Chapter

Sustainability and Determinate of Farmers' Mitigation Strategies to Greenhouse Gases Emission: A Case in Rice Agric-Food System of Nigeria

Nnaemaka Success Esiobu, Chinedu Gilbert Onubuogu, Sylvarlene Munachim Njoku and Blessing Chidinma Nwachukwu

Abstract

Sustainable production refers to the production that meets the needs of the present, without compromising the ability of future generations to meet their own needs. At global level and mainly across Nigeria, rice fields are considered as one of the most important sources of atmospheric concentration of two greenhouse gases, mainly anthropogenic methane (CH_4) and nitrous oxide (N_2O) emissions. These greenhouse gases (GHGs) are produced under anaerobic conditions, and their production has negative environmental and health implications. Additionally, the growing demand for rice across Nigeria exceeds supply, resulting in a rice deficit. To overcome this challenge, rice production should be increased, with so much regard to less GHG emission. Moving forward, understanding the determinate of farmers' mitigation strategies to GHGs will definitely enhance effort made for farmers to continue to mitigate easily over-time. Incidentally, empirical study on the present discourse is relatively scanty, isolated, and devoid of in-depth and quantitative analyses. Most empirical studies did not pay close attention to the determinants of rice farmers' decisions to mitigation options to GHGs. Studies on mitigation of GHGs at a farm or household level should rigorously examine the socioeconomic characteristics that influence farmers' decisions to practice GHG mitigation or not. These create a gap in research and make it extremely difficult if not impossible for the governments/interest groups to know the method they can adopt in helping farmers mitigate the negative impact of GHG emission in rice production. It was against this backdrop that this study was systematically undertaken.

Keywords: rice, greenhouse gases (GHGs), mitigation strategies, sustainability and multinomial model, Nigeria

1. Introduction

Sustainable production refers to the production that meets the needs of the present, without compromising the ability of future generations to meet their own

needs [1]. For an agricultural production to be sustainable, it must produce food with regard not only to the environment (to ensure production can continue on an indefinite basis) but also to generating sufficient production to meet the demand and producing an adequate return for farmers to support their standard of living of those yet unborn. Therefore, rice (*Oryza* spp.), which is the second-largest most consumed cereal (after wheat), shapes the lives of millions of households globally [2]. More than half of the worlds' population depends on rice for about 80% of its food calorie requirements [3, 4]. It has become a staple food in Nigeria such that every household, both the rich and the poor, consumes a great quantity. A combination of various factors seems to have triggered the structural increase in rice consumption over the years with consumption broadening across all socioeconomic classes, including the poor [5]. The rising demand could be as a result of increasing population growth and income level coupled with the ease of its preparation and storage. Currently, due to the present government objective on diversification of the economy, rice is grown in almost 36 states in Nigeria including Federal Capital Territory (FCT) under diverse production systems and agroclimatic conditions. Additionally, the growing demand for rice across sub-Saharan Africa and particularly in Nigeria exceeds supply, resulting in a rice deficit. In the same way, Nigeria is the continent's leading consumer of rice, one of the largest producers of rice in Africa, and simultaneously one of the largest rice importers in the world. Incidentally, rice field is a significant anthropogenic source of methane (CH_4) and nitrous oxide (N_2O), two important greenhouse gases (GHGs). Methane, which accounts for 20–30% of the global warming effect, is second only to carbon dioxide (CO_2) as the most significant GHG [6]. Methane from rice fields represents about 10% of non-CO_2 emissions from agriculture [7] and about 89% of the global warming potential (GWP) from rice [8]. The current understanding of the determinate of farmers' mitigation strategies to GHG emission in rice agric-food system in Nigeria has not much been empirically documented. Additionally, to the best of our knowledge, no study has systematically modeled farmers' mitigation strategies for GHG emission using multinomial logit regression. The multinomial logit model is an extension of the binary logit model for modeling categorical dependent variables with more than two categories. The dependent variable is assumed to follow a multinomial distribution, a generalization of the binomial distribution. This creates a gap in knowledge and makes it absolutely difficult if not impossible for researchers, the government, and policy-makers to know the method they can adopt in assisting the farmers increase their production, their standard of living and livelihood in a cleaner environment. Despite the importance attached to understanding rice production under a cleaner environment, it is somewhat surprising that little or nothing is known about farmers' socioeconomic characteristic; farmers' mitigation strategies for GHG emissions; how farmers' socioeconomic characteristic influences their mitigation strategies; and the barrier they encounter in mitigating GHGs in the area. Empirical evidence remains largely scanty, isolated, and devoid of in-depth and quantitative analysis. It was against these backdrops that it became increasingly pertinent that the study was systematically and logically undertaken.

2. Methodology

The study was carried out in Imo State, Nigeria. Imo State is located in the eastern zone of Nigeria. The state lies between latitude 4°45′N and 7°15′N and longitude 6°50′E and 7°25′E [9]. It is bounded on the east by Abia State, on the west by the river Niger and Delta State, and on the north by Anambra State, while Rivers State lies to the south. Imo State covers an area of about 5067.20 km^2, with a population of

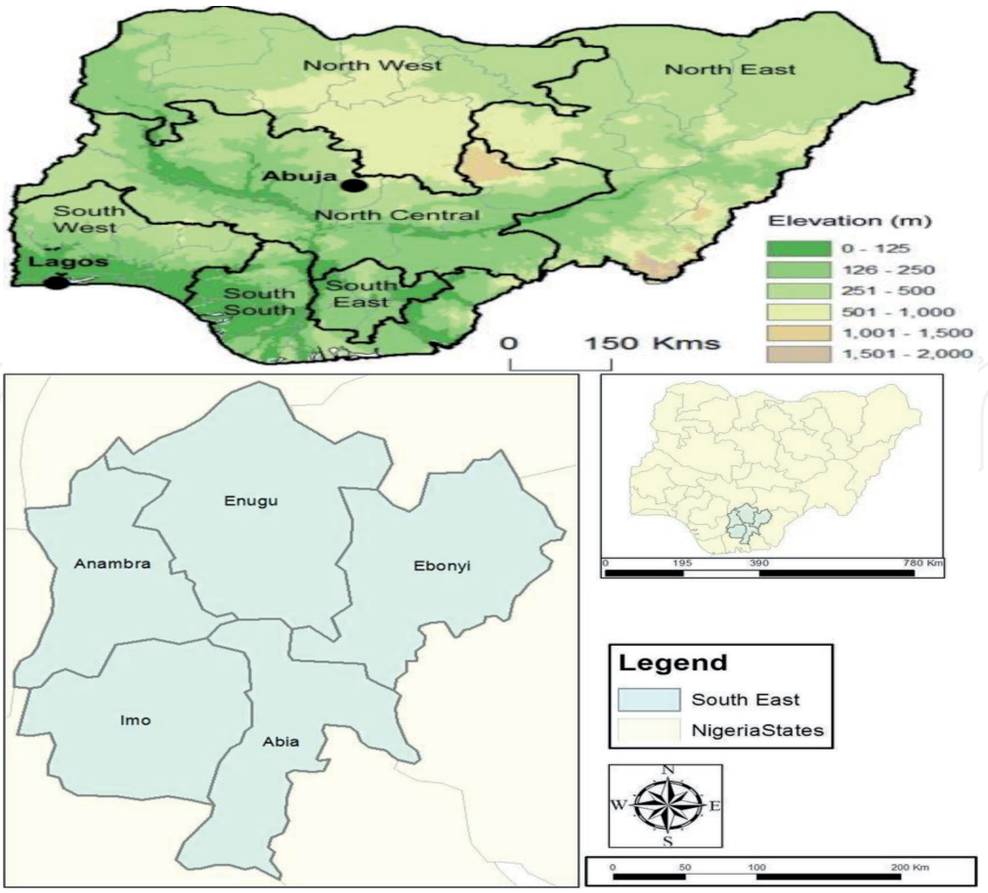

Figure 1.
Map of Nigeria showing the study area.

3,934,899 [10, 11] and population density of about 725 km^2 [12]. The state has three agricultural zones namely Orlu, Owerri, and Okigwe (**Figure 1**). The state has an average annual temperature of 28°C, an average annual relative humidity of 80%, average annual rainfall of 1800–2500 mm, and an altitude of about 100 m above sea level [12]. It experiences two major seasons: dry and rainy seasons. The state has fertile and well-drained soil suitable for rice farming and a good proportion of the population are essentially farmers. A multistage and purposive random method was used in the selection of respondents. Purposive sampling method was used to select respondents who are predominantly rice farmers. The sample size comprised 120 rice farms. A well-structured questionnaire was the main tool for data collection. Data collected were analyzed using descriptive statistical tools and a multinomial logit model. The model is given below:

If p_{ij} is the probability of y_i falling in category $j, j = 1,2,\ldots,J,$ then

$$\ln\left(\frac{p_{ij}}{p_{iJ}}\right) = \alpha_j + \beta_j X_i, j = 1,2,\ldots,J-1 \tag{1}$$

leading to

$$p_{ij} = \frac{e^{\alpha_j + \beta_j X_i}}{1 + \sum_{k=1}^{J-1} e^{\alpha_k + \beta_k X_i}}, j = 1,\ldots,J-1 \tag{2}$$

and

$$p_{ij} = \frac{1}{1 + \sum_{k=1}^{J-1} e^{\alpha_k + \beta_k X_i}} \tag{3}$$

where P = response probability (J = 0, 1, 2, 3,...7); Y = mitigation category, J = 1, 2,...,8; 1 = alternate wetting and drying of rice (AWD); 2 = system of rice intensification (SRI); 3 = changing tillage operations (CTO); 4 = Nitrogen Fertilizer Management (NFM); 5 = residue management (RM); 6 = aerobic rice varieties (ARC); 7 = no mitigation strategies.

The explanatory variables are as follows:

$$Y = f\left(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}\right) + ei \tag{4}$$

where X_1 = age (years); X_2 = sex (male = 1, female = 0); X_3 = educational level (years); X_4 = farming experience (years); X_5 = household size (number of persons); X_6 = farm income (N); X_7 = farm size (ha); X_8 = extension contact (contact = 1, no-contact = 0); X_9 = access to farm credit (access = 1, no-access = 0); X_{10} = access to GHG emission information (access = 1, no-access = 0); e_i = error term.

3. Results and discussion

3.1 Socioeconomic characteristics of rice farmers

Table 1 reveals that majority (59.17%) fell within the age range of 41–50 years. The mean age was 45.00 years. This shows that farmers in the area are vibrant, young, and still within the active age. Rice farming is so strenuous. The implication is that younger farmers are more likely to practice more and modern mitigation strategies in GHG emission faster than the older ones. Young farmers are more likely to know about new mitigation strategies to avert GHG emission with the willingness to bear risk. **Table 1** also reveals that majority (75.85%) of the farmers were males. The finding implies that both sexes are involved in rice farming but males are more in number in the area. This is true as male farmers have been found to be relatively more efficient than women [13].

Entries in **Table 1** also show that greater proportion (53.33%) had secondary school education. The main education level is 12 years, which is equivalent to secondary school education. The finding implies that approximately 95.00% of the farmers had formal education, which is expected to increase their level of understanding on the effect of GHG emissions in rice farms and various mitigation strategies to practice in thwarting the negative effect. Result in **Table 1** shows that majority (84.17%) were married. The finding implies that rice farming is an enterprise of married individuals who are expected to be responsible according to societal standard. Married farmers have more likelihood of adapting to climate change easily than their unmarried counterparts since they have access to labor. Result of farming experience is shown in **Table 1** and it shows that about 27.50% of the farmers had a farming experience ranging from 11 to 15 years. The mean year of experience in farming was 15.00 years. This shows that the farmers were quite experienced in rice farming and may have been adapting to several mitigation strategies for GHG emissions in the area. It is expected that farmers with more experience are more

	Frequency	Percentage	Mean (X)
Age (years)			
21–30	5	4.17	
31–40	11	9.16	
41–50	71	59.17	
51–60	30	25.00	
61–70	3	2.50	
Total	120	100.0	45.00
Sex			
Male	91	75.83	
Female	29	24.16	
Total	120	100.0	
Educational level (years)			
No formal education	6	5.00	
Primary	41	34.17	
Secondary	64	53.33	
Tertiary	9	7.50	
Total	120	100.0	12 years equivalent to secondary education
Marital status			
Single	8	6.67	
Married	101	84.17	
Divorced	4	3.33	
Widowed	7	5.83	
Total	120	100.0	
Farming experience (years)			
1–5	38	63.33	
6–10	9	15.00	
11–15	5	8.33	
16–20	8	13.33	
21–25	9	7.50	
Total	120	100.0	23
Household size (number of persons)			
1–2	2	1.67	
3–4	5	4.17	
5–6	11	9.17	
7–8	29	24.17	
9–10	51	42.50	
11–12	13	10.83	
13–14	9	6.67	
Total	120	100.0	9.00

	Frequency	Percentage	Mean (X)
Extension contact			
Contact (yes)	31	25.83	
No contact (no)	89	74.17	
Total	120	100.0	
Access to credit			
Access	46	76.67	
No access	14	23.33	
Total	120	100.0	
Access to GHG information			
Access	107	89.17	
No access	13	10.83	
Total	120	100.0	
Farm size (ha)			
0.1–0.99	27	22.50	
1.0–2.50	83	69.17	
2.60–3.00	10	8.33	2.28
Total	120	100	
Annual farm income (N)			
100,001–200,000	21	17.50	
200,001–300,000	25	20.83	
300,001–400,000	65	54.17	
400,001–500,000	9	7.50	
Total	120	100.0	400,790.00 (1034.40 USD)

Source: field survey data, 2020.

Table 1.
Socioeconomic characteristics of rice farmers.

likely to accept innovations and new mitigation strategies for GHG emissions than inexperienced farmers. The number of years of farming helps to cushion the effects of GHG emissions, since GHG emissions is yearly recurring decimal during rice farming. Results in **Table 1** also show that majority (74.17%) of the farmers had no contact with extension agents. The implication is that majority of the farmers may not have the opportunity of learning new mitigation options in GHG emissions and consequently exposing their rice farming to incidence of CH_4 and N_2O impact in the area. It becomes clear that there is a need for the government to strengthen the Agricultural Development Programme (ADP) to facilitate timely extension contacts with farmers in the area. The provision of information and guidance to farmers in any farming season would increase mitigation of GHG emissions and improvement in their faming enterprise in a cleaner environment. Entries in **Table 1** reveal that about 42.50% had a household size ranging from 9 to 10. The mean household size was found to be 9.00 persons. The result shows that farmers had large households. The implication is that they could draw farm labor from their households for the practice of various mitigation strategies for GHG emissions in rice farming. **Table 1** shows that majority (89.17%) of the farmers have access to GHG emission information. This implies that farmers in the study area have access to GHG emissions

information, which enhances their easy mitigation to multiple choices in GHG emissions. It is expected that farmers who have access to GHG emissions information will be more aware of effect of GHG emissions and practice better mitigation measures than farmers with no access to information. **Table 1** reveals that majority (69.17%) of the farmers had farm size of between 2.00 and 2.50 ha. The finding implies that the farmers in the area are mainly smallholder farmers operating on less than or equal to 2.50 ha of farmland. This could be as a result of land tenure system or increasing population prevalent in the area. Additionally, the small farm size is not even contiguous plot but rather small plots scattered in different areas of the community. It is expected that farmers with large farm size will practice more GHG strategies than those with lesser farmland in the area. More so, larger farm size enhances the probability of households choosing multiple and better measures to mitigate GHG emission than of households with smaller farm size. Finally, **Table 1** indicates that majority (54.14%) had an average annual farm income of between N300,001 and N400,000. The mean annual farm income was N400,790.00 while monthly farm income was estimated to be N33,399.167. The finding implies that the farmers have a relatively low farm income despite the larger household size, which they recorded. The implication of the findings is that farmers may not have the much needed financial capacity to mitigate GHG emission. This is true as some mitigation strategies for GHG emission are costly. Hence, farmers may have several GHG emission strategies they want to practice but limited fund will continue to hinder them.

3.2 Farmers' GHG emission mitigation strategies in rice farming

The result in **Figure 2** reveals farmers' GHG emission mitigation strategies in rice farming in the area. Similarly, it is very possible that the various mitigation strategies used by the rice farmers to reduce the negative impacts of GHG emission in their farming activities could be profit driven rather than GHG emission driven. In strengthening the above assertion, the study of [14] reported that the action of farmers in reducing the negative impact of climate change over time has basically been climate change driven; hence, the study assumed that the rice farmers' various mitigation measures are therefore GHG emission driven. The result reveals that about 98.10% of the farmers identified alternate wetting and drying of rice (AWD) as one of their several mitigation strategies for climate change. AWD is a method of reducing 30.00% of water in rice farms to influence GHG emission reduction by 48%. The AWD process influences rice production, CH_4 and N_2O emissions from rice systems. The finding is supported by the study of [15] who found that single or

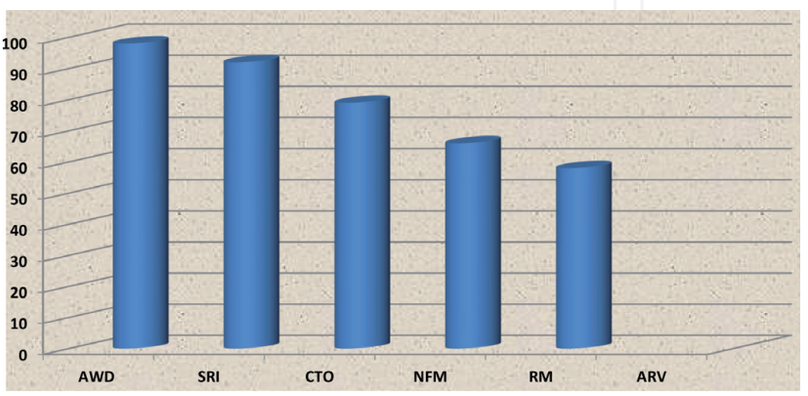

Figure 2.
GHG emission mitigation strategies of rice farmers in the study area. Keys: AWD: alternate wetting and drying of rice; SRI: system of rice intensification; CTO: changing tillage operations; NFM: Nitrogen Fertilizer Management; RM: residue management; ARV: aerobic rice varieties.

multiple drainage management during a rice-growing season (e.g., AWD) reduces CH_4 emissions by 48–93% compared to those observed under continuous flooding systems. Approximately, 92.00% identified system of rice intensification (SRI). The SRI is a holistic approach for sustainable rice cultivation. It involved planting a single seedling with more space between them rather than by the handful and bunched closely together. It also involves watering intermittently and allowing for dry spells rather than using continuous flooding and using organic input. The study of [16] confirmed a similar finding as one of the strategies used by rice farmers in GHG mitigation. Additionally, about 79.00% of the farmers practiced changing tillage operations (CTO). The study of [17, 18] concluded that biomass incorporation under conventional tillage is the main cause of the higher CH_4 emissions, implying that rice production systems where residue incorporation is excluded (no-till) may contribute to mitigation of GHG emissions. Similarly, the finding agrees with the study of Ahmad et al. [1] who also reported significant reductions in CH_4 emissions (21–60%) from no-till compared to tilled fields. In the same vein, Nitrogen Fertilizer Management (NFM) was identified by 66.00% of the farmers. The application of nitrogen (N) fertilizer to agricultural soils increases productivity and may also influence GHG emissions from rice systems. The finding of [19] found that N fertilizer-induced N_2O emissions were reported to be 0.21% under continuous flooding and 0.40% under alternate wetting and drying (AWD) rice production systems. In the same meta-analysis, an effect of fertilizer type was reported, with N_2O emissions shown to increase by 24% and CH_4 emissions to decrease by 40% when urea was replaced by ammonium sulfate. Others (58.00 and 35.00%) identified residue management (RM) and aerobic rice varieties (ARC), respectively. The incorporation of rice residues contributes toward long-term nutrient cycling but may, due to high C/N ratios, cause short-term N immobilization and thus affect N availability for subsequent crops [19]. Meanwhile, aerobic rice varieties (ARV) is a production system in which especially developed "aerobic rice" varieties are grown in well-drained, non-puddled, and non-saturated soils [20]. With a good management, the system aims for yields of at least 4–6 tons per ha. Therefore, the finding became clear that farmers are noticing changes in rice field and have started practicing several strategies to thwart the negative effect of GHG emission in their rice farming.

3.3 Determinants of rice farmers' mitigation strategies for GHG emission

Table 2 shows determinants of rice farmers' mitigation strategies for GHG emission. The estimation of the multinomial logit model for this study was undertaken by normalizing one category, which is normally referred to as the "reference or base category." In this analysis, the last category (no mitigation strategies) is the reference category. The model was run and tested for the validity of the independence of the irrelevant alternatives (IIA) assumption by using the Hausman test for IIA. The test accepted the null hypothesis of independence of the mitigation strategies for GHG emission, suggesting that the multinomial logit specification is appropriate and a good fit to model farmers' mitigation strategies for GHG emission. Results reveal a likelihood ratio chi-square (χ^2) value of 0.9770 implying that 97.70% of variation in the model for the mitigation strategies was explained by the explanatory variables while the remaining 2.30% was accounted for by stochastic error. The model was also statistically significant at 1% ($P < 0.00001$), suggesting that the models have strong explanatory power. This indicates that all the models had good fit to the model. The significance of this likelihood ratio statistics test indicates that rice farmers' socioeconomic characteristics significantly influence the use of mitigation strategies for GHG emission in the area. Consequently, the interpretation and discussion of the multinomial logit result indicate the following:

Explanatory variables	AWD	SRI	CTO	NFM	RM	ARV
Age (X_1)	−1.0079e-03 (−3.11)***	0.00085 (4.02)***	−0.021 (−3.10)***	0.004 (3.84)**	0.0093 (3.38)***	−0.0098 (−3.92)***
Sex (X_2)	−0.00015 (−0.11)	0.0006 (0.76)	0.234 (1.17)*	−0.155 (−0.12)	−0.23 (−0.05)	0.14 (0.87)
Educational level (X_3)	4.20e-06 (1.08)*	0.00009 (0.63)	0.008 (0.96)	0.012 (−0.68)	−0.02 (−1.64)*	−0.009 (−0.91)
Farming experience (X_4)	−4.96e-06 (−0.76)	−0.00005 (−0.51)	0.011 (1.35)*	0.0015 (1.01)	−0.011 (−0.52)	−0.007 (−0.63)
Household size (X_5)	−0.000042 (−0.25)	0.0004 (0.14)	0.003 (0.35)	0.017 (0.12)	−0.009 (−0.19)	−0.001 (−0.29)
Farm income (X_6)	1.39e-08 (2.16)**	3.79e-09 (1.94)*	7.54e-09 (1.09)	3.02e-06 (1.63)*	2.66e-06 (1.50)*	2.74e-06 (0.69)
Farm size (X_7)	−0.00046 (−0.68)	−0.0006 (−1.46)	−0.07 (−0.88)	−0.112 (−0.98)	−0.03 (−0.59)	−0.12 (−1.45)
Extension contact (X_8)	0.0051 (3.21)***	0.006 (5.04)***	0.013 (4.85)***	0.054 (5.10)***	0.08 (4.69)***	0.23 (4.97)***
Access to farm credit (X_9)	0.027 (4.04)***	−0.00098 (−1.63)	−0.134 (−1.60)	0.161 (1.84)*	0.11 (0.95)	0.08 (0.95)
Access to GHG emission information (X_{10})	4.37e-06 (0.37)	0.179 (5.01)***	−0.169 (−0.13)	−0.023 (−0.25)	0.04 (0.54)	−0.04 (−0.21)
Pseudo R^2	0.5919					
Likelihood Chi square	97.70***					
Sample size (n)	120					
Reference/base category	No mitigation strategies					

Output of STATA; values in parenthesis are Z values.
****Significant at 1% level.*
***Significant at 5% level.*
**Significant at 10% level.*
Field survey, 2020.
Keys: AWD: alternate wetting and drying of rice; SRI: system of rice intensification; CTO: changing tillage operations; NFM: Nitrogen Fertilizer Management; RM: residue management; ARV: aerobic rice varieties.

Table 2.
Estimated multinomial logit model of the determinants of rice farmers' mitigation strategies for GHG emission.

Age (X_1): age of the rice farmers significantly influences mitigation of GHG emission. Age of the farmers was positively related across the practice of alternate wetting and drying of rice (AWD); system of rice intensification (SRI); Nitrogen Fertilizer Management (NFM); residue management (RM); and aerobic rice varieties (ARV). This reason could be because the options have been practiced for a long period of time and are well known by older farmers than their younger counterparts. On the other hand, age of the farmers had a negative influence on the probability of uptake of CTO. The result shows that a unit increase in the age of the farmers decreases the likelihood of taking up CTO by 0.21 (2.10%). This could be because CTO may require more physical strength and energy to practice in rice farming of which older farmers may not have the capacity to do. The result is consistent with the findings of [14] who noted that the older farmers become more risk averse and practice less strategies, particularly those requiring more energy over time.

Sex (X_2): the result indicated that female-headed households practiced efficiently and more mitigation strategies for GHG emission than their male counterparts. On the other hand, male-headed households were more readily resilient to GHG emission than their female counterparts by practicing SRI and CTO. The finding tallies with the study of [21] who asserted that females are more involved in rural agriculture. This is true as women use it to support their families nutritionally and income-wise while the male households usually migrate to urban cities in search of nonagricultural jobs. Additionally, it is also expected that females will understand perceived effect of GHG emission in rice farming and practice modern mitigation strategies than their male counterpart.

Educational level (X_3): education of the farmers was positively related across all the mitigation strategies for GHG emission. This result is in line with the *a priori* expectation of the model. The finding is in line with the study of [22] who asserted that exposure to higher education of the farmer increases the probability of choosing different sustainable farming methods. The probable reason could be due to the fact that educated farmers have more knowledge of GHG emission and are already aware of various techniques and management practices that could be employed to mitigate the emissions easily. Additionally, the study of [23] also confirmed the importance of education on choice of mitigation strategies for GHG emission.

Farming experience (X_4): farming experience had a positive and significant relationship across all the mitigation strategies for GHG emissions modeled. This implies that increase in years of experience increases the probability of uptake of AWD, SRI, CTO, NFM, RM, and ARV. Highly experienced farmers are likely to have more information and knowledge on GHG emission than their counterpart with limited years of experience. In addition, experience exposes farmers to various GHG emission strategies they could employ in the face of anticipated environmental situations. The findings support [24] who asserted that farmers with more experience would be more efficient, have better knowledge of climatic conditions and market situation, and are, thus, expected to run a more efficient and profitable enterprise.

Household size (X_5): household size of farmers increased the likelihood of using CTO, RM, and SRI practices by 0.001(1.00%). This indicates that household size increases the probability of uptake of these mitigation measures to climate change because such options require additional labor from the farmers, which is usually provided by his/her household members. On the other hand, household size of farmers decreased the likelihood of practicing ARV and NFM by 0.0001 (0.1%). This is because, as the hectare of farmland cultivated by each farmer reduces, the labor needed by such farmers also reduces. The finding tallies with the study of [5] who reported that large household size is associated with a higher labor endowment, which would enable the household to accomplish various agricultural tasks especially at the peak seasons and ensure ease of adaptation to climate change. The finding is also supported by the result of [14] who opined that large household size has shown to provide cheap and available source of labor for farmers in adapting easily to climate change.

Farm income (X_6): the income of farmers had a positive and significant influence on the likelihood of practicing all the mitigation measures identified. Higher income farmers are less risk averse and have more access to information, a lower discount rate, a longer term planning horizon, and are wealthier than low-income farmers. Additionally, with more financial and other resources at their disposal, farmers are able to change their management practices in response to changing climatic, GHG emissions and other factors and are better able to make use of all the available information they might have on changing conditions, both climatic and

other socioeconomic factors. The result shows that a unit increase in the income of the farmers increased the likelihood of adopting the practice of AWD, SRI, CTO, NFM, RM, and ARV. The study of [15] reported that farmers with higher farm income will make better decision, use necessary productive inputs, and realize huge yield/output than their counterparts who have low farm income. Additionally, the study of [14] also reported that adaptation options to climate change are costly.

Farm size (X_7): farmers' land area cultivated was negatively related to mitigation strategies for GHG emissions in the area. The negative relationship between farmers' mitigation strategies for GHG emissions and farm size is inconsistent with the study carried out by [25] but in line with [14] who reported that the probable reason could be due to the fact that adaptation/mitigation measures are plot-specific. It is expected that farmers with large farm size will practice more mitigation strategies for GHG emissions than those with lesser farmland in the area. More so, larger farm size enhances the probability of household choosing multiple and better mitigation strategies for GHG emissions than households with smaller farm size. This means that it is not the size of the farm but the specific characteristics of the farm that dictate the need for specific adaptation mitigation strategies for GHG emissions in rice production.

Extension contact (X_8): extension contact had a positive and significant influence across all the mitigation strategies for GHG emissions modeled. The finding shows that a unit increase in the number of extension visits to the farmers increased the likelihood of AWD by 0.006 (0.6%), SRI by 0.013 (1.3%), CTO by 0.054 (5.4%), NFM by 0.08 (8.00%), RM by 0.0051 (5.1%), and ARV by 0.23 (23.00%). Contact with extension agents, which denotes access to information, had a positive effect across all adaption measures indicating that extension contact increases the likelihood of mitigating GHG emissions in rice farm easily. Access to extension services significantly increased the probability of taking up AWD, SRI, CTO, NFM, RM, and ARV. Extension services provide an important source of information on GHG emissions as well as agricultural production and management practices. Farmers who have significant extension contacts have better chances to be aware of changing climatic conditions and also of the various management practices that they can use to adapt to changes in climatic conditions. The findings are in line with the study [26] which argued that extension contact enhances farmers' production and promotes their knowledge on modern farming methods.

Access to farm credit (X_9): results showed that farmers' access to credit significantly increased the probability of uptake of AWD, SRI, CTO, NFM, RM, and ARV. Inadequate fund is one of the main constraints in adjusting to climate change [14]. Despite the various mitigation strategies farmers could be aware of and willing to practice, inadequate fund to purchase the necessary inputs and other associated equipment remains one of the significant barriers to mitigation strategies for GHG emissions in rice production.

Access to GHG emission information (X_{10}): this depicts the level of awareness of GHG emissions significantly increased the probability of uptake of all the mitigation strategies identified. Farmers who have access to GHG emissions and climate information are more aware of changes in climatic conditions and have higher chances of taking adaptive measures in response to observed changes. It is an important precondition for farmers to take up mitigation strategies. Information on climate variables like temperature amount, relative humidity, rainfall amount, and sunshine duration has really helped farmers in the area on the time to plant a particular breed of rice. Farmers' access to information on GHG emissions is likely to enhance their probability to understand GHG emissions and climate change impact and hence enable them take up better mitigation strategies to increase their farm yield and income.

3.4 Rice farmers' barrier to mitigation of GHG emission

The findings in **Figure 3** show rice farmers' barrier to mitigation of GHG emission in the area. The finding reveals that about 98.30% of the farmers identified inadequate information. This could be attributed to dearth in research on GHG emission and mitigation strategies as well as lack of information on GHG and climatic variables which should always be disseminated by Nigerian Meteorological Agency (NiMET) and agricultural extension agents. This constraint left the farmers unable to get the much needed information on climate change and GHG emission. In the present information age, inadequate information could pose serious challenges to the farmers' coping strategies as they may not be aware of recent developments regarding GHG emission, mitigation strategies, and the necessary readjustments. Poor information on mitigation strategies for GHG emission in rice farming may result in food insecurity and unsustainable production over time. About 94.75% identified inadequate fund. Inadequate fund left most of the rice farmers unable to get necessary resources in mitigating GHG emission in the area. This could be attributed to high cost of mitigation options. Inadequate fund hinders farmers from getting the necessary resources and technologies that assist to efficiently mitigate GHG emission. The result shares view with the study of [14] who argued that adaptation options are costly and hence farmers need adequate fund to adapt. Going forward, poor extension contact, high cost of inputs, poor access to farm credit, limited availability of farmland were identified by 87.50, 83.33, 82.50, and 75.74% of the rice farmers, respectively. High cost of farm inputs could also be attributed to inadequate fund. With limited fund, the acquisition of necessary facilities will be difficult. They may not only be costly, but may also appear scarce for poor farmers. In addition, the farmers may not also have the necessary facilities for current information like radio and television to obtain weather forecasts. Poor access to credit could be linked to lack of information or awareness of the presence of loan facilities, high collateral requirements, and location of banks in urban areas, which are far from the rural areas where farmers live. Limited farmland could be attributed to land tenure system or increasing population prevalent in the area. High population pressures compel farmers to intensively farm over a small plot of land and make them unable to practice several GHG mitigation strategies that will improve their farm yield and income. It becomes clear that this constraint is responsible for poor production of rice and GHG emission mitigation in the area. Curbing this barrier will be vital in promoting not just local mitigation strategies but global strategies of GHG emission in the area and perhaps beyond.

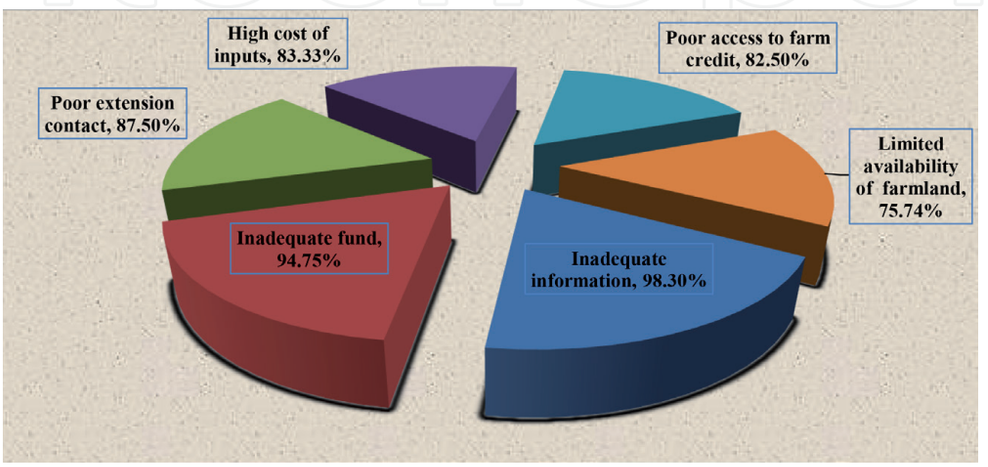

Figure 3.
Rice farmers' barrier to mitigation of GHG emission.

4. Conclusion

Conclusively, the study was logically guided by describing the socioeconomic characteristics of the rice farmers; identifying and describing the mitigation strategies for GHGs used by rice farmers and constraints in mitigating GHGs in rice farming. A multistage and purposive random method was used in the selection of respondents. Purposive sampling method was used to select respondents who are predominantly rice farmers. The sample size comprised 120 rice farms. A well-structured questionnaire was the main tool for data collection. Data collected were analyzed using descriptive statistical tools and a multinomial logit model. The result shows that the mean age was 45.00 years. Greater proportions (75.83%) were male. Majority (84.17%) were married with an average household size of nine persons. The mean educational level and farming experiences were 12 years (equivalent to secondary school education) and 23.00 years, respectively. Average farm size and annual farm income were 2.28 ha and N400,790.00 (1027.67 USD), respectively. The result confirmed the incidence of GHG emission in rice farm in the area. Interestingly, farmers are becoming increasingly aware and have started practicing several mitigation strategies. The major GHG mitigation strategies the farmers practice were alternate wetting and drying of rice (AWD) (98.10%) and the system of rice intensification (SRI) (92.00%) among various strategies they practiced simultaneously. Estimated multinomial logit model revealed that household size (X_5), farm size (X_7), and education (X_9) significantly influence their choice of GHG mitigation strategies at 1% level of probability. Regrettably, farmers complained of inadequate fund (98.33%). It was therefore recommended that farmers should form a stable cooperative to access fund, information and government support effectively. In the same way, the study confirmed the incidence of GHG emission in rice farm the area. Interestingly, farmers are becoming increasingly aware and are noticing the GHG emission. The farmers have started practicing several mitigation strategies to thwart the negative effect of GHG emission while remaining sustainable. The major GHG mitigation strategies of farmers were alternate wetting and drying of rice (98.10%) and the system of rice intensification (92.00%) among various strategies they practice simultaneously. The study also looked at the determinants of rice farmers' use of various mitigation options for GHG emission using a multinomial logit model. The model permits the analysis of decisions across dichotomous categories, allowing the determination of choice probabilities for different categories. Multinomial logit results confirmed that access to credit, extension services, farming experience, education, access to climate change information, and farm size were some of the significant determinants of farm-level mitigation options. The main barrier to the mitigation of GHG emission was lack of information on appropriate mitigation option, which could be attributed to dearth in research on GHG emission as well as poor information dissemination on the part of extension agents in the study area.

4.1 Recommendations

The following recommendations were made based on the major research observations and findings of the study.

i. Effective agricultural policies and programs should focus on how to intensify awareness on GHG emission in rice farm as well as its mitigation strategies. This should be done through strengthened agricultural extension delivery.

ii. Since education and farmland were found to significantly increase mitigation, investment strategies should also focus on expansion of farmers'

farmland and improvement of their education as this would affect their mitigation of GHG emission positively.

iii. The government must also design policies in such a way that farmers have access to affordable credit as well as subsidized agricultural inputs in order to increase their ability and flexibility to change production strategies in response to the forecasted climatic conditions.

iv. The government or interested organization should endeavor to build weather stations in all local government areas in Nigeria to reduce the incidence of poor climate record keeping and to provide mid-term forecast of weather and other climatic variables.

v. Ultimately, incorporating local knowledge into GHG emission concerns should not be done at the expense of modern/western scientific knowledge. Local knowledge should complement rather than compete with global modern practices in counteracting the negative impact of GHG emission in the area and beyond.

Acknowledgments

Special thanks to the local rice farmers in the study area who provided the data for the study. Additionally, many thanks to our volunteer field enumerator who helped in visiting the sampled farmers in their remote rice farms for evidence-based data collection. Thanks to all those involved in data entry, data cleaning, data coding, and analysis. We cannot thank you all enough.

Author details

Nnaemaka Success Esiobu[1*], Chinedu Gilbert Onubuogu[1], Sylvarlene Munachim Njoku[2] and Blessing Chidinma Nwachukwu[3]

1 Department of Agricultural Economics, Extension and Rural Development, Imo State University, Owerri, Nigeria

2 Department of Nutrition and Dietetics, Imo State University, Owerri, Nigeria

3 Food Security and Safety Niche, Faculty of Natural and Agricultural Sciences, North-West University, South Africa

*Address all correspondence to: esiobunnaemekasuccess@gmail.com

References

[1] Ahmad S, Li C, Dai G, Zhan M, Wang J, Pan S, et al. Greenhouse gas emission from direct seeding paddy field under different rice tillage systems in central China. Soil and Tillage Research. 2009;**106**:54-61

[2] Akande T. (2020). An Overview of The Nigerian Rice Economy; Agriculture and Rural Development Department The Nigerian Institute of Social and Economic Research (NISER). 2020. Available from: https://unep.ch/etb/etp/events/Agriculture/nigeria.pdf

[3] Ariyo OC, Ariyo MO, Okelola OE, Aasa OS, Awotide OG, Aaron AJ, et al. Assessment of the role of mass media in the dissemination of agricultural technologies among farmers in Kaduna North local government area of Kaduna State, Nigeria. Journal of Biology, Agriculture and Healthcare. 2013;**3**(6):19-28

[4] Food and Agricultural Organisation (FAO). The State of Food and Agriculture; 2010-2019. Rome: FAO; 2020. p. 2020

[5] Ojo OT, Ogundeji AA, Babu SC, Alimi T. Estimating financing gaps in rice production in Southwestern Nigeria. 2020;**9**:12. DOI: 10.1186/s40008-020-0190-y

[6] Intergovernmental Panel on Climate Change (IPCC) (2019) Climate Change 2019: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; The Intergovernmental Panel on Climate Change (IPCC) presented at the UN Climate Change Conference (COP 25) in Madrid on 2-13 December 2019; Available from: https://www.ipcc.ch/2019/

[7] Ngonidzashe C, Laura A, Maria K, Sandra L, Fernando C, Manabu I, et al. Sustainable and low greenhouse gas emitting rice production in Latin America and the Caribbean: A review on the transition from ideality to reality. Sustainability. 2018;**10**:671

[8] Zhang CL, Chao L, Jun Z, Aixing D, Kees J, Weijian Z. Acclimation of methane emissions from rice paddy fields to straw addition. Science Advances. 2019;**5**(1):eaau9038

[9] Nigerian Meteorological Agency (NiMET). Drought and Flood Monitoring in South East Bulletin. 2018. Available from: www.nimet.gov.ng [Accessed: 25 October 2018]

[10] National Bureau of Statistics (NBS). National Bureau of Statistics Official Gazette (FGP 71/52007/2,500(OL24)): Legal Notice on Publication of the Details of the Breakdown of the National and State Provisional Totals, 2006 Census. 2007. Available from: www.nigerianstat.gov.ng [Accessed: 28 February 2016]

[11] Nigeria Population Commission (NPC). Nigeria Population Commission, Nigeria Federal Government Initiative of individual head count by gender. Spread, State by State. MOFINEWS. 2006;**6**(3):01-32

[12] Imo State Agricultural Development Programme (Imo-ADP). Work Programme. Owerri, Imo State, Nigeria: Imo ADP; 2018

[13] Esiobu NS. Relative efficiencies of resource use among cassava farmers in Imo State, Nigeria [M.Sc. thesis]. Owerri, Nigeria: Department of Agricultural Economics, Extension and Rural Development, Faculty of Agriculture and Veterinary Medicine; Imo State University; 2018

[14] Esiobu NS, Onubuogu GC. Trend, perceptions and adaptation options of arable crop farmers to climate change

in Imo State, Nigeria; a multinomial logit approach. World Science Journal. 2014;**5**(9):12-24

[15] Munonye JO, Esiobu NS. Sustainability and agribusiness development in Nigeria. Journal of Sustainable Development; An International Peer-reviewed Journal. 2017;**27**:40-44

[16] Bharali A, Baruah KK, Gogoi N. Potential option for mitigating methane emission from tropical paddy rice through selection of suitable rice varieties. Crop & Pasture Science. 2017;**68**:421-433

[17] Bayer C, Costa FS, Pedroso GM, Zschornack T, Camargo ES, Lima MA, et al. Yield-scaled greenhouse gas emissions from flood irrigated rice under long term conventional tillage and no-till systems in a humid subtropical climate. Field Crops Research. 2014;**162**:60-69

[18] Bayer C, Zschornack T, Pedroso GM, da Rosa CM, Camargo ES, Boeni M, et al. A seven-year study on the effects of fall soil tillage on yield-scaled greenhouse gas emission from flood irrigated rice in a humid subtropical climate. Soil and Tillage Research. 2015;**145**:118-125

[19] Linquist BA, Adviento-Borbe MA, Pittelkow CM, van Kessel C, van Groenigen KJ. Fertilizer management practices and greenhouse gas emissions from rice systems: A quantitative review and analysis. Field Crops Research. 2012;**135**:10-21

[20] Yamano T, Arouna A, Labarta RA, Huelgas ZM. Adoption and impacts of international rice research technologies. Global Food Security. 2016;**8**:1-8

[21] Kughur P, Gyanden O, Omaku S, Isa M. Assessment of input needs of women vegetable farmers in Gwer-East local government area of Benue State, Nigeria. 2018;**2**:20-30. DOI: 10.31058/j.as.2018.23013

[22] Esiobu NS, Onubuogu GC. Determinant of risk-smart options among farming households in agricultural risk management in Imo State, Nigeria; (a multinomial logit model approach). Journal of Environment Protection and Sustainable Development. 2018;**3**(10):20-39

[23] Kushal KB. Analysis of greenhouse gas (methane and nitrous oxide) emission and global warming potential from rice fields: With reference to biological mitigation of climate change. Journal of Earth Sciences & Environmental Studies. 2018;**3**(2):395-407

[24] Onubuogu GC, Esiobu NS. Determinants of allocative (pricing) efficiency of cassava farms in Imo State, Nigeria. Journal of Agriculture and Food Sciences. 2020;**17**(2):86-99. Available from: https://www.ajol.info/index.php/jafs/article/view/194543

[25] Nhemachena C, Hassan R. Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa. International Food Policy Research Institute (IFPRI) Discussion Paper No. 00714. Washington, D.C.: Environment and Production Technology Division, IFPRI; 2007

[26] Nwaiwu JC. Farmers' adoption of some arable crop soil conservation practices in Imo State [unpublished PhD thesis]. Owerri, Nigeria: Department of Agricultural Economics, Extension and Rural Development, Imo State University; 2015