to understand. This was highlighted in the focus group discussion during which one participant stated this:

> Most at times, the climate information services received via television are too difficult to understand. The meteorologists who come on television use technical terms and speak big English of which we do not understand. Sometimes, it is even boring listening and watching them (Focus group participant, Kasuliyili, August 2019).

Few of the respondents (18%) received the weather forecasts but were unable to change their decisions on the farm. One of the farmers emphasized this in one of the focus group discussions:

> I receive the climate information services on my phone via text messages but they do not change the things I do on the farm including irrigation and time to apply the fertilizers. So

TABLE 7. Farmers' sources of climate information services; χ^2 is the Pearson chi-square value. Boldface type indicates statistical significance at the 95% level or better.

Sources	Gender: Men (n = 117)	Gender: Women (n = 83)	Total (n = 200)	χ^2	p value
Radio	84	48	132	4.752	**0.029**
Mobile telephone	32	17	49	0.478	0.489
Newspaper	31	8	39	7.441	**0.006**
Television	70	40	110	1.056	0.304
SMS	11	3	14	1.929	0.165
Extension agents	65	38	103	0.463	0.496
Community groups	36	22	58	0.017	0.896
Community leaders	23	10	33	1.246	0.264
Others	18	5	23	3.291	0.070

TABLE 8. Link between farmers' education and their sources of climate information services; χ^2 is the Pearson chi-square value. Boldface type indicates statistical significance at the 95% level or better.

	Educational level						
Sources	No formal	Basic	Secondary	Tertiary	Total (n = 200)	χ^2	p value
Radio	87	24	17	4	132	2.044	0.563
Mobile telephone	31	8	7	3	49	1.661	0.646
Newspaper	14	11	10	4	39	24.191	**0.000**
Television	68	24	13	5	110	7.491	**0.005**
SMS	6	3	2	3	14	15.2561	**0.002**
Extension agents	67	20	12	4	103	1.105	0.776
Community groups	42	7	6	3	58	3.371	0.292
Community leaders	20	6	5	2	33	1.100	0.777
Others	14	3	3	3	23	7.370	0.061

far, I have not encountered any challenge in sticking to this decision. The reason why I do that is because, sometimes they say, it will rain but it doesn't rain hence why should I change the things I do on the farm based on the climate information services received? (Focus group participant, Tampion, August 2019).

4. Discussion

a. Farmers' access and use of climate information services

Results indicated that most of the farmers had access to a variety of information on meteorological variables and climate products and services (Tables 4 and 5). This is in line with previous studies (Oyekale 2015; Antwi-Agyei et al. 2021a) suggesting that access, use, and importance of climate information services by smallholder farmers in developing countries typically reveal an awareness level and interest in using climate information services. Farmers still tend to rely on the daily and weekly weather forecasts to make important farming decisions (Zongo et al. 2015; Antwi-Agyei et al. 2021a). The daily and weekly forecasts provide useful information to help with decisions on the farm including irrigation, application of fertilizers, and drying of crops (Table 6). Prolonged periods of dryness can ruin cereals including maize (Bradford et al. 2018).

Few of the respondents received seasonal forecasts. This may be attributed to the fact that the farmers encounter a "digital divide" in the access to seasonal forecasts as a result of resources, theme, and awareness of particular needs (Bernardi 2011). Digital divide in this context refers to the

TABLE 9. Factors influencing farmers' access to climate information services. Boldface type indicates statistical significance at the 95% level or better.

	Gender			
	Men		Women	
Variable	B	p value	B	p value
Age	−0.613	0.166	−0.338	0.489
Household size	0.125	0.724	0.436	0.322
Education	−0.061	0.832	0.980	0.138
Type of farmland tenure system	−0.016	0.984	0.233	0.755
Years of farming experience	−0.256	0.319	1.094	0.611
Access to extension services	2.379	**0.000**	3.075	**0.000**
Access to radio	37.647	**0.000**	21.153	0.994
Access to television	17.311	0.150	19.704	0.995
Access to mobile telephones	53.477	**0.002**	19.850	0.625
Origin	16.032	0.998	−13.349	0.405
Farm income	−0.393	0.999	−28.895	1.000
Membership of an organization	0.540	0.999	−13.349	0.322
Model fit test	χ^2	Significance	−2 log likelihood	Percentage correctness
Test for overall model	61.138	0.000	137.093	78.000
Goodness of fit				
Pearson test	114.397	0.250		
Deviance test	105.154	0.477		

TABLE 10. Barriers to farmers' access and use of climate information services; χ^2 is the Pearson chi-square value.

Barriers	Gender		Total (n = 200)	χ^2	p value
	Men (n = 117)	Women (n = 83)			
Lack of mobile telephones	85	66	151	1.238	0.266
Lack of television	47	43	90	2.656	0.103
Lack of radio	40	28	68	0.004	0.947
The information is difficult to understand (the use of technical terms)	38	25	63	0.058	0.809
It is not clear how this information can be used to help with farming	37	28	65	0.099	0.753
I receive weather forecasts but I am unable to change things based on them	20	15	35	0.032	0.858
I do not trust weather and climate forecasts	41	28	69	0.037	0.848
Lack of weather symbols (graphics) in the forecast	57	39	96	0.058	0.809

gap between demographics and regions that have access to modern information and communications technology, and those that do not or have restricted access (Van Dijk 2017). This technology includes the telephone, television, personal computers, and the internet. Greater access to climate information services can influence several changes including the use of pesticides and fertilizers, harvesting of crops, and selection of crop varieties across farming systems (Mudombi and Nhamo 2014; Ouédraogo et al. 2018; Tarchiani et al. 2021). Nonetheless, this potential still remains unexploited because current climate information products and services did not meet the needs of some farmers (Table 5). Therefore, significant utilization of climate information services demands knowledge within the farming communities of what climate information services is accessible and how they could be used to make important crop choices and land management decisions. This requires closer collaboration between GMet and MoFA along with teaching climate researchers to appreciate farmers' needs and training farmers to comprehend, request, and utilize climate information services (Onyango et al. 2014).

Structure of seasonal forecasts must consider downscaling and local translation and precision communicated in straightforward, probabilistic terms as well as explanation of outcomes with regard to farming effects and farm management consequences (Hansen et al. 2011; Bernardi 2011). In addition, it would be useful for farmers if GMet shared with them an indication of how accurate and reliable seasonal forecasts have, or have not, been in the past years.

b. *Farmers' sources of climate information services*

The results showed that the majority of farmers accessed climate information services on radio (Table 7), reflecting its widespread use and cost-effectiveness as a communication medium in addition to its portability and presentation. This finding compares favorably to previous studies that revealed radio as the most common medium for the dissemination of climate information services in SSA (Diouf et al. 2019; Antwi-Agyei et al. 2021a). FGDs revealed that the climate information services disseminated through radio easily get to the farmers because it is mostly communicated in their local language. Radio stations in most Ghanaian communities now incorporate daily weather forecasts in their news programs and to a greater extent, some organize in-depth, proper weather segments (Anaman et al. 2017).

Results indicated that gender significantly influenced farmers' access to climate information services through radio (Table 7). Most of the male farmers accessed climate information through radio as opposed to the women (Table 7). This may be attributed to the fact that men tend to own and control capital assets including radio in households in Ghana. This observation corroborates a previous study conducted in the Upper East Region of Ghana (Antwi-Agyei et al. 2020).

The importance of television as a medium for receiving climate information services stems from the numerous TV stations operating across Ghana that deliver forecasts and corresponding information as segment of their daily news programs. Extension agents were also considered important source of climate information services in the study communities (Table 7) due to their comprehensive field experience and technical know-how. This agrees with previous studies conducted in Malawi and Ghana indicating that extension agents are heavily taken into account when disseminating climate information services to farmers (Coulibaly et al. 2015; Nyantakyi-Frimpong 2019). Though the farmers deemed extension officers as an important source of climate information services, they bemoaned the low numbers of such agents in the study communities that generally affect their reliability in disseminating climate information services.

Although mobile telephones, community leaders, community groups, SMS, newspaper, and other sources including workshops and conferences were rarely used to access climate information services (Table 7), they were still available as alternative channels to farmers in the study communities. For instance, the National Telecommunications Company provides mobile services and ensures successful transmission of climate information services to farmers in Ghana (Partey et al. 2019). Vodafone Ghana subscribes all farmers who apply to receive climate information services through the public–private partnership to its network of farmers called the "Vodafone Farmers Club" (VFC). Community leaders and community groups were termed as "old fashioned" in the focus group discussions but established to be relatively productive because they notify farmers of impending weather hazards such as floods.

c. Determinants of farmers' access to climate information services in Northern Region

Access to extension agents influenced the farmers' access to climate information services (Table 9), evidenced by the large number of both men and women who accessed extension services (refer to Table 3). Therefore, when the extension agents get climate information services, it is expected that they will provide the information to the farmers as part of their roles and responsibilities (Maponya and Mpandeli 2013; Antwi-Agyei and Stringer 2021).

Access to household information devices was a significant determinant of male farmers' access to climate information services. This may be due to the fact that male farmers tend to own these gadgets and have control over available funds to buy mobile telephones (Antwi-Agyei et al. 2020; Partey et al. 2020). This finding compares favorably to earlier studies including Antwi-Agyei et al. (2020) and Partey et al. (2020) conducted in Upper East and Upper West Regions of Ghana suggesting that access to household communication devices including radio and mobile telephone enhances male farmers' access to climate information services as opposed to their female counterparts.

Age, education, household size, type of farmland tenure system, origin, farm income, and membership of an organization were nonsignificant predictors in the regression model. This contradicts the findings of previous studies (Diouf et al. 2019; Antwi-Agyei et al. 2020) indicating that age, education, and household size had significant influence on farmers' access to climate information services. For instance, Antwi-Agyei et al. (2020) argued that age is an important correlate of farming experience; older farmers have substantial experience in farming practices and have also profited from accumulated financial resources to facilitate certain adaptation actions including eagerness to pay for climate information services. Also, education was a nonsignificant predictor in this model, and this could be due to the low number of literate farmers in the study communities (Table 3). Household size was also a nonsignificant determinant possibly due to the fact that large-sized households are compelled to redirect parts of their labor force to off-farm activities in an attempt to receive income so as to ease the consumption pressure (Legesse et al. 2013). Origin also did not significantly influence farmers' access to climate information services. The possible explanation could be that original inhabitants are often less open to innovations and normally tend to rely on indigenous knowledge (Diouf et al. 2019). Moreover, the ownership or access to household information devices such as radio or mobile telephones is not dependent on the origin of the farmer.

A possible reason for farm income not being a significant predictor could be that the farmers with high income are likely to pay for climate information services than farmers with lower incomes as suggested by a previous study (Antwi-Agyei et al. 2020). This study has also revealed that the majority of farmers earned an income less than GHS 1000 (USD 163.27) annually (Table 3) in the study communities indicating the unwillingness of the majority of the farmers to pay to access and use climate information services. Farmers' membership of a social group or organization enhances social networks and improves communication and discussions of new agricultural technologies (Deressa et al. 2008; Muema et al. 2018). However, the farmers' membership in an organization did not significantly affect their access to climate information services, and this could be due to the high number of farmers who did not belong to an organization in the study communities (Table 3).

d. Barriers to farmers' access and use of climate information services

Absence of household information devices including radios and televisions as well as mobile telephones for receiving climate information services has been shown to limit the accessibility to climate information (Nkiaka et al. 2019). For instance, Caine et al. (2015) and Magesa (2015) posited that mobile telephones are more appropriate to provide helpful up-to-date weather forecasts. These views are supported by the results of the current study, which revealed the lack of mobile telephones as the main barrier to farmers' access and utilization of climate information services in the study area (Table 10). However, the few farmers who owned mobile telephones and accessed the information through them bemoaned, in the focus group discussions, of some challenges including poor network coverage, technical nature of the information, intermittent electricity supply for charging their telephones, and high cost of accessing the information.

Results also highlighted mistrust, poor understanding, and uncertainty in the forecasts as limitations to the use of climate information services. The respondents highlighted false alarms as a major reason for mistrust in the forecasts. Low comprehension of the forecasts was due to the information containing technical terms that were not clearly explained by the forecasters. Uncertainty in the forecasts was attributed to the forecasts not covering the places of interest (Nkiaka et al. 2020). These barriers share similarity with previous studies conducted in SSA (see Onyango et al. 2014; Ochieng et al. 2017; Nkiaka et al. 2019).

To build trust among farmers, it is vital for forecasters to be open and honest about the reliability or skill of past forecasts and the complexity of forecasting, so that farmers can weigh up how much to rely on them. Another reason for the need for transparency and openness by forecasters is that farmers are impacted by the consequences of the decisions and choices that they make particularly with respect to yields, income, and food availability. Transparency and credibility may rely on improved communication and more careful use of language, particularly where the language is translated from English into local languages. Important is that impact-based forecasts (IBF) must be included as a regular forecast activity (Nkiaka et al. 2020). Impact-based forecasting provides information on the level of risk a hazard poses to a specific area. Impact-based forecasts and warnings provide an assessment of the forecast weather or climate hazard and an assessment of the possible impacts, including when, where and how likely the impacts are (WMO 2015). Due to the significant socioeconomic impacts of floods, strong winds and droughts on Ghanaian farmers, climate scientists need to highlight the formulation and application of IBF for these occurrences (Nkiaka et al. 2020).

5. Conclusions and management implications

The study identified the current climate information services available to farmers in the Northern Region of Ghana for their resilience building and adaptation planning. Results showed that, most of the farmers accessed information on rainfall, temperature, and windstorm indicating the crucial nature of these variables to agricultural production particularly in the context of climate change. Majority of the farmers also had access to weekly and daily weather forecasts via radio, television, and extension agents. This indicates that weather information is more accessible to the farmers in northern Ghana than seasonal forecasts and other forms of climate information services. Gender and education significantly influenced farmers' sources of climate information services.

The study also revealed that farmers' access to climate information services was influenced by their access to extension services. However, access to radio and mobile telephones influenced male farmers' access to climate information services as well. This was attributed to the fact that male farmers tend to have control over household financial resources to be able to purchase these household information devices relative to the female farmers. Absence of household information gadgets including mobile telephones, lack of trust in the climate forecasts, improper language use, and low literacy rates were reported as major barriers to the farmers' access and use of climate information services.

These findings indicate the need for a national framework for climate services to guide the communication of climate information to end users particularly farmers in northern Ghana including exploring the diverse dissemination channels that would address the barriers confronting farming households in their access and use of climate information services. This framework will assist GMet and other partnering institutions including MoFA and Environmental Protection Agency (EPA) at the national level engaged under the five pillars of the Global Framework for Climate Services. Such a national framework will coordinate the institutions and enable them to work together, to codesign, coproduce, communicate, deliver, and utilize climate information services for decision-making in climate-sensitive socioeconomic sectors including agriculture, energy, and forestry.

The framework could also enhance the mainstreaming of climate information services into sectoral plans and national policies for resilient agricultural systems. It is also recommended that GMet creates a platform where they can solicit for feedbacks from users particularly farmers on their weather and climate forecasts. This would incentivize GMet to be more transparent about forecast accuracy in the country. Ameliorating the challenges farmers face in accessing climate information services has the potential to contribute to building their adaptive capacities and coping mechanisms to the risks associated with climate change and help increase food production in northern Ghana. Extensions services are vital in strengthening the adaptive capacity of farmers to tackle climate risks on agriculture. Therefore, building the capacity of agricultural extension agents including enhancing communication skills and developing practical skills as well as the utilization of information communication technologies should be prioritized through regular capacity building workshops.

6. Limitations of the study

Other variables including ethnolinguistic group, religion, and diversity of activities of farmers should have been included in the model to determine whether they influence their access to climate information services. However, such variables were not taken from the field.

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