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Farmers' Knowledge and Perceptions of the Effects of Climate Variability and Pollution on Crop Production and Their Varying Adaptation Strategies in The Gambia

Pierre Anthony Mendy[1,2*], Mawa Kone[2], Ado Baba Ahmed[1], Sidat Yaffa[3], Alpha Kargbo[1], Afua Amponsah Amankwah[2], Kossi-Messan Jacques Agboka[2], Blessing Chinomso Okorie[2], Assan Sowe[4], Echene Jatta[5]

[1]Department of Physical and Natural Sciences, School of Arts & Sciences, University of The Gambia, Banjul, The Gambia
[2]West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL), Department of Biosciences, Université Félix Houphouët-Boigny, Abidjan, Côte d'Ivoire
[3]School of Agriculture and Environmental Sciences, University of The Gambia, Banjul, The Gambia
[4]School of Education, University of The Gambia, Banjul, The Gambia
[5]Department of Sociology and Social Work, College of Humanities and Social Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
Email: *pstmendy@utg.edu.gm

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Abstract

Crop and livestock production is critical to food security in The Gambia. Over the years, the country has experienced a reduced yield due to perceived climate change events with limited studies on how climate change and pollution affect crop production. This study assesses farmers' knowledge and perceptions of the effects of climate variability and pollution on crop production and their varying adaptation strategies in The Gambia. Both quantitative and qualitative methods were used in this study. The sample size for quantitative data collection was calculated as 432 while the qualitative data involves both the focus group discussions and key informant interviews. The focus group discussions comprised two districts in each of the six agricultural regions and two farming communities engaged in crop production were chosen from each district. Furthermore, eight key informant interviews from relevant institutions were conducted. The study shows that The Gambia is highly vulnerable to extreme climatic events. Although most farmers opined that agricultural land contamination emanates from farm runoff and indiscriminate waste dumping, they had little knowledge of heavy metal pollution and bioremediation. The results showed that farmers experienced constraints such as inadequate access to credit, water, and irrigation facilities, insufficient access to efficient inputs, salt intrusion, etc. which threatened food security. The study concludes that crop farmers acknowledged the existence and impacts of climate change, and therefore recommend the availability and affordability of climate change resilient crops and promote variability awareness campaigns to address climate change impacts in The Gambia.

Keywords

Climate Change, Extreme Weather, Vulnerability, Risks, Hazards, Adaptation Strategies

1. Introduction

Climate change is an environmental menace with devastating effects that have drawn scientists' attention over the past several decades (Patt & Schröter, 2008; Abid et al., 2015). In developing nations, the projections of weather and climate variabilities forecast changing climates with high vulnerability (Easterling et al., 2000; Khan et al., 2020). Regarding vulnerabilities, climate change has injurious effects on poor agricultural and rural communities of developing countries because of their low-income status and inadequate adaptive mechanisms (Barker et al., 2007; Skoufias et al., 2011). In addition, fluctuations in weather conditions are likely to upsurge the frequency and magnitude of several climatic threats, such as floods, storms, droughts, etc. (Khan et al., 2020).

Nowadays, climate change is one of the main environmental hazards that greatly threatens plants, animals, and humans. This phenomenon can generate fluctuations, such as rising sea levels, erratic rainfall, and shifts in climatic regions due to increasing temperatures. The degree of droughts, storms, and floods is predicted to rise and be influenced greatly by the changes in climate patterns. The hazards associated with weather and extreme climate events can increase significantly due to the increase in climatic variability (Akcaoz & Ozkan, 2005; Ahmad et al., 2007), consequently changing the degree, rate, and spatial amount of disasters, such as floods and droughts (Udmale et al., 2014). Such changes will cause the manifestation of extreme weather and climate events with substantial impact (Barker et al., 2007; Hay & Mimura, 2010), which will generate immense pressure on communities, natural systems, societies, and economies struggling to cope with other non-climatic threats that seriously impede the sustainable development endeavours of the government and non-governmental organizations (Hay & Mimura, 2010).

Although there is rapid advancement in technology concerning mechanization, the weather is still a primary factor in determining agricultural productivity (Khan et al., 2020). Rainfall and temperature are the main drivers in crop production and rural food security (Wheeler & Braun, 2013; Akhtar et al., 2019). Elevated climate variability and extreme weather conditions affect crop and livestock production (Howden et al., 2007; Chaudhary & Aryal, 2009) with a considerable increase in the incidence of insects, pests, and diseases which are projected to affect the farming sector adversely as it would result to the deterioration of soil microorganisms' metabolism and water content (Liverman, 2008; Paudel et al., 2014). Extreme weather and climate variabilities highly influence agricultural mechanization in climate conditions (e.g., rainfall, temperature, humidity, etc.), shaping the natural hazards and influencing income distribution and farmers' livelihoods. The crop productivity in a specific area, region, or location is determined greatly by local rather than global climatic conditions (Paudel et al., 2014; Khan et al., 2020).

Floods and droughts are the most common and frequent natural hazards that extensively cause economic and social risks for humans, especially in less economically endowed and vulnerable communities with meagre adaptive capabilities. Further, an increase in these extreme events can cause global warming and might impose additional hurdles to sustainable development, which will cause food insecurity and hinder poverty alleviation. Countries located at low latitudes, especially developing countries, are more prone to extreme weather and climate events than countries in high latitudes because they are highly exposed to climatic hazards in the form of increased surface temperature and fluctuation in precipitation (Ali & Erenstein, 2017). Research has predicted that by 2080, the risk of hunger and starvation can seriously affect over 170 million people globally (Schmidhuber & Tubiello, 2007).

Although The Gambia contributes very little (less than 0.01%) to global greenhouse gas emissions as compared to other nations (Cham et al., 2018), its development agenda could be seriously impacted by climate events. Already droughts, floods, windstorms, increased temperatures, and shortened rainfall lengths are recorded and projected to occur in the future. Due to the subsistence nature of the agricultural production system, characterized by low investment and being highly rain-fed dependent, it is apparent that these menaces will affect agricultural productivity (Cham et al., 2018).

There is little research being done on the risks associated with extreme weather and climate events, farm-level vulnerability, and adaptation strategies in The Gambia. Therefore, the specific objective of this study is to assess farmers' knowledge and perceptions of the effects of climate variability and pollution on crop production and their varying adaptation strategies in The Gambia. This would enable the government, NGOs, and philanthropists to have a clearer picture and put more effort into the development of the agrarian industry in the country. The outcome of this research will serve as a benchmark for future research and a reference point for policymakers in devising appropriate adaptation policies to facilitate agrarian communities in sustaining their livelihoods against future climate-related risks.

2. Materials and Methods

2.1. Study Area

The Gambia is at the western end of West Africa, located at 13˚28.02' North 16˚34.02' West. The total territory area of the country is approximately 11,300 km^2, which is divided into landmass and water surface areas of approximately 1300 km^2 and 10,000 km^2, respectively, thus making the country one of the smallest in mainland Africa (Ampomah et al., 2012; Belford et al., 2023). The country is situated in the tropical sub-humid ecoclimatic zone, with annual rainfall ranging from 800 to 1200 mm annually (Kargbo et al., 2021). There are two seasons experienced in this climate zone: a rainy season (June to October) and a dry season (November to May) consisting of approximately six to seven months of dry period (Josephine et al., 2020; Barrow et al., 2020). During the dry season, the climate is dominated by dry, and dusty winds, which originate from the Sahara Desert (Kargbo et al., 2021).

The socio-cultural activities are associated with customs, lifestyles, and values, which characterize the demographics, religion, attitudes, economic status, class, and language (Mutsikiwa & Basera, 2012). The 2013 Population and Housing Census revealed that The Gambia has a population of 1,882,450 with a density of 176 persons per km^2 (Gambia Bureau of Statistics (GBoS), 2013; Josephine et al., 2020). The country has six Agricultural Administration Regions and an Urban Region, which comprises of Kanifing Municipal Council and Banjul. According to Jaiteh and Saho (2003), the main ethnic groups were as follows: Mandingoes (36%), Fulani (22%), Wollofs (15%), Jolas (11%), Sarahuli (8%), Serer (2.5%)), Manjaku (1.7%) and others (4%) (Badgie, 2018).

The Gambia is among those countries most vulnerable to climate change (Camara, 2013). The Coastal wetlands, tidal flats, marshes, colluvial slopes, and uplands along the River Gambia characterize the topography of The Gambia. Rice and other crops are cultivated in all these highly variable environments, with land preparation and cropping techniques depending on the soil type, hydraulic conductivity, and tidal flows (Engel-Di Mauro, 2012) (**Figure 1**).

2.2. Research Design

A cross-sectional study was conducted in the six Agricultural Regions of The Gambia from Number 2022 to March 2023. Primary data was used for the study. Primary data used was in the form of structured (quantitative research) questionnaires, Focus Group Discussions (FGDs), and Key Informant Interviews (KIIs) in 2023. The FGDs and KIIs used unstructured questionnaires (qualitative research). The structured questionnaires were administered to 432 crop farmers. Both the questionnaires (quantitative and qualitative) covered farmers' knowledge and perceptions of the effects of climate variability and pollution on crop production and their varying adaptation strategies in The Gambia. The combination of both quantitative and qualitative approaches provides a more holistic understanding of the research question than either approach singly (Creswell & Angeles, 2006).

2.3. Data Collection

Participants were carefully chosen using a random sampling approach. Adopting Al Mansour (2020) formula, where n is the sample size, z is the standard error associated with the chosen level of confidence (1.96), p is the estimated prevalence (0.50), q is $1-p$ (0.50), and d is the acceptable error (0.05):

$$n = Z^2 \times p(1-p)/d^2$$

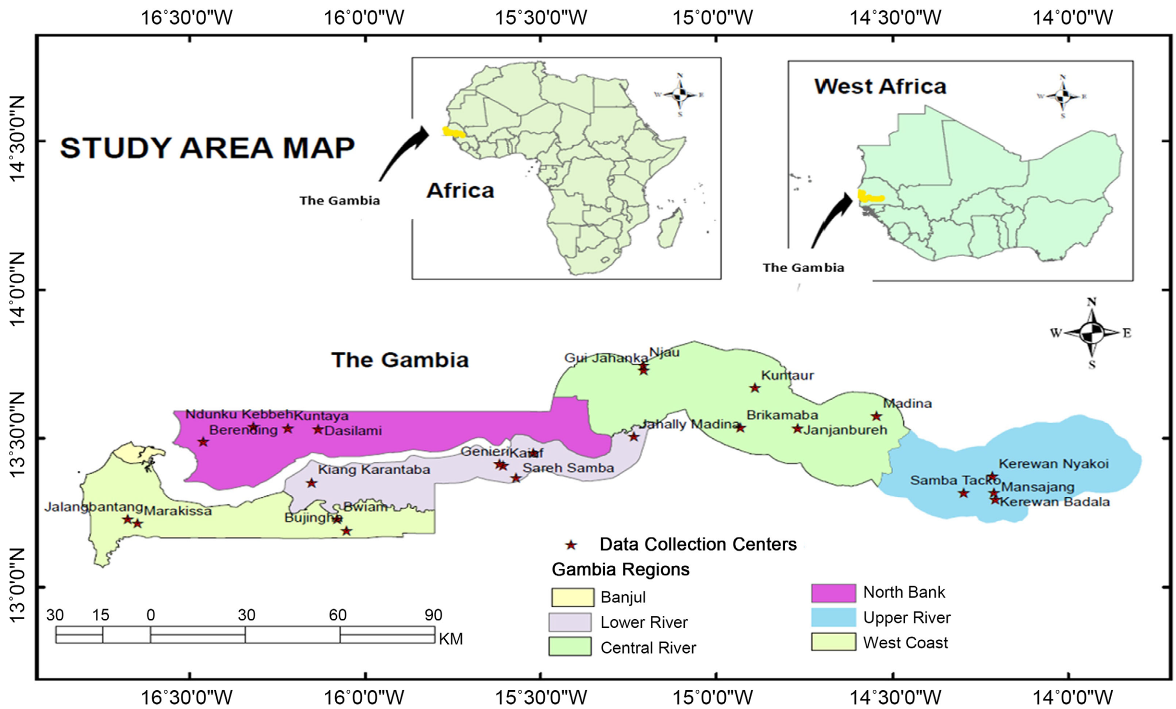

Figure 1. Map of The Gambia showing the study areas. The figure was generated and modified using ArcGIS 9.

From the above formula, a sample size of 384 was obtained, which was multiplied by 10% for sampling error to obtain 432 as the number of participants (Al Mansour, 2020). Two districts from each of the five regions already described were randomly selected and within each selected district, two farming communities were purposively chosen for data collection. The purposive method of choosing the two communities for data collection stemmed from the fact that not all the communities were seriously engaged in crop farming but only the chosen communities were more involved in farming. In CRR-S, three districts such as Janjanbureh, Lower Fulladu, and Lower Fulladu West were chosen with one farming community in each of them except in Lower Fulladu West where two farming communities were chosen for data collection. The survey was conducted using 432 structured pre-tested questionnaires (228 males and 204 females) administered to crop farmers. The questionnaires were made up of both closed and open-ended questions, which were interpreted orally in the local languages (Mandinka, Fula, and Wolof) to the farmers and later translated back to the English Language consistently to enhance their applicability in various contexts.

2.4. Statistical and Data Analyses

Microsoft Excel spreadsheet program was used to manage the raw data. Epi info

7.2.5.0. Software statistical analysis tools were used to analyze and interpret the data. The obtained data was analyzed using descriptive statistics. The relationships between the predictor variable (gender, age, ethnic group, religion, marital status, and level of education) with knowledge and perceptions variables were examined using Pearson's chi-square and Binomial Logistic Regression. *P*-value < 0.05 was considered statistically significant.

3. Results and Discussion

This study sought to investigate the existing farmers' knowledge and perceptions of the effects of climate variability and pollution on crop production and their varying adaptation strategies in The Gambia. The findings of this study showed that the effects of climatic variability have had a significant impact on crop production in The Gambia. A report from Ethiopia by Mengistu (2011) observed that vulnerability analysis to climate change is closely linked to poverty and the living conditions of farmers, which determine their vulnerability and adaptation to climate change. An increase in the frequency of climate-related risks can lead households to anticipate lower income, potentially pushing them below the poverty threshold in the country. Other researchers have emphasized the strong effects of vulnerability on climate change in poor agricultural and rural communities of developing countries because of their low income and deprived adaptive capabilities (Barker et al., 2007; Skoufias et al., 2011). In addition, deviations in weather situations are likely to use the frequency and magnitude of several climatic hazards, such as floods, storms, droughts, etc. (Khan et al., 2020).

3.1. Social Demographic Characteristics of the Participants

Out of the 432 crop farmers that participated in this study, 228 (52.78%) are males while 204 (47.22%) are females. About one-quarter of the participants 92 (21.30%) were between 40 - 49 years old, about half of the respondents 194 (44.91%) were between 50 and 59 years old, and about a quarter of the respondents 117 (27.08%) were 60 years and above. The findings showed that the main population engaged in crop farming is the aged population (50 years and above), which accounted for about 72%. This is attributed to the fact that most people believed that farming was meant for the illiterates, the less educated, and the poor. In contrast to the study conducted in Uganda by Ahaibwe et al. (2013), which revealed that young farmers were concentrated more on agricultural production than adults despite the fact that the majority of them are less educated. The majority of the respondents 157 (36.34%) are Mandinkas by ethnicity followed by Fulas 107 (24.77%) and then Wolof 75 (17.36%) and others accounted for the rest of the respondents. On marital status, 354 (81.94%) of the respondents are married while 58 (13.43%) were single and the rest are either widowed or divorced. Regarding educational status, the highest number 171 (39.58%) of the respondents were illiterate followed by those who only attained primary education 82 (18.98%) (**Table 1**).

Table 1. Demography of crop farmers.

Characteristics	Frequency	Percentage
Gender		
Male	228	52.78
Female	204	47.22
Total	432	100.00
Age (years)		
20 - 29	10	2.31
30 - 39	19	4.40
40 - 49	92	21.30
50 - 59	194	44.91
60 and above	117	27.08
Total	432	100.00
Ethnic group		
Mandinka	157	36.34
Fula	107	24.77
Wolof	75	17.36
Others	93	21.53
Total	432	100.00
Religion		
Islam	403	93.29
Christianity	29	6.71
Total	432	100.00
Marital status		
Married	354	81.94
Single	58	13.43
Widowed	15	3.47
Divorced	5	1.16
Total	432	100.00
Highest level of education		
Primary	82	18.98
Secondary	74	17.13
Tertiary/University	32	7.41
Informal/Madarasa	171	39.58
None	73	16.90
Total	432	100.00

3.2. Percentage of Farmers Involved in the Cultivation of Various Crops and Land Tenure Systems Used

Participants in this survey were asked about the main crop they grow, the type of farmland, whether they have changed crops in the past 20 years, and if they have changed crops, what the reason for the change of crops was. The results showed that 138 (31.94%) of the respondents grew rice, 212 (49.07%) grew groundnuts, 21 (4.86%) grew maize, 41 (9.49%) grew millet, 9 (2.08%) grew cassava and the rest grew one of the following crops; banana, lettuce, okra, and onion as shown in **Table 2**. A similar study was conducted in the Central River Region of The Gambia, which indicated that 46.8% of the respondents grew rice, 45.2% grew groundnuts, while 1.4%, 5.3% and 2.08% grew maize, millet, and cassava respectively, and the rest grew other crops in the study area (Badgie, 2018). About the type of farmland, 6 (1.39%) of the respondents cultivated their crops on state land, 81 (18.75%) cultivated their crops on communal land, 304 (70.37%) cultivated on individual land and 41 (9.49%) grown on rented land (**Table 2**). In contrast, Badgie (2018) revealed that 18.75% of respondents cultivated their crops on communal land, 49.3% on individual land, and 9.49% on rented land. On the question of change of crops in the last 20 years, 421 (97.45%) of the respondents agreed that they have changed crops in the last 20 years and 11 (2.55%) said they have not changed crops in the last 20 years. The reasons for the change of crops were as follows; 135 (31.25% of the respondents argued that they changed crops due to short rainfall duration, 43 (9.95%) of them said because of drought, 175 (40.51%) attributed their change of crops to low soil fertility and 79 (18.29%) opined that incidence of pest and disease compelled them to change crops. Although these findings were supported by Seo and Mendelsohn, (2008) in South American farms, they pointed out that this may not be the case if the adjustment requires heavy investment. These findings are contrasted by the study conducted by Crane et al. (2011), which reported that high climatic variability and unpredictable rain have led not only to changes in crops but almost every farmer now practices mixed agro-pastoralism and may also intermittently engage in fishing and hunting when possible. The diversification of crops and other sectors of the economy would minimize the total failure of the enterprises should the farmer encounter extreme climate events.

Table 2. The main crops grown under various land tenure systems.

Characteristics	Frequency	Percentage
Rice	138	31.95
Groundnuts	212	49.07
Maize	21	4.86
Millet	41	9.49
Cassava	9	2.08
Others	11	2.55
Total	432	100.00

Continued

Type of farmland		
State	6	1.39
Communal	81	18.75
Individual	304	70.37
Rented	41	9.49
Total	432	100.00
Have you changed crops in the past 20 years?		
Yes	421	97.45
No	11	2.55
Total	432	100.00
If yes, what was the reason for the change of crops?		
Short rainfall duration	130	30.88
Drought	43	10.21
Low soil fertility	171	40.62
Incidence of pest and disease	77	18.29
Total	421	100.00

3.3. Farmers' Perception of the Effects of Climate Variability on Crop Production in The Gambia

The perception of farmers on the effects of climate variability on crop production shows that, 426 (98.61%) respondents reported being aware of climate change. Almost all the respondents except for salt intrusion 241 (55.79%) reported that they have observed and experienced a change in temperature 422 (97.69%), rainfall pattern 430 (99.54%), erosion 427 (98.84%), windstorm 426 (98.61%, drought 418 (96.76%) and flood 432 (100.00%) over the past 20 years (**Table 3**). According to meteorological evidence from Cham et al. (2018), rainfall has decreased, the period of the rainy season has decreased, minimum temperatures have decreased, maximum temperatures have increased and the frequency of severe weather events such as drought and dust storms has increased in The Gambia over the past 60 years. This study revealed that crop farmers in The Gambia are very aware of the effects of climate variability on crop production. Except for salt intrusion, the overwhelming majority of more than 95% of the respondents are aware of climate change and perceived changes in temperature and rainfall patterns, a frequent occurrence in erosion, windstorms, drought, and flood as the main hazards caused by climate variability in the study area. A similar study was conducted in Ebonyi State, Nigeria, which demonstrated the majority of rice farmers perceived climate change events such as unpredictable rainfall patterns and distribution, prolonged dry season, frequent floods, increased temperature, and severe windstorms, which are in consonant with other scientific data resulting in poor yields and products (Onyeneke et al., 2021). Another similar study in Uganda also revealed almost 99% of the respondents had perceived a change in the climate in the last decade (Okonya et al., 2013). The farmers' views on the causes of climate variability on crop production in The Gambia in the last 20 years are consistent with the study conducted in South Africa which shows that the risk of unprecedented high January-March (JFM) average temperatures is increasing, posing a growing threat to Agriculture (Bradshaw et al., 2022). The majority (98.61%) of the respondents in The Gambia perceived the effects of climate variability on crop production. This is similar to the study conducted in Pakistan which reported that 91% of respondents in Pashawar perceived droughts as a major threat caused by weather and climate variability (Khan et al., 2020). During the FGDs and KIIs with stakeholders, it was established that all the informants from the selected communities and institutions respectively were fully aware of climate variability and its effects on crop production.

Table 3. Crop farmers' perception of the occurrence of climate variability on crop production in The Gambia in the last 20 years.

Climate variable	Yes	No
Awareness of climate change	426 (98.61%)	6 (1.39%)
Observed changes in temperature pattern	422 (97.69%)	10 (2.31%)
Observed changes in rainfall pattern	430 (99.54%)	2 (0.46%)
Experienced erosion	427 (98.84%)	5 (1.16%)
Experienced windstorm	426 (98.61%)	6 (1.39%)
Experienced salt intrusion on arable land	241 (55.79%)	191 (44.21%)
Experienced drought in this region	418 (96.76%)	14 (3.24%)
Experienced flood	432 (100.00%)	0 (0.00%)

Under the causes of climate variability, 71 (16.67%), 76 (17.59%), and 76 (17.59%) of respondents attributed climate change, temperature change, and change in rainfall to natural causes, whereas 100 (23.47%), 105 (24.31%) and 101 (23.38%) opined that it is due to human-induced activities. In contrast, the other respondents 245 (57.51%), 244 (56.48%), and 251 (58.10%) argued that both natural and human-induced activities are the causes of change in climate, change in temperature and change in rainfall respectively while 10 (2.34%), 7 (1.62%) and 4 (0.93%) said that they do not know the cause of climate change, change in temperature and change in rainfall respectively (**Table 4**).

Table 4. Perceived causes of climate variability on crop production in The Gambia.

Climate variable	Natural	Human-induced	Natural & human-induced	I don't know
Change in climate	71 (16.67%)	100 (23.47%)	245 (57.51%)	10 (2.34%)
Change in temperature	76 (17.59%)	105 (24.31%)	244 (56.48%)	7 (1.62%)
Change in rainfall	76 (17.59%)	101 (23.38%)	251 (58.10%)	4 (0.93%)

The findings as shown in **Table 4**, revealed that more than 50% of the farmers attributed the causes of climate variability such as temperature and rainfall to the interplay of both natural and human-induced activities. A similar study was conducted in Nigeria, which opined that changes in climate and environmental conditions occur as a result of both natural and human factors (Nwankwoala, 2015). This is in consonant with the study conducted by Hartter et al. (2018) in eastern Oregon (USA), where most of the respondents did not accept human causation as the only agent of climate change. However, a large majority (85% - 86%) of them agree that the climate is changing, either by natural or human-induced causes (Hartter et al., 2018). In contrast with the study conducted by Perkins-Kirkpatrick et al. (2022) which opined that extreme events that influence climate change are attributed to anthropogenic activities.

The perception of crop farmers towards the effects of elevated temperature on crop production shows that 400 respondents (92.59%) reported a decrease in crop production, 20 (4.63%) stated an increase, 8 (1.85%) believed that the elevated temperature has no effect, and 4 (0.93%) were unsure of any effects (**Figure 2**). This is in consonant with the research conducted in Slovakia by Varga (2021), which argued that the impacts of climate change would be felt in agriculture leading to reduced production in warmer areas due to temperature stress, risk of erosion as a result of more extreme weather conditions, the occurrence of new pests, etc.

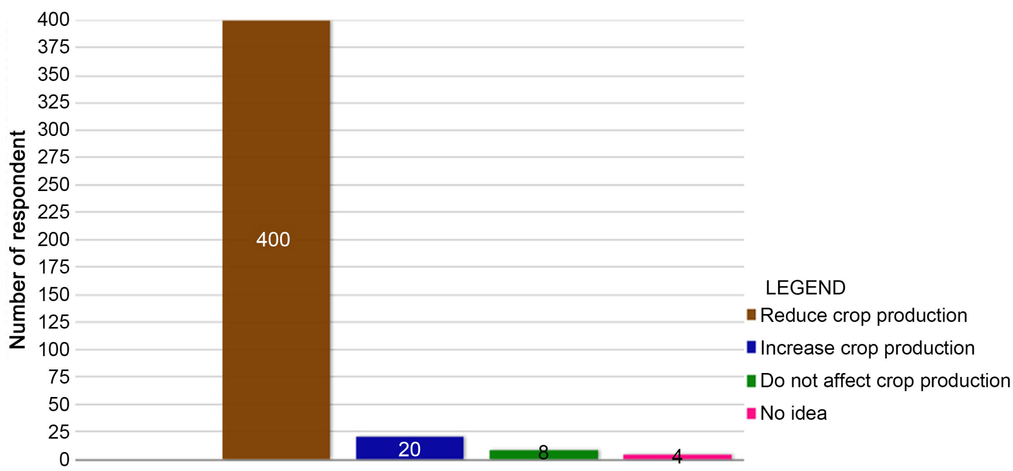

Figure 2. Effects of elevated temperature on crop production.

The crop farmers were asked about the effects of changes in rainfall patterns on crop growth, development, and production. The results show that 403 (93.29%) reported that they observed reduced crop growth, development, and production, 22 (5.09%) stated that there was an increase in crop growth, development, and production, 3 (0.69%) said that it does not affect crop growth, development, and production while 4 (0.93%) reported that they had no idea about the resultant effects of changes in rainfall pattern on crop growth, development, and production (**Figure 3**).

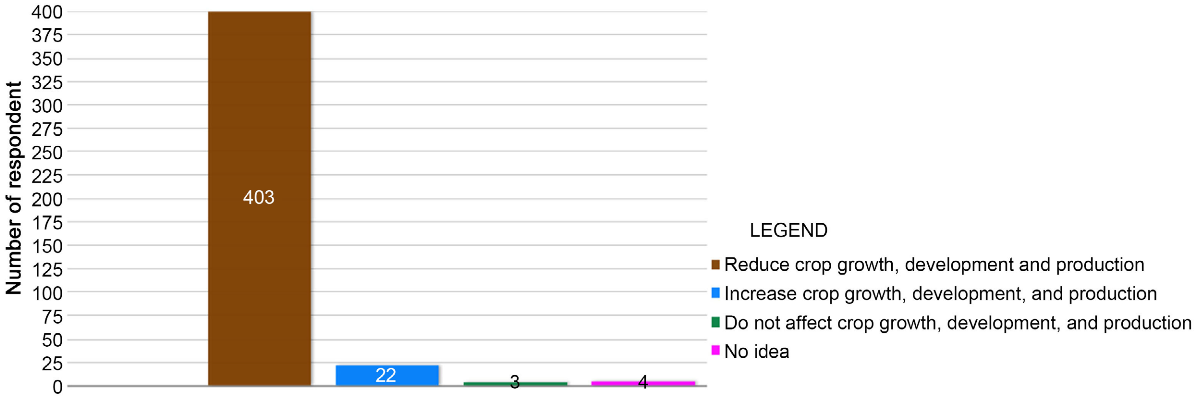

Figure 3. Effects of changes in rainfall pattern on crop growth, development, and production.

Figure 4 shows the various effects of climate variability and pollution on the environment such as high temperatures 198 (45.83%), less or erratic rainfall 48 (11.11%), floods increase on farms 28 (6.48%), late onset of rains 34 (7.87%), less crop yield 79 (18.29%), increased winds before rains 17 (3.94%) and land degradation 28 (6.48%). A similar study in Nigeria pointed out that the majority (more than 70%) of farmers perceived an increase in temperature and a decrease in precipitation patterns (Sofoluwe et al., 2011).

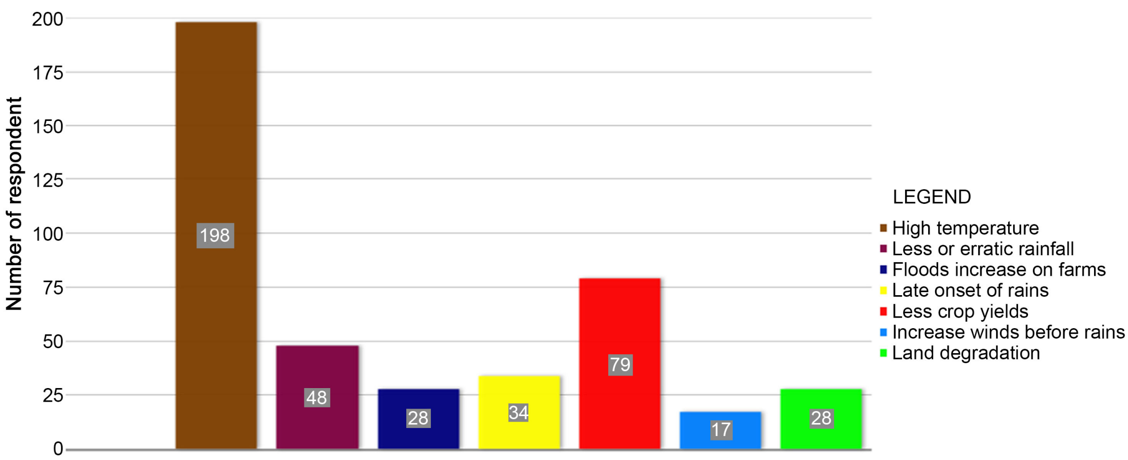

Figure 4. Observed changes in climate variability and pollution in the environment.

A study conducted by Agwu et al. (2018) showed that farmers in Nigeria are well aware of climate change, and its impact on crop productivity stressing that the variability of the Harmattan season influences fruit production of the *Garcinia kola*. Mertz et al. (2009), which analyzed the perceptions of climate change and the strategies for coping and adaptation in the savannah zone of central Senegal agreed that households are aware of climate variability and identified wind and occasional excess rainfall as the most destructive climate events. The findings of Odewumi et al. (2013) in Ibadan, South-western Nigeria, on farmers' perception of the effect of climate change and variations on urban agriculture indicated that 89.6% of the respondents had agreed that climate is changing. Similarly, research has revealed that about 89% of the farmers perceived a significant increase in temperature, 72% perceived high evapotranspiration rates, 68% showed that there had been violent rain and hailstorms, and 65% experienced delayed rainfall and early cessation (Chalchisa & Sani, 2016).

3.4. Factors Associated with Farmers' Perception of the Effects of Climate Variability on Crop Production in The Gambia Using Pearson Chi-Square Test

Table 5 shows Pearson chi-square results on farmers' perception of the effects of climate variability on crop production in The Gambia. The analysis indicates that marital status is the only demographic variable that showed a significant association with all questions about climate variability effects on crop husbandry in The Gambia. Furthermore, the chi-square analysis test showed that the highest level of education is significantly associated with farmers' perception of the effects of erosion, windstorms, and salt intrusion on crop production in their communities. These findings suggest that crop farmers in The Gambia know the adverse effects of climate variability on food security. Furthermore, the chi-square analysis tests also showed that age and ethnic group were also significant in determining crop farmers' perception of the effects of salt intrusion on crop production in their communities. In contrast, a study conducted in the Nile Basin of Ethiopia by Deressa et al. (2011), showed only age as being significantly related to farmers' perception of climate change.

Table 5. Pearson chi-square results on farmers' perception of the effects of climate variability on crop production in The Gambia.

Items	Factors	X^2 values	*P*-value
Have you ever experienced erosion in the last 20 years in The Gambia?	Age	3.1008	0.541^{ns}
	Ethnic group	0.6677	0.716^{ns}
	Marital status	15.7696	0.001*
	Highest level of education	13.1948	0.010*
Have you experienced windstorms in the past 20 years?	Age	3.2733	0.513^{ns}
	Ethnic group	0.6955	0.706^{ns}
	Marital status	9.2015	0.027*
	Highest level of education	9.7389	0.044*
Have you experienced salt intrusion for the past 20 years on your arable land?	Age	9.8123	0.044*
	Ethnic group	26.7692	<0.001*
	Marital status	9.9964	0.019*
	Highest level of education	17.6778	0.001*
Have you ever experienced drought in the last 20 years in this region?	Age	2.4970	0.645^{ns}
	Ethnic group	5.1251	0.077^{ns}
	Marital status	8.5958	0.035*
	Highest level of education	8.3664	0.079^{ns}

*= significant difference at $P < 0.05$; ^{ns} = not significant.

3.5. Farmers' Perceptions of the Contamination of Agricultural Land

Table 6 shows the binomial logistic regression result of how crop farmers perceived the contamination of agricultural land in The Gambia. This result shows that farmers' ages (CL −0.135 to −0.020 and $P = 0.008$) and ethnic groups (CL 0.068 to 0.188 and $P \leq 0.001$) were the main factors significantly influencing their perception of the awareness of HM pollution on land. Farmers' ages (CL −0.167 to −0.054 and $P \leq 0.001$) and ethnic groups (CL 0.053 to 0.171 and $P \leq 0.001$) were also highly significantly associated with their awareness of threats posed by HM contamination in soil and water.

Table 6. Binomial logistic result of Farmers' perceptions on the contamination of agricultural land.

Variables		95% C	Limits	*P*-Value
Outcome	Independence			
Have you experienced soil and water pollution for farming?	Gender	−0.037	0.099	0.375
	Age	−0.021	0.061	0.344
	Ethnic group	−0.003	0.083	0.070
	Religion	−0.044	0.845	0.077
	Marital status	−0.051	0.068	0.772
	Highest level of education	−0.011	0.039	0.283
Are you aware of heavy metal (HM) pollution?	Gender	−0.149	0.039	0.251
	Age	−0.135	−0.020	0.008*
	Ethnic group	0.068	0.188	<0.001*
	Religion	−0.516	0.715	0.750
	Marital status	−0.045	0.120	0.368
	Highest level of education	−0.018	0.051	0.348
Are you aware of threats posed by HM contamination in soil and water?	Gender	−0.152	0.034	0.213
	Age	−0.167	−0.054	<0.001*
	Ethnic group	0.053	0.171	<0.001*
	Religion	−0.549	0.666	0.849
	Marital status	−0.049	0.113	0.437
	Highest level of education	−0.013	0.055	0.231

The age of the respondents represents experience in farming and research has shown that experienced farmers are more likely to perceive climate change (Ishaya & Abaje, 2008; Deressa et al., 2011).

Table 7 shows the responses of crop farmers about their perceptions of the contamination of agricultural land. The majority of 358 (82.87%) of the informants had experienced soil and water pollution on their farms. These findings revealed that although the farmers in The Gambia had never experienced HM pollution on their farms, 109 (25.23%) of them are aware of the threats posed by these recalcitrant substances to the environment (**Table 7**). This may be because there is little or no analysis of the content of heavy metals in the fertilizers, chemicals, and pesticides used on the arable soil. With this little knowledge of HM contamination in The Gambia, bioremediation technology, which is not only meant for HM removal but also those contaminants with organic substances origin, is an exotic phenomenon. In contrast with the study conducted in Lankao County, China by Ren et al. (2018), which showed from the questionnaire that the content of heavy metal in various arable soils is closely related to the input of fertilizer, pesticide, farmyard manure, etc. In addition, another study conducted by Lu (2019), opined that farmers in China believe that their cultivated land is moderately polluted by heavy metals and they have a strong awareness of HM pollution in locally cultivated land. Research conducted by Ren et al. (2018) revealed that HM contamination remediation of arable soil indicates that the adoption of appropriate treatment measures can reduce the HM content of arable soil to some extent, such as the adjustment of planting patterns, deep ploughing for soil amelioration, formula fertilization, and adoption of phytoremediation (an aspect of bioremediation), etc.

Table 7. Farmers' perceptions of the contamination of agricultural land.

Variables	Yes	No
Have you experienced soil and water pollution on your farm?	358 (82.87%)	74 (17.13%)
Are you aware of heavy metal (HM) pollution?	109 (25.23%)	323 (74.77%)
If yes, have you experienced HM pollution on your farmland in the last 20 years?	…	109 (100.00%)
Are you aware of HM contamination's threats to soil and water?	109 (25.23%)	323 (74.77%)

Figure 5 shows the main soil and water pollution in The Gambia. The findings revealed that the main soil and water pollution emanates from both organic and inorganic contaminants, 163 (45.53%) attributed the pollution to chemical fertilizers, 39 (10.89%) said that pesticides cause the pollution, 81 (22.63%) argued that industrial and agricultural wastes cause the pollution, 74 (20.67%) of them opined that their farmlands are polluted by sewage and 1 (0.28%) of the farmers said that other agents cause the pollution (**Figure 5**). Similarly, the research of Srivastav (2020), showed that several researchers have reported the risks to environmental systems due to overuse and prolonged application of chemical fertilizers and pesticides, which would invariably promote soil health deterioration along with environmental pollution.

It was also revealed in the FGD sessions that, most of the upstream farmers were less affected by pollution than those farmers in the coastal and riverine agricultural areas. Contrastingly, the research conducted in the United States by Chakraborti (2021) concluded that point sources have a significant negative impact on ambient water quality net of non-point sources of contamination at upstream locations. However, during the FDG sessions, the coastal and riverine farmers complained of pollution emanating from indiscriminate disposal of plastic bags, agrochemicals, pesticides, salt intrusion, oil spillage, and runoff from dump sites, to name a few. HM pollution was not mentioned which could be attributed to the fact that there is little or no evidence of any study on HM pollution in The Gambia.

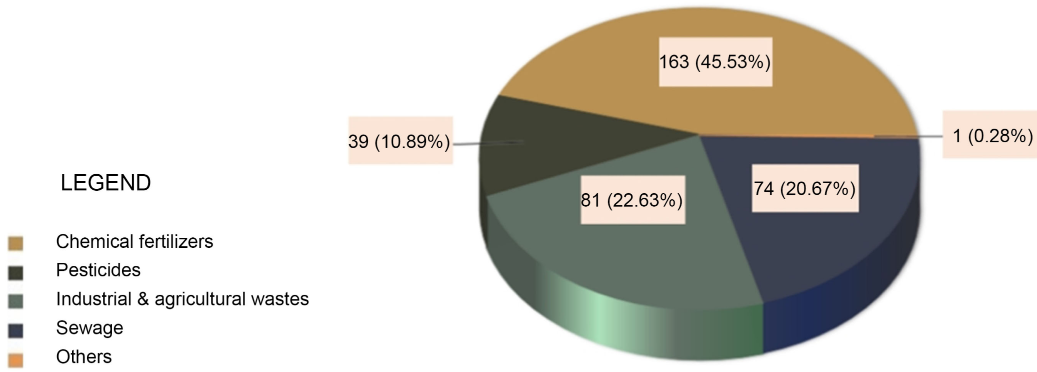

Figure 5. The main soil and water pollutants on farmland in The Gambia.

3.6. Constraints Militating against Farmers' Response in the GAMBIA in Their Crop Production toward Climate Change

The field surveys showed (**Table 8**) the challenges faced in responding to climate variability in the study area. Inadequate access to credit facilities and efficient inputs was ranked first with a high number of respondents 288 (66.67%) each in militating against farmers in their response to climate change. This was followed by labour constraints, inadequate access to the market, inadequate access to water and irrigation facilities, inadequate access to information, and use of poor skills, salt intrusion, and inadequate access to ideal land as they ranked third 240 (55.56%), fourth 239 (55.32%), fifth 222 (51.39%), sixth 165 (38.19%), seventh 134 (31.02%) and eighth 101 (23.38%) respectively. These findings are in consonant with that of Idrisa et al. (2012) who reported that inadequate financial resources (credit), inadequate access to extension services, poor access to technologies required for adaptation and inadequate weather information were the challenges confronting farmers' adaptation to climate change in Borno State, Nigeria. However, research conducted in India by Satishkumar et al. (2013) had a divergent perspective which revealed that personal constraints like the small size and fragmented landholdings, low literacy level, and inadequate knowledge of how to cope or build resilience are the main hurdles confronting agrarian industry. The same research also pointed out that the farmers faced poor extension service on climate risk management, non-availability of drought-tolerant varieties, lack of access to weather forecasting technology, poor reliability, and dependence on monsoon were the major institutional and technological constraints.

Table 8. Constraints militating against farmers' response in The Gambia in their crop production toward climate change.

Constraints	High	Medium	Low	None	Rank
Inadequate access to credit facilities	288 (66.67%)	101(23.38%)	35 (8.10%)	8 (1.85%)	1st
Inadequate access to efficient inputs	288 (66.67%)	101 (23.38%)	35 (8.10%)	8 (1.85%)	1st
Labour constraints	240 (55.56%)	123 (28.47%)	65 (15.05%)	4 (0.93%)	3rd
Inadequate access to the market	239 (55.32%)	104 (24.07%)	48 (11.11%)	41 (9.49%)	4th
Inadequate access to water and irrigation facilities	222 (51.39%)	149 (34.49%)	52 (12.04%)	9 (2.08%)	5th
Inadequate access to information and the use of poor skills	165 (38.19%)	164 (37.96%)	90 (20.83%)	13 (3.01%)	6th
Salt intrusion	134 (31.02%)	49 (11.34%)	78 (18.06%)	171 (39.58%)	7th
Inadequate access to an ideal land	101 (23.38%)	131 (30.32%)	174 (40.28%)	26 (6.02%)	8th

3.7. Adaptation Strategies Employed by Farmers in The Gambia toward Climate Change

The agrarian industry has over the years proven to have the capability of responding to changing climate events by adopting various strategies and innovations as the circumstances may deem fit. The survey shows the most common adaptation strategies employed by farmers to cope with the changing climate (Table 9).

Table 9. Agricultural crop production adaptation strategies employed by farmers in The Gambia toward climate change.

Adaptation strategies	Always	Occasionally	Rarely	Never
Planting of drought-resistant varieties of crops	141 (32.79%)	160 (37.21%)	113 (26.28%)	16 (3.72%)
Crop diversification	187 (43.29%)	164 (37.96%)	67 (15.51%)	14 (03.24%)
Improved irrigation efficiency	60 (13.89%)	144 (33.33%)	181 (41.90%)	47 (10.88%)
Afforestation and agroforestry	61 (14.12%)	137 (31.71%)	188 (43.52%)	46 (10.65%)
Crop rotation system	118 (27.31%)	139 (32.18%)	121 (28.01%)	54 (12.50%)
Chemical fertilizer	101 (23.38%)	189 (43.75%)	122 (28.24%)	20 (4.63%)
Organic manure	215 (49.77%)	178 (41.20%)	32 (7.41%)	7 (1.62%)
Zero tillage	27 (6.25%)	68 (15.74%)	98 (22.69%)	239 (55.32%)
Early maturing varieties	254 (58.80%)	121 (28.01%)	46 (10.65%)	11(2.55%)
Migration to different locations	252 (58.33%)	80 (18.52%)	66 (15.28%)	34 (7.87%)

The possible adaptation strategies employed by farmers in The Gambia towards climate change indicated that about 141 (32.79%) of the farmers specified that planting drought-resistant crop varieties would help solve challenges and increase their crop yields. This is in agreement with research conducted in Nigeria, Senegal, Burkina Faso, and Ghana, which pointed out that smallholder farmers have used, drought-resistant crop varieties as an adaptation method to climate change (Akinnagbe & Irohibe, 2015). Again, 187 (43.29%) of the informants opined that the adoption of crop diversification has helped a great deal to reduce the loss they normally encountered on their farms. According to them, if the government can supply them with various crop varieties to grow, some may fail because of the harsh climatic conditions but others will thrive. Similar research conducted in Tanzania revealed that farmers diversified crop varieties as a way of spreading risks on the farm (Orindi & Eriksen, 2005; Adger et al., 2003). Crop diversification can serve as insurance against rainfall variability (Akinnagbe & Irohibe, 2015).

Other respondents representing 60 (13.89%) indicated that improved irrigation efficiency would enable them to grow their crops all year round. This would ensure the availability of food security at all times instead of seasonality. A study conducted by Akinnagbe and Irohibe (2015) stressed that the impacts of climate change have resulted in elevated crop water demand due to high evapotranspiration (FAO, 2006). In addition, 61 (14.12%) of the respondents argued that afforestation and agroforestry would help prevent erosion and maintain soil fertility, eventually boosting their crop yields. Research has revealed that a practice similar to this has been described in the southwestern part of Nigeria to raise shade-tolerant crops, such as *Dioscorea* spp., and cocoyam in essentially permanent forest settings. In the drier parts of the Sahel, African baobab (*Adansonia digitata*) and acacia (*Acacia* spp.) trees are usually planted by local farmers since they are also economically valuable trees, especially during the hot and dry parts of the year (Akinnagbe & Irohibe, 2015). Another 118 (27.31%) of the respondents opined that the practice of a crop rotation system would help replenish the depleted soil nutrients thereby improving crop yield. Further, 101 (23.38%) of the respondents pointed out that the use of chemical fertilizers could also help enhance their adaptation to climate change and reduce the losses incurred on farms. They cried out that the price of fertilizers set by the government was too high for average farmers hence most of them could not afford them. Almost half 215 (49.77%) of the respondents settled for the use of organic manure as a means of adaptation strategy to mitigate the effect of climate change. Although zero tillage is not a familiar method used by farmers in The Gambia to reduce the adverse effects of climate change on their crop production, few 27 (6.25%) of them embraced the strategy to improve crop yields. The majority 254 (58.80%) and 252 (58.33%) of the respondents employed early maturing varieties and migration to different locations respectively as crop adaptation strategies towards climate change. These findings are in line with a survey conducted in the Zou Department of South Benin, which revealed that farmers adopted many strategies such as mulching, organic fertilizer, the use of improved varieties, chemical fertilizers, and pesticides in response to climate change: agroforestry and perennial plantation diversification of income-generating activities (Fadina & Barjolle, 2018). Although the findings of this research show some similarities with research conducted by Akinnagbe and Irohibe (2015), the common agricultural adaptation strategies adopted by farmers in Nigeria were the use of drought-resistant varieties of crops, crop diversification, changes in cropping patterns and calendar of planting, conserving soil moisture through appropriate tillage methods, improving irrigation efficiency, and afforestation and agro-forestry. In the West African Sahel, recent studies have shown that the region has suffered a prolonged drought for much of the past three decades and one way that farmers have adapted is by sending young men and women in search of wage labour after each harvest. However, how far they travel depends, in part, on the success of the harvest (Akinnagbe & Irohibe, 2015). More generally, environmental migrants are, most of the time, people affected by long-term and permanent climate variations in temperature and precipitations; hence, they consider the migration process as a long-run adaptation strategy (Falco et al., 2018). This study showed that adaptation strategies such as improved irrigation efficiency, afforestation and agroforestry, and zero tillage were not always used (**Table 9**).

However, participants in the KIIs stressed that activities such as the use of clean energy (solar, windmills, hydrogen-powered vehicles), afforestation, selective exploitation, avoidance of excessive use of fertilizers, the use of anti-littering policy, crop rotation, bush fallowing, adoption of climate-smart agricultural practices (minimum tillage, improved crop varieties, farmyard manure, water-saving technology, biopesticides, etc.), raise awareness through campaigns would help attitudinal change towards the environment and environmental policy formulation and implementation can help mitigate the effects of climate change.

4. Conclusion

Climate change is a global phenomenon and its impacts on agricultural production cannot be overemphasized. The agricultural sector has played a significant role for many communities because it is a source of food, income, and foreign exchange earnings. Therefore, understanding the farmers' knowledge and perceptions of the effects of climate variability and pollution on crop production is important for formulating adaptation strategies. Arising from this research, the conclusion is that, farmers were relatively the aged adult population with a minimal level of education. With the necessary support and interventions from the government, NGOs, and philanthropists, there is a likely shift from the aged population to the active youthful population engaged in agricultural production. The study unearthed the fact that climate change and pollution are phenomena that are closely linked, and are capable of affecting all spheres of life, such as the economy, and urban and rural development patterns, just to name but a few. However, very little is known about bioremediation in The Gambia. For this reason, more research and awareness creation are needed to help farmers understand the need to employ bioremediation technology, which has the advantage of using natural processes that are eco-friendly, cost-effective, and scalable to clean up sites without having to dig, pump, or transport them elsewhere.

The challenges farmers in The Gambia faced include but are not limited to inadequate credit facilities, inadequate access to efficient inputs, inadequate access to information and poor skills, labour constraints, and inadequate market access. It is recommended that the government and NGOs help farmers adopt the following adaptation strategies but are not limited to improved irrigation efficiency, afforestation and agroforestry, crop rotation system, chemical fertilizer, and zero tillage through financial assistance in the form of loans, grants, and subsidies.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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