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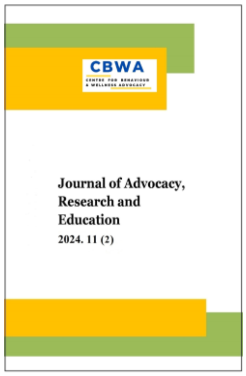

Climate Change Effects, Multi-Actor Interactions, and Effectiveness of Adaptation Activities on Rice Production in Ghana's Northern Region

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Abstract

The study evaluated the level of interactions and efficacy of climate change adaptation efforts among farmers, agricultural extension agents (AEAs), and researchers in the northern region of Ghana. The study employed a cross-sectional survey design technique. Three hundred and twenty-one smallholder farmers were used for the study. Factor analysis, analysis of variance, frequencies, means, and standard deviations were tools used for quantitative analysis. The results revealed about 68 % variations in the effect of climate change on rice production. The findings also showed that researchers ($\bar{X} = 3.52^{a}$) interacted significantly more with AEAs ($\bar{X} = 3.16^{b}$) than farmers ($\bar{X} = 2.81^{c}$). Farmers stated that the technique and outcome demonstrations were effective in adopting adaption technology, with a mean score of 4.53. Farmers' limited engagement with Agricultural Extension Agents (AEAs) and researchers hinders the development, modification, and dissemination of adaptation technologies for rice production. The study's outcome is crucial for understanding the impact of climate change on rice production. Additionally, it reveals how various actors in rice production interact to address climate change through various adaptive measures. Also, the theoretical implication is embedded in higher levels of interaction by researchers and AEAs, compared to farmers, suggesting potential communication and technology transfer gaps that hinder the successful adoption of adaptation technologies among farmers. The originality of this study lies in the interaction among rice production actors in addressing the climate change effect, which is absent in current climate change literature.

Keywords: Climate Change Effects, Effectiveness of Adaptation Activities, Ghana, Multi-Actor Interactions, Northern Region, Rice Production.

1. Introduction

Climate change continues to have devastating consequences and effects on rice productivity globally due to the crops' sensitivity to changes in climate parameters. Variabilities in parameters, especially temperature and rainfall, negatively impact rice germination, development, and yield (Abbas et al., 2021; Chairan, 2022; Guo et al., 2019). For instance, fluctuations in temperature and rainfall cause flooding, drought or dry spells and increase the incidence of weeds, pests, and diseases (Duchenne-Moutien, Neetoo, 2021; Mahdu, 2019; Skendžić et al., 2021). Extreme changes in rainfall and temperature changes will also present unfavourable growing conditions in the

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cropping calendars, thereby modifying growing seasons, which could subsequently reduce rice productivity. The changing patterns of rainfall and rising temperatures frequently influence the incidence and spread of pests and diseases in rice fields (Ansari et al., 2021). Furthermore, Irawan and Antriyandarti (2021) discovered soil degradation in the rice sector in Indonesia was a result of deforestation, erosion, and unrestricted use of inorganic fertiliser. According to Mahdu (2019), excessive rainfall and heavy winds caused by climate change led rice plants to lodge. Climate change, according to Ma et al. (2021), has the potential to increase pest dispersion and resistance, resulting in crop losses and food security issues.

As a result, climate change adaptation technologies are increasingly being advocated for to adjust farmer practices and compensate for the negative effects of climate change on crop production by strengthening resilience to climate change, thereby increasing yield and, as a result, increasing food security (Ahmed et al., 2019; Onyeneke, 2021).

Communication and collaboration among pertinent parties are critical for the success of climate change adaptation as a whole. The involvement of researchers, extension agents, and farmers is crucial for ensuring that adaptation measures are pertinent to local requirements. This involvement encompasses problem identification, technology development, localisation of technologies, and feedback provision on the implemented technologies (Kokwe et al., 2022; World Bank, 2019). Establishing connections between researchers and agricultural extension agents (AEAs) is crucial for the adaptation of technologies to farmers' demands and requirements while also ensuring that extension agents are well-versed in the technologies they are tasked with promoting (Hamed et al., 2021).

The importance of agricultural extension agents and researchers in assisting farmers with production issues cannot be overstated, particularly in light of climate. As a result, strong interactions among and between farmers, AEAs, and researchers are critical in ensuring that technologies are well adapted to farmer situations and that farmers are familiar with their use. In an analysis of farmers' level of interaction with Agricultural Extension Agencies in Ethiopia, Gebremariam et al. (2021) discovered that farmers had fewer interactions with AEAs. Similarly, Ifejika et al. (2018) reported that interactions between farmers and extension agents were almost non-existent in many local government areas in Nigeria. In a study conducted in Sudan, Hamed et al. (2021) found that most farmers, extension agents, and researchers perceived weak connections between research and extension services. In the same vein, Bereir (2022), in evaluating research-extension-farmer linkages in Sudan, hinted that poor research-extension-farmer linkages were often the results of inadequate budgets for linkage activities, poor infrastructure, continuous transfer of extension agents and different administrations spearheading the activities of extension and research.

Collaboration between farmers, Agricultural Extension Agents (AEAs), and academics is crucial for advancing, adjusting, and spreading adaptive solutions related to climate change. According to Maake and Antwi (2022), an extension was inadequate in providing demand-driven services, including information as well as agricultural technologies, due to poor prioritising of farmers' specifications, which frequently resulted in farmers receiving irrelevant extension services. Jamal et al. (2023) claimed in their study in Bangladesh that researchers are exceptionally proficient in generating climate-resilient rice varieties and approaches that have the potential to boost food security.

Literature using factor analysis to study the effects of climate change on rice production in Northern Ghana is scanty. In addition, the interactions between researchers, AEAs, and farmers in the region regarding adaptation to climate change have not been exhaustively studied. As a result, the purpose of the study was to evaluate the efficacy of multi-actor partnerships in rice production climate change adaptation activities. The study yielded data regarding the stakeholders with the greatest and least amount of interaction, in addition to identifying the most effective adaptation activities carried out by AEAs and researchers.

Specifically, the study:

1. Assessed the effect of climate change on rice production;
2. Analysed the extent of interactions in climate change adaptation among rice farmers, agricultural extension agents and researchers in climate change adaptation activities; and
3. Evaluate the effectiveness of interactions among farmers, AEAs, and researchers in rice adaptation technologies.

Hypothesis tested: There is no statistically significant difference in interaction among farmers, AEAs and researchers.

2. Materials and Methods

The Northern area of Ghana is predominantly Savannah grassland and has boundaries with the Oti, Savannah, and North East regions of Ghana, as well as Togo to the south, west, north, and east. The region is located at latitude 9.660000049942276°N and longitude -0.39437989999999995°W. The precipitation in the Northern Region follows an unimodal trend, starting in April/May and ending in October. The average annual precipitation ranges from 750 to 1,050 millimeters. The area's relative humidity of 75-76 % worsens the effects of daytime heat (Mabe et al., 2014). The dry season starts in November and ends in March when temperatures peak. The area's principal soils are Voltarian sandstones that easily tolerate slight weathering, resulting in cultivated soils with Guinea savannah vegetation (Obeng, 2000). The primary agricultural products in the region include Bambara groundnuts, maise, millet, rice, yam, sorghum, groundnuts, and cowpeas. The Northern Region Department of Agriculture Extension Services ensures that agricultural extension agents contribute effectively to the region's social and economic development by providing farmers with new information on agricultural practices and scientific research through education (MoFA, 2019). SARI is one of the few research institutes in the Northern Region. It is one of thirteen research institutes in Ghana that fall under the jurisdiction of the Council for Scientific and Industrial Research Institute (CSIR). The main goal of SARI is to provide farmers in Northern Ghana with suitable technologies to improve food and fibre production using sustainable ways while also maintaining and increasing soil fertility. Figure 1 displays a diagram of the research area.

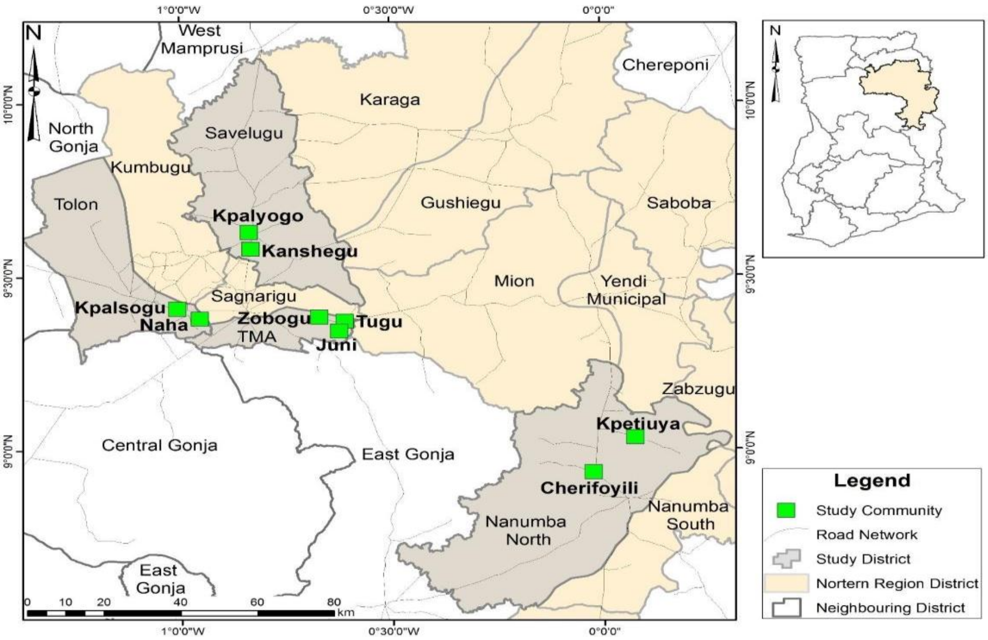

Fig. 1. Map of the Study Area
Source: cartography and Remote Sensing Unit of the Department of Geography and Regional Planning, University of Cape Coast (2019)

A cross-sectional survey design with a quantitative data collection process was used for data collection. The Northern region's rice farmer population is approximately 50,000. Thus, a sample size of 381 was determined using the Krecjie and Morgan table for sample size determination, which is recommended when employing probability sampling methods (Memon et al., 2020). A multi-stage sampling technique was used to select the rice farmers. Tolon, Savelugu, Nanumba North Districts, and Tamale Metropolis were chosen at random from the Northern Region's ten rice-growing districts in the first stage. Following that, two communities from each district and three communities from the Metropolis were picked at random for a total sample size of 381 farmers from the eight communities. A response rate of 85 %, representing 324 rice farmers utilising an interview schedule, demonstrated reliability (Wu et al., 2022). The data was obtained between June 22nd and August 8th, 2019. Table 1 shows the population and sample size of the study.

Table 1. Population and Sample Size

Study area	**Sampling frame**	**Sample size**
Tamale Metropolitan		
Tugu	55	48
Zoborgu	45	40
Juni	42	38
Tolon District		
Voggu Kpalsogu	36	33
Naha	48	42
Savelugu District		
Kanshegu	31	29
Kpalyogo	35	32
Nanumba North District		
Cherifoyili	37	34
Kpetiuya	30	28
Total	381	324

Source: Field Survey, 2019

A census of 30 AEAs and 30 researchers involved in climate change and rice production was used for the quantitative method. Data from farmers, AEAs, and researchers was collected using questionnaires.

Quantitative data were analysed using means and standard deviations for objectives two and three, while factor analysis was employed for objective one.

Kaiser-Meyer-Olkin sampling adequacy of 0.819 and Barlett test were significant $X^2(55) = 1034.04$, $p<0.000$), indicating the factorability of the sample. Communalities greater than 0.5 indicated suitability for factor analysis. A three-factor solution with loadings smaller than 0.40 removed explained 67.83 % of the variance in the impact of climate change on rice production in the Northern Region, with eigenvalues exceeding one. The mean scores were interpreted on a scale of: 1= very poor, 2 = poor, 3 = moderate effective, 4= effective, and 5 = highly effective.

3. Results

Effect of Climate Change on the Production of Rice

The results in Table 2 revealed eleven successful climate change effect variables on rice production factor loadings, where lodging of rice plant (0.872) had the highest factor loading followed by withering of seedlings (0.838). In contrast, low rice yields (0.518) had the lowest factor loading out of the eleven.

Factor 1 with five items was named soil, time, and yield effect due to high loadings in soil erosion (0.799), changes in the duration of the rainy season (0.744), loss of soil nutrients (0.697), low yield (0.651) and reduction in length of the growing season (0.620). These factors accounted for 27.3 % of the variability in the impact of climate change on rice output. The washing away of the topsoil has negative implications on soil nutrients, which are essential for the survival and yield of rice crops. Four items were loaded onto factor 2 (grain and seedling effect) due to high loadings in the lodging of the rice plant (0.872), a withering of seedlings (0.838), reduced grain quality (0.714) and poor seed germination (0.599) which explained 24.54 % of the variance.

Table 2. Effect of Climate Change on the Production of Rice

Effects	Factor loadings			Communalities
	1	2	3	
Soil erosion	0.799			0.652
Changing rainfall pattern	0.744			0.632
Loss of soil nutrient	0.697			0.685
Low rice yields	0.651			0.518
Reduction in length of growing season	0.620			0.566
Lodging of rice plant		0.872		0.767
Withering of seedlings		0.838		0.786
Reduced rice quality		0.714		0.704
Poor seed germination		0.599		0.735
Widespread of new crop pests			0.835	0.787
Pesticide no longer effective			0.760	0.631
Eigenvalues	4.83	1.63	1.00	
% of variance	27.38	24.54	15.91	

Source: Field Survey, 2019 Loadings ≤.40 are omitted.

These factors generally affect seed and seedling qualities, which have considerable effects on the overall growth and development of the rice plant. Finally, factor 3, also known as pest and pesticide effects, had high loadings in widespread new crop pests (0.835) and pesticides no longer effective (0.760). Pest infestations on rice fields have the potential to negatively impact crop quality and yield, and pesticides are commonly used to manage these pests, which causes the pests to become resistant to pesticides over time and, potentially reduce microbial populations in soils. This component accounted for 15.91 % of the variability in the impact of climate change on rice output. The results demonstrate that the Eigenvalues for soil, time, yield impact, grain and seedling effect, and insect and pesticide effects were 4.83, 1.63, and 1, respectively, indicating the relative importance of these components.

Extent of Interactions in Climate Change Adaptation Activities among Farmers, AEAs and Researchers

The assessment of the level of interactions among many parties involved in the development, modification, transfer, and deployment of adaptation technologies was conducted using a five-point Likert-type scale ranging from 1 (extremely bad) to 5 (very effective). Table 3 reveals that farmers and AEAs had moderate ($\bar{X}$ = 2.81, $\bar{X}$ = 3.16) interactions on climate change issues, whereas researchers had substantial ($\bar{X}$ = 3.52) interactions and linkages on climate change issues. Researchers indicated that most interactions may have involved multiple interactions with different farmers and AEAs during technology development to evaluate these technologies and ensure that they were suitable for farmer needs.

Farmers' perspectives on interactions with other stakeholders indicated effective farmer-AEA interaction ($\bar{X}$ = 3.64), but weak interactions with farmer-researchers ($\bar{X}$ = 2.25) and poor farmer-AEA-research ($\bar{X}$ = 2.54). According to AEAs and researchers' perspectives, effective interactions existed between AEA-researcher ($\bar{X}$ = 3.51) and farmer-AEA-researcher ($\bar{X}$ = 3.63) respectively, with AEA-farmer-researcher interactions being poor ($\bar{X}$ = 2.50) from the perspective of AEAs. In contrast, the researchers discovered no indication of poor interactions with other stakeholders. Specifically, farmers showed a moderate interaction in farmer-AEA-researcher ($\bar{X}$ = 2.54) linkages.

Table 3. Extent of Interactions by Farmers, AEAs and Researchers on Climate Change Adaptation Activities

Type of interactions	Farmers		AEAs		Researchers	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Farmer-researcher linkage	2.25	1.52	-	-	3.50	0.51
Farmer-AEA linkage	3.64	2.69	3.48	0.64	-	-
AEA-researcher linkage	-	-	3.51	0.94	3.43	0.57
Farmer-AEA-researcher linkage	2.54	0.76	2.50	0.51	3.63	0.25
Weighted mean ($\bar{X}$w)	2.81		3.16		3.52	

Source: Field Survey, 2019

Statistically significant variations were found in the means of farmers, AEAs, and researchers' level of interaction, as indicated by a one-way analysis of variance in Table 4 ($F(2, 376) = 5.95$, $P = 0.003$). The level of collaboration among farmers, AEAs, and researchers in climate change adaptation initiatives differed. An examination conducted after the fact showed that the number of encounters between researchers and AEAs was much higher, with AEAs perceiving a significantly higher level of interaction compared to farmers.

Table 4. Mean comparison of the extent of interactions among farmers

Actors of interactions	$\bar{X}$	SD
Researchers	3.52^{a}	0.32
AEAs	3.16^{b}	0.48
Farmers	2.81^{c}	1.14
Total	3.19	0.65

Source: Field Survey, 2019 *$P \leq 0.05$

Poor farmer-AEA-researcher interactions in the study were due to commercial farmers who have resources available to them often being chosen for the Research-Extension-Farmer Linkage Committee (RELC) instead of smallholder farmers who felt the impact of climate change more due to resource constraints. Also, due to budget constraints, just a few farmers are normally invited to RELC meetings where farmers, AEAs, and researchers meet to discuss difficulties impacting farmers and present solutions or carry out research into how to remedy the issues.

Rice Farmers' Comparison of the Effectiveness of AEAs and Researchers' Adaptive Activities

Table 5 reveals that generally, farmers perceived interactions on adaptation activities with AEAs ($\bar{X}$w = 3.89) to be more effective compared to interactions with researchers ($\bar{X}$w = 3.34). Specifically, information on planting dates ($\bar{X}$ =3.84) and rainfall ($\bar{X}$ =3.86) from AEAs was effective compared to information on planting dates ($\bar{X}$ =2.13) and rainfall ($\bar{X}$ =2.45) from AEAs, which were lowly effective and moderately effective, respectively. On method and results demonstration and varietal selection, it was found that researchers were highly effective ($\bar{X}$ =4.53, $\bar{X}$ =4.43) compared to AEAs ($\bar{X}$ =3.91, $\bar{X}$ =3.72) who were effective. Results from the study also revealed that AEAs were effective in bunding and pest and disease control compared to researchers who were moderately effective in weed control ($\bar{X}$ =2.85) and bunding ($\bar{X}$ =3.24).

Table 5. Comparison of the Effectiveness of AEAS And Researchers' Interactions with Farmers' Adaptive Activities

Adaptive Activities		AEAs			Researchers	
	f	$\bar{X}$	SD	f	$\bar{X}$	SD
Information on planting dates	25	3.84	0.73	6	2.13	0.42
Information on rainfall	22	3.86	0.58	8	2.45	0.66
Method and results demonstration	28	3.91	1.24	6	4.53	1.10

Adaptive Activities		AEAs			Researchers	
Pests and disease control	25	4.11	0.82	12	2.85	0.72
Bunding	30	4.33	0.61	8	3.24	0.90
Fertiliser application	18	3.44	0.92	13	3.21	0.54
Varietal selection	15	3.72	1.21	13	4.45	0.82
Rice-legume intercrop	9	3.91	1.13	12	3.88	0.86
Weighted mean ($\bar{X}w$)		3.89	0.92		3.34	0.75

Source: Field Survey, 2019

4. Discussion

Effect of Climate Change on the Production of Rice

The paper effectively highlights that soil erosion (0.799) causes the topsoil, the most nutrient-rich layer, to be scraped off, which is linked to soil nutrient loss (0.697), whose resultant effect is reduced rice yields (0.651). This is consistent with the findings of Irawan and Antriyandarti (2021), who found that soil erosion damages the soil, resulting in low yields.

The changing rainfall pattern (0.744) has significant effects on rice production, typically resulting in altered planting and harvesting dates, which might affect management strategies. Changing rainfall patterns also fosters an atmosphere conducive to the spread of pests and diseases (0.835). Ansari et al. (2021), Duchenne-Moutien and Neetoo (2021) and Skendžić et al. (2021) findings are consistent with this study, who discovered that altering rainfall patterns increases the prevalence of diseases and pests. With changes in temperature and rainfall, there is a possibility of increasing pest pressure, which would result in increased pesticide application frequency. This situation leads to the development of pesticide resistance, where pesticides are no longer effective (0.760). This result is in line with Ma et al. (2021), who explained that the increase in pest populations often resulted in pesticide resistance. Floods and drought cause plant lodging (0.872), seedling withering (0.838) and poor seed germination (0.599), respectively, which is consistent with Mahdu's (2019) findings that floods weaken plants, causing them to lodge.

Extent of Interactions in Climate Change Adaptation Activities among Farmers, AEAs and Researchers

Farmers' reports of inadequate contact with researchers may be due to researchers' failure to include farmers in the creation and testing of climate change adaptation solutions. This is consistent with the findings of Hamed et al. (2021), who reported that in Sudan, interactions between researchers and farmers were low to non-existent. The effective linkages between AEAs and farmers, according to farmers in the study, can be attributed to AEAs' presence in farmers' communities to conduct normal extension work, which translates into discussions on climate change adaptation activities such as the development, modification and use of adaptive technologies. This is in contrast to studies in Ethiopia by Gebremariam et al. (2021) and Nigeria by Ifejika et al. (2018), which found farmers had fewer and almost no interactions with AEAs, respectively. Additionally, Bereir's (2022) findings stated that poor research-extension-farmer links were frequently the result of insufficient resources for linkage operations.

4.3 Rice Farmers' Comparison of the Effectiveness of AEAs and Researchers' Adaptive Activities

Researchers' low effectiveness in providing information on rainfall and planting dates may be due to the fact that these are not within their mandate, and information on planting dates and rainfall is not readily available to them, resulting in their inability to do so. The result is parallel to that of Maake et al. (2022), who indicated that extension agents were inadequate in providing information to farmers.

Interactions on varietal selection with researchers were more effective than with AEAs because they are often the developers of these varieties and thus are able to explain vividly to farmers the requirements of each variety of rice compared to the AEAs who have limited knowledge of the varieties. This is congruent with the findings of Jamal et al. (2023), who state that researchers are highly specialised in developing climate-resilient rice varieties.

Farmers agreed that pest and disease control, as well as bunding, were more effective when performed by AEAs rather than researchers because, while researchers were the developers of technologies, their feedback loop was longer because they would need to experiment on the geographical location before advising farmers. In the case of AEAs, responses on pest and disease control and bunding were nearly instant in the event of pest and disease outbreaks or in anticipation of dry spells or drought.

5. Conclusion and Recommendation

The study determined that soil quality, time constraints, and yield variability are the primary challenges encountered by rice growers in the Northern region. Farmers' limited engagement with Agricultural Extension Agents (AEAs) and researchers could hinder the development, modification, and distribution of adaptation technologies tailored to farmers' needs. The study found that farmers responded better to researchers' methods and results demonstrations as well as varietal selection compared to that of AEAs. On the other hand, farmers were more receptive to AEAs' information on rainfall, planting dates, pest and disease control, bunding, fertiliser application, and rice-legume intercrop. The Department of Agriculture and CSIR-SARI should offer workshops for farmers on adapting to the impacts of climate change on soil, crop yield, seeds, seedlings, pests, and insecticides. To increase farmer involvement in climate change adaptation efforts, researchers and Agricultural Extension Agents (AEAs) should arrange local community engagements with farmers to ensure that the technologies created align well with farmers' requirements.

For AEAs to enhance their effectiveness in conveying adaptation knowledge to farmers, the Department of Agriculture and CSIR-SARI should offer training in teaching methodologies and rice varietal selection. This study is distinctive for its comprehensive analysis of the impact of climate change, interactions among several actors, and the effectiveness of adaptation efforts on rice production in the Northern Region of Ghana.

6. Strengths and Limitations

The study had the following strengths: Farmers possessed extensive knowledge of the effect of climate change on rice production in the Northern region. Researchers and agricultural extension agents provided valuable insights into the linkages and interactions for climate change adaptation activities.

The limitations were as follows: Farmers' information was based primarily on recollection, which resulted in the omission of critical facts. Heavy farm work made it difficult to get farmers to answer all questions. Farmers also answered questions quickly in order to continue with farm work, which could have resulted in false replies.

7. Implication of the Study

The study's results show a significant difference in how climate change affects rice production in various parts of Ghana's northern region. Regional differences highlight the necessity of developing adaptation techniques tailored to individual regions to tackle the various challenges encountered by small-scale farmers in different locations. The study's findings highlight the significance of enhancing collaboration and communication channels among farmers, AEAs, and researchers at the national level. National agriculture policies and programs should focus on promoting initiatives that improve the distribution of adaptation technology and best practices to strengthen farmers' ability to adapt nationwide. The study highlights the importance of demonstration methods in encouraging the use of adaption technologies, emphasising the significance of participatory approaches and farmer-led innovation in promoting sustainable farming practices.

The study's findings on the efficacy of climate change adaptation initiatives among farmers, AEAs, and researchers in Ghana's northern region have significant implications for global endeavours to mitigate climate change effects on agriculture. The results emphasise the significance of promoting interdisciplinary collaboration and knowledge sharing among agricultural stakeholders worldwide. International organisations and donor agencies engaged in agricultural development and climate resilience projects may need to assist in enhancing collaborations and capacity-building programs at the local level. Ghana's experience could provide valuable insights for developing global strategies to promote climate-smart agriculture and improve food security in the context of climate change.

8. Declarations

Ethics approval and consent to participate

The researchers requested ethical approval from the University of Cape Coast Institutional Review Board (UCCIRB/CANS/2019/02). The research was granted approval to be conducted responsibly and ethically, resulting in approved data collecting for good effects.

Consent for Publication

Not applicable

Availability of data and materials

Data and other relevant documents to this manuscript are available upon request.

Conflict of interest statement

The authors declare no conflict of interest.

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