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Enhancing Adoption Intensity: Exploring the Nexus between Climate Information Access and Climate-Smart Adaptation Practices among Smallholder Farmers in Ghana

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Globally, climate change is a significant development challenge. Sub-Saharan Africa is particularly vulnerable to the negative effects of climate change because of the region's low adaptive capacity and its excessive reliance on rain-fed agriculture for food security and livelihood. Climate information accessibility is promoted to improve smallholder farmers' adoption intensity of climate-smart adaptation practices. The object of this research is to examine climate information access as a driver of climate-smart adaptation practices. This study utilized primary data from 475 smallholder farmers in the Northern Region of Ghana. The Endogenous-Switching Poisson regression model was fitted to examine the determinants of access to climate information and the subsequent effect of access to climate information on climate-smart adaptation practices adoption intensity. According to the study, access to climate information is endogenous and is influenced positively by gender, farming experience, off-farm income and the number of times smallholder farmers listen to the radio. Age, farm income, access to extension, education, off-farm income, farm experience, perception of temperature and Access to climate information thus had a significant influence on the adoption intensity of smallholder farmers' climate-smart adaptation practices. Based on these results, we suggest that climate change and agricultural programs should encourage smallholder farmers' subscription to access climate information in promoting the adoption of numerous climate-smart adaptation practices. To provide climate information to smallholder farmers in this situation, extension agents should be the main targets. The large effect of income that is both farm and off-farm income on the rate of climate-smart adaptation practices adoption is one of the study's key findings. We contend that agricultural programmes should include ways to improve both farm and off-farm income of smallholder farmers to enable them to intensify their climate-smart adaptation practices adoption.
Keywords: Poisson, endogenous, switching, regression, random, utility, model.

INTRODUCTION

Lack of climatic knowledge hinders smallholder farmers' use of climate-smart adaptation technology. Access to climate data may help scale up climate-smart adaption technology (Ngigi and Muange, 2022). According to the World Meteorological Organisation (WMO), science-based climate information improves resilience, climate change adaptation, and sustainable livelihoods and development. Prepared smallholder farmers who make informed decisions are more robust to climate change and unpredictability, reducing its negative consequences. Timely climate information distribution and access enable this.

Access to climate information is crucial for fostering climate-smart adaptation solutions in Africa, according to evidence (Djido *et al.,* 2021). Climate change is causing flooding, unpredictable rainfall, sea level rise, droughts, and soil erosion in Africa, reducing food yield. These effects imperil millions of Africans' livelihoods and aggravate food insecurity and poverty. Finding strategies to mitigate climate

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change's effects in Africa is crucial. Timely climate information is essential for managing climate change risks (Antwi-Agyei *et al.*, 2021).

Despite the impressive body of knowledge about climate change and its effects, climate information services are usually insufficient and rare in Sub-Saharan Africa (SSA) because most National Meteorological and Hydrological Services (NMHS) telecommunication networks are insufficient, ineffective, and outdated, making it difficult to deliver observations and products efficiently, especially to rural areas. Sub-Saharan African NMHS also struggle to use available science and technology because to infrastructure issues. Thus, nothing is known about integrating climatic information services into SSA's agricultural systems.

Although it may aid climate change adaptation (Thottadi and singh, 2024).

Climate shocks threaten northern Ghanaian smallholder farmers. Climate change causes floods, which affect agriculture. Floods damage infrastructure and cause socioeconomic upheavals in agriculture, which may affect food production. This reduces food stability, availability, and accessibility. Climate change has increased Northern Ghanaian floods. Statistics show that prolonged rainfall and the Bagre dam in Burkina Faso overflowing over caused major floods in 2007, 2010, 2012, 2017, 2018, and 2019. These floods threatened rural livelihoods and agricultural productivity Owusu *et al.* (2021). Thus, the National Climate Change Policy's sustainable agriculture development policy includes climate-smart adaptation methods and technology.

Despite efforts to increase climate-smart adaptation uptake by smallholder farmers in northern Ghana, their adoption rate remains low. Thus, research is needed to fully understand the elements that drive climate information availability and climate-smart adaptation technology adoption intensity to build policies and programs that address this issue.

Climate information services in Ghana, especially in the north, have been little studied. Smallholder farmers in northern Ghana, a climate change-vulnerable region, are especially vulnerable. Climate change threatens the Northern Region's monomodal rainfall patterns, making it hard for smallholder farmers to meet consumer demand.

Some research has examined how climate information service access affects farmers' climate change adaptation decisions, but the results are mixed. In Ghana, mobile-based weather and climate information services improved the use of climate-smart adaption technologies like various cropping patterns, water management, and pest-resistant crops, according to Djido *et al.* (2021). Alidu *et al.* (2022) revealed a substantial association between smallholder farmers' joint decision to acquire climate information and apply climate-smart adaptation techniques. However, Owusu *et al.* (2021) found in Ghana that household heads' climate data use did not affect climate-smart technology adoption. According to these studies, climate information services may or may not impact a farmer's decision to deploy climate smart adaption solutions. Alidu *et al.* (2022) employed bivariate probit, but Djido *et al.* (2021) used recursive bivariate probit and found inconsistent results. This research employs Endogenous-Switching Poisson Regression to assess the effect of climatic information on smallholder farmers' climate smart adaption practice adoption intensity. The rest of the paper follows this format. The next section describes the study area and methods. The third portion presents the study's results and discussions, followed by a conclusion and policy recommendations.

MATERIALS AND METHODS

***Study area*:** The study was conducted in Ghana's Northern Region, where climate change affects agriculture. Savelegu, Sagnarigu, Nantong, Kumbungu, and Tolon districts were studied. The Northeast Region, Ghana-Togo international border, Oti Region, and Savannah Region border the Northern Region to the north, east, south, and west. Ghana's second-largest region is Northern. Figure 1 shows the research area map. It covered 70,384 square kilometres 2—31% of Ghana's land area—before the split (Ghana Statistical Service, 2014). Northern regions have average annual rainfall of 750mm to 1050mm with temperatures of 140C at night and 400C during the day. Most smallholders grow maize, rice, groundnut sorghum, and millet (Ghana Statistical Service, 2014). These crops meet most Ghanaians' nutritional demands.

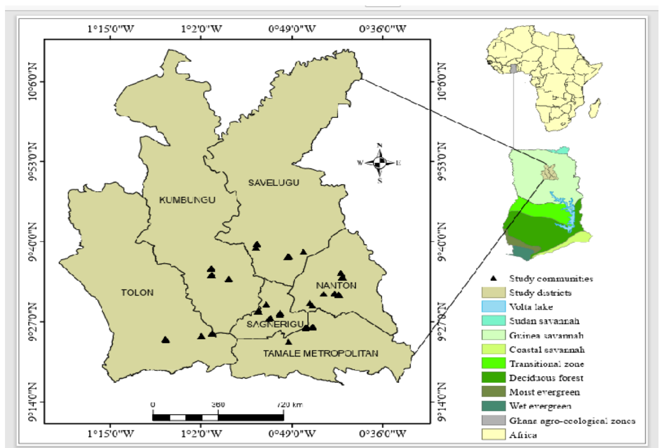

Figure 1. Map of the study area.

***Sampling, data collection, and analysis*:** This study selected the study region and respondents using multi-stage sampling. Three districts and two municipals were chosen for the study at the start due to their increased rainfall variability and rising temperatures. In the second stage, simple random sampling picked two communities from each city and district. Smallholder farmers from each community were selected by simple random sampling. Finally, proportionate stratified sampling chose 20% of smallholder farmers. From Savelegu, Nantong, Sagnarigu, Kumbungu, and Tolon districts/Municipalities, 107, 134, 80,84, and 70 smallholder farmers were chosen Overall, 475 smallholder farmers were interviewed for the study. Primary data came from smallholder farmers. These statistics include smallholders' socioeconomic status, climate information access, and climate-smart adaptation intensity. Descriptive statistics and Endogenous-Switching Poisson Regression were used in STATA 14.

***Theoretical framework and empirical model*:** Climate information may motivate smallholder farmers to adopt climate-smart adaptation measures, which enhance productivity. Access to climate information may boost smallholder farmers' climate wise adaption efforts. What will motivate smallholder farmers to acquire climate information and employ climate-smart adaptation practices?

This study uses random utility theory. The hypothesis suggests that smallholder farmers will choose between climate and information based on their benefits. This study also assumed that smallholder farmers obtained climatic information if the resulting benefit was significantly higher than not doing so. Access to climate information motivates smallholder farmers to adopt climate-smart adaptation strategies, according to the random utility theory. The random utility hypothesis can also explain smallholder farmers' climate-smart adaptation choices. The idea suggests that smallholder farmers would implement more climate-smart adaption measures if they realised their higher advantages or lower risk compared to non-adoption. This study employed count data model to analyse climate-smart adaptation adoption by smallholder farmers (Miranda, 2004; Terza, 1998). Using a random sample of N = (1..............n) smallholder farmers, a vector of predictor variables Zi, an endogenous dummy, and a stochastic term εi, the count predicted variable, climate smart adaptation adoption (CSAA), is expected to follow the standard Poisson distribution function:

$$f\left(\frac{CSAA_i}{\varepsilon_i}\right) = \frac{exp\{-exp(Z_i^{'}\gamma + \beta CIA_i + \varepsilon_i)\}\{exp(Z_i^{'}\gamma + \beta CIA_i + \varepsilon_i)\}^{y_i}}{CSAAs_i} \quad (1)$$

To assess socioeconomic traits (z) and climate information access (CIA), use γ and β coefficients. The stochastic error term εi accounts for information loss and omitted variables. A directory process considers CIAi as a vector of control variables ki that may include Zi:

$$CIA_i = \begin{Bmatrix} 1 \; if \; k_i\alpha + g \; > 0 \\ 0 \quad otherwise \end{Bmatrix} \quad (2)$$

α is a vector of variable coefficients to be estimated. Assumed that d_i embodies all endogenous variables and εi and gi are jointly normally distributed with a mean zero and covariance matrix.

$$\Sigma = \begin{pmatrix} \sigma^2 \sigma\pi \\ \sigma\pi 1 \end{pmatrix}$$

Table 1. Description and measurement variables.

Variable	Description	Measurement	Expected sign	
			Adoption	Climate information
Adoption intensity	Climate smart adaptation practices (CSAP) adopted per smallholder farmer	Number of CSAPs	N/A	N/A
Climate information Access	Smallholder farmers who accessed climate information	Smallholder farmers who accessed climate information	+	N/A
Age	Age of smallholder farmer	Number of years	+	+
Gender	Gender of smallholder farmer	1= male, 0=female	+	+
Farm income	Net farm income	Ghana cedis	+	+
Farm size	Farm size of smallholder	Acres	+	+
Remittance	Net remittance received	Ghana cedis	+	+
Household size	Number of household members	Number of humans	+	+
Education	Respondents attended formal school	1= formal education, 0=no formal education	+	+
Off-farm income	Net off farm income	Ghana cedis	+	+
Temperature perception	Respondents' perception about temperature	1=increased, 0=otherwise	+	+
Rainfall perception	Respondents' perception about rainfall	1=decreased, 0=0therwise	+	+
Experience	Respondents farming experience	years	+	+
TV	Respondents net number of times of watching TV	Number of times	+	+
Radio	Respondents net number of times of listening to radio	Number of times	+	+

given that εi, CIA_i, and $CSAA_i$ are independent. Based on the above, the joint restrictive probability density expression of $CSAA_i$ and CIA_i, given d_i can be illustrated as:

$$f\left(CSAA, \frac{CIA_i}{d_i}\right) = \int_{-\infty}^{\infty} \left\{ \begin{matrix} CIA_i f\left(\frac{CSAA_i}{CIA_i=1, d_i, \varepsilon_i}\right) prob\left(CIA_i = \frac{1}{d_i, \varepsilon_i}\right) + (1 - CIA_i) \\ f\left(CSAA_i \frac{1}{CIA_i=0, d_i, \varepsilon_i}\right) prob\left(CIA_i = \frac{0}{d_i, \varepsilon_i}\right) \end{matrix} \right\} f(\varepsilon_i) CIA_i \varepsilon_i \quad (3)$$

where f(εi) represents the probability density function for the stochastic error term εi. Endogenous-switching Poisson regression corrects endogeneity in two stages. The first stage assesses climate information access determinants using probit distribution, while the second stage uses Poisson distribution to examine smallholder farmer adoption intensity (Miranda, 2004). Access to climate information is thought to be causal, while adoption intensity is the impact. Estimating two simultaneous equations using equation (1)'s theoretical structure achieves this study's goals.

The first goal is to identify smallholder farmers' climate information access drivers, and the second is to assess how climate information access affects climate smart adaption strategies. In this study, climate change adaptation practices included mixed cropping, early or delayed planting, irrigation, chemical fertiliser, mulching, planting climate-tolerant crop varieties, crop rotation, cover cropping (legume/fodder crops), integrating crop and livestock systems, and increased agroforestry. Access to climate information affects climate smart adaption behaviours, hence the substantial equation estimates the latter equation while the former is the selection equation in a recursive design.

Access to climatic information by smallholders is optional and may be influenced by socioeconomic factors and other farmer attributes. This may induce endogeneity since smallholder farmers choose to acquire climatic information. Estimating the effect of climate information access on climate-smart adaption adoption without controlling for sample may be biassed. The model is ideal for fixing this simultaneous equation model issue. Practically, the empirical model specification for measuring climate information access's effect on climate-smart adaption strategies is:

$$CIA_i = \beta_0 + \beta_1 Age + \beta_2\, Gender + \beta_3\, Househould\ size + \beta_4\, Education + \beta_5\, experience + \beta_6\, Off\ farm\ income + \beta_7 TV(number\ of\ times) + \beta_8\, Radio(number\ of\ times) + \mu_i \quad (4)$$

$$CSAA_s = \gamma_0 + \gamma_1\, age + \gamma_2\, gender + \gamma_3\, farm\ income + \gamma_4\, farm\ size + \gamma_5\, remittance + \gamma_6\, household\ size + \gamma_7\, extension + \gamma_8\, education + \gamma_9\, off\ farm\ income + \gamma_{10}\, experience + \gamma_{11}\, temperature\ perception + \gamma_{12}\, rainfall\ perception + \gamma_{13}\, climate\ information\ access + \varepsilon_i \quad (5)$$

RESULTS AND DISCUSSION

***Summary statistics of variables*: ** Table 2 provides the descriptive and summary statistics of the variables used in the analysis. About 77% of the respondents were males which does not reflect the national situation of males being 48.5 % proportion of the national population (GLSS, 2017). The predominance of male farmers in the study is consistent with that of Ouattara *et al.* (2022), however, contradicts that of Ngaiwi *et al.* (2023).

About 86% of the respondents have a perception of an increase in temperature over the years and over 76% of them believed rainfall has decreased over that same period. This is confirmed by Tofu and Mengistu (2023) who reported about increase in temperature and a decrease in rainfall.

About 78% of the respondents have access to extension services. This implies that the majority of the respondents had access to the extension which agrees with the findings of Bessah *et al.* (2021) who also found that the majority (77.33%) of maize respondents interviewed had access to extension service. The result from this study indicates that the majority (81%) of the respondents had access to climate change information. This confirms the findings of Ngigi and Muange (2022); Muema *et al.* (2018) who both indicated that the majority 87.50% and 94% respectively of the respondents in their study had access to climate information. More than half (61%) of the smallholder farmers have no formal education and this agrees with Djido *et al.* (2021) who reported that a similar number of the respondents (69.9%) in their study also did not have formal education.

The average age of the respondents interviewed was about 39 years. This implies that the respondents interviewed fall within the working age. The average farming experience was 18 years with the average farm size of a smallholder farmer reported to be about 5.30 acres. The average household size of the respondents interviewed was 10 persons. The mean household size of the respondents is above the regional average of 5.8 persons (GLSS, 2017), a conclusion that is expected given that agricultural households tend to be larger than average households partly because of the labour required for agricultural activities. The average annual farm income of a smallholder farmer was about GHC 2375 with an average annual off-farm income reported to be around GHC 1302. While the average annual remittance received was GHC 171, smallholder farmers listen to the radio and watch TV about 4 and 1 times respectively on average per week (Table 2).

***Adoption levels of climate smart adaptation practices*: ** All together eleven (11) climate-smart adaptation practices were discovered (see Table 3). Among the climate-smart adaptation practices, planting adjustment was highly practice by the smallholder (72.84%) to adapt to climate change, climate variability and climate-related shocks.

Table 2. Socioeconomic characteristics of respondents.

Item	Frequency	Percent (%)
Gender		
Female	111	23.37
Male	364	76.63
Total	475	100.00
Perception of Temperature		
Otherwise	66	13.89
Increase	409	86.11
Total	475	100.00
Perception of Rainfall		
Otherwise	110	23.16
Decrease	365	76.84
Total	475	100.00
Access to Extension Services		
No	103	21.68
Yes	372	78.32
Total	475	100.00
Education		
No formal education	292	61.47
Formal education	183	38.53
Total	475	100.00
CCI Access		
No	90	18.95
Yes	385	81.05
Total	475	100.00
Descriptive Statistics for Continue Variables	Mean	Std. Dev.
Age	39.084	11.411
Farm income	2375.621	2013.132
Off farm income	1302.147	3584.628
Farming experience	18.943	12.666
remittance	171.027	289.394
HH Size	10.314	6.441
Farm size	5.297	3.565
Number of Times Radio	3.777	2.756
Number of Times TV	1.305	3.258

This high rate of adopting the varying date of planting agrees with the findings of Zakaria *et al.* (2020);Adzawla and Baumüller (2021); Adzawla *et al.* (2020) who also found adjusting planting date to be the most adopted (99.67%) and (99.7%) respectively. The second most practised climate-smart adaptation adopted by the respondents is mixed cropping (58.53%) followed by composting (50.95%). The least practised climate-smart adaptation adopted is crop rotation (1.47%) and irrigation (6.95%).

Table 3. Adoption of climate-smart adaptation practices.

Climate Smart Adaptation Practices	Frequency	Proportion adopted (%)
Mixed Cropping	278	58.53
Chemical Fertilizer	231	48.63
Crop Rotation	7	1.47
Planting Adjustment	346	72.84
Cover Cropping	78	16.42
Composting	242	50.95
Agroforestry	236	49.68
Drought Tolerant Variety	97	20.42
Mulching	122	25.68
Crop-Livestock Integration	179	37.68
Irrigation	33	6.95

***The intensity of adoption of climate-smart adaptation practices*:** Table 4 describes the intensity of adoption of adaptation strategies among smallholders. The estimates showed that about 19% of the respondents adopted five (5) strategies, followed by about 15 % and 14 % who adopted 3 and 4 strategies respectively. About 11 % of the smallholder farmers did not adopt any CSA strategy. The average number of strategies practiced by a respondent is around 3,983 with a standard deviation of 2.218. This indicates that on average a smallholder adopted up to four climate-smart adaptation practices in an effort to increase agricultural productivity. Aryal *et al.* (2018); Donkoh *et al.* (2019); Azumah *et al.* (2020); Zakaria *et al.* (2020) among other recent research have shown that some climate-smart agricultural activities have complementing effects. As a result, the adoption of various climate-smart agricultural practices was anticipated. It can also be concluded from the results that smallholder farmers are better prepared to combat climate change and its effects on agricultural productivity and production when they use a variety of complementary climate-smart adaptation practices.

Table 4. Intensity of CSA adoption.

No. of CSA adopted	Frequency	Percent
0	52	10.95
1	18	3.79
2	62	13.05
3	69	14.53
4	67	14.11
5	92	19.37
6	57	12.00
7	40	8.42
8	14	2.95
9	2	0.42
10	2	0.42
Total	475	100.00
Average Adoption Intensity (CSA)	3.893	
Standard Deviation	2.218	

***Factors influencing access to climate change information*:** The results from Table 5 show that four (4) factors significantly influence access to climate change information in the study area. These include the gender of the respondents, the number of times a smallholder farmer listens to a radio in a week, off-farm income, and experience of the smallholder farmers.

Gender plays a crucial role in the access to climate information. There is a significant (1%) positive relationship between gender and access to climate change information which means that male smallholder farmers are more likely to access climate change information than their female counterparts. The findings of this study contradict the findings of Owusu *et al.* (2021);Muema *et al.* (2018). This finding is revealing, and it exposes the existence of sociocultural barriers in society that restrict women's participation in certain social programmes, it also suggests that female smallholder farmers lack the resources that will help them access climate change information.

Respondents' farming experience is positively and marginally significant (10%) to access to climate information. This implies that experienced smallholder farmers are more likely to access climate information than less experienced ones. That is a one-year increase in the experience of smallholder farmers will increase their probability of accessing climate information by 2 %. This is expected in that the relatively experienced smallholder farmers will access climate information to make informed decisions after their long years in the venture of various situations they have to deal with to improve their productivity as a result of adopting climate-smart adaptation practices. This is consistent with the findings of Antwi-Agyei *et al.* (2021) who also found experience as a strong predictor of access to climate information by smallholder farmers. This outcome demonstrates the

Table 5. Estimates of climate change information access on the adoption of climate-smart adaptation practices.

Variable	Exogenous-Switch Poisson Regression				Endogenous-Switch Poisson Regression			
Intensity CSA	**Coef.**	**Std. Err.**	**z**	**P>z**	**Coef.**	**Std. Err.**	**z**	**P>z**
Age	-0.007	0.004	-1.750	0.080	-0.007*	0.004	-1.840	0.065
Gender	-0.064	0.075	-0.840	0.398	-0.081	0.077	-1.050	0.295
Farm income	0.144	0.033	4.420	0.000	0.142***	0.033	4.350	0.000
Farm size	-0.013	0.009	-1.560	0.119	-0.013	0.009	-1.550	0.122
Remittance	0.000	0.000	0.640	0.524	0.000	0.000	0.630	0.531
Household Size	0.005	0.004	1.290	0.196	0.005	0.004	1.320	0.187
Extension	0.269	0.084	3.200	0.001	0.269**	0.084	3.190	0.001
Education dummy	0.129	0.054	2.390	0.017	0.124**	0.055	2.280	0.022
Off-farm income	-0.054	0.014	-3.840	0.000	-0.057***	0.014	-3.970	0.000
experience	0.013	0.004	3.610	0.000	0.013***	0.004	3.540	0.000
Temperature Perception	0.147	0.086	1.710	0.087	0.145*	0.086	1.680	0.093
Rainfall perception	0.060	0.067	0.900	0.370	0.062	0.067	0.920	0.358
CCI access	0.822	0.104	7.880	0.000	0.907***	0.125	7.260	0.000
_cons	-0.536	0.255	-2.100	0.035	-0.542	0.256	-2.120	0.034
CCI Access								
Age	0.018	0.013	1.380	0.168	0.016	0.013	1.240	0.216
Gender	0.695	0.185	3.750	0.000	0.685***	0.187	3.670	0.000
Household Size	-0.006	0.013	-0.500	0.620	-0.007	0.013	-0.530	0.599
Education dummy	0.308	0.191	1.610	0.108	0.307	0.193	1.590	0.112
Experience	0.021	0.012	1.710	0.087	0.022*	0.012	1.790	0.074
Off-farm income	0.217	0.055	3.980	0.000	0.223***	0.055	4.030	0.000
TV (Number times)	0.082	0.056	1.450	0.146	0.086	0.058	1.470	0.142
Radio (Number times)	0.109	0.039	2.770	0.006	0.117**	0.040	2.930	0.003
_cons	-2.185	0.468	-4.670	0.000	-2.196	0.473	-4.640	0.000
sigma	0.000	0.027	0.000	0.998	0.056	0.044	1.260	0.209
Rho					-0.921***	0.091	-10.120	0.000
Model Summary								
Number of obs.	475				475			
Wald chi2(13)	257.60				237.73			
Prob > chi2	0.0000				0.0000			
Log likelihood	-1089.9296				-1089.1625			

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

importance of smallholder farmer's knowledge gained through experience as a significant element in driving up access and use of climate information in the study area (Donkoh *et al*., 2019).
Off-farm income was also found to have a positive relationship with access to climate change information. From the results, an increase in one Ghana cedis of the smallholder farmers off farm income consequently results in their probability of accessing climate information by 22%. There are some specifically designed climates change programmes that are aired on radios or television stations or sent in the form of short message settings (SMS) and most of them require people to subscribe before they can receive information from such programmes. It, therefore, makes sense that smallholder farmers who have more off-farm income would be able to access these programmes. This finding corroborates that of Muema *et al.* (2018) who indicated that the monthly off-farm monthly income of smallholder farmers significantly influenced their likelihood of accessing climate information.
The number of times a respondent listens to radio programmes also showed a positive relationship with access to climate change information. This finding is similar to (Muema *et al.*, 2018) who indicated that the chance of smallholder farmers' using seasonal climate information services increased with radio ownership and number of times they listen to the radio. This is relevant given that radio was the most popular medium for disseminating climate information services in the research area. Hampson *et al.* (2015)'s research, which found that radio was the most widely used and trusted medium for disseminating climate information, supports this conclusion. Additionally, most radio stations in the study area broadcast information in the vernacular, enhancing the access and use of climate information by all smallholder farmers.
***Effect of climate change information access on adoption intensity of climate smart adaptation practices*:** The study examines how climate change knowledge access affects climate-smart adaptation strategy adoption intensity. Table 5 shows how climate information access and other factors affect smallholder farmers' climate smart adaption practice adoption intensity. The endogenous-switching Poisson regression corrected for selectivity bias in climate information access and climate-smart adaption practice adoption intensity. The Rho was statistically significant at 1%, correcting unbiased factors that may affect adoption intensity with a robust estimation. The endogenous and exogenous Poisson models have equal estimated coefficients, which is interesting. The climate information access variable matters in both models. Due of the large Rho, the endogenous switching Poisson model will be discussed Zakaria *et al.* (2020) agree.
Researchers found that smallholder farmers who have access to climate change knowledge are more likely to implement climate-smart agricultural techniques. According to the data, smallholder farmers with climate information are 91% more likely to use climate-wise adaptation techniques. This suggests that smallholder farmers with climate information will increase climate smart adaption methods virtually certainly. This meets the study's expectations and is consistent with Alidu *et al.* (2022), who found that smallholder farmers' climate-smart practice adoption is affected by climate information access. The findings contradict Owusu *et al.* (2021), who found that climate change information does not affect climate smart adaption methods.
The likelihood of adoption intensity decreases with age. Climate-smart adaptation is less likely to increase among older farmers. According to Table 5, 1 year of smallholder farmer age affects climate adaptation adoption by 0.7%. Younger smallholder farmers are more likely to adopt climate-smart farming practices. Age predicts smallholder adoption. The assumption is that older smallholder farmers have more resources and expertise to experiment with and adopt new technologies. However, educated young smallholder farmers are more inclined to use new technologies. Many agricultural technology adoption studies found inconsistent results on age and adoption intensity. Age may hinder smallholder farmers' adoption, according to some research. However, other agricultural technology adoption research found that age increased adoption intensity. The negative link between age and adoption intensity matches (Obuobisa-Darko, 2015)findings on increased manufacturing technology adoption. This contradicts earlier findings (Donkoh *et al.*, 2019; Obuobisa-Darko, 2015). The reason may be that younger smallholder farmers are more open to new farming methods than older ones, who rarely adapt. This may also indicate that younger smallholder farmers are using climate change knowledge on their fields.
Farm revenue is positively associated with adoption intensity, suggesting that it increases climate-wise adaption strategies. One Ghana cedi increase in farm revenue is estimated to enhance climate-wise adaption measures by 14.2%. Smallholder farmers may have more money to invest in their fields as they earn more. New gear, technology, higher-quality inputs like seeds and fertiliser, or expensive farming procedures could be invested in. Higher-income smallholder farmers may be less risk-averse and more willing to try climate-smart adaptation practices with higher potential returns, as they have a larger cushion to absorb losses (Obuobisa-Darko, 2015).
Off-farm income has a negative connection, showing that smallholder farmers with more income are less likely to use climate-smart adaptation techniques. Adoption was negatively correlated with off-farm income. Increasing off-farm income reduces smallholder farmers' likelihood of adopting climate-smart adaptation techniques by 5.7%. Off-farm income makes smallholder farmers less likely to adopt climate-smart adaptation methods. As shown by a prior study, smallholder farmers with off-farm income are less likely to

adopt climate-smart adaptation techniques. Smallholder farmers with outside jobs may not have enough time to run their farms. Adopting climate-smart adaptation techniques may be harder and take longer. Studies by Owusu *et al.* (2021) found that relying less on agricultural revenue can reduce one's motivation to dedicate competing resources to the farm. Donkoh *et al.* (2020) reported that off-farm income increased the adoption of enhanced maize varieties in Uganda and Benin, respectively, contradicting our study. Many CSAPs have costs, but non-farming income can balance them. Reduced supplemental income did not affect adoption intensity, possibly because most climate-smart adaption techniques in our study need low initial capital expenditure (Zakaria *et al.*, 2020).

Extension services significantly enhance adoption intensity, with smallholders who receive such services being 26.9% more likely to intensify the adoption of climate-smart adaptation practices. This has met aprior expectations. It is expected that knowledge received from the extension service will include information on climate change adaptations, encouraging climate-friendly practices. It lends credence to other studies like (Arslan *et al.*, 2014); Obuobisa-Darko (2015), who support the prediction that adoption intensity is positively correlated with the frequency of extension guidance but contradicts with Owusu *et al.* (2021) who reported a negative significant relationship between extension and adoption of climate-smart adaptation intensity.

Formal education increases climate smart adoption practices adoption by 12.4% in farmers. In many farming communities, many years of education means leaving agriculture for nonfarm work. Education may increase climate-smart agriculture adoption because educated farmers understand the need to adapt production methods and are more likely to implement climate-smart techniques. This supports Adzawla *et al.* (2020)'s finding that formal education helps farmers accept new technologies.

The results show that climate-smart agriculture adoption intensity increases with farming experience. As smallholder farmers gain experience, they are more likely to embrace climate-smart farming practices. This meets expectations since smallholder farmers with many years of farming experience may have suffered the worst consequences of climate change and may adopt new techniques to limit its impact on their lives and livelihoods. This supported Donkoh *et al.* (2020) results on Northern Ghanaian rice farmers adopting technology.

Temperature perception increases adoption intensity, suggesting that smallholders who perceive temperature fluctuations are more likely to adopt climate-smart adaptation methods. This suggests that farmers who detect temperature increases are more likely to undertake climate-smart techniques to address climate change. This confirms Owusu *et al.* (2021) that the perception variable coefficient in the adaptation equation is statistically significant and positive.

***Conclusion*:** This study examined how climate information access affects climate smart adaptation in Ghana's Northern Region. The study examined the elements that affect smallholder farmers' access to climate information and how it affects climate smart adaption practices in Ghana. Based on Endogenous-Switching Poisson regression model estimates, climatic information availability is endogenous. Gender, farming experience, off-farm income, and radio frequency improve climate information availability for smallholder farmers. Farm revenue, extension, education, farming experience, smallholder farmers' perception of temperature, and climate information availability significantly increase climate smart adaption intensity in the second stage. Age and off-farm income hinder smallholder farmers' climate-smart adaptation efforts. Based on these findings, climate change agriculture programs should educate smallholder farmers on climate wise adaptation strategies to guide the adoption of several adaption methods. Extension agents should provide farmer information. One of the study's primary conclusions is that climate information access strongly influences climate smart adaption adoption. To build resilience to climate risks and shocks in Ghana, agricultural policies should make it easier for smallholder farmers to access climate information. This lowers the risk of them investing in climate change mitigation techniques.

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