

Research article

Smallholder farmers access to climate information and climate smart adaptation practices in the northern region of Ghana



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ARTICLE INFO

Keywords:

Smallholder farmers
Climate information access
Climate smart adaptation practices
Bivariate probit model

ABSTRACT

In Ghana over 70% of people who are employed in the agricultural sector are smallholder farmers' living in less developed communities engaging in rudimentary agriculture. Climate change poses a serious threat to smallholder farmers which impacts on their income, food security and wellbeing. Climate information could be a vital resort for smallholder farmers' adoption of climate smart adaptation strategies in order to better manage climate risk. This study is aimed at investigating factors that influence smallholder farmers' joint decision to access climate information as well as adopt climate smart adaptation practices in the Northern Region. Data used was collected from a cross-sectional survey of 475 smallholder farmers'. The joint decision of smallholder farmers to access climate information and also adopt climate smart adaptation practices was analysed by using bivariate probit regression model. The econometric estimates reveal that age, household size, farm income, access to agricultural extension services and assets are the key drivers of smallholder farmers joint decision to access climate information and adopt climate smart adaption practices. Government, district assemblies and non governmental organisations supporting smallholder farmers' adoption of climate smart adaptation strategies in order to overcome climate risk should also assist in the accessibility of climate information since they complement one another. Smallholder farmers literacy and knowledge level should be increased through non-formal and informal educational programmes, and extension education using the farmer-field schools method.

1. Introduction

There are several researches conducted across the globe over the past few decades that provide the scientific evidence that both physical and biological systems have been impacted by climate change in all the continents. It is clearly apparent from literature that change in climate has worsen pests and diseases pressure in agricultural crops globally as a result of increased temperature (Heeb et al., 2019; Matzrafi, 2019; Pathak et al., 2021). Climate change related natural disasters have caused economic losses in tuned of USD 225 billion across the world in 2018. About 95% of these losses are through the incidences of cyclones, floods and drought which is directly related to climate change put pressure on agricultural lands (Arora, 2019; Schmidt et al., 2021). Climate related disaster also includes rising level of the sea, loss of biodiversity, glacial retreat, increasing temperature, land degradation, desertification and ocean acidification (Matias, 2017; Schmidt et al., 2021; UNFCCC, 2012).

Climate change also possess a global challenge directly affecting human beings and their socio-economic day to day activities including health, livelihood, income, food security and wellbeing (Abdul-Razak and Kruse, 2017; Adeagbo et al., 2021; Ayanlade et al., 2017; Norsida et al., 2018). It is also indicated that climate change has a negative effect on the livelihoods of people, agricultural production, fresh water supply as well as other essential natural resources that are very vital for the survival for human (IPCC, 2013). Over the past three decades' climate change has globally contributed to agricultural production decline by 1–5% per decade (Porter et al., 2014). The effects of climate change are also predicted to extremely manifest in serious consequences globally for the agricultural sector in both developed and underdeveloped nations as well as rich and poor persons who are also affected by its impacts. Also most underdeveloped nations including tropical, sub-tropical regions and the poor are to a greater extent vulnerable to the general impact of climate change (Abdul-Razak and Kruse, 2017; Adger et al., 2003; Ayanlade

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<https://doi.org/10.1016/j.heliyon.2022.e09513>

Received 23 July 2021; Received in revised form 2 February 2022; Accepted 16 May 2022

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et al., 2017; Dewi, 2009; Thornton, 2012). For over the past 100 years the earth's climate has warmed on the average by about 0.7 °C between the decades of the 1990s and 2000s being recorded as the warmest period in the instrumental records (Watson, 2008).

Climate change predictions indicate that there is the likelihood for Africa to undergo a significant change in climate as there will be the occurrence of extremely warm and dry weather in the subtropical areas with slight increment in rainfall in the tropics (Abegaz and Wims, 2015; Adebisi-Adelani and Oyesola, 2014; Ayanlade et al., 2017; Christensen et al., 2007). Also climate change models project that the effect of climate change will be greater in many parts of Africa (Ayanlade et al., 2017; Christensen et al., 2007; Sylla et al., 2016). Climate variability with regards to temperature as well as rainfall raises a lot of concerns about the food situation in African which is as a result of less developed irrigation schemes with minimal conservation agricultural adoption amid pressing constraints of agricultural development (Waha et al., 2013). There is currently a sense of urgency being attached to the need of acting now in the face of threats from climate change therefore accounting for high expectations placed on provision of climate information (IPCC, 2014). Since it was finally agreed by the scientific community that change in climate is real and it is already impacting different aspects of human life in Africa, policy efforts have been oriented towards reinforcing climate information dissemination to smallholder farmers in these high risk regions to adapt to the threats of climate change.

Studies recently conducted have established that West Africa belongs to part of the globe that is very vulnerable to the effects of climate change as results of a combination of low adaptive capacity and exposure (IPCC, 2014a; Niang et al., 2014; Serdeczny et al., 2017). In both the low and high emission scenarios, temperature within the West African sub region will approximately increase to 1.5 °C and 5 °C respectively by 2050 which will be above the 1951–1980 baseline and it is also projected to remain the same till the end of the century (Jalloh et al., 2013; Serdeczny et al., 2017). The temperature increases will aggravate the already very high variability of rainfall patterns in the area. Consequently, it will affect the availability of water resources, the services of ecosystem and agricultural production (Aich et al., 2014; Rosenzweig et al., 2014).

Ghana is one of the countries in the West African sub region which is very vulnerable to the adverse effect of climate change because of its overdependence on rainfed agricultural systems and natural resources based livelihood strategies. Research conducted indicates that Ghana will be experiencing high temperature, suffer very intense droughts and unpredictable rainfall patterns which will make crop and animal production very less resilient, which will definitely threaten the accomplishment of the Sustainable Development Goals specifically those associated with Goal Two (Food Security) and Goal One (Poverty Eradication) which will further perpetuate the existent households that are already suffering from climate vulnerability and poverty (Chris, 2007; Antwi-Agyei et al., 2012; Antwi-Agyei et al., 2021; Antwi-Agyei et al., 2012; Asante and Amuakwa-Mensah, 2015; Christensen et al., 2007).

In Ghana about 40% of the population is employed in the agricultural sector (WB, 2018). Slightly over 70% of the people employed in the agricultural sector are smallholders living in rural areas engaging in rudimentary agriculture (WB, 2018). The contribution of agriculture to employment nonetheless continuously declined to 18.9%, from 31.2% in 2005 (GSS, 2016). Ghana is currently experiencing erratic and unpredictable rainfall patterns and levels with rising temperature (Ndamani and Watanabe, 2014). Ghana's agricultural production system is preponderantly dependent on rainfall where fortunes of smallholder farmers are dependent on year to year rainfall patterns. As a result climate variability is able to take a devastating toll on animal and crop production per year (GSS, 2010). The onset and cessation dates of the rainy season is enough prove for low yields crop production in Ghana. Available statistics shows that Ghana has experienced a temperature rise of about 1 °C over three decades (1970–2000) now (Abdul-Rahaman and Owusu-Sekyere, 2017; EPA, 2015).

In northern region which is part of the driest savannah ecological zone, experiences increasing number of floods, droughts, and bushfires which heavily affect nature and humans (Abdul-Razak and Kruse, 2017; Akudugu and Alhassan, 2012; Dazé, 2013). It has been ascertained that it is one of the vulnerable and most exposed to climate change and variability in Ghana (Etwire et al., 2013; Stanturf et al., 2011). Millions of smallholder farmers encounter the impact of climate change with very minimum livelihood options because they are already marginalized, poor and mostly rely on nature for income and food (Frank and Penrose Buckley, 2012; Morton, 2007). The dominant economic activity in northern region is rain-fed agriculture (Antwi-Agyei et al., 2012), which to a great extent relies on a single and already modified pattern of rainy season (Abdul-Razak and Kruse, 2017).

In Ghana, more efforts have been made by the government, international organizations and business entities to promote the access and utilization of climate change communicated information to mitigate and adapt climate change impacts in most of the agro-ecological zones (FAO, 2014; MOFA, 2015). The Adventist Development and Relief Agency and Farm Radio International, for example, have pushed the use of mobile phones and radios for uptake of weather information while Care Gulf Agriculture and Natural Resources (CGGANR) advanced the establishment of farmer organization which encouraged farmer-to-farmer knowledge sharing. Also German Development Cooperation (GIZ) in collaboration with Ministry of Food and Agriculture established about 13 community based meteorological agencies to provide farmers with direct and prompt weather information (ECASARD, 2013; MOFA, 2015).

Smallholder farmers in Northern region are more vulnerable to the impacts of climate because of the joined effects of their high dependence on rain-fed agriculture, high poverty levels and poor access to resources and services. The region has suffered from lack of attention and investment by central government resulting to less development of infrastructure and other services that can support the enhancement of livelihood and also build the resilience of smallholder farmers. The biggest climate change related hazards faced by this smallholder farmers are droughts, floods and storms that come with heavy rains and strong winds (Care International, 2014).

The smallholder farmers in the Northern region are not only confronted with climatic stressors (such as rainfall variability, high temperatures, lack of rainfall and drought) but also non climatic stressors (such as socioeconomic and political factors that includes ethnicity, class, historical inequalities in access to capital resources, poverty, lack of credit facilities, high cost of inputs, lack of electricity, lack of irrigation facilities, bad roads inadequate agricultural equipment, etc.) which compound the vulnerabilities of smallholder farmers households (Antwi-Agyei et al., 2017; Bennett et al., 2015; McCubbin et al., 2015; Tschakert, 2007; Vásquez-León et al., 2003).

Nevertheless literature indicates that smallholder farmers timely improved access to climate information enable them to maintain productivity and also establish resilient systems of agriculture in the face of variable rainfall pattern (Hansen et al., 2019; Jones et al., 2015; Singh et al., 2018). Useful climate information is climate forecast that are accompanied by some agronomic advice that is meaningful for smallholder farmers to use for their farm management decisions in order to offset the risk of climate change (Dilling and Lemos, 2011; Nkiaka et al., 2019). Also any climate information that smallholder can easily understand and use to address the threats posed by climate change are considered useful climate information (Muema et al., 2018).

Availability, access to and ability to utilize climate change information is a serious challenge to smallholder farmers (Dinku et al., 2014). Apparently access to useful and useable climate change information to smallholder farmers is considered a significant step in the direction of building their climate resilience, reduced their risk and potential cost effective way of adapting to climate change (Goddard, 2016; Street, 2016). Climate information that is reliable equips smallholder farmers' environmental knowledge that enable them to predict risk which help them to overcome knowledge constraints earlier in time (Adger et al.,

2005; Adger et al., 2009; Rosenzweig and Udry, 2013). These information received by the smallholder farmers' assist them to decide the kind of agricultural technologies as well as the adaptation mechanisms that are useful enough to respond to weather variability and climate change (Hansen et al., 2007; Ziervogel and Ericksen, 2010). It has become very crucial in the South for the need to develop effective mitigation and adaptation strategies in order to secure livelihoods and community development. Communication is the most vital factor that can be used to advance effectively a successful mitigation and adaptation strategy. A critical element in promoting effective and successful adaptation and mitigation strategies is communication. However, in order to successfully communicate about climate change and its suitable strategies for responding to it, it is necessary to understand and acknowledge how people from various backgrounds think about, interpret, and discuss its drivers and implications (Anna et al., 2010). Research conducted previously reveals that farmers' perspectives on adjusting to climate variability are influenced by the trust in the source of information, values, beliefs, personal experiences, opinions and perceived risks rather than only the scientific facts (Arbuckle et al., 2015). The study conducted by (Cherotich et al., 2012) indicated that different routes are utilized to transmit climatic information to farmers, and that men and women have distinct preferences when it comes to receiving climate change information. Radio, television, extension officers, and face-to-face contact are some of the available techniques for delivering information to smallholder farmers (Churi et al., 2012). Moreover (Cherotich et al., 2012; Churi et al., 2012), indicated that women favoured the use of radio, whereas the elderly preferred indigenous knowledge from their own localities.

Most of the studies done in Northern Region and Ghana as a whole are largely centered on perception of climate change and adaption techniques for climate change (Akudugu et al., 2012; Al-Hassan et al., 2013; Armah et al., 2011; Asante, Boakyee, Egyir and Jatoo, 2012; Bawakyille-nuo et al., 2016; Laube et al., 2012; Nantui et al., 2012; Nii Ardey Codjoe and Owusu, 2011; Quayee, 2008; Sarpong and Anyidoho, 2012; Wossen et al., 2014; Yaro, 2013). Nevertheless, there appear to be no clear

research done on how access to information on climate change influences smallholder farmers adoption of climate smart adaptation practices in Ghana. Since this gap hasn't been looked into clearly in the body of knowledge, therefore studying the determinants of smallholder farmers' successful joint decision to access climate information and adopt climate smart adaptation practices is a noteworthy research effort.

2. Methodology

2.1. Study design and area

The research used a quantitative method with a cross-sectional investigation approach where primary data from households in the study area was obtained. The cross-sectional sample survey method was used because the study mainly sought to determine the influencing factors of the smallholder farmers joint decision to access climate information and adopt climate smart adaptation practices. The study employed structured questionnaire (Creswell and Creswell, 2017).

This research was carried out in Ghana's Northern Region. The study area lies approximately between 9°29'59.99" N -1°00'0.00" W and is the largest among the sixteen regions which covers an area of about 70384 square kilometres or 31 % of Ghana's land area until the creation of Savannah and North East regions from it. Tamale is the capital of Northern region. Figure 1 shows a map of the research area. Northern Region is much drier with vegetation consisting predominantly of grassland especially savanna and also cluster of baobab and acacia trees that are drought-resistant. The dry season of the region falls between January and March while the wet season falls between July and December with an annual rainfall average falling between 750 to 1050 mm (30–40 inches) as showed in Figure 2 below. In addition the hot harmattan winds from the sahara blows between December and February. Usually the temperature of the region varies between 14 °C (59 °F) at night and 40 °C (104 °F) during the day. Agriculture employs more than 75% of the people in the Northern Region. More than 75 % of the people in Northern Region are involved in agriculture(GSS, 2014).

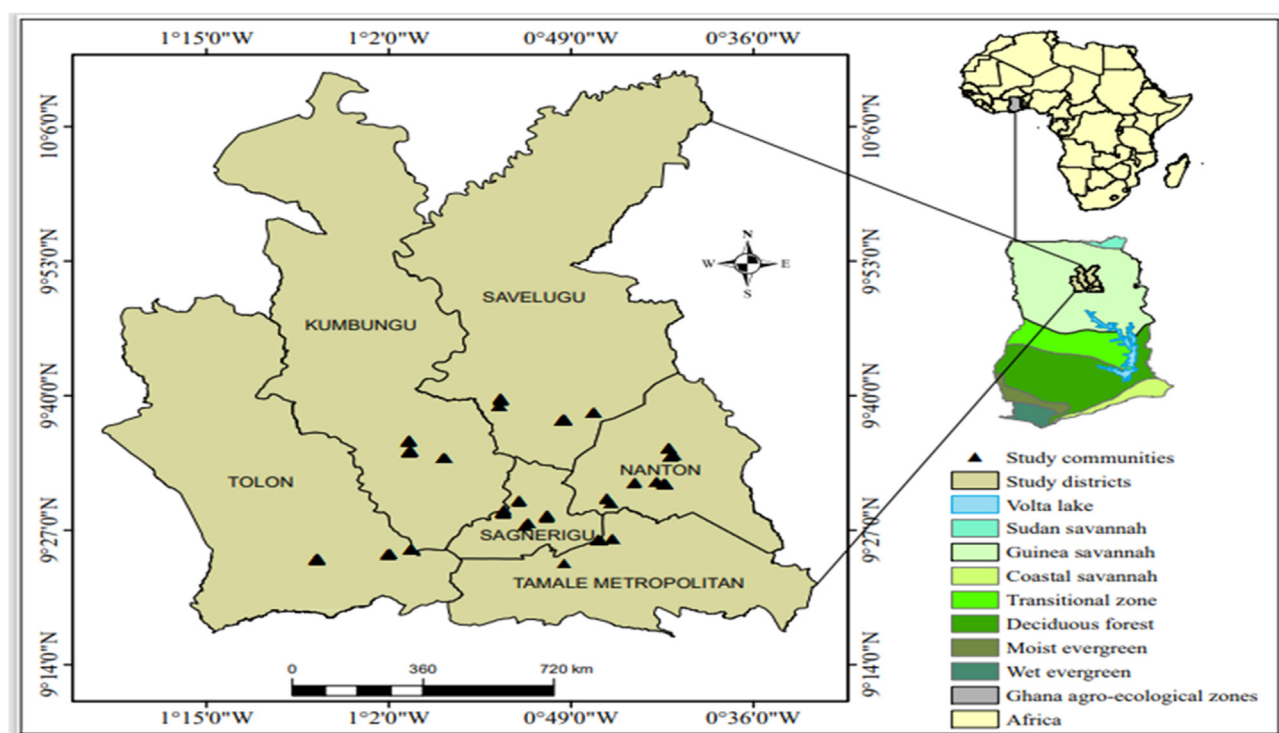


Figure 1. Map of the study area.

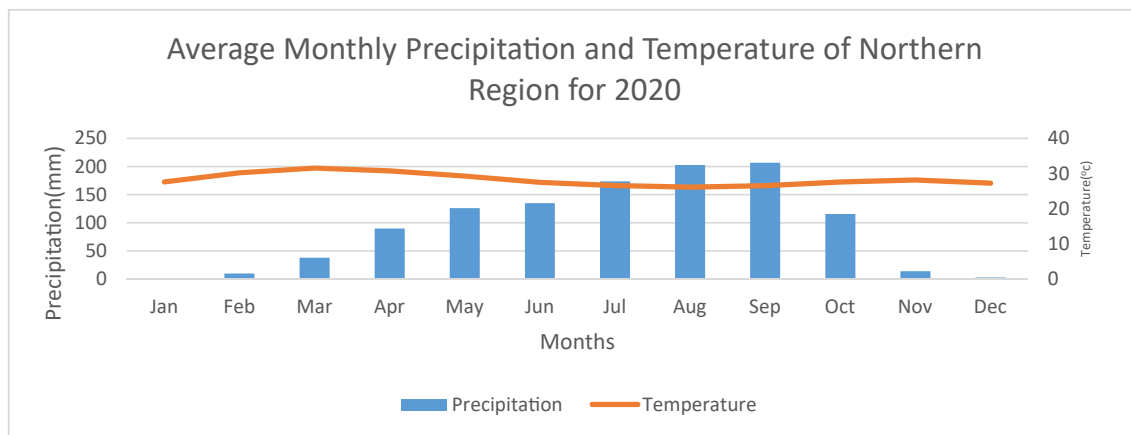


Figure 2. Average monthly precipitation and temperature of northern region for 2020.

2.2. Sampling, sampling technique, data collection and analysis

The population of this study is smallholder farmers in the northern region. Multistage sampling technique was used for the purpose of this study. Metropolitan, Municipal and District Assemblies (MMDAs) in the study area were sampled using simple random sampling method. One community each in each of the MMDAs was also selected using simple random sampling technique. Lastly one-fifth of population of smallholder farmers was selected using proportionate stratified sampling technique. Household heads who are smallholder farmers were selected to provide response on behalf of the smallholder farming households. About 70, 84, 134, 80 and 107 smallholder farmers were selected from Tolon District, Kunbung District, Nantong District, Sagnarigu Municipal and Savelegu Municipal respectively. In all a total of 475 smallholder farmers were selected. Primary data collected from the smallholder farmers included their socioeconomic characteristics, access to climate information and adoption of climate smart adaptation strategies. Data analysis was done using t-test and bivariate regression model with the aid of STATA 14.

2.3. Ethical consideration

When conducting research, there are four ethical criteria to remember. "a) Is there any risk to participants?" b) Is there an absence of informed consent? c) Whether or if there has been a breach of privacy. d) Is there any deception involved?" (Bryman, 2012). Although the study's subject is not very sensitive, ethical concerns were made prior to its execution. I produced an information and consent letter for the study's participants prior to fieldwork. The letter explained the research project, why they had been requested to join, and their rights. They were advised that they might withdraw at any time and that the information would be destroyed after the project was completed. Before the interviews, I identified myself and the study's goal, as well as the letter in case the informants had low literacy ability.

2.4. Empirical model specification: the bivariate probit model

Smallholder farmers are confronted with countless decisions to take as far as production is concern. Some of the choice that they take from the numerous alternative decisions is interrelated. The objective of this research is to analyse the interrelationship between smallholder farmers' choice of accessing climate information and subsequent adoption of climate smart adaptation practices. This will further provide insight to, whether if smallholder farmers' who have accessed climate information have to a greater extent or less probability to also adopt climate smart adaptation practices. Therefore, the two choices in this study represents the decision by the smallholder farmers' to access information about climate change and also adopt climate smart adaptation practices. This makes access to information about climate change and adoption of

climate smart adaptation practices decisions potentially jointly determined. Since bivariate probit regression is usually used to empirically estimate decisions and choices that are interrelated we employed the bivariate probit model to investigate the joint determination of the groups' access to climate change information and adoption of climate smart adaptation practices and the related determinants of both decisions. This approach involves an estimation of specification of two-equation model that captures smallholder farmers' decision to access climate information and as a result adopt climate smart agriculture.

The bivariate probit is used for this research to enable the researchers correct sample selection bias. Further, the correlation value rho (ρ) may be statistically significant or not. When the two dependent discrete variables are statistically significant, then it indicates that bivariate probit (or logit) is the good option for estimating the two decisions jointly. When the correlation coefficient is not significant for the two binary dependent variables then separate probit model is the good model for estimation. Endogeneity of the two related options is controlled by the bivariate probit model, which is a simultaneous equations model (Anang, 2018; Nieto and Santamaría, 2010).

The bivariate probit model provides two binary results which is mathematically expressed as two unobserved continuous latent variables (Cameron and Trivedi, 2009). For this study Y_1^* represents adoption of climate smart adaptation strategies by smallholder farmers and Y_2^* represents smallholder farmers information access about climate change. Eqs. (1) and (2) can be used to represent the two unobserved latent variables.

$$y_1^* = x_1\beta_1 + \mu_1 \quad (1)$$

$$y_2^* = x_1 + \mu_2 \quad (2)$$

Both (μ_1, μ_2) errors are jointly distributed normally with a mean of 0 and a variance 1. The variable x_1 is a vector of the independent variables with estimators β that are common to both outcomes respectively. The two binary outcomes are expected to be observed as shown in Eqs. (3) and (4).

$$y_1 = \begin{cases} 1 & \text{if } y_1^* > 0 \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

$$y_2 = \begin{cases} 1 & \text{if } y_2^* > 0 \\ 0 & \text{otherwise} \end{cases} \quad (4)$$

3. Results and discussion

3.1. Descriptive analysis and summary statistics

Table 1 shows the definition, measurement and descriptive statistics for the variables utilized in the analysis. The dependent variables are

Table 1. Definition of variables, measurement and summary statistics.

Variable	Definition	Measurement	Mean	SD
Dependent Variables				
Climate information access	Access to climate information	1 = if yes; 0 = otherwise	0.811	0.392
Climate smart Adaptation practices adoption	Adoption of climate smart adaptation practices	1 = if yes; 0 = otherwise	0.853	0.355
Independent Variables				
Gender	Gender of household head	1 = if male; 0 = female	0.766	0.424
Age	Age of household head	Number of years	39.084	11.410
Household size	Number of household members	Number of household members	10.313	6.440
Education	Years of education of household head	Total number of years in formal education	3.718	5.250
Farm size	Farm size	Acres	5.300	3.565
Farm income	Household total farm income	Ghana cedis	2375.621	2013.132
Extension	Access to extension services	1 = if yes; 0 = otherwise	0.783	0.413
Social group	Social group membership	1 = if yes; 0 = otherwise	0.863	0.344
Assets	Assets of household head	1 = if yes; 0 = otherwise	0.846	0.361

access to climate information and adoption of climate smart adaptation practices. Access to climate information is a dummy and is being assigned a value of 1 if the smallholder interviewed had accessed climate information and 0 if otherwise. As shown in Table 1, 77% of the smallholder farmers interviewed had accessed climate information. Climate smart adaptation practices adoption is also recorded as a dummy variable, with 1 denoting the case where a smallholder farmer had adopted climate smart adaptation practices as result of accessing climate information and 0 if otherwise. About 85% of the smallholder farmers interviewed adopted climate smart adaptation practices.

As presented in Table 1, 77% of the smallholder farmers are males. The dominance in male farmers in this research concurs with the findings of (Adeagbo et al., 2021; Maina et al., 2019) but contradicts with that of (Nyang'au, Mohamed, Mango, Makate and Wangeci, 2021) who found a considerable number of smallholder farmers interviewed were females because most of the male smallholder farmers migrated to urban centres for extra income as farm sizes shrank. Majority (78%) of the smallholder farmers interviewed had access to agricultural extension services and this agrees with the findings of (Adeagbo et al., 2021; Muema et al., 2018). As opined by (Anang et al., 2021; Anang et al., 2020; Muema et al., 2018) that access to agricultural extension services by smallholder farmers is a vital human capital that gives them information on current as well as contemporary agricultural methods in order to enhance adoption in the farming system. Majority (86%) of the smallholder farmers interviewed belonged to social group which corroborate the findings of (Muema et al., 2018). It has been established that smallholder farmers who belong to a group or an association gives them a type of social capital not merely for the assessment of agricultural credit and inputs for farming but also provides them the opportunity to share vital information to market their produce (Adeagbo et al., 2021). Majority (85%) of the smallholder farmers had assets. Accumulation of assets by smallholder farmers is essential because these can be transformed in order to generate income as well as invest in the adoption of agricultural technologies (Shinbrot et al., 2019). As shown in Table 1, household size of approximately 10 members is very typical of families of smallholder farmers in developing countries like Ghana where large household size serves as assets signifying availability of farm labour (Adeagbo et al., 2021; Anang et al., 2020; Nyang'au et al., 2021). The average age of smallholder farmers interviewed is approximately 39 years and this is a sign that smallholder farmers are in the active working age group for agricultural production (Anang et al., 2021). This contradicts with (Muema et al., 2018) who recorded the average age of farmers to be 53 years indicating that majority of the youth in Kenya do not participate in agriculture. The mean number of years used by the smallholder farmers in acquisition of formal education is 4 years indicating that the smallholder farmers interviewed do not possess sufficient formal education and insufficient formal education is suggested to likely hinder adoption since education increases

the awareness and knowledge of smallholder farmers about modern technologies preceding to higher adoption (Anang et al., 2020, 2021). The average farm size of the smallholder farmers is 5.3 acres which is approximately two (2) hectares of land confirms the fact that farmers interviewed in the study area are actually smallholder farmers. Their annual total farm income is 2375.621 Ghana cedis which is less than \$500 which is an indication that the smallholder farmers in the study area are poor.

3.2. Differences in smallholder characteristics by climate information access and adoption of climate smart adaptation practices

Table 2 reports the characteristics of smallholder farmers according to climate information access and adoption of climate smart adaptation practices as well as the mean differences by climate information access and adoption of climate smart adaptation practices. Results in Table 2 shows that 83% and 81% of smallholder farmers who accessed climate information and adopted climate smart agricultural practices respectively are males. This implies that more males accessed climate information and adopted climate smart adaptation practices. With respect to gender, statistically significant difference exist among smallholder farmers with access to information about climate change and those without at 1%. Also statistically significant difference exists among smallholder farmers who adopted climate smart adaptation practices and non-adopters at 1% level. The result of male dominance in adoption in this study concurs with that of the results of (Anang et al., 2020; Maina et al., 2019).

Table 2 reports that older smallholder farmers that are approximately about 40 years had access to climate information and also adopted climate smart adaptation practices as compared to those without access to climate information and non-adopters of climate smart adaptation practices. There is the likelihood that age of smallholder farmers correlates with their level of experience. This implies that experience could play a vital role in smallholder farmers accessed to climate information as well as adoption of climate smart adaptation practices. With regard to age of smallholder farmers, statistical significant difference exist between those who accessed climate information and those who did not, as well as those who adopted climate smart adaptation practices and non-adopters at 1% level. This concurs with results of (Anang et al., 2020; Maina et al., 2019) who both reported that the age of adopters were significantly different from non-adopters.

Education plays an important role in smallholder farmers access to climate information as presented in Table 2. Statistically, significant differences are found for smallholder farmers access to climate information with regard to education at 5% level. Smallholder farmers who have accessed climate information possessed more number of years in formal education than those with no access. Smallholder farmers who

Table 2. Differences in smallholder farmers characteristics by climate information access and adoption of climate smart adaptation practices.

Variable	Climate information access					Adoption of climate smart adaptation practices				
	Access		No Access		Mean Difference	Adopters		Non-Adopters		Mean Difference
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Gender	0.834	0.372	0.478	0.502	0.356***	0.810	0.393	0.514	0.503	0.210***
Age	40.314	11.627	33.822	8.693	6.492***	40.370	11.578	31.642	0.790	8.728***
Household size	10.283	6.559	10.444	5.944	-0.161	10.363	6.579	10.029	5.608	0.334
Education	3.974	5.310	2.622	4.863	1.352**	3.872	5.353	2.829	4.543	1.043
Farm size	5.767	3.645	3.283	2.307	2.484***	5.715	3.583	2.879	2.280	2.836***
Farm income	2671.92	2034.02	1108.11	1314.94	1563.81***	2636.44	2010.85	866.571	1207.85	1769.87***
Extension	0.890	0.312	0.322	0.470	0.569***	0.862	0.346	0.329	0.473	0.533***
Social group	0.917	0.276	0.633	0.484	0.284***	0.909	0.288	0.600	0.493	0.309***
Assets	0.971	0.167	0.311	0.466	0.660***	0.926	0.490	0.386	0.490	0.540***

Note:***, **, * represent significance 1%, 5% and 10% levels respectively.

adopted climate smart adaptation practices spent more years in education than non-adopters. This agrees with the findings of (Anang et al., 2020) but the difference is not statistically significant (Maina et al., 2019).

With regard to farm size and farm income, statistically significant difference exists between smallholder farmers who had accessed climate information and those without access as well as those who adopted climate smart adaptation practices and non-adopters at 1% level. Those who accessed climate information have farm size of 2.5 acres more than those without access and that of those who adopted climate smart adaptation practices have farm size of 2.8 acres more than non-adopters. This concurs with results of (Anang et al., 2020; Maina et al., 2019) who reported that the average farm size of adopters was significantly higher than non-adopters. For farm income smallholder farmers who accessed climate information have about 1,564 Ghana cedis more than those without access and also those who adopted climate smart adaptation practices have about 2,376 Ghana cedis as farm income more than non-adopters. Consistent with the results adopters had higher farm income compared non-adopters (Anang et al., 2020; Maina et al., 2019).

Table 2 reports that the probability of accessing climate information and also adopt climate smart adaptation practices are greater for smallholder farmers who have access to agricultural extension services, belong to social group and have assets. The difference is significant at 1% level showing that access to extension services, belonging to social group and having assets encourages smallholder farmers to access climate information and as well adopt climate smart adaptation practices. Membership of social group increases the likelihood of adoption. Similar findings were discovered by (Kanyenji, Oluoch-Kosura, Onyango, & Karanja Ng'ang'a, 2020; Kassie et al., 2011; Kassie et al., 2015; Maina et al., 2019; Marwa et al., 2020).

3.3. Determinants of climate information access and climate smart adaptation strategies adoption

The bivariate probit regression estimates of smallholder farmers' joint decision to access climate information and adopt climate smart adaptation strategies are presented in Table 3 below. The decision to estimate using bivariate probit regression model requires that the error terms of the two models (dependent variables) are correlated. The hypothesis that the error terms of the two decisions are not correlated was rejected as indicated by the value of rho (Rho= (0.910, SE (0.045)). This implies that the two decisions are jointly determined. In other words, once the standard error is far lower than the coefficient, then the estimated parameter will be significant. The use of bivariate probit model was validated by testing the hypothesis that smallholder farmers' access to climate information and climate smart agricultural adaptation adoption are correlated ($H_0: \rho = 0, H_1: \rho \neq 0$). The statistical significance of the ancillary parameter rho (ρ) was tested for. This was carried out by testing the statistical significance of the ancillary parameter. We failed to reject null hypothesis ($H_0: \rho = 0$) because $\rho \neq 0$. This means that the two error terms are correlated and related. It further means that there are unobserved factors that influence both smallholder farmers access to climate change information and climate smart adaptation adoption. The likelihood ratio test of rho(ρ) for the two equations indicated statistical significance at 1 percent level. The significance of rho(ρ) indicates that the two models are strongly correlated and related therefore the need to estimate the two equations using bivariate probit.

The age of the household head was related positively to the joint decision of accessing climate information and climate smart adaptation strategies adoption by smallholder farmers at 1%. Older smallholder farmers are more likely to access climate information and at the same

Table 3. Determinants of climate information access and climate smart adaptation adoption.

Variable	Climate Information Access		Climate Smart Agriculture Adoption		Marginal Effect (in %)	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Constant	-2.112	0.435				
Gender	0.266	0.234	-1.967	0.435		
Age	0.032***	0.010	-0.084	0.236	0.042	0.050
Household size	-0.037**	0.014	0.050***	0.110	0.007***	0.002
Education(years)	0.018	0.020	-0.028*	0.015	-0.007***	0.003
Farm size	0.001	0.039	0.028	0.020	0.003	0.004
Farm income	0.000**	0.000	0.043	0.042	0.002	0.007
Extension service	0.604**	0.352	0.000	0.000	0.000**	0.000
Social group	-0.505	0.357	0.668**	0.323	0.150*	0.087
Assets	2.111***	0.288	-0.117	0.293	-0.060	0.040
Rho	0.910***	0.45	0.994***	0.270	0.632***	0.090

time adopt climate smart adaptation strategies compared to the younger ones. The results in Table 3 show that a unit increase in age of the smallholder farmers' increases the probability of them jointly accessing climate information and adopting climate smart adaptation strategies by 0.007. The direction of effect of age on access of climate information and adoption of climate smart agricultural strategies separately is the same as the joint decision to access climate information and adopt climate smart adaptation strategies. The results of the study corroborate with other previous findings that found age to be positively associated with adoption (Anang, 2018; B. O. Asante, Villano and Battese, 2014; Nabara et al., 2020). This implies that older smallholder farmers', by the virtue of their cumulative experience have the highest possibility to have acquired more knowledge about technology that boosts productivity hence the more likelihood to access climate information and adoption of climate smart agricultural strategies.

The findings show that larger households are to a lower extent likely to access climate information and at the same time adopt climate smart adaptation strategies. Larger household does not necessarily mean farm labour and moreover accessing climate information is not labour intensive to require larger household. The results in Table 3 indicate that one addition of a household decreases the likelihood of household being able to jointly access climate information and adopt climate smart adaptation strategies by 0.687 at 1 percent statistically significant level. Both (Anang, 2018; Khonje et al., 2015) found adoption to be negatively related to household size contrary to the findings of (Sodjinou et al., 2015).

The results in Table 3 show that smallholder farmers with a high income are more likely to have access climate information and at the same time adopt smart adaptation techniques to the changing climate. Income of the smallholder farmers is positively and significantly related to the joint access to climate information and adoption of climate smart adaptation strategies at 5 percent. Smallholder farmers with more income are able to afford devices that enables them to access climate information. Also they are able to hire labour to enable them adopt to climate smart adaptation strategies. The results are indicating that an additional GH¢ 1 earned by a smallholder farmer increases their access to climate information and at the same time adopt climate smart adaptation strategies.

Access to agricultural extension services by the smallholder farmers' was associated positively to their joint decision to access climate information and as well as adopt climate smart adaptation strategies is marginally statistically significant at 10%. The results in Table 3 reveal that smallholder farmers who have access to agricultural extension service are likely to access climate information and also adopt climate smart adaptation strategies by 15 %.

Assets was associated positively to smallholder farmers' joint decision to access climate information and at the same time adopt to climate smart adaptation strategies is also statistically significant at 1%. Smallholder farmers who own assets are more likely to jointly access climate change information and also adopt climate smart adaptation strategies by 63%.

4. Conclusion and policy implication

The paper investigated the determinants of smallholder farmers decision to access climate information and also adopt climate smart adaptation practices. Researchers used survey data of 475 smallholder farmers in five districts in the Northern region of Ghana. The study shows that there are more male smallholder farmers than females with very few years spent on attaining formal education as well as being poor. Gender, age education, farm size, farm income, access to extension services, social group membership and assets increase the probability of smallholder farmers access to climate information. Gender, age, size of the farm, income from farm, access to agricultural extension services, social group membership and assets increase the probability of smallholder farmers adoption of climate smart adaptation practices. The results indicated that smallholder farmers decision to access climate information and as well

adopt climate smart adaptation practices is shown to be jointly made revealing that most smallholder farmers who accessed climate information also adopted climate smart adaptation practices. This research reveals that age, farm income, access to extension service and assets with the exception of household size positively influenced the joint decision of smallholder farmers to access climate information and adopt climate smart adaptation practices.

The research findings of the study reveals that government, districts assemblies and non governmental organisations who support smallholder farmers' for their adoption to climate smart adaptation practices in order to overcome the hazards of climate change should make climate information also accessible. Even though the smallholder farmers interviewed do not possess sufficient formal education the result indicated significant difference in access to climate information and adoption of climate smart adaptation practices with regards to education. Therefore other means of improving smallholder farmers literacy and knowledge level such as non-formal and informal educational programmes, and extension education using the farmer-field schools method. Government should facilitate smallholder farmers to engage in other livelihood activities in order increase the income of the smallholder farmers. This will consequently improve their access to climate information and adoption of climate smart adaptation practices.

5. Consent for publication

All authors agree and consent for the article to be published.

6. Ethical approval and consent to participate

Each respondent orally consented to participate in the study.

7. Availability of supporting data

On request, the corresponding author can provide the data set utilized in this work.

Declarations

Author contribution statement

Abdul-Fatahi Alidu: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Norsida Man: Conceived and designed the experiments; Analyzed and interpreted the data.

Nurul Nadia Ramli: Performed the experiments.

Nur Bahiah Mohd Haris: Contributed reagents, materials, analysis tools or data.

Amin Alhassan: Analyzed and interpreted the data.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

Authors are very grateful to smallholder farmers who participated in the study.

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