Asia Pacific Journal of Sustainable Agriculture Food and Energy (APJSAFE)

Interceding Role of Agricultural Extension Services in Adoption of Climate-Smart Agricultural Technologies in Northern Ghana

Benjamin Tetteh Anang

Department of Agricultural and Food Economics, University for Development Studies, Tamale, Ghana
E-mail address: benjamin.anang@uds.edu.gh

Abstract— As a result of the effect of climate change on food security and rural livelihoods, the promotion and adoption of climate-smart agricultural practices have become very crucial. The role of agricultural extension in the adoption decision process is an important factor. However, extension delivery systems in most developing countries face numerous challenges that raise concerns about their ability to bring about the desired impact on farm households' decisions. Relying on data from a cross-section of smallholder farmers in Ghana's northern savanna area, specifically the Tolon district, the study assessed the determinants of farmers' decision to adopt climate-smart agriculture (CSA) practices as well as the intensity of adoption and the role agricultural extension plays in CSA adoption. Using a Poisson regression with endogenous treatment effects model to account for selectivity bias, the study observed that farmers adopt multiple CSA practices, with adoption being influenced by farmer group membership, size of herd and participation in off-farm work. Intensity of adoption, on the other hand, increased with access to agricultural extension, farm credit and input subsidy, but decreased with farm size and participation in off-farm work. Furthermore, an impact assessment indicated that participants in agricultural extension had 1.27 more adoption of CSA practices than they would if they had not participated in agricultural extension. The study concludes that there is a strong association between adoption intensity and access to agricultural support services such as extension, input subsidy and agricultural credit. The interceding role of extension in the adoption of CSA practices calls for more resources to be channeled towards extension service provision as a means to mitigate the effects of climate change and promote sustainable production at the farm level. The positive externalities from CSA adoption will go a long way to protect the environment, promote food security and rural livelihoods.

***Keywords*— Count data, Poisson regression with endogenous treatment effects, adoption intensity, climate-smart agriculture, Ghana.**

Received: 11 Nov 2022
Accepted: 5 Dec 2022

INTRODUCTION

Climate change has over the years proven to be a major menace to the development of many countries around the world (Shaw, 2012). Climate change is a phenomenon that has taken place over the years and has always drawn the attention of many researchers because of its impact on society, food systems, and people's livelihoods. The exposure to and impact of climate change are more intense in developing countries, especially in Sub-Sahara Africa (SSA) (CARE International, 2013). This is because of the absence of capacity to build resilience to climate shocks, develop adaptive capacities to climate change, among other constraints. The Intergovernmental Panel on Climate Change (IPCC) in the early 2000s highlighted the problem of change in the climate (Minx et al., 2017). These changes in the climate affect food security and lead to ineffective and unsustainable agricultural development and production systems (Adzawla et al., 2020). Climate change imposes negative challenges on agriculture and the food system and affects the development of a sustainable economy (Le Roux et al., 2016). According to the Centre for Climate and Energy Solutions (CCES), the rapid growth of the population imposes pressure on agriculture for food, hence the need for a sustainable agricultural system to meet the required demand and ensure an effective food security system (CCES, 2019). Climate change severely impacts agricultural activities and influences the rate of productivity of agriculture. This tends to affect the livelihood of smallholder farmers (Lawson et al., 2020).

In Ghana, there is concurrently erratic rainfed, high temperature, drought, strong wind (storm) and other extreme weather conditions that influence farming activities (Karbo & Crentsil, 2021). These extreme changes in the weather pattern affect the livelihood of smallholder farmers. Smallholder farmers play a pivotal role in the rural economic system in Ghana and largely depend on rain-fed farming as the main source of livelihood (Lawson et al., 2020). Largely, these smallholder farmers live in rural areas of the country and depend on farming for a living. Climate change affects the welfare and livelihood of these smallholder farmers who depend on rain-fed agriculture (Alare et al., 2018). Notwithstanding the critical nature of farming to the livelihood of households in the rural economy and national development in general, farming is still very susceptible to the negative effect of climate change, hence the need for farmers to adopt mechanisms that can help them to lessen the devastating effects of climate change (Amin et al., 2015). The strategies that farmers adopt to reduce the negative effects of severe weather patterns include adaptation and mitigation measures as well as building resilience to climate change.

Climate smart agricultural practices (CSAPs) are informed agronomic practices that help to reduce the negative consequences of climate change (Minx et al., 2017). Several researchers and institutions over time have advocated the need for farmers to adopt improved technologies to improve production (Zakaria et al., 2020). This is because these improved technologies, such as irrigation and drought-tolerant and early maturing varieties, have the potential to withstand changes in the climate. The objective of CSA is to ensure a vigorous and sustainable agricultural system that addresses the problem of food insecurity (Alare et al., 2018). The government of Ghana and other institutions have over some time now been working to ensure that farmers develop positive attitude toward CSA practices in their production process to maximize output (Wongnaa & Babu, 2020). Notwithstanding these efforts, farmers still do not intensively adopt CSA practices. Farmers' knowledge about a new technology is related to the decision to either embrace or reject the new technology (Shaw, 2012). Farmers acquire knowledge about new technologies through extension agents, non-governmental organizations and colleague farmers. By far, the closest source of information on CSA to farmers is extension agents. They demonstrate and disseminate information and technologies to farmers regarding their production activities (Amin et al., 2015).

The Sustainable Development Goals (SDGs) seek to end hunger across nations (SDG2), yet poverty and hunger prevail in many parts of the developing world (World Bank, 2015; Feldmeyer et al., 2019). Ghana as a developing country has developed internal policies to help alleviate poverty and hunger, such as the Growth and Poverty Reduction Policy (GRPR II) (Adzawla et al., 2020).

Not many smallholder farmers have the requisite knowledge of new technologies, which is a barrier limiting technology adoption and retarding productivity. Extension officers are important agents in facilitating technology adoption among farmers. Wongnaa & Babu (2020) identified that farmers who received effective extension service had higher adoption of CSA practices in the production of cocoa in Ghana. This study focuses on crop farmers in the Guinea savanna area of Ghana where the threat of climate change is very pronounced. The study intends to fill the knowledge gap in terms of the climate change literature on the link between adoption of CSA and access to agricultural extension service. The findings of the study will help in the formulation of climate change policies in developing countries and give impetus to the role and position of agricultural extension service to address a complex challenge facing most farmers and economies in developing countries in particular.

MATERIALS AND METHODS

Study area

Tolon district where the study was conducted is located in the northern savanna of Ghana which covers about a third of the land mass of the country. The district is located in the Northern Region and is characterized by a single rainfall season. Agriculture is the predominant economic activity in the area. Due to the long dry season, generally high temperatures and frequent bush fires, the soils in the area are generally low in fertility. Climate change and its effects are evident in the area as evidenced by pest and disease incidences, flooding, long dry spells, and changes in the onset of the rainy season and planting dates for major crops.

Sampling and data collection

The study identified smallholder farmers in four communities in the Tolon district for the study. The communities were randomly selected and from each community, 35-40 farmers were selected to give a total sample of 151 respondents who were interviewed face-to-face using a semi-structured questionnaire. The information solicited from farmers covered individual and household demographic characteristics, production data, climate-smart agricultural practices adopted, access to services, among other. The respondents participated in the research on their own volition after the enumerators have explained the purpose of the research to them and asked for their willing participation. All the respondents gave their consent to participate in the study.

Method of data analysis: the Poisson regression with endogenous treatment effects model

The study's aim was to assess the impact of agricultural extension (endogenous binary treatment regressor) on adoption of climate smart agricultural practices (count response data). The Poisson regression with endogenous treatment effects model estimates consistent parameters of a Poisson regression model having an endogenous binary treatment regressor. The use of Poisson model in this study is appropriate since the study is dealing with count data; the dependent variable in this case must be a Poisson distributed count. The parameters estimated using the Poisson regression with endogenous treatment effects model can be used to derive impact parameters such as the average treatment effect (ATE) and the average treatment effect on the treated (ATET). The average treatment effect estimates the impact of extension on CSA adoption among the population, whereas the average treatment effect on the treated estimates the impact of extension on those who participated in agricultural extension. The endogenous-binary variable model fit by Poisson regression with endogenous treatment effects model is a nonlinear potential-outcome model that controls for unobservable factors associated with both the treatment and the potential outcomes thus accounting for selection bias. Denoting the outcome by y_j and the treatment by t_j, we can express the equation for the outcome and the equation for the treatment as follows

$$E(y_j|x_j, t_j, \varepsilon_j) = exp(x_j\beta + \delta t_j + \varepsilon_j) \quad (1)$$

$$t_j^* = w_j\gamma + u_j \quad (2)$$

$$t_j = \begin{cases} 1, & w_j\gamma + u_j > 0 \\ 0, & otherwise \end{cases} \quad (3)$$

where x_j and w_j are the covariates used to model the outcome and treatment equations respectively, t_j^* is the unobserved treatment variable measuring the probability of access to agricultural extension, t_j is the endogenous binary extension variable, while ε_j and u_j are error terms which are bivariate with mean of zero and a covariance matrix given as

$$\begin{bmatrix} \sigma^2 & \sigma\rho \\ \sigma\rho & 1 \end{bmatrix} \quad (4)$$

The x_j covariates included age of the farmer and its quadratic term, marital status, household size, farm size and its quadratic term, herd size, participation in off-farm work, farmer group membership, distance to the local market, and distance to extension office. For the outcome equation, the explanatory variables included age of the farmer and its quadratic term, marital status, household size, farm size and its quadratic term, herd size, participation in off-farm work, farmer group membership, distance to the local market, and access to extension, credit and input subsidy. The choice of variables for estimating the models were based on *a priori* expectations and the existing literature. For example, Anang et al. (2020) and Anang and Asante (2020) have shown that access to agricultural extension is influenced by factors such as gender, farm size, household size, farmer group membership, and herd ownership. Also, Tran et al. (2019) and Aryal et al. (2018) observed that CSA adoption is influenced by factors such as respondent's age, gender, household size, farm size, participation in off-farm work, tropical livestock unit, distance to the input and product markets, access to extension, access to credit, and group membership.

Kendall's Coefficient of Concordance

Kendall's coefficient of concordance (*W*) was used to rank the perceived severity of the climate change variables on the production activities of respondents in the study area. This model measures the degree of agreement among the various responses given by the respondents regarding the severity of the climate change variables. The responses are put in a rank order ranging from zero to one representing no agreement to complete agreement respectively. The coefficient of concordance represents the ratio of the variability of the total rank for the rank entities to the maximum possible variability of the total rank; a small ratio implies disagreement between judges (Laliberté and Legendre, 2010).

Kendall's W is given as:

$$W = \frac{12S}{m^2(n^3-n)-mT} \quad (5)$$

where W = Kendall's coefficient of concordance, m = number of respondents ranking the constraints, n = number of constraints, T = correction factor for tied ranks and S = sum of squares deviation over the row sum of ranks R_i.

The sum of square deviation is given as

$$S = \sum_{i=1}^{n}(R_i - \bar{R})^2 \quad (6)$$

where R_i is row sum of ranks

$$R_i = \sum_{j=1}^{n} r_{ij} \quad (7)$$

$\bar{R}$ is the mean of the row sum of ranks; given as

$$\bar{R}_i = \frac{1}{n}\sum_{i=1}^{n} R_i \quad (8)$$

RESULTS AND DISCUSSIONS

Description of the sample

Table 1 shows the description and summary statistics of the variables used in the research. The results show that the respondents adopted an average of five CSA practices, with a minimum of zero and maximum of 9. The average age of the respondents is 42 years with a minimum age of 20 years and maximum of 68 years. This mean active age group is lower than the active age (55 years) of farmers identified by MoFA (2016). The active working class ranges from 18 to 65 years (Zakaria et al., 2020) and the result shows that farmers are in their active age which is conducive for agricultural production.

Majority of the farmers (88%) were married, while 93% were household heads and 55% adopted CSA practices to mitigate the effects of climate change. Again, 53% of the respondents had access to agricultural extension services, whiles 17% and 84% of the respondents had access to credit and subsidy, respectively. The cost of adopting a technology influences adoption hence farmers who have access to credit are more likely to adopt CSA. Close to 20% of the respondents belonged to a farmer group with 70% of the sample engaged in off-farm activities to generate extra income to support their livelihood. Farmer groups are expected to provide peer learning that promotes adoption of technologies. The average distance to the local market and extension office is 4.4 and 5.5 kilometres respectively. The adoption of new technology depends on farmers' access to extension services and access to information. The average herd size (number of cattle) of the respondents was approximately one with an average farm size of 6.7 acres. The average farm size of the respondents shows that they are small-scale producers, who typically are adversely affected by climate variability and change, hence the need to adopt CSA to mitigate the risk of climate change.

Table 1: Description of the data used for the analysis

Variable	Mean	S. D.	Min.	Max.
Intensity of adoption (number of CSAPs)	4.980	2.356	0	9
Household head	0.934	0.250	0	1
Age (years)	41.88	10.80	20	68
Marital status (1 = married)	0.881	0.325	0	1
Access to extension (1= access)	0.530	0.501	0	1
Access to credit (1 = access)	0.172	0.379	0	1
Access to subsidy (1 = access)	0.841	0.367	0	1
Member of farmer group (1 = member)	0.199	0.400	0	1
Distance to local market (km)	4.356	2.171	1.9	6.8
Distance to extension office (kilometers)	5.536	4.063	1	10
Herd size (number)	0.821	2.803	0	18
Farm size (acres)	6.745	3.838	1	25
Off-farm work (1 = off-farm work)	0.702	0.459	0	1

S. D. means standard deviation

Climate-smart agriculture (CSA) practices adopted by farmers

Table 2 shows the various climate smart agricultural practices adopted by farmers in the study area. In all, 14 CSA practices were identified as the main practices used by the respondents to mitigate the effects of climate variability and change. The results indicate that majority (68%) of the farmers adopted crop rotation as a mechanism to reduce the stress of climate change. Crop rotation is identified as the most effective measure by farmers in Tolon district as a climate resilient practice. Several studies have reported similar findings (Adzawla et al., 2019; Zakaria et al., 2020). Due to declining soil fertility and farmers' inability to afford the cost of chemical fertilizer, crop rotation offers farmers a natural way to manage the fertility of their soils.

About 48% of the respondents adopted the use of weather forecast and small ruminant rearing to reduce the effect of climate stress on their production activities. Farmers are becoming increasing aware and interested in climate information as a means to mitigate the effects of climate variability and change. Small ruminant rearing is both a livelihood diversification strategy and a means to mitigate the effect of climate variability that leads to loss of livelihood. Furthermore, some farmers also adopted tree planting, planting of stress-tolerant crops, capacity building, mixed cropping, mixed farming and income diversification with the respective averages reported in table 2 (35%, 32%, 23%, 22%, 29% and 35% respectively). On average, less than 20% of the farmers adopted individual-group loans, legume-maize intercropping, and manual ploughing as a CSA practice.

Table 2: Climate-smart agriculture (CSA) practices adopted by farmers

Variable	**Mean**	**S. D.**
Plant trees	0.351	0.479
Small ruminant rearing	0.483	0.501
Stress-tolerant crops	0.318	0.467
Use of weather forecast	0.483	0.501
Capacity building	0.232	0.423
Individual-group loans	0.146	0.354
Improved seed/Early maturing	0.424	0.496
Planting in rows	0.702	0.459
Legume-maize intercrop	0.179	0.384
Income diversification	0.351	0.479
Mixed cropping	0.219	0.415
Mixed farming	0.291	0.456
Crop rotation	0.682	0.467
Manual ploughing	0.119	0.325

S. D. means standard deviation

Intensity of adoption

Table 3 shows the adoption intensity of CSA practices among the smallholder farmers in the Tolon district.

Table 3: Intensity of adoption of CSA practices by farmers

Intensity of adoption	Frequency	Percent
0	5	3.31
1	4	2.65
2	17	11.3
3	19	12.6
4	19	12.6
5	21	13.9
6	21	13.9
7	20	13.3
8	15	9.93
9	10	6.62
Total	151	100
Mean	4.98	

From the results, it was observed that a maximum of nine (9) of the CSA practice were adopted simultaneously by 6.6% of the farmers, with only 3.31% failing to adopt any of the practices. In addition, 2.67% adopted only one (1) CSA practice, 11.3% adopted two (2) practices whiles 12.6% adopted three (3) of the CSA practices. The percentage adopting four (4) of the CSA practices represented 12.6% of farmers. Furthermore, 13.9% adopted five (5) practices with a similar percentage of farmers adopting six (6) CSA practices to reduce the risks and negative impacts of climate change. Similarly, 13.3%, 9.93% and 6.62% adopted seven (7), eight (8) and nine (9) CSA practices respectively.

The mean adoption of the CSA practices was approximated to be 4.98 implying that on the average a farmer in the area will adopt five of the CSA practices. This result confirms the finding of Zakaria et al., (2020) which indicated that an average farmer adopted about 5 CSA practices in Ghana. The study anticipates complementarity between the CSA practices which is beneficial in reducing the effects of climate variability and change. The use of multiple CSA practices is identified as the best mechanism to combat the effect of climate change due to complementarity in the use of these practices (Adzawla et al., 2020; Donkoh, et al., 2019).

Determinants of extension access and intensity of adoption

The results of the Poisson regression with endogenous treatment effects model are presented in Table 4. The model has a good fit as portrayed by the statistical significance of the Wald chi squared variable.

Access to extension was influenced by farmer group membership, herd size, and participation in off-farm work. Belonging to a farmer group enhanced access to agricultural extension at 1% level. The result is consistent with a priori expectation because farmer groups are major channels for the dissemination of agricultural information to farmers by both governmental and non-governmental organizations working with rural farmers. The result agrees with Anang et al. (2020) who found a positive correlation between farmer group membership and access to agricultural extension services in northern Ghana.

The results also showed that access to agricultural extension was higher for farmers who engaged in off-farm work. In other words, farmers who engaged in income diversification have a higher probability of accessing agricultural extension services. Furthermore, extension access decreased with herd size. In other words, farmers who owned more cattle have a lower likelihood of accessing agricultural extension services.

The variable of interest, access to agricultural extension, is positively related to adoption intensity of CSA practices. The positive coefficient of the extension variable in the outcome equation indicates that access to agricultural extension enhances adoption of CSA practices by smallholder farmers. The result is in consonance with a priori expectation since extension agents play a critical role in information dissemination to small-scale farmers. Farmers' knowledge of CSA practices depends to a greater extent on contact with extension agents, hence the higher likelihood of CSA adoption with access to extension. Anang et al. (2020) obtained a similar result in their study in northern Ghana.

Table 4: Determinants of extension access and the intensity of adoption of CSA practices

Variable	Access to extension		Adoption intensity	
	Coef.	S. E.	Coef.	S. E.
Household head	- 0.230	0.486	0.207	0.196
Age	- 0.014	0.085	- 0.009	0.690
Age squared	0.0004	0.001	0.0001	0.674
Marital status	0.124	0.407	0.194	0.115
Member of farmer group	2.612***	0.542	- 0.038	0.637
Herd size	- 0.084*	0.046	0.011	0.325
Farm size	0.170	0.136	- 0.06**	0.013
Farm size squared	- 0.002	0.007	0.002**	0.033
Off-farm work	- 0.83***	0.283	- 0.134*	0.050
Distance to local market	- 1.265	1.705	0.07***	0.000
Distance to extension office	- 0.599	0.916		
Access to extension			0.247***	0.009
Access to credit			0.175**	0.012
Access to subsidy			0.49***	0.001
Constant	8.232	12.66	0.817*	0.093
Model diagnostics				
/athrho	- 1.53***	0.371		
/lnsigma	- 4.623**	1.977		
rho	- 0.91***	0.063		
Sigma	0.010	0.019		
Wald chi2 (13)	95.46***			
Log-likelihood	- 379.1			

***, ** and * are significant levels at 1%, 5% and 10% respectively. Wald test of independent equations (rho = 0): chi2(1) = 17.06, Prob > chi2 = 0.000. S. E. is standard error.

Other factors influencing adoption intensity of CSA practices include farm size which is negatively related to adoption intensity, but the quadratic term is positive in its effect on adoption intensity. Farmers with smaller land holdings have a lower likelihood of adopting CSAPs. However, as farm size increases, there is a positive correlation with CSA adoption. Respondents with smaller land holdings may be less-endowed farmers who find it difficult to afford the cost of adopting CSA practices. Also, adoption intensity decreased with income diversification (off-farm activity participation) at 10% level, suggesting that participants in off-farm work have lower adoption of CSA practices compared to non-participants.

Furthermore, intensity of adoption of CSA practices increased with access to subsidy in line with the study's a priori expectation. Input subsidy reduces the cost of adoption to farmers, thereby enhancing the ability of many farmers to utilize CSA practices.

Intensity of adoption also increased with access to credit, which is consistent with *a priori* expectation. Farmers with access to credit are anticipated to have higher likelihood to adopt productivity-enhancing technologies as well as CSA practices. This is because credit reduces the liquidity constraints facing most farmers thereby enabling adoption of innovations in line with the extant literature.

Distance to the local market correlated positively with adoption intensity of CSA practices at 1% level, which is contrary to expectation. It was expected that an increase in market distance would decrease adoption intensity, as the cost of adoption is increased by distance travelled to access inputs, but the reverse was observed.

Impact of agricultural extension on CSA adoption intensity

Table 5 reports the estimates of the impact of agricultural extension on CSA adoption intensity. Three different impact parameters were estimated to gain better insight into the mediating role of agricultural extension on CSA adoption intensity. The impact parameters used in this study, namely the potential outcome means, average treatment effect, and average treatment effect on the treated, provide unique measures of the impact of agricultural extension on the adoption intensity of climate smart agricultural practices among the respondents.

Table 5: Impact of agricultural extension on CSA adoption intensity

Impact parameter	Coefficient	S. E.
Potential-outcome mean for participants (POM)	1.279***	0.121
Average treatment effect (ATE)	1.206***	0.448
Average treatment effect on the treated (ATT)	1.271***	0.448

S. E. is standard error.

The results show that the potential-outcome mean (POM) for participants in agricultural extension is 1.28 more than that for non-participants. Hence, the average number of CSA practices adopted by participants in agricultural extension is 1.28 times the average number of CSA practices adopted by non-participants in agricultural extension. Agricultural extension therefore impacts positively on CSA adoption in line with the results obtained using the Poisson regression with endogenous treatment effects model.

Another impact parameter of interest is the average treatment effect (ATE), that is, the impact of agricultural extension on adoption intensity of the average farmer in the sample. The margin command in Stata was used to estimate the ATE of extension on CSA adoption. The estimated ATE of 1.21 means that the average farmer will have 1.21 more adoption of CSA practices if he or she had access to agricultural extension. Thus, extension's interceding role in adoption of CSA practices is that it increases the average farmer's adoption by 1.21. This result gives credence to the importance of agricultural extension services and the role it plays in mitigate the challenges of climate change.

An impact parameter of keen interest to economists and evaluation analysts is the average treatment effect on the treated (ATET), that is, the impact of agricultural extension on adoption intensity of participants in agricultural extension (those in the treatment group). The estimated ATET value means that the average farmer in the treatment group had 1.27 more adoption of CSA practices than it would if he or she did not have access to agricultural extension. The implication is that, through the intermediating role of extension, recipients of agricultural extension increased their adoption of CSA practices by 1.27. Expanding smallholder farmers' access to agricultural extension service is therefore one of the critical ways to promote climate-smart agricultural technology adoption to ensure sustainable agricultural production. This is very imperative because of the threats of climate change and its negative impact on crop production in fragile environments such as the northern savanna of Ghana.

Ranking of the perceived severity of climate change variables

The perceived severity of the climate change variables on the production activities of respondents in the study area are ranked and presented in Table 6. Farmers' ability to attain high level of productivity depends on their ability to overcome the myriad challenges they face in production. Climate change is one of the major challenges affecting farm output and productivity in northern Ghana (Alare et al., 2018). As a result, farmers in the study area were asked to rank the severity of the major climate change variables that affect their production. Table 6 presents the ranking of the perceived severity of the climate change variables on the production activities of respondents in the study area.

Table 6: Ranking of the perceived severity of climate change variables

Climate change variable	Mean rank	Ranking
Drought	2.15	1st
Erratic rainfall pattern	2.16	2nd
High temperatures	3.48	3rd
Incidence of new pests and diseases	4.05	4th
Variation in the planting season	4.77	5th
Strong winds	5.20	6th
Excessive rainfall	6.17	7th
Kendall's W	0.49	

In the ranking by the farmers, the variable with the least mean rank is identified as the severest in terms of its impact on farmers production activities, and vice versa. The result indicates that respondents ranked drought, erratic rainfall pattern, high temperature, incidence of new pest and diseases, and variation in planting season as the top five challenges of climate change. Drought was ranked as the topmost climatic challenge facing farmers in the study area. Agricultural production in northern Ghana depends on rainfall, hence absence of rainfall for a prolonged period is a major concern to farmers in the study area. Drought occasioned by climate change is therefore a major factor causing food insecurity and poverty to persist (MoFA, 2016). The northern savanna of Ghana is a semi-arid region, and the effect of droughts is pronounced. The second constraint identified by the respondents was erratic rainfall which affects crop growth and activities of farmers in the production process and subsequently affects livelihood of the farmers. Erratic rainfall leads to spells of drought, resulting in crop loss. The results of the study suggest that making irrigation available to farmers is a necessity to improve crop production and productivity.

High temperatures ranked as the third most severe climate change constraint. The northern savanna ecology experiences high temperatures throughout the year. High temperatures exacerbate drought conditions, and promote pest and disease build-up. Incidence of pests and diseases was the next constraint, which is of major concern to farmers due to the high cost involved in chemical pest control and the high crop loss due to the incidence of pests and diseases.

Climate change has also brought about variation in the onset of the planting season which is a major concern of farmers. Due to this challenge, farmers encounter crop loss when there is a slight change in the planting season. This necessitates the reliance on weather information, which most smallholder farmers are not accustomed to.

Strong winds and excessive rainfall were the least ranked factors. While strong wings can lead to dislodgement of plants, they do not constitute the most serious challenge facing smallholder farmers in the study area. Similarly, farmers did not consider excessive rainfall to be of topmost importance as a climate change factor.

The study estimated the level of agreement among the farmers on the ranking of the challenges using the Kendall coefficient of concordance. The estimated coefficient of 0.49 indicates 49% level of agreement among the respondents in the ranking of the climate change constraints.

CONCLUSIONS

The study assessed the effect of agricultural extension on adoption of climate-smart agricultural practices by Ghanaian smallholder farmers, as well as an assessment of farmers' perception of the severity of major climate change variables on their production. Data for the study came from a sample of smallholder farmers in the Tolon district in the Northern Region of Ghana. Poisson regression with endogenous treatment effects model and Kendall's coefficient of concordance were used to analyze the data.

The study concluded that access to agricultural services like agricultural extension, farm credit and input subsidy enhanced adoption intensity of CSA practices by farmers. In particular, access to agricultural extension was found to be critical to adoption of climate-smart agricultural practices in northern Ghana. It was established that those who had access to agricultural extension had 1.27 more adoption of CSA practices than they would if they did not have access to agricultural extension. Similarly, the average farmer in the sample would have 1.21 more adoption of CSA practices if he or she had access to agricultural extension.

Hence, it is imperative to promote access to agricultural extension as an important way to promote the adoption of CSA practices by farmers to mitigate the negative effects of climate change on agricultural production. Inclusion of CSA practices in agricultural extension information dissemination is therefore expected to promote adoption of CSA practices to mitigate the effects of climate change on agricultural production.

In addition, encouraging farmers to join farmer groups has the potential to enhance access to extension service, and hence, adoption of CSA practices. There is therefore the need to incentivize existing farmer organizations to act as conduits for agricultural information delivery among smallholders to promote sustainable production. Furthermore, developing and promoting rural financial markets to meet the needs of smallholders is one critical way to promote adoption of CSA practices. Also, subsidies reduced the cost of adoption, thus promoting adoption of CSA practices among smallholder farmers. Hence, the existing input subsidy policy under the Planting for Food and Jobs programme that covers chemical fertilizer and improved seeds should be expanded to include, for example, herbicides and tree seedlings, to promote adoption.

The study also recommends a further study with a broader scope, using a larger sample size across several geographical areas of northern Ghana to shed additional light on CSA technology adoption by smallholder farmers.

REFERENCES

Adzawla, W., Azumah, S. B., Anani, P. Y., & Donkoh, S. A. 2020. Analysis of farm households' perceived climate change impacts, vulnerability and resilience in Ghana. *Scientific African, 8*. https://doi.org/10.1016/j.sciaf.2020.e00397.

Adzawla, W., Kudadze, S., Mohammed, A. R., & Ibrahim, I. I. 2019. Climate perceptions, farmers' willingness-to-insure farms and resilience to climate change in Northern region, Ghana. *Environmental Development*, *32*, 100466. https://doi.org/10.1016/j.envdev.2019.100466.

Alare, R. S., Owusu, E. H., & Owusu, K. 2018. Climate Smart Agriculture Practices in Semi-arid Northern Ghana: Implications for Sustainable Livelihoods. *Journal of Sustainable Development*, *11*(5), 57. https://doi.org/10.5539/jsd.v11n5p57.

Anang, B. T., & Asante, B. O. 2020. Farm household access to agricultural services in northern Ghana. *Heliyon*, 6(11), e05517.

Anang, B. T., Bäckman, S., & Sipiläinen, T. 2020. Adoption and income effects of agricultural extension in northern Ghana. *Scientific African*, 7, e00219.

Aryal, J. P., Jat, M. L., Sapkota, T. B., Khatri-Chhetri, A., Kassie, M., & Maharjan, S. 2018. Adoption of multiple climate-smart agricultural practices in the Gangetic plains of Bihar, India. *International Journal of Climate Change Strategies and Management*, 10(3): 407-427.

World Bank. 2015. *No Title Gender in climate-smart agriculture. IBRD, FAO and IFAD, Rome R. Ruben et al*.

CARE International. 2013. *Adaptation Learning Programme* (*ALP) climate change vulnerability and adaptive capacity in Northern Ghana*. 1–16.

CCES (Centre for Climate and Energy Solutions) 2019. What Is Climate Resilience and Why Does It Matter? *Climate Essentials*, *April*, 12.

Donkoh, S. A., Azumah, S. B., & Awuni, J. A. 2019. Adoption of improved agricultural technologies among rice farmers in Ghana: A multivariate probit approach. *Ghana Journal of Development Studies*, 16(1), 46-67. https://www.ajol.info/index.php/gjds/article/%0Aview/186964.

Feldmeyer, D., Wilden, D., Kind, C., Kaiser, T., Goldschmidt, R., Diller, C., & Birkmann, J. 2019. Indicators for monitoring urban climate change resilience and adaptation. *Sustainability (Switzerland)*, *11*(10). https://doi.org/10.3390/su11102931.

Karbo, R. T., & Crentsil, A. O. 2021. Climate-Smart Agriculture (CSA) Adaptation Strategies of Farmers against Climate Change in Lawra Municipality, Upper West Region, Ghana. *Journal of Scientific Research and Reports*, *27*(2), 10–19. https://doi.org/10.9734/jsrr/2021/v27i230355.

Lawson, E. T., Alare, R. S., Salifu, A. R. Z., & Thompson-Hall, M. 2020. Dealing with climate change in semi-arid Ghana: understanding intersectional perceptions and adaptation strategies of women farmers. *GeoJournal*, *85*(2), 439–452. https://doi.org/10.1007/s10708-019-09974-4.

Le Roux, A., Engelbrecht, F., Paige-Green, P., Verhaeghe, B., Khuluse-Makhanya, S., McKelly, D., Dedekind, Z., Muthige, M., Van Der Merwe, J., & Maditse, K. 2016. Climate adaptation: Risk management and resilience optimisation for vulnerable road access in Africa. *Climate Threats Report: Council of Scientific and Industrial Research (CSIR), Paige-Green Consulting (Pty) Ltd and St Helens Consulting Ltd*, *July* (December), 1–65.

MOFA (Ministry of Food and Agriculture). 2016. Agriculture in Ghana: Facts and Figures MOFA, Accra, Ghana, 2017. *Report*, *2017*.

Minx, J. C., Callaghan, M., Lamb, W. F., Garard, J., & Edenhofer, O. 2017. Learning about climate change solutions in the IPCC and beyond. *Environmental Science and Policy*, *77*(October 2016), 252–259. https://doi.org/10.1016/j.envsci.2017.05.014.

Amin, A., Mubeen, M., Hammad, H. M., & Nasim, W. (2015). Climate Smart Agriculture: an approach for sustainable food security. Agricultural Research Communication, 3(2), 13–21.

Shaw, A. and K. P. 2012. Working Paper No. 19 CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). *Ccafs*, *19*, 1–30.

Tran, N. L. D., Rañola, R. F., Sander, B. O., Reiner, W., Nguyen, D. T., & Nong, N. K. N. 2020. Determinants of adoption of climate-smart agriculture technologies in rice production in Vietnam. *International Journal of Climate Change Strategies and Management*, 12(2): 238-256.

Wongnaa, C. A., & Babu, S. 2020. Building resilience to shocks of climate change in Ghana’s cocoa production and its effect on productivity and incomes. *Technology in Society*, *62*(June), 101288. https://doi.org/10.1016/j.techsoc.2020.101288.

Zakaria, A., Baanni, S., Appiah-Twumasi, M., & Dagunga, G. 2020. Adoption of climate-smart agricultural practices among farm households in Ghana: The role of farmer participation in training programmes. *Technology in Society*, *63*(June), 101338. https://doi.org/10.1016/j.techsoc.2020.101338.