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Climate change and adaptation strategies in rural Ghana: a study on smallholder farmers in the Mamprugu-Moaduri district

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Abstract

Purpose – This study aims to analyze the perceptions of smallholder farmers on climate change and events and further explores climate change adaptation strategies and associated challenges. The findings provide useful information for enhancing the adaptive capacity of smallholder farmers to adjust to climate-related hazards and improve their resilience and disaster preparedness in northern Ghana.

Design/methodology/approach – This study uses a multistage sampling procedure and sample size of 150 farmers, the Binary Probit Model (BPM), to identify and examine the determinants of climate change adaptation strategies adopted by smallholder farmers. Also, the constraints of adaptation were analyzed using Kendall's coefficient of concordance.

Findings – The results from the BPM and statistics of Kendall's coefficient revealed that the farm risk level, ability to adapt, farmer's income, age, farming experience, climate change awareness and extension visits

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were factors that significantly influenced the adaptation strategies of smallholder farmers (in order of importance). The majority (60%) of the farmers ranked farm risk level as the major constraint to adopting climate change strategies.

Originality/value – The findings of this study enhance understanding on access to relevant and timely climate change adaptation information such as an early warning to farmers during the start of the farming/rainy season to support their adaptive responses to climate change.

Keywords Agricultural adaptation, Climate change, Adaptation strategies, Smallholder farmers, Adaptive capacity

Paper type Research paper

1. Introduction

Faced with a high poverty rate, increased rate of environmental degradation and increasingly erratic rainfall, the Northern part of Ghana remains more vulnerable to climate variability and change than other parts of the country (Addaney *et al.*, 2022; Abdul-Razak and Kruse, 2017). To mitigate the effects of severe weather conditions and climatic variations, these agriculture-dependent communities (through the efforts of government and donor organizations) have adopted strategies that include intensive irrigation and different soil conservation approaches, the use of drought-tolerant crop varieties, crop rotation, changing planting dates and the expansion of farms to secure their livelihoods (Lawson *et al.*, 2020; Omerkhil *et al.*, 2020). However, recent studies have identified some weaknesses in the effective implementation of these climate change adaptation strategies in several households of these vulnerable communities (Zakari *et al.*, 2022). Some of the weaknesses include the poor integration of different policy domains and projects, low environmental protection, diminished autonomy in decision-making and inequity (Addaney *et al.*, 2021).

Northern Ghana, and more particularly the Mamprugu-Moaduri District, is characterized by unsustainable land use practices such as overgrazing by livestock and the cutting down of trees. These land and resource use practices increase the susceptibility of the environment to climate change as evidenced by inconsistent patterns in rainfall and droughts, the spread of desertification and other factors that include soil erosion and poor soil fertility (Abdul-Razak and Kruse, 2017). Of these factors, climate change poses the most serious challenge because it may create water and heat stress, loss of productive lands through the destruction of ecosystems and reduced harvests, which undermine food security by affecting food supply chains (Vermeulen *et al.*, 2012). Consequently, climate change effects on agriculture may play out through the economic system by impacting on food prices, output, productivity, demand, calorie availability and ultimately, human well-being (Mbow *et al.*, 2019; Amikuzuno and Hathie, 2013). The susceptibility of northern Ghana to changing climate is greater than that of the southern part due to its agriculturally unfavorable terrain and agroecological conditions. The adverse effects of these intervening factors in this region are aggravated by climate change–driven periodic floods and drought as happened in 2007 when floods were followed by prolonged droughts that affected more than 325,000 people in the country's Northern Savannah Zone (Abdul-Razak and Kruse, 2017). The savanna agroecological zone is dominated by grassland and trees with low density, it is warmer than the rain forest and has a unimodal rainfall season with 600–1,500 mm/year alternated with pronounced dry seasons (Antwi-Agyei *et al.*, 2014). More recently, floods in 2019 resulted in widespread crop losses that adversely affected the livelihoods of farmers along the Volta basin in the North East region when the Bagre Dam overflowed (Almoradie, 2020). To effectively adapt to these climate change effects, technical know-how, farmers' income levels, societal support systems and the provision of farmers' support services need to be improved (Assan *et al.*, 2020).

Traditional Ecological Knowledge (TEK) also plays an important role by enhancing the adaptive capacities of resource-poor communities that are vulnerable to the adverse effects of climate change (Aswani *et al.*, 2018; Mensah *et al.*, 2021). This underscores the need for the scientific community to promote awareness of the long-term adverse effects of climate change by tapping on the different knowledge at our disposal. The use of experiential knowledge in climate change adaptation responses is therefore timely in Africa (Adenle *et al.*, 2017). Adaptation to climate change involves the careful use of both modern knowledge and indigenous knowledge in building the capacities of vulnerable farmers through behavioral transformation (De Pinto *et al.*, 2012). In Ghana, some mechanisms have already been developed because of farmers' historical experience with climate change and extreme events (Abdul-Razak and Kruse, 2017).

Climate change has caused considerable welfare losses for smallholder farmers in Northern Ghana, particularly in Mamprugu-Moaduri District, where the main source of livelihood for most people is agriculture. For these people, the most promising way forward is for them to adapt to climate change (Owusu *et al.*, 2021; Abdul-Razak and Kruse, 2017). Previous studies have focused on the general impacts of climate change and adaptation responses. Aniah *et al.* (2019) have argued that adaptation strategies are peculiar to localities and ecological zones and usually center on the specific climatic characteristics of different areas. With the peculiar situation of the Mamprugu-Moaduri District, there is a need to explore the specific impacts of climate change on smallholder farmers and their particular adaptation responses. However, as the outcomes of adaptation are more location-specific, there is a need for further research on the adaptation effects at the community/district level to better inform climate adaptation responses.

Moreover, climate change has become a threat to smallholder farmers, with an estimated 475 million smallholder farmers in the world cultivating less than 2 *hectares* of farmland (Lowder *et al.*, 2016), many of whom are poor, food insecure and living in highly precarious conditions (Morton, 2007; Cohn *et al.*, 2017). In the semi-arid areas of Northern Ghana and other areas in different countries in West Africa including Burkina Faso, Niger and Mali, extreme events such as high temperature, floods, droughts and land degradation are inducing high crop failure and increased food insecurity (Donatti *et al.*, 2018). The susceptibility of the agricultural sector in Ghana to climate alteration is largely due to it being mainly rain-fed (Yaro, 2010), particularly in the country's semi-arid north. Northern Ghana collectively comprises the poorest regions of the country, with poverty rates ranging from 69% to 88% across the region (Shepherd *et al.*, 2005; Nyantakyi-Frimpong, 2013) and thus have lower fundamental resilience to any livelihood shock (Euronet Consortium, 2012). In contrast to the more urbanized southern parts of the country, most people in Northern Ghana reside in rural areas and depend mainly on agricultural activities for their livelihoods. Societal susceptibility to the impacts and risks of climate change is therefore probable to be worse off in these five regions: Northern, Savannah, North East, Upper East and Upper West (Euronet Consortium, 2012). In Northern Ghana, farming is mainly rain-fed for the cultivation of cereals, groundnut and vegetables (Nyantakyi-Frimpong, 2013). This part of the country is categorized by a single rainfall pattern (starting in April/May and ending in September/October) followed by a dry season that lasts for the remainder of the year. In the past 40 years, drought has become a common occurrence and annual rainfall levels are increasingly variable, corresponding to changes in food availability. This has led farmers to develop intricate strategies to adapt to the changing climate and environmental conditions (Nyantakyi-Frimpong, 2013).

In Ghana, particularly the Northern region, the variability of rainfall is a danger to the existence of smallholder farmers who are involved in predominantly rain-fed cultivation. Over the past few years, rainfall-related crop failure has become a common phenomenon due to incidents of late rains for planting, variability in the pattern and levels of rainfall and intermittent droughts and floods in Northern Ghana (Amikuzuno and Donkoh, 2012). Smallholder farmers have become more susceptible and therefore, environmental variability has become a risk in Ghana, particularly in the dryer regions (Amikuzuno and Donkoh, 2012). There is therefore the need for smallholder farmers to strengthen their resilience through adopting practices that will protect their livelihood. Adaptation (both planned and unplanned) is central in ensuring the resilience of farmers and farm households. There is a growing body of literature on the definition and conceptualization of adaptation. The Intergovernmental Panel on Climate Change (IPCC) (2007) defines adaptation as an alteration in natural or human systems in response to real or predictable climatic stimuli or their influence which regulates damage or exploits advantageous opportunities. Several forms of adaptation can be notable such as anticipatory, autonomous and planned adaptation (IPCC, 2007). According to the IPCC (2007), anticipatory adaptation is a type of adaptation where farmers adapt to climate change before any possible bearings of climate variability are observed; this is also called proactive adaptation. On the contrary, independent adaptation is an adaptation strategy by farmers when they experience alterations in the natural system through changes in human welfare but does not constitute a mindful reaction to changes in the climate. Thus, adaptation implies the actions of people in response to, or in expectation of, an expected or real variations in the environment to help lessen the hostile influence or benefit from the opportunities posed by climate variability and climate change.

Research has projected specific strategies and technical know-how to address climate influences and farmers' adaptation in precise places (Deressa *et al.*, 2008; Vermeulen *et al.*, 2012). Scholars (e.g. Acquah, 2011) observe that farmers' knowledge and responsiveness to the negative consequences of environmental variation and their adaptive abilities are low because of the weak institutional policies, deficiency of data and little financial support for smallholder farmers. Barriers to climate change adaptations include lack of access to early warning systems, inadequate cropland and the undependability of periodic forecast (Gandure *et al.*, 2012). Additional studies highlight inadequate improved seeds, absence of adaptation options, insufficient water supply, lack of climate change information, high rate of adaptation and insecure property rights as the main constraints (Acquah, 2011; Acquah and Onuma, 2011; Deressa *et al.*, 2008). Furthermore, information irregularity, inadequate extension services, poor governmental response to climate change, unavailable information, the poor nature of local farming methods, little knowledge on adaptation, low technical capacity and the absence of government strategy on climate change also hinder farmers from adapting effectively to climate change impacts (Nzeadibe *et al.*, 2011; de Wit, 2006; Maddison, 2006). It is within the foregoing context that this paper inquires: are local perceptions of smallholder farmers in northern Ghana on climate change important in influencing adaptive options in rural communities? Using the Mamprugu-Moaduri District in Ghana as a case study, the paper addresses two research objectives:

(1) to analyze the perceptions of smallholder farmers on climate change and events; and

(2) to explore climate change adaptation strategies and associated challenges.

The findings of the study provide useful information for enhancing the capacity of smallholder farmers to adjust to climate-related hazards and improve their resilience and disaster preparedness (Morton, 2007; Holland *et al.*, 2017; Donatti *et al.*, 2018).

2. Methods

2.1 The study area

The study was conducted in the Mamprugu-Moaduri District in Ghana. The Mamprugu-Moagduri District was created out of the West Mamprusi District with Yagaba being established as the capital (LI 2063 of 2012). The study area is located between longitudes 0° 35′W and 1° 45′W and latitudes 9° 55′N and 10° 35′N. About 83.7% of the inhabitants within this district are dependent on rain-fed subsistence agriculture and this makes them vulnerable to the adverse effects of extreme climatic events such as perennial floods and periods of dry spells (Aniah *et al.*, 2019. Ghana is divided into six main agroecological zones defined on the basis of the climate, reflected by the natural vegetation and influenced by the soils. These zones are Sudan, Guinea and Coastal Savannas, the Forest-Savanna Transitional, the Semi-deciduous Forest and the High Forest zones. The Mamprugu-Maogduri District which is situated in the Northeastern part of the country lies within the Sudan Savanna. Though there have been some reported variabilities in the rainfall pattern (ranging from the onset, cessation, length and amount) across other climatic zones (especially in the forest and coastal zones), the Sudan savannah has not recorded much of these changes spatially but remains to be increasingly dry and vulnerable to the frequent occurrence of extreme weather events such as drought and heat stress (Bessah *et al.*, 2022). Consequently, the impacts of climate change affect farming activities in the region, and thus, the main focus of this study is to assess the climate change adaptation strategies adopted by smallholder farmers to moderate these effects.

From Figure 1, the district lies within the savannah climatic belt with a single maximum rainfall season. The mean seasonal rainfall ranges from 1,000 to 1,400 mm and occurs

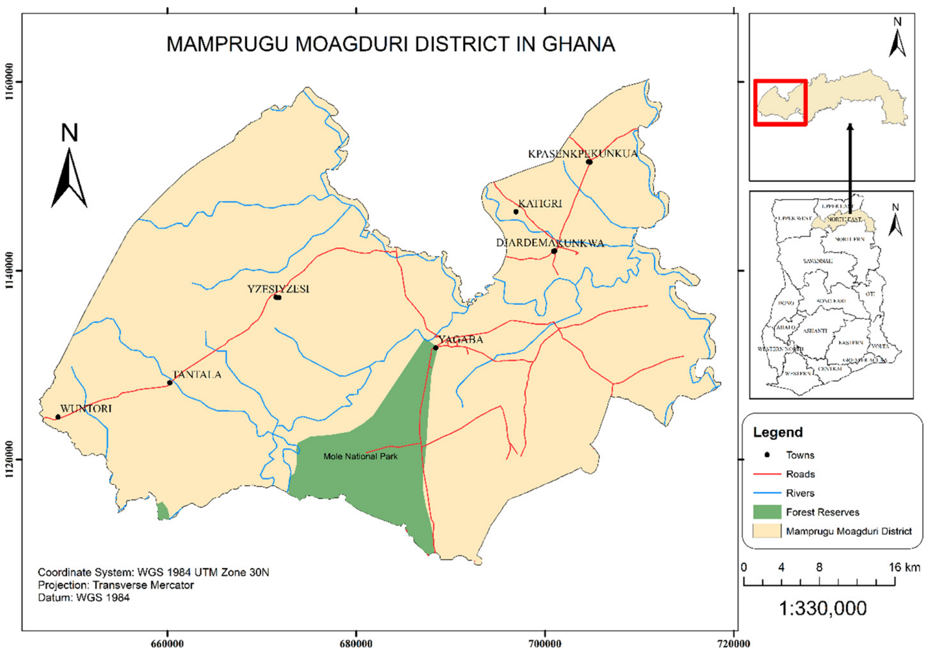


Figure 1.
Map of Mamprugu-Moagduri district

Source: Authors' own creation

between May and October with July to September as the peak period (Abdul-Razak and Kruse, 2017). There are all-year-round high temperatures with the hottest month being March, with average temperatures ranging between 25.5°C and 35°C. The area's geology consists of Middle Voltain rocks. The biggest river in the area is the White Volta and its tributaries include Sissili and the Kulpawn rivers. Along the valleys of these rivers are large arable lands, good for the cultivation of rice and other cereals. The soils are mostly alluvial, rich in nutrients, especially along the valleys, with considerable soil erosion due to bad farming practices and the rampant bush burning. The district's natural vegetation is a Guinea Savannah Woodland, composed of short trees of varying sizes and density, growing over a dispersed cover of perennial grasses and shrubs (Nkrumah *et al.*, 2014).

2.2 Study methods and research design

The study adopted a case study research method (Babbie, 2007) and used quantitative methods for the data collection and analysis (Driscoll *et al.*, 2007). A household survey was conducted with the sampled respondents to understand the extent of impacts of climate change in the community and assess the diversity of climate change adaptation strategies used by the smallholder farmers. The study used the Yamane (1967, p. 886) formula in determining the sample size as follows:

$$n = \frac{N}{1 + N(e)^2}$$

where

n = sample size

N = Population size

e = margin of error is 0.05 at 95% confidence interval

Primary data was collected from the smallholder farmers through the administration of pretested questionnaire with both open- and closed-ended questions. The questionnaire was designed to solicit information on the socioeconomic background of the farmers, their perceptions on the impacts of climate change and associated extreme conditions on crop production and related farming activities over the past 20 years and the adaptation strategies being used on their farms. The questionnaire used for the study is provided in the Appendix. Table 1 below indicates the geographical spread of the respondents across the study communities.

The study used a systematic sampling procedure in the selection of the respondents. This sampling procedure offers the advantage of facilitating sequential sampling across two or more hierarchical levels. In the initial sampling phase, a purposive sampling based on

Communities	No. of respondents	% of respondents
Yagaba	30	20
Loagri	30	20
Zanwara	30	20
Primaand	30	20
Tantala	30	20
Total	150	100

Source: Authors' own creation

Table 1. Distributions of respondents by communities

information gathered from three key governmental institutions (National Disaster Management, Ministry of Food and Agriculture [MoFA] and the Water Resource Commission) and other interviews with some inhabitants within the district was used to select five communities including Yagaba, Loagri, Zanwara, Prima and Tantala. A simple random sampling was later used to select the respondents for the study. In total, 150 smallholder farmers' households from the five selected communities were involved in the study. This comprised of 30 smallholder farmers' households being selected from each of the communities (Table 1).

3. Data presentation

A Binary Probit Model (BPM) was used to assess the factors that influenced the adoption of a particular adaptation strategy by these smallholder farmers' households. The BPM has the advantage of minimizing the dependencies among individual factors considered in the study. This approach is normally used when the dependent variable is dichotomous. According to Assan *et al.* (2020), the usefulness of adaptation is approach-dependent and based on several factors such as the knowledge level of farmers, income level, the environment, social support systems as well as provision of farmers' funding services that make such adjustments possible. The BPM was used to analyze farmers' decision to adapt to climate change impacts. The BPM is defined as follows (D'Ambra *et al.*, 2022; Reggiani, 1999):

$$Di = F(Ri, Li, Ai(Yi, Ci)), Si \tag{3.1}$$

The above equation represents farmers' decisions to adapt to climate change (*D*i) which depends on the level of risk exposure (*R*i), level of damage caused by an event (*L*i) and ability to adapt (*A*i), which is determined by the flow of income (*Y*i) and in part access to credit (*C*i) and relevant socioeconomic factors of the farmer (*S*i). In explaining the dichotomous variable *D*i, if the farmer participates in any adaptation strategy, then let $Di = 1$ and $Di = 0$, if the farmer does not participate. The Binary Choice Logit model', is an estimating model that emerges from the normal cumulative distribution frequency as shown in Table 2 below:

$$Di = \beta_{\mathrm{IXi}} + \mu \tag{3.2}$$

The empirical model is expressed as:

$$Y = \beta_0 + \beta_i X_i + u_i \tag{3.3}$$

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_{n15} X_{n15} + u_i \tag{3.4}$$

where

Y = adaptation strategy (dependent variable)

Independent variables

X_1 = level of risk exposure

X_2 = level of damage caused by an event

X_3 = ability to adapt

X_4 = income of farmer (previous year's income)

X_5 = access to credit

X_6 = household size

X_7 = gender

	Description	Measurement	Expected signs
Gender	Gender of respondent	Dummy, Male = 1, Female = 0	+
Age	Age of respondent	Continuous Years	−
Educational level	Level of education	Continuous Years	+
Farming experience	Farming experience of respondent	Continuous Years	−/+
Awareness of climate change impact	Respondent awareness Level of adaptation	Dummy, Aware = 1, Not aware = 0	+
Land ownership	Type of landownership of respondent	Dummy, Personal = 1, Others = 0	+
Size of farm	Size of farmland	Continuous, Acres	−/+
Farm risk level	Level of risk a farmer is expose to	Indicator, High = 1 Medium = 2 Low = 0	−/+
Damage course	Level of damage course by an event	Indicator, High = 1 Medium = 2 Low = 0	+
Ability to adapt	Ability to adjust to climate change	Dummy Yes = 1, No = 0	−/+
Income	Level of farmer income from previous year	Continuous GHS	+
Credit	Access to credit	Dummy, Access = 1 Others = 0	+
Extension visit	How often does the agricultural extension officer visit you during the week in the farming season	Dummy, Once = 1 More than once = 0	+
Household size	Number of people in the farming household	Continuous	−/+
Farming methods	Type of farming method farmer is practicing	Indicator, Mono cropping = 0 Mixed cropping = 1 Crop rotation = 2 Mixed farming = 3 Others = 4	−

Source: Authors' own creation

Table 2. A priori expectation for the BPM regression

X_8 = age (years)
X_9 = educational level (years)
X_{10} = farming experience (years)
X_{11} = awareness of climate change impact
X_{12} = land ownership
X_{13} = farm size (acres)
X_{14} =extension visit

X_{15} =farming methods
β_o = constant
$\beta_1 - \beta_{15}$ = coefficients
μ = error term

Furthermore, the Kendell's coefficient of concordance (Legendre, 2005) was used to rank the constraints concerning climate change adaptation strategies. The use of this technique helped identify and rank the constraints faced by smallholder farmers in the quest to adapt to climate change according to the most pressing to the least pressing using numerals: 1, 2, 3, 4, . . . *n*, in that order. The lowest score rank is the most important and the highest score is the least important. In this study, farmers were asked to rank in order of agreement, some constraints they faced in their quest to effectively adapt to climate change effects by assigning 1 to strongly disagree and 5 to strongly agree. The farmers' constraints are as follows:

- deficiency of access to initial early warning signs;
- the irregularity of periodic forecast, limited knowledge on adaptation events;
- high cost of adaptation; and
- lack of access to improved crop varieties/seeds.

Computing the total rank score for each constraint, the constraint with the least score is ranked as the most pressing, whereas the one with the highest score is ranked as the least pressing. The total rank score computed is then used to calculate for the coefficient of concordance (*W*), to measure the degree of agreement in the rankings.

W takes a value of 0–1. *W* equals 1 if the ranks assigned by a judge (respondent) are the same as those assigned by other judges (respondents) and 0 otherwise.

T represents the sum of ranks for each constraint being ranked, the variance of the sum of ranks is given by the formula:

$$Var_T = \frac{\sum T^2 - \left(\sum T^2\right)/n}{n} \tag{3.5}$$

The maximum of *T* is then given by

$$VarT_{(max)} = \frac{m^2(n^2 - 1)}{12} \tag{3.6}$$

The formula for the coefficient *W* is then given by

$$W = \frac{\left[\sum T^2 - \left(\sum \frac{T^2}{n}\right)/n\right]}{m^2(n^2 - 1)/12} \tag{3.7}$$

W is simplified as

$$W = \frac{12\left[\sum T^2 - \left(\sum T\right)^2/n\right]}{nm^2(n^2 - 1)} \tag{3.8}$$

Kendell's coefficient of concordance is specified as:

$$W = \frac{12\left[\sum T^2 - \left(\sum T\right)^2/n\right]}{nm^2(n^2-1)} \tag{3.9}$$

where

W = Kendell's coefficient of concordance

T = sum of ranks of constraints

n = number of constraints being ranked

m = number of respondents

The coefficient of concordance (W) may then be tested for significance using the F-distribution as follows:

F-ratio $(F_c) = (m-1) \times W/1 - W$

Degree of freedom for the numerator $(df) = (n-1) - (2/m)$

Degrees of freedom for the denominator $(df) = (m-1)\{(n-1) - (2/m)\}$

4. Results and discussion

4.1 Demographic features of respondents

Some key demographic features such as marital status, age, gender, knowledge of climate change and education have been identified as significant predictors of farmers' understanding of the need to adopt specific climate change adaptation strategies in mitigating the negative impacts of climate change on food production in most rural Ghanaian communities (Appiah *et al.*, 2018; Adzawla *et al.*, 2020; Asare-Nuamah and Amungwa, 2020). Table 3 shows the demographic characteristics of the respondents within the selected communities. A total number of 104 respondents, representing about 69.3% of males, were mostly engaged in crop farming more than their female counterparts from the population in the northern region. This finding is consistent with the findings of Abukari *et al.* (2022) who report that the proportion of males engaged in agriculture is higher than females. In addition, the influence of marital status on the adoption of specific farming activities was also evident as about 64% of the respondents who were married were mostly engaged in crop farming to provide for their partners and family. In addition, these respondents with partners had support/help from their partners in providing access to productive resources which enhanced livelihoods.

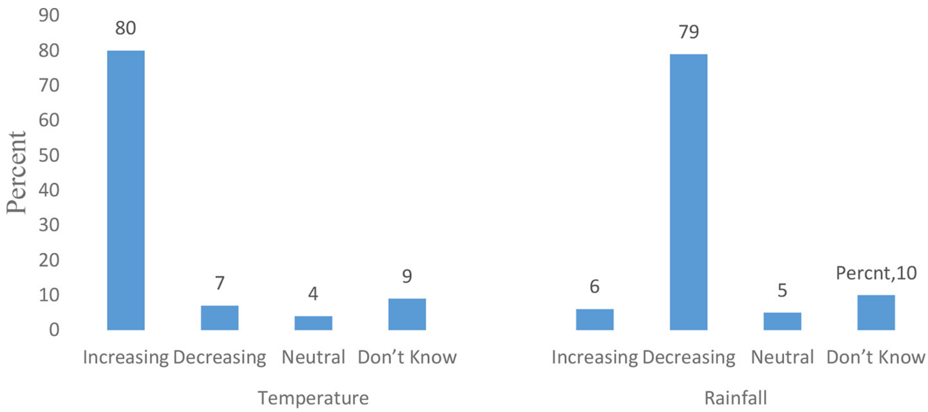
The level of literacy of the respondents was important in understanding how they perceived the impact of climate change on their farming activities and how to adapt to the impacts it has on their farm production. An enhanced education is significant in convincing farmers to adapt to sound climate change adaptation strategies to reduce vulnerability of these farmlands to the negative impacts of climate change (Asare-Nuamah and Amungwa, 2020). The results showed that majority of farmers (about 56% of the total respondents) had no formal education, whereas the remaining farmers had some kind of formal education, with only 8% of them having an education to the tertiary level (Table 3). Moreover, results showed that the majority of the farmers (43% of the respondents) mostly relied on family support as source of income to invest in their farm production. Only 1% had benefited from bank loans to invest in their farming activities with about 19% and 7% investing their personal savings and salaries (own capital) in farming activities, respectively (Figure 2).

Concerning the perceptions of the farmers on climate extremes (both temperature and rainfall), they based their opinions on four main alternatives (increasing, decreasing, neutral/unchanged and unknown) as shown in Figure 2.

Variable	No. of respondents	%
Gender of respondents		
Male	104	69.3
Female	46	30.7
Marital status		
Single	18	12.0
Engaged	11	7.3
Married	96	64.0
Divorced	9	6.0
Widow/widower	16	10.7
Level of literacy		
No formal education	84	56
Arabic	3	2
Junior high school	15	10
Primary	27	18
Senior high school	9	6
Tertiary	12	8
Income distribution		
Bank loan	2	1.33
Family	65	43.33
Farming	42	28.00
Friends	2	1.33
Personal savings	29	19.33
Wages and salaries	10	6.67

Source: Authors' own creation

Table 3. Demographical data of respondents



Source: Authors' own creation

Figure 2. Perceived level of risk and exposure for farmers

As shown in Figure 2, as high as 80% of farmers indicated that temperatures had increased significantly over the years, with about 79% of them reporting a decreasing trend in rainfall. They further indicated a reduction in the number of rainy days and length of the rainfall season over the years, suggesting the frequent occurrence of drought within this area. However, a smaller percentage (<16%) were unsure of the current trend in both temperature and rainfall patterns. Nonetheless, the results show that a greater percentage of the farmers within the district is fully aware of the changes in climatic conditions and the direct impact of such climatic conditions on their agricultural activities and consequently on their livelihood (Thanh *et al.*, 2014; Jawid and Khadjavi, 2019; Omerkhil *et al.*, 2020). To mitigate negative impacts of these trends on their source of livelihood, the farmers had to resort to a change in their planting times and farming methods (Akinbami *et al.*, 2016).

4.2 Sources of climate information

Providing useful information such as weather and flood forecasts together with the best agronomic practices can help reduce the effects of climate change on farmers. Table 4 shows the sources of relevant climate information for the farmers; 44% of these farmers reported that they relied mainly on their "personal discovery" for climate information with only 10% reporting that they sought for reliable climate information from the MoFA's agricultural extension officers.

Though a majority of the farmers perceived an increasing trend in the occurrence of extreme weather events in their localities, over half of the farmers interviewed were not in direct contact with the extension officers. Thus, there continues to be a low level of awareness creation and education on the causes and effects of climate change by MoFA's professionals. Most of the climatic information available to farmers was from their personal experiences and informal sources. For effective implementation of informed adaptation strategies within these communities, there is need for these agricultural extension officers to improve their outreach and training programs through innovative ways of communication that reach the majority of the farmers for them to be able to improve their understanding of climate change. With improved adaptive capacity, smallholder farmers will be empowered to adapt to climate change (De Pinto *et al.*, 2012). Several studies on climate change across West Africa (Kumi and Abiodun, 2018) have reported a significant rise in temperatures and frequent occurrences and severity in dry spells during the wet season period due to the variations in the daily and seasonal rainfall pattern and amount being experienced. These major impacts of climate change increase the vulnerability of the region and pose serious threats to other socioeconomic activities including rain-fed agriculture.

These results corroborate an earlier findings by Zakari *et al.* (2022) and Lawson *et al.* (2020) that showed that about 325,000 households in the northern savannah zone alone were severely affected by floods during the peak rainfall period of August and early September of both 2007 and 2008 which was immediately followed by a long period of drought. These are

Source of information	Frequency	%
Experiential knowledge	66	44.00
From extension officers	10	6.67
Radio broadcasting	20	13.33
From other farmers	54	36
Total	150	100

Source: Authors' own creation

Table 4. Farmers sources of climate change information

post-flood dry spells that retarded the growth of food crops, thereby aggravating the losses incurred by farmers from floods, as food production severely declined.

4.3 Farmers' adaptation strategies to climate change

4.3.1 Determinants of farmers' willingness to adopt climate change adaptation strategies. Climate change adaptation strategies are necessary for smallholder farmers to help build resilience against climate change while improving agricultural productivity and further reducing rural poverty (Asrat and Simane, 2017). Some of these climate change adaptation strategies already being practiced within this region include agroecology (Pandey *et al.*, 2017), Climate-smart Agriculture, climate-smart landscapes, conservation agriculture and sustainable intensifications (Ansah, 2015; Jones and Tanner, 2017; Kongsager, 2018). These adaptive strategies help farmers to properly manage water under both heavy rainfall and dry periods (Altieri *et al.*, 2015; Perez *et al.*, 2015; Malano and van Hofwegen, 2018). Some of these smallholder farmers have also introduced new pest-resistant crop varieties with suitable planting times and high productivity with increased resistance to heat and water stresses (Mueller *et al.*, 2012; Varadan and Kumar, 2014; Khanal and Mishra, 2017).

However, the results (see Tables 5 and 6) show that though these smallholder farmers well perceived the impacts of climate change, their decision to adapt to the new farming techniques in fighting climate change depended on different socioeconomic (age, farming experiences and income levels), environmental (the farm risk level) and institutional factors (level of climate change awareness). These findings meet the a priori expectation of older farmers less likely to adopt to climate change adaptation measures. Likewise, the coefficients for the farmers' risk level (−0.366) and the income of farmers (−0.00) with significance at 5% showed that as farmers' risk level increases, they are less able to adapt to climate change (see Table 5).

Variable	Coef.	Std. err.	Z	$p>\|z\|$
Farm risk level	−0.366	0.167	−2.19	0.029**
Damage caused by an event	−0.182	0.128	−1.43	0.154
Ability to adapt	0.452	0.251	1.80	0.072*
Income of farmer	−0.000	0.000	−2.31	0.021**
Access to credit	0.207	0.265	0.78	0.435
Household size	−0.056	0.087	−0.64	0.520
Sex	0.077	0.268	0.29	0.773
Age	−0.082	0.021	−3.82	0.000***
Educational level (years)	−0.010	0.079	−0.13	0.897
Farming experience (years)	0.066	0.024	2.74	0.006***
Climate change awareness	0.617	0.277	2.23	0.026**
Land ownership	−0.054	0.107	−0.50	0.616
Farm size (acres)	−0.028	0.029	−0.97	0.333
Extension visit	0.898	0.495	1.82	0.069*
Farming methods	0.063	0.148	0.43	0.670
Constant	1.618	0.697	2.32	0.020
Dependent variable: adaptation	Strategy = 0.284	Number of prob> χ^2	Obs: 150 = 0.000	–
LR χ^2 (15) = 58.94 pseudo R^2	*p = 0.1	p** = 0.05	p*** = 0.01	
Log likelihood = −74.167				

Source: Authors' own creation

Table 5. Results of binary probit analysis for climate change strategies adopted

Marginal Variable	Effects Dy/dx	Std. err.	Z	$p>\|z\|$
Farm risk level	−0.145	0.067	−2.19	0.029**
Damage caused by an event	−0.072	0.051	−1.42	0.154
Ability to adapt	0.178	0.010	1.80	0.071*
Income of farmer	−0.000	0.000	−2.30	0.021**
Access to credit	0.0822	0.105	0.78	0.434
Household size	−0.022	0.034	−0.64	0.520
Gender	0.077	0.268	0.29	0.773
Age	−0.033	0.009	−3.83	0.000***
Educational level (years)	−0.004	0.031	−0.13	0.897
Farming experience (years)	0.026	0.09	2.74	0.006***
Climate change awareness	0.237	0.100	2.36	0.019**
Land ownership	−0.021	0.042	−0.50	0.616
Farm size (acres)	−0.011	0.011	−0.97	0.332
Extension visit	0.316	0.139	2.28	0.023**
Farming methods	0.025	0.059	0.43	0.670

Notes: *p = 0.1; **p = 0.05; and ***p = 0.01
Source: Authors' own creation

Table 6. Average marginal effects after probit

The results further revealed that the farmers with their farmlands within the vulnerable areas of the community (such as hillsides, deserts and floodplains) perceived more changes in climate because their farmlands were more exposed to several climatic hazards (Donatti *et al.*, 2018). Also, 35% of the respondents indicated that climate change has resulted in seasonal flooding, whereas 20% indicated that there is prolonged drought as a result of climate change. Furthermore, 18%, 12% and 15% of the respondents, respectively, indicate that climate change has resulted in crop yield reductions, increased temperature regimes and an increased incidence of pests and diseases, respectively. The evidence reported by the farmers, especially at these vulnerable locations, calls for an enhanced effort to facilitate the implementation of sound climate change adaptation strategies in these areas (Donatti *et al.*, 2018). However, with high farm risk levels and adequate climate change awareness, the local farmers were willing to adapt to certain climate change strategies as to others whose farms were not situated in more vulnerable areas.

Income positively influences adaptation because the more a farmer has financial capital the more he or she can afford an adaptation measure. On the contrary, poverty reduces farmers' willingness and ability to invest in agriculture. Empirical studies have reported a positive relationship between income and adaptation of agricultural technologies (Faye and Deininger, 2005). The coefficients for extension visit (0.898) and the ability to adapt (0.452) are both significant at 10% (Table 6). Extension visits and the adaptive capacity of farmers both affect adaptation positively and have met the a priori expectation. The significance level of the extension visits suggests that farmers who have experience extension services will have some level of education on climate change effects and some adaptation methods and will have learned how to adapt effectively against such negative effects. The LR χ^2 (58.94) was significant at a 1% level of significance, meaning that the repressors jointly and significantly affect climate change adaptation in the district.

4.3.2 Kendall's W test on smallholder farmers' constraints. Per Kendall's coefficient of concordance in Tables 7 and 8, the respondents also ranked the constraints they faced in their quest to adapt to some specific climate change adaptation strategies. Considering the unpredictability of climatic conditions as perceived by the farmers, lack of access to early warning systems was ranked as the major constraint. In addition, limited knowledge of the adaptation measures proposed to farmers by the relevant institutions made it difficult for most of them farmers, who had not received any formal education on the climate to quickly accept the new farming techniques. This further indicates the need for more training programs on the new suggested farming techniques before implementation. This can boost the farmers' confidence in accepting these new farming techniques for improved productivity and mitigation of climate change impacts. The study showed a significant positive impact of extension services and climate information on improving farmers' investment in climate change adaptation strategies. This is consistent with other findings (Ketema and Bauer, 2012; Guteta and Abegaz, 2016; Asrat and Simane, 2018) that suggest that these agricultural extension services enhance the effective implementation of smallholder farmers' adaptation strategies, as farmers acquire new skills to improve food production on their farmlands. It is therefore not surprising that many of the farmers reported that limited knowledge of the adaptation measures and unreliable sources of seasonal forecasts undermine their willingness to accept and continue using these new farming techniques. Thus, farmers who had received some education on climate change (high level of climate change awareness) easily acknowledged the impacts of climate change and willingly accepted the new farming techniques or technologies (Asrat and Simane, 2018). Also, reliable seasonal forecasts from the appropriate actors can help the farmers plan on the type of adaptation measure to undertake. For instance, the inability of farmers to forecast rainfall trends during the growing season makes it difficult for them to plan their planting and harvesting times (Abrams *et al.*, 2018; Zakari *et al.*, 2022). Moreover, some farmers have chosen to use improved crop seeds that can withstand the climate conditions even under unpredictable situations. However, these improved or climate change–friendly crops are not easily accessible. Even in situations where these seeds are available, they tend to be expensive and unaffordable for resource poor farmers.

Constraints	Mean rank	Rank
Constraint 1. Lack of access to early warning signs	1.70	1
Constraint 3. Limited knowledge on adaptation measures	2.90	2
Constraint 4. High cost of adaptation	3.40	3
Constraint 2. Unreliable seasonal forecast	3.43	4
Constraint 5. Lack of access to improved seeds	3.58	5

Source: Authors' own creation

Table 7.
Kendall's W test results on smallholder farmers' constraints

Test	Statistics
N	150
Kendall's W[a]	0.601
Degrees of freedom	470.686
Asymp. significance	0.000

Source: Authors' own creation

Table 8.
Kendall's W test statistics

5. Conclusion

The study identified and examined the main drivers affecting smallholder farmers' decisions to adopt specific climate change adaptation strategies by using the BPM. In addition, the observed constraints of adaptation were analyzed using the Kendall's coefficient of concordance. The results show that any intervention to mitigate the impacts of climate change on rain-fed agriculture within the district must consider the farmers' age, experience, level of climate change awareness and exposure of the farmlands to risk factors. Based on this, there is the need for increased climate change awareness on the benefits of adapting to new farming techniques that could help in mitigating the negative effects of climate change on crop production. Therefore, for the effective development and implementation of efficient adaptation strategies within the district, all key socioeconomic, environmental and institutional factors must be considered in adaptation planning and policymaking. Furthermore, given the limited resources available to smallholder farmers, it will be challenging for them to adopt sound adaptation policies that seek to promote increased food production. There is also the need for an enhanced public–private cooperation with the goal of formulation of actionable strategies for increasing the uptake of adaptation strategies by farmers in those areas where agriculture is depended on natural rainfall.

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Appendix

RESEARCH QUESTIONNAIRE

A. BIODATA.

1. Date: ……………………………………………………………………………………..
2. Name of respondent: …………………………………………………………………
3. Sex: 1 = Male ( ) 2 = Female ( )
4. Age (years)……………………………………………………………………………..
5. Name of Community: ……………………..……………………………………………
6. Educational level: 1 = Primary ( ) 2 = JHS ( ) 3 = SHS ( ) 4 = Tertiary 5 = No Education ( ) 6 = Other ……………………………………………………………………….
7. Household Head. 1 = Male ( ) 2 = Female ( )
8. What is the number of persons in the household? 1 = Male |___|___| 2 = Female |___|___|
9. What is your marital status? 1 = Single ( ) 2 = Engaged ( ) 3 = Married ( ) 4 = Divorced ( ) 5 = Widow/Widower ( )
10. If married man, how many wives? ....
11. How many children do you have? 1 = Male |___|___| 2 = Female |___|___|
12. Does your household (dependents) comprise members of : 1 = Only Nuclear family ( ) 2 = Only Extended family ( ) 3 = Both Nuclear and Extended family ( )

B. CLIMATE CHANGE EFFECTS EXPERIENCED

13. Have you experience any change in climate for the past years Yes ( ) No ( )
14. What is your view on the reason for climate change?

    ………………………………………………………………………………………

    ……………………………………………..
15. What is your sources of climate information?
    a. Experiential knowledge ( )
    b. From extension officers ( )
    c. Radio broadcasting ( )
    d. From other farmers ( )

(*continued*)

16. What is your perceived level of risk and exposure of your farm to climate extremes (temperature)?

    a. Increasing ( )
    b. Decreasing ( )
    c. Neutral ( )
    d. Do not know ( )

17. What is your perceived level of risk and exposure of your farm to climate extremes (rainfall)?

    a. Increasing ( )
    b. Decreasing ( )
    c. Neutral ( )
    d. Do not know ( )

18. To what extent is your farm exposed to climate change risks? Highly ( ) Medium ( ) Low ( )

19. What type of risk are you exposed to? Drought ( ) Flood ( ) Storm ( ) Rainfall Variation ( ) Others …………………………………………………………..

20. Has your farm ever been affected by climate change? Yes ( ) No ( )

21. If yes, which of these effects of climate change have you experienced?

    a. Erratic rainfall ( )
    b. Increased temperature ( )
    c. Shorter rainfall season ( )
    d. Reduced quantity of rain ( )
    e. Floods ( )
    f. Increased incidence of diseases ( )
    g. Others…………………………………………………………...…………

22. What was the level of damage caused? Very severe ( ) Severe ( ) Medium ( ) Low ( )

23. Considering your farm output, how many bags were you harvesting before climate change ……………………..

(*continued*)

24. Considering your farm output, how many bags are you harvesting now ……………………..

C. ADAPTATION STRATEGIES USED BY THE SMALLHOLDER FARMERS

25. What kind of labor do you employ? Family labour ( ) Outside labour ( )

26. Which adaptation strategies have you ever adopted as a result of climate change?

…………………………………………………………………………………………

……………………………………………………………………………………

27. Which adaptation strategies do you prefer?

e. Changed Planting Dates ( )
f. Irrigation ( )
g. Early Planting ( )
h. Mixed Cropping ( )
i. Improved Crop Variety ( )
j. Planting Tree Crops ( )
k. Off-Farm Income Activities ( )
l. Agroforestry ( )
m. Others………… ………………………………………………………..

D. FARMING METHODS OF SMALLHOLDER FARMERS

28. How did you acquire the land for farming? Own Land ( ) Inherited land ( ) communal land ( ) leased land ( ) borrowed land ( ) sharecropped land ( ) others, specify……………………………………………………………………..

29. What farming systems are you using? Subsistence farming ( ) cash crop farming ( ) commercial farming ( )

30. What farming methods were you practicing before climate change? Mono cropping ( ) mixed cropping ( ) crop rotation ( ) mixed farming ( ) Agroforestry ( ) others, specify…………………………………………………………..…………

(*continued*)

31. What farming methods are you practicing now because of climate change? Mono cropping ( ) mixed cropping ( ) crop rotation ( ) mixed farming ( ) Agroforestry ( ) others, specify……………………………………………..……………

32. What is the size of your farmland? …..

E. *SOCIO-ECONOMIC FACTORS*

33. Are you engaged in any economic activity? 1 = Yes ( ) 2 = No ( )

34. If yes, Specify………………………………………………..………………………..

35. What is the source of your income? 1 = Family ( ) 2 = personal savings ( ) 3 = friends ( ) 4 = Microfinance/credit union/bank ( ) 5 = wages/salary) 6 = others, specify…………………………………………………………..…………

36. How much did you earn in a month? Gh□………………..

37. How do you receive your earnings? 1 = Daily ( ) 2 = Weekly ( ) 3 = Monthly ( ) 4 = Quarterly ( ) 5 = Yearly ( )

38. What is your means of transportation? 1 = On foot ( ) 2 = bicycle ( ) 3 = motorbike ( ) 4 = car ( )

39. Do you have access to an available credit/Loan facility? 1 = Yes ( ) 2 = No ( )

40. If yes, what is the name of the source of this loan/credit facility?

....

41. If no, why

………………………………………………………..……………………….

42. Do you own a livestock? 1 = Yes ( ) 2 = No ( )

43. Do you have access to an agricultural extension

44. n officer? 1 = Yes ( ) 2 = No ( )

45. If yes, how many times in a week? ....

(*continued*)

F. CONSTRAINTS FACED BY SMALLHOLDER FARMERS

46. Rank the following constraints you face in your quest to elevate poverty.

1. = Strongly disagree. 2. = Disagree. 3. = Neutral. 4. = Agree. 5. = Strongly Agree

CONSTRAINTS	1	2	3	4	5
Lack of Access to Early Warning Signs					
Unreliability of Seasonal Forecast					
Limited Knowledge on Adaptation Measures					
High Cost of Adaptation					
Lack of Access to Improved Crop Varieties/Seeds					

Source: Author's own creation

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