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RICE (*Oryza sativa*) FARMERS' KNOWLEDGE ABOUT EFFECTS OF CLIMATE CHANGE IN THE NORTH EAST REGION OF GHANA

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ABSTRACT

The study surveyed rice (*Oryzae sativa*) farmers to determine their knowledge and perceptions about effects of climate change on rice farming in the North East Region of Ghana. Two hundred respondents were randomly sampled from four communities to respond to a questionnaire. Reliability of the questionnaire was determined with Cronbach's Alpha reliability coefficient of 0.793. Descriptive and inferential statistics were used to analyse the data. It was revealed that 89.5% of respondents agreed that climate change is caused by natural and anthropogenic factors. Observable effects of climate change on rice farming stated are**,** changes in temperature and precipitation patterns (mean of4.58); high risks to rice production (mean of 4.64) and continuous negative effect on rice storage (Mean of 4.16). Adaptation challenges faced by farmers include inadequate capital (Mean of 5.68) and lack of access to water for irrigation (mean of 5.84). In all cases differences among the mean responses were statistically significant ($p<0.05$). Though the farmers had very high knowledge about many of the effects of climate change on rice farming, there were equally a number of cases of wrong understanding of issues. A way out is for agricultural extension officers to have well designed education programmes for educating farmers on climate change and its effects on rice farming.

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INTRODUCTION

The world is generally concerned about climate change and its effects on agriculture. The long-term changes in temperature and weather conditions can be described as climate change (Ravikumar, 2023). Intergovernmental Panel on Climate Change (IPCC, 2007), considers climate change as the changes in the state of the climate identified by changes in the mean or variability of its properties persisting for long periods or decades. On the other hand, climate variability is the short-term changes or variations in weather parameters/elements (Adu-Boahen*et al*., 2019). According to Belloumi (2014), in recent years, changes in temperature and precipitation due to climate change have tremendous influence on agriculture worldwide. Climate change can be attributed to natural and human causes (National Research Council; NRC, 2005; National Academy of Sciences; NAS, 2008). The natural causes includes changes in earth's orbital, solar variations, volcanic eruptions and ocean currents (Onoja *et al*., 2011). On the other hand, human causes which are also described as anthropogenic causes involve fossil fuels, land-use and deforestation (Paehler, 2007, cited by Onoja*et al*., 2011; Luo, 2020); greenhouse effect, agricultural activities, mines, and infrastructure or urbanization (Luo, 2020). The effects are rising sea levels, melting of ice caps, heat waves, violent downpours, animal metabolism and others (Onoja*et al*., 2011). Anthropogenic activities like burning of firewood and fossil fuels beyond a safe limit can lead to increased production of carbon dioxide and nitrogen oxides (Ravikumar, 2023). Ravikumar (2023) further indicated that deforestation activities such as tree cuttingincrease the levels of carbon dioxide, which in turn leads to the greenhouse effect. In addition, increased livestock results in the release of higher amounts of methane, whereas overuse of nitrogen fertilizers leads to increased nitrous oxide levels (Ravikumar, 2023).Some other effects include environmental disasters, reduction in the effectiveness of agricultural techniques, large human displacements leading to humanitarian crisis, low GDP, high insurance cost, unemployment, national insecurity and high food prices (Luo, 2020). One major effect of climate change that can affect human existence in every segment of society is agriculture. Luo (2020) observed that climate change affects the Earth's biota leading to changing weather patterns thereby causing altered farming cycles and reduced effectiveness of agricultural techniques.Roudier *et al*.(2011) also intimated that it is expected that yields of main crops in the world be negative as a result of the impact of climate change. In fact, crop yield and stability worldwide are under serious threats from climate change and increasing extreme weather conditions (Reyes *et al*., 2021).Worldwide, increased atmospheric carbon monoxide (CO) levels associated with climate change will affect future agriculture through changing plant growth and development, respiration, transpiration and photosynthetic rates (Crawford *et al.,* 2012; Rezaei *et al*., 2015). A further alarming situation is that climate change poses threats to the strategic reservoir of crops and their genetic resources (Alotaibi, 2023). Worst of all changing climatic conditions would cause farmers to stop growing some varieties of crops leading to their loss forever (Gitz *et al*., 2016 as cited by Alotaibi, 2023). Agriculture plays very important role in the economy of Ghana. This is because approximately 30% of the country's GDP is agricultural driven and agriculture employs about 50% of Ghanaians (Kolavalli*et al*., 2012). However, just like other countries, Ghana's agriculture is at the threat of climate change.Ghana's economy to a large extent depends on climate-sensitive sectors such as agriculture, forestry, and hydroelectric energy (Nti, 2012). The country's agriculture is predominantly dependent on rainfall. This makes it very vulnerable to climate change (Yaro, 2010). Asante and Amuakwa-Mensah (2014) rated Ghana as one of the most vulnerable countries to global climate change in sub - Saharan Africa. De Pinto *et al.* (2012) reported that Ghana experienced increased mean annual temperature of 1°C per decade since 1960. In addition to that, over the same period, in each decade monthly rainfall decreased about 2.4 percent (McSweeney *et al*., 2010). Furthermore, Stephens (1996) reported significant differences in temperature from 1961-70, 1971-80 and 1981-90. One crop that contributes tremendously to food security, especially in Northern Ghana is rice. However, rice is very sensitive to climatic, environmental and soil conditions (Mabe *et al*., 2014). Hence, rice farming in Northern Ghana is suffering from the effects of climate change. In actual fact, Ghana's northern savanna zones have historically experienced unpredictable rainfall and periodic drought (Adu-Boahen *et al.,* 2019) partly due to climate change. In January to March temperatures are high while rainfalls are generally low. In June and July temperatures are relatively low whereas rainfalls are above average (Nti, 2012). In Ghana, as a result of the effects of climate change, many rice farmers are abandoning their rice fields. Hence, rice production may reduce by 36% (Oppong-Ansah, 2011). The most affected areas of the country are the northern regions, which experience highest mean temperatures with accompanying low rainfall patterns (Oppong-Ansah, 2011). A way out of the effects of climate change on rice farming in the northern regions is farmer knowledge and adaptability. According to Mitchell and Tanner (2006) adaptability is how individuals, groups and natural systems make preparation for and react to the changes in climate. Knowledge here refers to what the rice farmers know about the causes of climate change and their implications for rice farming; the effects of climate change on rice farming and farmers' livelihood; impact of human activities on climate change as well as adaptation strategies and sustainable practices for rice farming. Farmer knowledge about these stated events is very important for farmers to make informed decisions regarding how best to ameliorate the causes and effects of climate change on rice farming. However, very scanty evidence exists to point to how much the rice farmers in the northern zone of the country, especially North East Region of Ghana have about climate change, its effects and adaptation measures. Lack of knowledge or low knowledge by farmers concerning climate change and its effects on rice farming in the area can serve as a setback to the fight against climate change and its effects on agriculture, specifically rice farming in the North East Region of Ghana. Knowing what knowledge the farmers already have would serve as the foundation for appropriately helping them to adopt farming practices and measures that will reduce the negative impacts on the rice industry in the North East Region of Ghana. Hence, this study aimed at ascertaining the knowledge and perceptions of rice farmers in the North East Region of Ghana about the causes and effects of climate change on rice farming and probable adaptations that would help them to undertake profitable rice farming activities in their communities.

The specific objectives of the study were to determine the knowledge and perceptions of rice farmers from the North East Region of Ghana about the:

i. *Causes* of climate change and their implications for rice farming;
ii. Effects of climate change on rice farming and farmers' livelihood;
iii. Adaptation strategies and sustainable practices to mitigate the effects of climate change on their farming activities;
iv. Factors hindering their implementation of adaptation strategies.

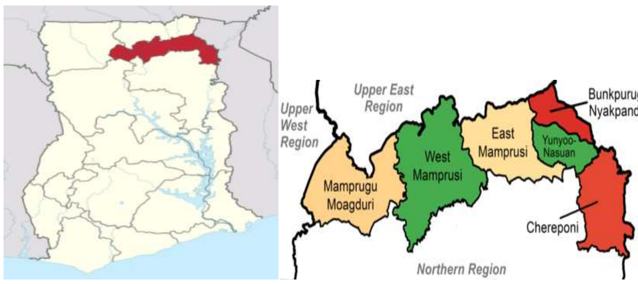
The research questions answered by the study were:

i. What are the views of rice farmers of North East Region about the main causes of climate change and their implication for climate variability?
ii. What are farmers' views about the effects of climate change on rice farming and farmers' livelihood?
iii. Which adaptation strategies and sustainable practices to mitigate the effects of climate change on rice farming activities are farmers aware of?
iv. Which factors do farmers consider as hindering their implementation of adaptation strategies?

The null hypothesis tested across board was that there is no statistically significant difference in respondents' views about climate change and rice farming. The alternate hypothesis was that there is statistically significant difference in respondents' views about climate change and rice farming.

METHODOLOGY

Research area: The study was carried out in the North East Region of Ghana. The Region covers an area of 9,072 km^2 and shares borders with the Upper East Region on the north, on the east by Togo, on the south by the Northern Region, and the west by the Savannah Region. The region has six Municipal and District Assemblies (MDAs) under its jurisdiction: East Mamprusi Municipal, West Mamprusi Municipal, Bunkpurugu District, Yonyoo-Nasuan District, Mamprugu-Moagduri District, and Chereponi District Assemblies. The capital of the North East Region is Nalerigu. According to the 2021 Population and Housing Census, the North East Region of Ghana has a population of approximately 658,903 (GSS, 2021; https://en.wikipedia.org/wiki/File:Ghana_-_North_East.png).(Figure 1). The study was conducted in four towns within the Region: Yagaba, Kubore, Soo, and Goriba.



a) Map of Ghana showing North East Region (Brown) **b) Map of North East Region**

Figure 1. Map of Ghana and North East Region

Research Design: The study employed a cross-sectional survey research design to explore the perceived effects of climate change on rice production among farmers in the North-East Region of Ghana. This design was pivotal as it enabled data aggregation from various sources at a single point in time, providing a comprehensive and multi-faceted understanding of the issues (Creswell & Creswell, 2018).

Population: The population for this research encompassed all rice farmers within the North-Eastern Region of Ghana, representing the targeted population. The Region was specifically chosen for its unique climatic conditions, agricultural practices, and the significant role rice farming plays in its economy. The accessible population covered farmers from four towns, namely, Yagaba, Kubore, Soe, and Goriba, which are known for intensive rice farming.

Sampling Technique and Sample Size: A multistage sampling technique was employed in this study to ensure a diverse and representative sample of rice farmers from various towns in the Northern East Region. For stage one, four major rice-producing towns were chosen. These towns (Yagaba, Kubore, Soe, and Goriba) were selected purposively due to their prominence in rice farming activities in the Region. Purposive sampling was deemed appropriate for this stage because it allowed for the specific selection of towns that hold notable importance in the Region's rice production. At stage two, 50 respondents were randomly selected from each of the four towns. Random selection ensured that every rice farmer in these towns had an equal chance of being selected, promoting fairness and representation. So, in all 200 farmers were sampled for the study.

Research instrument: A researcher designed questionnaire was the main instrument used. The items covered farmers' knowledge about the causes of climate change and their implications for rice farming; effects of climate change on rice farming and farmers' livelihood; adaptation strategies and sustainable practices to mitigate the effects of climate change on their farming activities; and factors hindering their implementation of adaptation strategies. There were three multiple choice questions demanding selection of only one response; one open –ended question and 27 Likert-Scale type of items with three, five and six levels of response.

Validity and reliability of Research Instrument: The questionnaire was given to two agricultural and one Biology experts to determine its content, construct and face validity. This was to ensure the authenticity and appropriateness of the instrument in measuring what it was intended to measure (Creswell & Creswell, 2018). The reliability which measures the consistency of the instrument to produce the same results at different times from same respondents (Sürücü & Maslakçi, 2020) was ensured by pilot testing the instrument in two communities in the Oti Region with 40 rice farmers. A Cronbach's Alpha reliability coefficient of 0.793 was obtained, which is acceptable (Gizaw *et al*., 2022).

***Data Collection Procedure**:* Four Biology graduates were trained to collect data from the four communities. They were equipped to clarify any questions the participants had, ensuring the validity of the responses. The trained research assistants visited the farmers on their farms and various homes and gave them the questionnaire to respond to. Each respondent was allotted a set time, typically between 30 to 40 minutes, to complete the questionnaire, after which it was immediately collected by the research assistants. This ensured 100% retrieval.

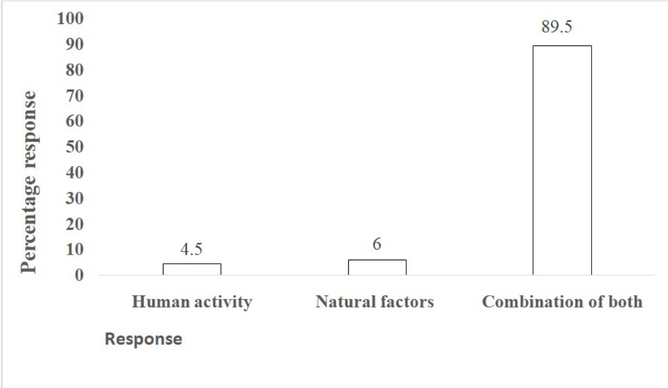
***Data Analysis**:* The data were entered into MS Excel 2021 for cleaning and analysed with IBM SPSS 26.0, with quality checks performed to ensure the accuracy of the data entry. Descriptive statistic such as frequencies, percentage frequencies, means and standard deviations were determined for interpretation. Independent sample t-tests were also conducted to compare the means of the various variables at p= 0.05 probability. Bar charts were also drawn for interpretation.

Ethical Considerations: Ethical considerations were upheld throughout the data collection process. Informed consent was obtained from all participants, ensuring that they were fully aware of the study's scope and their involvement in it. Confidentiality and anonymity of the participants were maintained diligently throughout the study. Respondents were free to withdraw from the research if they wished to do so.

RESULTS AND DISCUSSIONS

Research question 1: What are the views of rice farmers of North East Region about the main causes of climate change and their implication for climate variability?

Understanding the primary causes of climate change is essential in addressing its far-reaching impacts on rice farming. This question seeks to answer farmers' perceptions regarding the primary cause of climate change, the extent of their contribution, and the human activities with significant impacts on climate change.



Source: Field survey, 2023

Figure 2. Farmers' responses on the primary cause of climate change

From Figure 2, 4.5% of the farmers attributed climate change primarily to human activities, 6.0% attributed it to natural factors, whereas 89.505 attributed it to both natural and human causes. The belief that both human and natural factors contribute to climate change is in the right direction. This perception of a combination of natural and anthropogenic causes of climate change is in line with findings of studies conducted by Asante and Amuakwa-Mensah (2014) that farmers' recognition of both anthropogenic and natural influences on climate change is indicative of their direct experience with local environmental changes. The farmers' awareness aligns with the global view that while natural factors have historically influenced climate variability, human actions have accelerated the changes observed in recent decades [Intergovernmental Panel on Climate Change (IPCC, 2014)].

The high percentage of farmers (89.5%) who acknowledge the role of both human and natural factors in climate change has significant implications for policy and education. This understanding suggests that farmers may be more open to engaging in both mitigation and adaptation strategies that address human-causedclimate change. It also underscores the importance of providing tailored education and support to enhance their knowledge of how their agricultural practices can contribute to climate change, and how they can adjust those practices to reduce their environmental impact.

The small proportion of farmers attributing climate change solely to human activities (4.5%) or natural factors (6.0%) highlights the potential gaps in awareness or education regarding the complex interactions between human activities and natural climate systems. These findings are consistent with another study in the region that shows variability in farmers' perceptions based on factors such as education level, access to information, and personal experiences with climate-related events (Akudugu *et al*., 2021). Understanding these perceptions is crucial for developing effective communication strategies that address any misconceptions and enhance adaptive capacities.

Table 1. Respondents' views about extent to which main causes of climate change contribute to climate variability

Mean	Decision	SD	t-value	p - value
4.22	Significantly (SF)	0.415	41.55	0.001

Decision points: Not all (NA) = 1-1.4; Not sure (NS) = 1.5 – 2.4; Slightly (S) = 2.5 – 3.4; Significantly (SF) = 3.5 - 4.4; Entirely (E) = 4.5 – 5.0
Source: Field survey, 2023

The mean value of 4.22 from Table 1 suggests that majority of the respondents agreed that the main or primary causes of climate change significantly contribute to climate variability. There were also statistically significant differences among the responses (t = 41.55; p<0.05) and the views appear not to be too dispersed as depicted by SD of 0.415. Therefore, the null hypothesis was rejected and the alternative hypothesis accepted. The results reflect a high level of agreement among the respondents.

Research question 2: What are farmers' views about the effects of climate change on rice farming and farmers' livelihood?

Table 3 shows that 91% of the respondents acknowledged negative impact of climate change on rice farming, with no reports of positive or no noticeable effect. This high level perception underscores the probable significant and universally adverse effects that climate change has on rice production in the region. A small proportion of respondents (9%) linked the negative impacts to changes in the growing season, which indicates that alterations in traditional planting and harvesting times are affecting rice cultivation.

Table 2. Farmers' perceptions of effects of climate change on rice farming (n=200)

Statement about the effect	Mean	Decision	SD	t-value	df	p-value
Changes in temperature and precipitation patterns in recent years negatively affect rice production in my area	4.58	HA	0.49	45.16	199	0.001
Climate change poses high risks to rice production in my area	4.64	HA	0.69	33.73	199	0.001
Climate change will lower rice production in the future	4.18	A	0.82	20.37	199	0.001
Climate change will continue to affect rice storage negatively	4.16	A	0.90	18.13	199	0.001

Decision Points: Highly disagree (HD) = 1 – 1.4; Disagree (D) = 1.5 – 2.4; Not sure (NS) = 2.5 – 3.4; Agree (A) = 3.5 – 4.4; Highly agree (HA) = 4.5 – 5.0
Source: Field survey, 2023

Table 3. Farmers' perceived impact of climate change on rice yield and reasons

Perceived impact	Response	% Number of respondents
	Positive	0
	Negative	91
	No noticeable impact	0
	Changes in the growing season	9
Reasons given	Increased frequency of drought and crop failure	69
	Reduced cropping season	3
	Increased pest invasion	22
	No response	6

Source: Field survey, 2023

Table 4. Responses concerning observable long term negative impacts of climate change (n=200)

Observable long term negative impacts	Mean	Decision	SD	t-value	p-value
Changed timing of rain	4.71	VS	1.509	16.03	0.0001
Changes in the growing season	4.76	VS	1.474	16.88	0.0001
Increased frequency of drought and crop failure	2.59	IDN	1.481	-3.92	0.0001
Reduced cropping season	5.78	ES	0.415	94.67	0.0001
Increased frequency of flood and farm destruction	1.62	SS	0.848	-23.01	0.0001
Postharvest losses	1.68	SS	0.468	-39.92	0.0001
Pest invasion	4.69	VS	1.551	15.41	0.0001
Erosions	5.54	ES	0.500	71.89	0.0001

Decision Points: Not severe (NS)=1 – 1.4; Somehow severe (SS) = 1.5 – 2.4; I do not know (IDN) = 2.5 – 3.4; Severe (S) =3.5 – 4.4; Very severe (VS) = 4.5 – 5.4; Extremely severe (ES) = 5.5 – 6.0
Source: Field survey, 2023

It can be deduced from Table 2 that concerning observable effects of climate change on rice farming in their communities farmers highly agreed (HA) (Mean of 4.58) that changes in temperature and precipitation patterns in recent years negatively affect rice production and that climate change poses high risks to rice production respectively (Mean of 4.64). Views from literature point to the fact that rice shows sensitivity to changes in temperature and precipitation, affecting yield and quality (Adjei, 2021).

Furthermore, majority of the respondents agreed (A) that climate change will lower rice production in the future (mean of 4.18) and that climate change will continue to affect rice storage negatively (Mean of 4.16). The results again indicate that there were statistically significant differences in the responses at p = 0.001 (Table 2). This implies that the null hypothesis in all cases was rejected and the alternative hypothesis accepted. A study done by Karunaratne*et al.* (2016) suggests that farmers believed that climate change would reduce agricultural productivity over time. Overall, the views of rice farmers in the North East Region of Ghana highlight a strong awareness of the observable effects of climate change on rice farming. The significant consensus among farmers on the detrimental effects of temperature and precipitation changes on production and storage emphasizes the vulnerability of the Region's rice farming practices to climate variability. These findings suggest that climate change has far-reaching impacts on agricultural production, especially in developing countries where farming practices are often less adaptable to changing environmental conditions.

This perception is consistent with literature suggesting that shifting climatic conditions can lead to disruptions in planting cycles and reduce the effectiveness of crop yields (Karunaratne *et al*., 2016). The main reason given is increased frequency of drought and crop failure (69%), followed by increased pest invasion (22%) and then reduced cropping season (3%). Six percent however, did not give any reason.It is established that rising temperatures and changing rainfall patterns can contribute to the increased vulnerability of crops to pests, which further exacerbates losses in rice farming (Velásquez *et al*., 2018). This connection between climate change and pest invasion suggests a multi-layered challenge for farmers, requiring both climate adaptation and pest management strategies. Furthermore, it can be said that the 6% of the respondents who did not give any reason might not be sure of what to say. This may be more dangerous than those who gave opinions because sitting on the fence is a recipe for undertaking wrong farming practices.

Table 4 presents responses concerning long term negative effects of climate change. The rating showing very severe for "Changed timing of rain" (Mean of 4.71) and "Changes in the growing season" (Mean of 4.76) highlight the fact that farmers were aware of how altered rainfall patterns and growing seasons affect rice production in their areas. This perception aligns with some studies indicating that rice is highly sensitive to water availability and the timing of rainfall, which directly influences the crop's growth stages and yield outcomes (Wassmann *et al.,* 2009; Lobell *et al.,* 2011).

Table 5. Responses to the impact of climate conditions on vulnerability of rice farmers

Climatic condition making farmers vulnerable	Mean	Decision	SD	t-value	p-value
Floods	2.84	IDN	0.544	-4.16	0.0047
Increased temperature	5.93	EV	0.256	162.00	0.001
Decreased rainfall during the cropping season	5.54	EV	0.500	71.70	0.001
Droughts (During cropping season)	5.65	EV	0.480	77.98	0.001
Changed timing of rain	4.26	V	1.281	13.91	0.001
Abrupt change in season	4.91	VV	0.710	38.03	0.001

Decision Points: Not vulnerable (NV) = 1-1.4; Somehow vulnerable (SV) = 1.5 – 2.4; I do not know (IDN) = 2.5 – 3.4; Vulnerable (V) = 3.5 – 4.4; Very vulnerable (VV) = 4.5 – 5.4; Extremely vulnerable (EV) = 5.5 – 6.0

Source: Field survey, 2023.

The high significant statistical difference shown by p-value of 0.001 is indicative of the fact that the null hypothesis was rejected and the alternate hypothesis accepted. In any case, rainfall patterns have been shifting globally due to climate change, with many regions experiencing either delayed onset or erratic distribution, leading to potential droughts or flooding (IPCC, 2014). The timing of rainfall is particularly crucial for rice farmers as it determines planting schedules, water management, and ultimately the harvest period. These findings suggest that rice farmers are highly attuned to such changes, which significantly impact their agricultural planning and outputs. Changes in the growing season also imply shifts in temperature and precipitation that alter the duration and quality of rice cultivation periods.

Other negative effects that received high approval from the farmers are “Reduced cropping season” (mean of 5.78) which is extremely severe; “Pest invasion” (mean of 4.69), which is very severe and “Erosions” (mean of 5.54), which is extremely severe. In all cases the differences among the responses were highly statistically significant (p = 0.001) showing that the null hypothesis was rejected and the alternate hypothesis accepted. Reduced cropping seasons can be a result of altered rainfall patterns, increased temperature, and extreme weather events that disrupt normal growing periods (Nelson *et al*., 2010). The level of rating put on "Reduced cropping season," suggests that farmers perceived a direct and substantial threat to their livelihoods from the shortening of the period available for rice cultivation. The statistically significant differences among the responses suggest that the perception is statistically robust, reflecting widespread consensus on the issue.

A shortened cropping season affects the length of time rice can mature, often leading to incomplete grain filling, lower yields, and poorer grain quality. In regions like the North East of Ghana, where agriculture is rain-fed, any reduction in the growing season could have devastating impacts on food security and farmers’ income (Mendelsohn & Dinar, 2009). Therefore, the finding is not only illustrating farmers' awareness of climate change impacts but also pointing to an urgent need for adaptation strategies, such as the adoption of early-maturing rice varieties or changes in agricultural practices to align with the altered growing seasons.

Pest invasions are a common consequence of climate change, as altered temperature and humidity conditions create conducive environments for pests to proliferate (Ziska *et al*., 2012). The severe perception of pest invasion by the farmers aligns with studies in West Africa, where increases in temperatures and erratic rainfall have been linked to greater pest and disease pressures on crops (Rosenzweig *et al*., 2014).

Erosions" was perceived as one of the most severe impacts of climate change, likely due to its direct impact on soil quality and agricultural productivity. In areas with heavy rains or flooding, soil erosion can lead to the loss of fertile topsoil, reducing the land's capacity to support rice cultivation (Lal, 2001). This is particularly concerning in the context of climate change, as increased intensity of rainfall events can exacerbate erosion, leaving the soil structure compromised and potentially unfit for future planting. Therefore, it is encouraging that the farmers rated it so high, showing that they were very familiar with this negative effect of climate change on agriculture. If this high level of awareness is put into behavioural change then farmers would undertake farming practices that would not exacerbate climate change conditions that would negatively affect their livelihoods. According to Zhao *et al*. (2017); Calicioglu *et al*. (2019) and Dindaroglu*et al*. (2023) the high rises in temperature have resulted in increased incidence of drought, floods, irregular rainfall patterns, heat waves, decrease in glaciers, high intensity of typhoons and hurricanes, changes in animal habitats, northward movement of plant habitats, and other extreme events in the world. The immediate observations fall in line with the observable long term negative impacts indicated in Table 4 of this study**.** Meanwhile, some of the observable long term negative impacts had low ratings from the respondents.

Effects that received low ratings from the farmers are “Increased frequency of drought and crop failure” (Mean of 2.59), depicting I do not know; “Increased frequency of flood and farm destruction” with mean value of 1.62, indicating somehow severe; and “Postharvest losses” with a mean of 1.68, which also indicates somehow severe. However, there were significant mean differences among the responses. This suggests that the null hypothesis was rejected whereas the alternate hypothesis was accepted. The low ratings of these observable effects are worrying, suggesting that they did not have enough knowledge about the issues. For example, the “I do not know response about the case that “Increased frequency of drought and crop failure is a longterm negative impact of climatechange” does not put the respondents in the right position to take acceptable actions that will help them take the necessary precautionary steps that would help reduce the effects of climate change on their farming practices.

The findings in Table 4 align with a finding which emphasizes the point that rice farming is vulnerable to climate change (Lobell *et al.,* 2008). The perceptions of farmers highlight critical areas where climate change is impacting rice production, with emphasis on rainfall patterns, growing seasonal changes, and shortened cropping periods. These perceptions underscore the need for timely interventions that address both mitigation and adaptation in agricultural practices, ensuring the sustainability of rice farming in the North East Region of Ghana.

How climate change makes rice farmers vulnerable: The results in Table 5 cover rice farmers’ perceived effects of climate change on their livelihoods and vulnerability. It provides insights into the challenges farmers face and the extent of their exposure to climate-induced risks. From Table 5, majority of respondents indicated that they did not know that floods are climatic conditions that make rice farmers vulnerable (Mean of 2.84). The standard deviation of 0.544 suggests that the views of respondents did not very much, though the differences were statistically significant ($p<0.05$). On the other hand majority of respondents agreed that farmers were extremely vulnerable to increased temperatures (Mean of 5.93). The differences among the responses were statistically significant ($p<0.05$). Again majority of respondents agreed that farmers were extremely vulnerable to decreased rainfall during cropping seasons (Mean of 5.54); and drought during cropping season (mean of 5.65); vulnerable to changes in timing of rains (mean of 4.26); and very vulnerable to abrupt changes in the season. In all cases the differences among the responses were statistically significant ($p<0.05$). Therefore, in all cases the null hypothesis was rejected and the alternative hypothesis accepted.

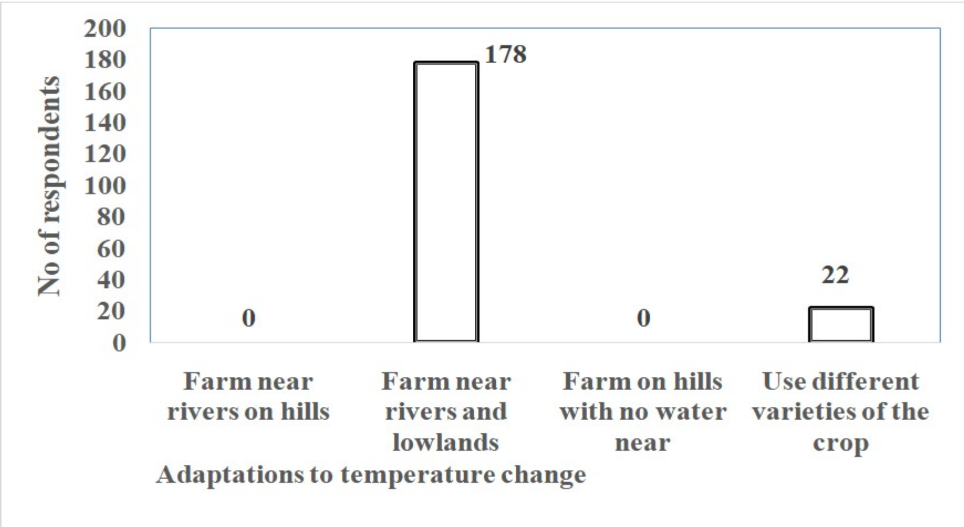
Responses to floods suggest that most of the farmers lacked certainty on the extent of impact of climate change on flooding that can affect their livelihoods. The response to increased temperatures point to the fact that the farmers were aware that high temperatures can negatively affect rice farms and thereby affecting farmers' livelihoods. This can make farmers vulnerable to poverty. This highlights the urgent need for adaptive strategies, such as developing heat-tolerant crop varieties and improving irrigation systems to mitigate the effects of increased temperatures (Karunaratne *et al.,* 2016). The overwhelming response of the farmers pointing out that reduced rainfall during the cropping season can lead to farmer vulnerability suggests that farmers rely on availability of sufficient water for their farming activities. This condition is seen as a critical threat to crop growth and productivity, necessitating strategies like efficient water management (Adjei, 2021).

Droughts represent a critical concern due to their capacity to significantly diminish water supply, damage crops, and lead to lower yields. This perception aligns with literature indicating that drought is one of the major risks to agricultural production, particularly in rain-fed systems like those in Ghana (Field & Barros, 2014). This emphasizes the need for comprehensive drought management and adaptive practices such as improved irrigation and water conservation techniques. Farmers perceived abrupt seasonal changes as particularly disruptive to agricultural activities, potentially impacting the timing of planting, crop growth, and harvest. This is consistent with the view that sudden shifts in seasonal patterns can have profound effects on farming practices (Gornall *et al*., 2010). Adaptive strategies like developing season-resilient crop varieties and improving weather forecasting systems are crucial to enhancing resilience.

vulnerabilities by farmers, posing significant threats to rice farming. Decreased rainfall and abrupt changes in seasons also contribute to high vulnerability perceptions, requiring urgent attention in adaptation strategies. Floods and changes in rainfall timing, although viewed as moderately vulnerable, still require strategic planning to mitigate their impacts on rice farming activities. The consistent agreement among farmers on the extreme risks posed by droughts and increased temperatures reflects the critical nature of these climatic conditions on agricultural productivity and food security. It is also in line with the view that climate change impacts on agriculture, particularly in rain-fed farming systems in sub-Saharan Africa (Afokpe *et al*., 2022). Addressing these vulnerabilities will require implementing comprehensive adaptation strategies, including water-efficient farming, use of resilient crop varieties, improved weather forecasting, and enhancing farmers' capacity for climate-smart agriculture.

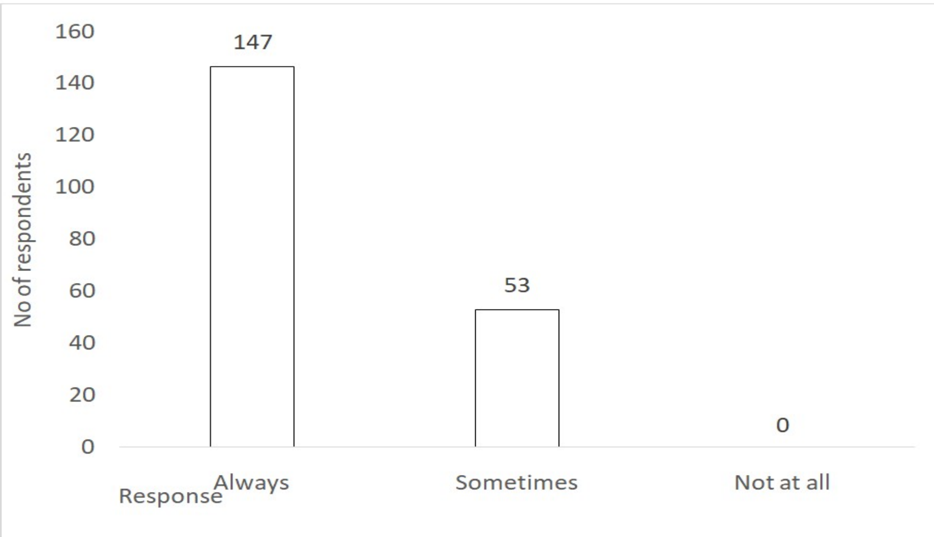
Research question 3: Which adaptation strategies and sustainable practices to mitigate the effects of climate change on rice farming activities are farmers aware of?

Figures 3, 4 and 5 present key insights into how farmers adapt their rice farming practices in response to climate change. The adaptation strategies are grouped into three main areas: adjustments to temperature and rainfall shifts, use of improved rice varieties, and changes in cultivation techniques. From Figure 3, it is clear that 178 farmers do farms near rivers and lowlands, while 22 farmers adapted by diversifying their crops and using different varieties.



Source: Field survey, 2023

Figure 3. Farmers' Adaptation Strategies to temperature change



Source: Field survey, 2023

Figure 4. How often farmers use improved rice varieties

This suggests that while reliance on proximity to water remains a primary strategy, there is growing recognition of crop genetic diversity as a viable adaptation strategy. According to Allan *et al*., (2020), using varied crop varieties enhances resilience to erratic rainfall, ensuring better survival and productivity under changing climatic conditions.

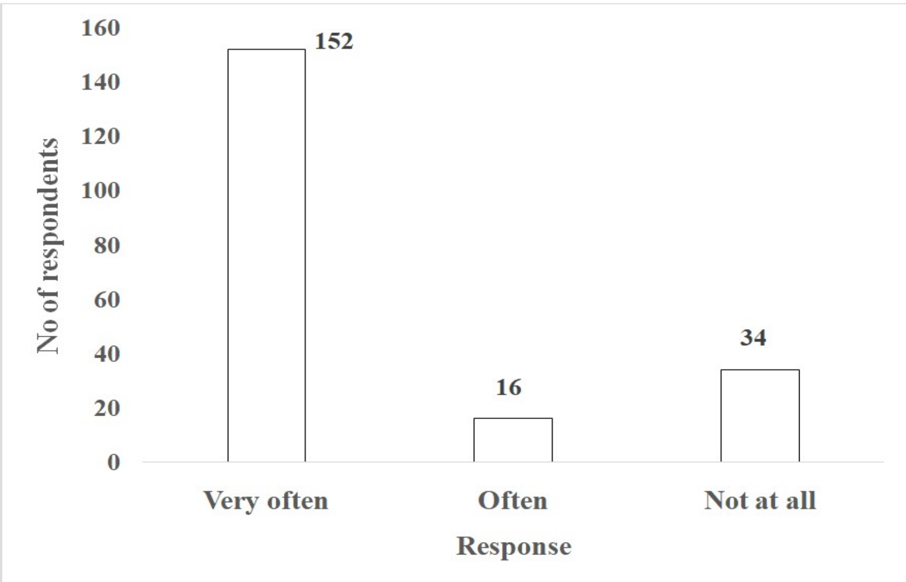
Figure 4 reveals that a significant majority of farmers (147) always used improved rice varieties, while 53 farmers used them sometimes, whereas no farmer responded that they do not use improved rice varieties. This high adoption rate demonstrates a strong awareness of the benefits of improved varieties, such as drought tolerance, pest resistance, and higher yields. Such adoption aligns with agricultural practices in climate-resilient farming as these varieties are designed to withstand environmental stresses and improve productivity (Sasaki *et al.*, 2015).

Farmers' frequency of changing cultivation techniques reflects their responsiveness to environmental conditions. A total of 152 farmers reported changing their farming techniques very often, while 16 farmers indicated they did so often, and 34 stated they did not change their techniques at all (Figure 5). The high number of farmers who stated that they change their farming techniques illustrates a proactive approach to farming in the face of climate challenges, demonstrating adaptability and resilience. However, the 34 farmers who do not change their techniques may face heightened risks due to lack of resources, knowledge, or unwillingness to adopt new practices. Studies have shown that a dynamic approach to cultivation techniques is crucial for maintaining productivity under climate variability (Tesfaye *et al*., 2021).

techniques reflects farmers' efforts to enhance yield stability and minimize climate-induced risks. The fact that some farmers do not change cultivation techniques points to potential gaps in knowledge or access to a wider range of adaptation strategies. This points to a need for extension services and education to promote more sustainable and varied approaches to climate adaptation, as highlighted by Antwi-Agyei and Stringer (2021). The proactive nature of the adaptation strategies, combined with a strong reliance on proven techniques like improved rice varieties and strategic location of farms, demonstrates a keen awareness levels of farmers about climate impacts and their willingness to adapt.

Research question 4: Which factors do farmers consider as hindering their implementation of adaptation strategies?

The perceived factors hindering farmers' implementation of adaptation strategies have been presented in Table 6. The results from Table 6 suggest that farmers did not see educational levela severe hindrance to adaptation (Mean of 1.38). The differences among the means were statistically significant, meaning that the null hypothesis was rejected and the alternative hypothesis accepted. While education is generally associated with better adaptation due to increased awareness and understanding of climatic risks and strategies (Deressa *et al*., 2009), its significance is often context-dependent. In regions where farming practices are traditionally based and knowledge is transferred through local customs, the impact of formal education on adaptation may not be as profound. This finding echos the idea that there is the need for farmer-centres, locally-tailored education and capacity-building programs (Nyanga *et al*., 2011).



Source: Field survey, 2023

Figure 5. Frequency of changing cultivation techniques as adaptation strategy by farmers

Table 6. Responses about challenges facing implementation of climate adaptation strategies among rice farmers (n = 200)

Item	Mean	Decision	SD	t value	p value
Educational level	1.38	NS	0.631	-36.33	0.001
No access to information	1.08	NS	0.272	-99.84	0.001
Inadequate capital	5.68	ES	0.468	81.05	0.001
Lack of extension services	1.38	NS	0.487	-47.08	0.001
No access to water for irrigation	5.84	ES	0.368	109.28	0.001
Infertile soil	3.60	S	0.802	10.58	0.001

Decision Points: Not severe (NS) =1 – 1.4; Somehow severe (SS) = 1.5 – 2.4; I do not know (IDN) = 2.5 – 3.4; Severe (S) =3.5 – 4.4; Very severe (VS = 4.5 – 5.4; Extremely severe (ES) = 5.5 – 6.0; Source: Field survey, 2023

The findings from Figures 3, 4 and 5 are very refreshing so far as adaptation strategies in agriculture are concerned. The consistent focus on farming near water sources underscores the critical role of water availability in agricultural resilience. Furthermore, the emphasis on improved crop varieties and frequent changes in cultivation

Access to information, such as weather forecasts, climate change impacts, and potential adaptation practices, is considered not to severely impacting implementation of climate adaptation strategies. While it is recognized that access to information can aid in timely adaptation (Chetri *et al*., 2024), the perception among farmers is that the lack of access is not a critical constraint. This finding aligns with the point that information alone is insufficient to drive adaptation; it must be relevant, accessible, and actionable (Jagannathan *et al*., 2023). In many cases, farmers may also rely on traditional knowledge and observation, which could mitigate the perceived need for external climate information.

The findings underscore inadequate capital as a significant barrier to adaptation, with a weighted mean of 5.68 indicating its severity. There were statistically significant differences among the responses ($p<0.05$). Thus, the null hypothesis was rejected and the alternate hypothesis accepted. The lack of financial resources is documented as a primary barrier to adaptation (Mertz *et al*., 2009), affecting the capacity to invest in new technologies, improved seeds, irrigation, and other inputs required to mitigate the impacts of climate change. The findings from this study reflect a need for financial support mechanisms such as credit schemes, subsidies, and micro-finance opportunities to enhance the adaptive capacity of farmers.

The role of agricultural extension services in facilitating adaptation is highlighted in the responses, where the lack of such services is considered "Somewhat Severe." Extension services are crucial for disseminating information on best practices, new technologies, and climate-resilient farming techniques (Antwi-Agyei & Stringer, 2021). The lack of access to such services can hinder farmers' ability to implement effective adaptation strategies. This finding is in line with the observation that extension services serve as conduit for knowledge transfer and capacity building to enhance the use of climate-smart agricultural practices (Westermann *et al*., 2018).

Water scarcity stands out as one of the most severe barriers, with a weighted mean of 5.84 and statistically significant differences among the responses ($p<0.05$). Here also, the null hypothesis was rejected and the alternate hypothesis was accepted. Access to water is fundamental for irrigation, especially in rice farming, which is water-intensive. Therefore the responses of the farmers about water scarcity is in the right direction. This corroborates the fact that water scarcity serves as a major constraint for agricultural adaptation in regions affected by erratic rainfall patterns and prolonged droughts (Kassie *et al*., 2011). Without reliable water sources, farmers are limited in their capacity to implement effective irrigation strategies, highlighting the need for investments in water management infrastructure, rainwater harvesting, and irrigation technology to support sustainable agriculture.

The presence of infertile soil is another factor recognized as a severe hindrance to adaptation strategies. The weighted mean of 3.60 suggests that soil fertility is a moderate to highly perceived barrier. Soil health is integral to crop yield and adaptation, as nutrient-poor soils require more inputs to maintain productivity under climate change conditions (Gwandu, 2023). This finding mirrors the need for soil conservation practices, organic amendments, and agroforestry as methods to enhance soil fertility and sustainability. Building soil health is often a prerequisite for successful adaptation strategies, making it an essential area for policy and practical intervention.

Barriers such as financial constraints, extension services, water scarcity, and soil fertility are very important to progressive agriculture. For example, financial limitations are frequently cited as the most immediate and critical constraint, often exacerbating other issues such as access to resources and inputs for adaptation (Gyimah & Gibba, 2020). Additionally, access to extension services is fundamental to building adaptive capacity, as they do not only provide technical guidance but also serve as a bridge between farmers and adaptive policies or programs (Amadu *et al*., 2020).

CONCLUSIONS AND RECOMMENDATIONS

The fact that majority (89.50%) of the respondents agreed that both natural and human causes lead to climate change suggests that farmers may be more open to engaging in both mitigation and adaptation strategies that address human-caused climate change. This calls for tailored education and support to farmers to enhance their knowledge of how their agricultural practices can contribute to climate change and their role to reduce their contribution to the environmental impact of climate change. This will significantly contribute to reduction in the effects of climate change on climate variability.

Indications are that the farmers had very high knowledge about the negative impacts of climate change on rice farming. As a result, the Regional Agricultural Officers need to mobilize these farmers into groups where they can serve as resource people to other farmers.

The perceptions of farmers highlight critical areas where climate change is impacting rice production such as on rainfall patterns, growing seasonal changes, and shortened cropping periods. Therefore, it will not be out of place if agricultural officers and scientists in the country consider agricultural mitigation and adaptation practices to ensure sustainability of rice farming in the North East Region of Ghana. The consistent agreement among the farmers on the extreme risks posed by droughts and increased temperatures reflects the critical nature of these climatic conditions on agricultural productivity and food security in the South East Region. Therefore, these vulnerabilities can be addressed by stakeholders by implementing comprehensive adaptation strategies including efficient farming, use of resilient crop varieties, improved weather forecasting, and enhancing farmers' capacity for climate-smart agriculture.

The critical role of water availability in agricultural resilience was aptly underscored by farmers. Furthermore, the idea of the use of improved crop varieties and frequent changes in cultivation techniques reflects the position of farmers to enhance yield stability and minimize climate-induced risks. These positions of the farmers can be enhanced by authorities organizing frequent further training of the farmers in practices that bring about acceptable adaptabilities. However, since some farmers do not change cultivation techniques then there is some gaps in knowledge and adaptation strategies in the Region. This also calls for agricultural extension officers to educate farmers in the Region on the promotion of viable sustainable climate adaptation strategies to improve rice production in the Region. Clearly, indications are that farmers faced constraints against progressive agriculture such as financial, extension services, water scarcity, and soil infertility. For effective rice farming to go on in the Region, authorities need to see to it that these needs are taken care of.

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