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Greenhouse Gas Emission Determinants in Nigeria: Implications for Trade, Climate Change Mitigation and Adaptation Policies

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Authors' contributions

This work was carried out in collaboration between both authors. Author AOO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

This study investigated and analyzed the determinants of Carbon Dioxide (CO_2) emission in Nigeria. The study relied on secondary data from World Bank and Central Bank of Nigeria covering 40 years (1970-2009). The data were analyzed using Zellner's Seemingly Unrelated Regression (SURE) model. The results of the analysis show that fossil energy demand or consumption, rents from forestry trade, agricultural land area expansion and farm technology were significant determinants of greenhouse gas (GHG) emission in the study area. On the other hand, the second equation indicated that fossil fuel energy demand was exogenously determined by economic growth rate (proxied by GDP growth rate) and farm technology applied in the country. It was recommended that Nigeria should put in place policies that will tax companies or firms emitting GHGs and utilize such tax proceeds for research and building the capacities of farmers to adapt to deleterious effect of climate change in the country and continent. The development of existing and new technologies for adapting to climate change and variability, building of environmental consciousness of Nigerians through curriculum restructuring and provision of weather information services by the Nigerian governments and their agencies to enable farmers plan against weather uncertainty and risks were also recommended.

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1. INTRODUCTION

The world's greatest environmental challenges are climate change and resource depletion [1]. The effects of these challenges and vulnerabilities to these challenges however are not uniform across regions of the world. Some continents are more vulnerable to the impacts of climate change and environmental degradation than others. For instance, it is feared that Africa might experience the most severe impacts of climate change than other parts of the world and it is the continent that is least prepared to handle these impacts [2,3].

Growing evidence has shown that Green House Gas emission such as Carbon Dioxide ($CO_{2)}$ and Sulphur Dioxide (SO_2) are some of the major causes of climate change [4]. Even though Africa contributes relatively less to GHG in the world [4], the major determinants of GHG emission in this continent has not been sufficiently explored to give evidence based indices for effective mitigation and proactive adaptation policies implementation in the continent. The role of trade and economic activities on GHG emission and climate change mitigation drive also begs for scholastic inputs. In recent years, the agricultural sector had to face increased environmental challenges due to new production methods and intensified production systems adopted to meet continued population growth and new energy demands around the world [5]. Fossil energy sources such as oil and gas are extensively exploited in Africa but are mostly exported or wasted through leakages, or flaring [6] with attendant consequence of threat to increase in GHG and global warming. Nigeria is one of the leading producers and users of fossil fuel in the world but it appears that the oil resource could be a source of danger to her economy in the future if issues of sustainable environmental management (such as abatement of GHG emission and climate change adaptation strategies) are not taken seriously now. Unfortunately there are no sufficient data or studies to give empirical evidence about the actual major determinants of Green House Gas (GHG) emissions in sub-Sahara Africa (SSA). This situation, if unchanged can lead to the occurrence of the forecasts on the deleterious effects of climate change on livelihoods and economies predicted by IPCC [1] and Yohe et al. [7] more especially as there is sufficient evidence to show that CO_2 emission has significant relationship with global warming. Researchers [8] warned that the cost of limiting CO_2 emissions is likely to be much higher in developing countries such as Nigeria and other Sub-Sahara African countries due to their faster underlying growth rate. Even if they were allowed to double or triple their emissions over another 100 years, they may still face higher costs than developed countries under much more stringent targets, they noted. On the other hand, large reductions in man-made CO_2 emissions are possible on a global scale only if the developing countries also take action.

Given the foregoing background it is pertinent to conduct a study that is capable of uncovering some of the major drivers of GHG emissions in Africa, especially in its most populous country, Nigeria so as to obtain data for proactive policy making in combating and adapting to the problem of climate change in Africa; hence the need for this study.

1.1 Objectives of the Study

The research was designed to specifically ascertain the influences of commercial activities especially forestry trades, fossil fuel demand (petroleum) and agricultural production strategy (proxied by farm mechanization) on the level of GHG (CO_2) emissions in her economy. The study also identified other indirect factors which influence the level of GHG emission level in Nigeria and then discussed the implications of the findings for greener trade policy implementation and climate change adaptation/mitigation strategies in Nigeria and Africa.

1.2 Theoretical and Empirical Issues

It has been noted that the artificial inputs of energy (especially demand for fossil fuel energy), chemical products and agricultural labour or technological input necessary to maintain the agro-ecosystems and to reach the necessary production levels deeply alter natural biogeochemical cycles and can provoke serious damages to the environment: soil degradation; pollution of water; air and soil; loss of biodiversity and increased greenhouse gases emissions [9]. These are all examples of environmental damages which can be caused by agricultural practices, mining activities, industrial activities, technology application as well as other commercial ventures in the economy.

As the global population continues to grow, which is estimated to reach 9 billion by 2050, there is an increasing strain on the forest resources, agriculture and fisheries sectors to meet food security needs. This increases the quest for more "virgin" lands or forests. The recent upsurge in quest for forest lands by foreign investors in Africa has been associated with pollution and forestry depletion in parts of Africa with attendant dangerous consequences for the planet's ecosystem and trade. This has drawn the attention of many international organizations lately including Trade Policy Centre for Africa (TRAPCA) who made it a conference theme in November, 2011. Land acquisitions as well as arable crop land expansion can indirectly lead to negative environmental impacts as shown by Dossou [10] who observed the case of the municipalities neighbouring Cotonou, where rural emigrants who lost their lands settled en masse on "unserviced plots", leading to extreme pollution and health problems. Meanwhile, the conversion of forested and uncultivated lands is associated with biodiversity loss, degradation, diversion of water from environmental flows and loss of ecosystem services such as the maintenance of soil and water quality, as well as carbon sequestration [11,12]. Deforestation of tropical forests is reported to be contributing significantly to CO_2 emissions: estimates of carbon released range from *0.5* to *3* billion tons of carbon per year [13] relative to the *6* billion tons associated with current fossil-fuel use. Many observers argue that forest clearing is to a large extent uneconomic and mainly due to the absence of property rights for rain forests. If so, noted Nordhaus, a significant reduction of emissions might therefore be achieved at low economic cost through a cessation of forest clearing.

It has been noted [14] that deforestation cases are widespread in the context of increasing commercial pressures on land and deepening of forest depletion which is worsening global warming. Reports [15] indicated that deforestation in Nigeria is a major area of environmental concerns and indeed one of the most important issues of the last ten decades. The relationship between deforestation and GHG emissions was explained by Botkin and Keller [16] who noted that when forests are cleared and the trees are burnt or rot, carbon is released as carbon dioxide which then goes to increase the volume of greenhouse gas in the atmosphere that can combine with ozone in the ozone layer to deplete the protective layer of the atmosphere thus stepping up global warming.

Levels of Green House Gas (GHG) emission into the atmosphere (which includes Carbon Dioxide CO_2) levels have been associated with increase in climate change and hence much of the thinking to date on how to address climate change has focused on incrementally reducing GHG emissions – such as the commitment to reduce emissions to 5percent below 1990 levels under the Kyoto Protocol [17]. The United Nations Framework Convention on Climate Change (UNFCCC) identifies two responses to climate change: mitigation of climate change by reducing greenhouse-gas emissions and enhancing sinks and adaptation to the impacts of climate change. Most industrialized countries committed themselves, as signatories to the UNFCCC and the Kyoto Protocol, to adopting national policies and taking corresponding measures on the mitigation of climate change and to reducing their overall greenhouse-gas emissions [17,18]. The Kyoto Protocol recognizes a strong linkage between CO_2 emission reduction goals, emissions trading and the role of developing economies including sub-Sahara Africa [19].

Technology has also been reported to have some effects on level of GHG emissions. IPCC [20] noted that improvements in technologies and measures that can be adopted in three energy end-use sectors (commercial/residential/institutional buildings, transportation and industry), as well as in the energy supply sector and the agriculture, forestry and waste management sectors could drastically reduce the levels of greenhouse emissions globally. These incremental improvements are important first steps in addressing the global problem of climate change, which this paper attempts to address. Agricultural production systems and technology really have roles to play in reducing levels of GHG emissions. Greenhouse Gases emissions databases, Agri-Environmental statistics and indicators and environmental accounting frameworks are methodologies to monitor the environmental performance of the different countries [9]. FAO maintained that these tools have been recognized as useful for formulation of policies designed to provide an effective incentive structure for sustainable management of natural resources, ensuring that national agricultural practices are developed and implemented in a holistic approach. For instance IPCC [20] monetized the likely damage that would be caused by a doubling of CO_2 concentrations and noted that for developed countries, estimated damages were of the order of 1% of GDP. Developing countries including sub-Sahara Africa were expected to suffer larger percentage damages, so mean global losses of 1.5 to 3.5 percent of world GDP were therefore reported. IPCC [4] reported essentially the same range because more modest estimates of market damages were balanced by other factors such as higher non-market impacts and improved coverage of a wide range of uncertainties. Recently Stern [21] took account of a full range of both impacts and possible outcomes (i.e., it employed the basic economics of risk premiums) to suggest that the economic effects of unmitigated climate change could reduce welfare by an amount equivalent to a persistent average reduction in global per capita consumption of at least 5%. Including direct impacts on the environment and human health (i.e., 'non-market' impacts) increased their estimate of the total (average) cost of climate change to 11 percent GDP; including evidence which indicates that the climate system may be more responsive to GHG emissions than previously thought increased their estimates to 14 percent GDP. Using equity weights to reflect the expectation that a disproportionate share of the climate-change burden will fall on poor regions (which includes Sub-Sahara Africa) of the world increased their estimated reduction in equivalent consumption per head to 20 percent.

It has been established that over the past century human activities have been releasing GHGs at a rate unprecedented in geologic time. As a consequence of this acceleration in the rate of emissions, the concentration of GHGs in the atmosphere has increased by 30 percent, since pre-industrial times [22]. Examples of such anthropogenic activities include trade, agriculture, deforestation (or forestry activities), fossil energy or fuel consumption and those other activities associated with economic growth. Thus most structural models of climate–economy interactions have followed the Ramsey–Cass–Koopmans infinitely-lived agent framework [23,24,25]. According to González-Marrero, Lorenzo-Alegría and Marrero noted that the fact that the growth in the demand for transport in Spain over the last decade has exceeded that of GDP suggests that there must be other factors besides income to explain mobility and fuel consumption. Our present paper attempted to explore possible causes of fuel consumption which has been shown to be an exogenous variable in determination of GHG emission. Fossil fuel consumption has been, in large part, attributed to economic growth. According to Sharma [26], the Environmental Kuznets Curve (EKC) has been used to explain the relationship between the economic activities and the emission of pollutants and between the economic activity and the use of natural resources. The EKC hypothesis posits that environmental degradation initially exaggerates when a country's per capita income is low but over time, as the economy grows, environmental degradation falls. This results in an inverted U-shaped relationship between income and the use of natural resources and waste emissions. This branch of research on the relationship between economic growth and environmental pollution can be categorized into three strands [26]. This study intends to verify the claim that certain economic activities influence CO_2 emission levels.

Sharma reiterated that energy, such as crude oil, natural gas and coal, plays a major role in residential and industrial energy needs, transportation, and electricity. The burning of fossil fuel is essential in every country as it is used for the production of goods and services. While it is true that burning of fossil fuel emits a high amount of CO_2 and pollutes our environment, it has been empirically and theoretically shown that an increase in energy consumption results in greater economic activity [26]. It follows that higher economic growth (GDP) will have a positive effect on carbon dioxide emissions at least in the short-run. According to Hooi and Smyth [27] a boost in energy consumption results in higher GDP because, in addition to the undeviating effect of energy consumed for commercial use which stimulates higher rates of economic growth, higher energy consumption results in an increase in energy production. Thus, an increase in pollution emissions is expected due to fast economic growth and ensuing greater fossil fuel consumption. Our proposed model, because it is in growth form, is essentially a short-run model. Hence, a priori, we expect income to have a positive effect on emissions. Similarly, a higher consumption of energy, a pre-requisite for economic growth, will also lead to more emissions. Hence, a positive relationship between energy consumption and carbon emissions is expected. Trade is expected to have a positive effect on CO_2 emissions. This effect has roots in the Hecksher-Ohlin (H-O) trade theory [26]. This trade theory proposes that under free trade, developing countries (mostly middle and low income countries) would focus on the production of goods that are rigorous in factors in which they have a comparative advantage, such as labour and natural resources. Thus, trade causes the movement of goods produced in one country for either consumption or further processing. More consumption of goods and further processing of goods, which takes place due to greater trade openness, is a source of pollution. Hence, the H-O theory actually perceives that pollution is stimulated from further processing and manufacturing of goods, which results from greater trade openness [28].

1.3 Analytical Framework

In simultaneous equation models, unlike single equation models, what is a dependent (endogenous) variable in another equation appears as an explanatory (exogenous) variable in another equation [29,30]. Thus, there is a feedback relationship between the variables. This feedback creates the *simultaneity problem*, rendering OLS inappropriate to estimate the parameters of each equation individually. Besides, a simultaneous equation model may have *identification problem*. One of the several ways of resolving this problem is via the *order condition of identification*. An equation is said to be identified (has a unique statistical form) if it is exactly identified or over identified. If an equation is *exactly identified* or *overidentified*, it can only be estimated using Two Stage Least Squares (2SLS) or Zellner's [31] Seemingly Unrelated Regression (SURE) Model but not OLS. If it is overidentified, besides 2SLS, maximum likelihood methods can be used to estimate the coefficients. The system of equation that is similar to the foregoing can be exemplified as follows:

$$Y_{1t} = A_1 + A_2Y_{2t} + A_3X_{1t} + U_{1t}$$
$$Y_{2t} = B_1 + B_2Y_{1t} + B_3X_{2t} + U_{2t}$$

Where the Ys are the endogenous variables (e.g. CO_2 emissions in tons per annum and fossil fuel energy demand), the Xs the exogenous variables (such as agricultural land under cultivation, farm technology, trade as percentage of GDP, forestry income and growth rate of GDP); the As and Bs, respective intercepts and slope coefficients of the variables and the U's the stochastic error terms.

Jang and Koo [32] have used this model to identify the impact of weather variation on crop yield in the Northern Plains. Beasley [33] noted that SURE is relatively underutilized despite its robustness in analyzing multiple dependent variables. He therefore encouraged social researchers to make more use of it. According to this scientist, there many situations in educational and behavioral research in which multiple dependent variables are of interest. Oftentimes these variables may take the pattern of path analytic model, but there are many other cases where they do not. However, it is commonplace for educational researchers to conduct separate analyses for multiple dependent variables even though they are likely to be correlated and have similar although not identical design matrices. For example, researchers in counseling often have multiple outcomes (measure of symptoms, coping, etc.) that are assumed to have some of the same predictors but to also have predictors that are unique to each measure. This is a situation that calls for a SUR model; however, a search of ERIC and PSYCHINFO located 11 applications of SUR models despite the enormous number of articles that analyze multiple dependent variables [33].

2. RESEARCH METHODS

2.1 Study Area

Nigeria is in West African sub-region; bordering the North Atlantic Ocean, between Benin Republic and Cameroon. Nigeria has a total land area of 923,773 square kilometers populated by over 140,003,542 people (going by 2006 population census). Her major revenue earner is crude oil. Climate varies - equatorial in south, tropical in centre, arid in north. Average rainfall hovers around 1282.2 mm varying from 500 - 1800mm. In 2007 agriculture contributed 42.08 percent to Nigerian's GDP. Out of this figure, crops, livestock, forestry and fishing contributed 37.54 percent, 2.64 percent, 0.53 percent and 1.37 percent to the country's economy respectively. Agricultural *Products*- include cocoa, palm oil, yams, cassava, sorghum, millet, corn, rice, livestock, groundnuts, cotton. Industry types include textiles, cement, food products, footwear, metal products, lumber, beer, detergents and car assembly [34].

2.2 Sampling and Data Collection Method

Secondary data, mainly time series data from Central Bank of Nigeria's Annual Report, World Bank data and Nigerian Bureau of Statistics data were used for this study. The data collected covered a period of 40 years (1970 – 2009).

2.3 Data Analysis Method

The data gathered were analyzed using Zellner's Seemingly Unrelated Regression model. The specific model used is given as follows:

Equation 1 $CO_2 = \alpha o + \alpha_1$ agriclanda $+ \alpha_2$ farmtech $+ \alpha_3$ forest $+ \alpha_4$fsflendemand $+ \alpha_5$tradeperctgdp $+ u_1$

Equation 2 fsflendemand $= \beta_0 + \beta_1$ farmtech $+ \beta_2$ tradeperctgdp $+ \beta_3$gdpgrwthrate $+ u_2$

Where the CO_2 = level of CO_2 emissions in kilo tons per annum; fsflendemand = fossil fuel energy demand in millions of naira per annum. The exogenous variables include: agriclanda = agricultural land under cultivation (in thousands of hectares per year), farmtech = farm technology proxied by number of tractors/farm machineries in thousands acquired per year, tradeperctgdp = aggregate trade in the economy per annum as percentage of GDP (in percentage), forestry income (in millions of naira) and growth rate of GDP in percentage; the As and Bs, respective intercepts and slope coefficients of the variables and the U's the stochastic error terms.

3. RESULTS AND DISCUSSIONS

Results of the model estimates are presented in Table 1. The model fitness test is presented at the top most side of the table. From the table it would be seen that the primary equation, CO_2 recorded an R^2 of 0.70, implying that 70 percent variation in the CO_2 emission levels in Nigerian economy estimated in this model was explained by the variables in the first equation. This indicates a very good fitting. The Chi-square estimate which tests the null hypothesis of no joint effects of the independent variables of the model was significant at 1 percent statistical level. This further buttresses the fitness of the model. An evaluation of the second equation shows that the fossil energy fuel demand equation indicated an R^2 of about 0.50, implying that about half of the increase in level of fossil energy or fuel demand (which in turn could exert some influences on the level of CO_2 emission) was explained by the exogenous variables included in the second equation. The results of the Breusch-Pagan test (test for serial correlation) which gave a Chi-square estimate of 0.004 at p=0.95, indicates that there is no dependency in the errors of the two equations gave us the room to accept the null hypothesis of no interdependence of errors and conclude that our model is free of such dependence.

From the primary equation, i.e. the CO_2 equation, it is indicated that all the explanatory variables of the model, except forestry activities (proxied by forestry income) exerted positive influences on the level of CO_2 emission in Nigerian economy. This implies that increase in any of these variables, i.e. agricultural land under cultivation, farm technology, trade as percentage of GDP and fossil fuel energy utilization or demand is associated with an increase in the level of CO_2 emissions in the nations' environment. Interestingly, almost all the hypothesized factors returned statistically significant slope coefficients except trade as a percentage of GDP.

Table 1. Seemingly unrelated regression results

Equation	Obs	Par	RMSE	R-Sq	Chi2	P
CO_2	40	5	11516.34	0.70	94.95	0.000
Fsflen demand	40	3	2.890085	0.49	38.51	0.000
			Coef.	**Std.**	**z**	**P>|z|**
CO_2						
	Agriclanda		0.38	0.13	2.92***	0.00
	Farmtech		4590.51	2470.54	1.86*	0.06
	Forest		-9509.46	2423.59	-3.92***	0.00
	fsflendemand		1542.99	578.77	2.67***	0.01
	Tradeperctgdp		-219.96	181.23	-1.21NS	0.23
	Intercept		-226080.00	90486.65	-2.50***	0.01
Fsflendemand						
	Farmtech		1.226	0.450	2.730***	0.006
	Tradeperctgdp		0.000	0.039	0.000NS	1.000
	gdpgrwthrate		-0.260	0.075	-3.470***	0.001
	Intercept		11.573	1.351	8.570***	0.000
Correlation matrix of residuals						
	CO_2	fsflendemand				
	CO_2	1				
Fsflendemand	0.0103	1				
Breusch-Pagan	test of	independence:	chi2(1) =	0.004,	Pr =	0.948

Source: Analysis of CBN and World Bank Data using STATA by Authors (2012). NB: (***) = Figures significant at p =<0.01, (**) = Figures significant at p =<0.05, (*) = Figures significant at p =<0.10, while NS = Not significant below p =0.10.

Agricultural land area under cultivation (agriclanda) returned a Z-value of 2.92, which was statistically significant at p<0.01. This shows that the probability of this factor increasing the levels of CO_2 emission in the country's environment is very significant and not by chance. The finding is in line with FAO's [9] worry that expansion of forest lands for agricultural expansion and even the rush for land by foreigners to invest in agriculture [14] will not do Africa any good rather it will worsen the environmental problem, particularly the problem of increased CO_2 emission in the continent's environment. This fear is even more pronounced when one observes that accompanying farm technology (especially tractorization and use of farm machineries) as seen in our model parameter estimate (Table 1) also indicated that farm technology adoption is associated with increase in the level of CO_2 emissions in Nigeria. This variable is statistically significant at p<0.10. The findings justifies the fears of all those who are campaigning against land grabbing in Africa. Contrary to our expectations on forestry activities, however, the forestry income variable which represent the level of forestry activities in Nigeria by our model did not show a positive sign but instead returned a negative sign which is statistically significant at p<0.01 with a Z-statistic of -3.92. This may be construed to be a sign that forestry activities or explorations are still being carried out sustainably in Nigeria at the period in review. However, after some years of continuous forestry exploitation, a threshold will be reached when the activities of forestry such as timber exports and utilization of fuel wood will combine to bring about significant forest cover loss and carbon sequestration drive maybe jeopardized. It would be recalled that Nordhaus [11] indicated that forestry activities or deforestation has a significant impact on GHG emission. This assertion is related to the next findings which indicated that fossil fuel energy demand in Nigerian economy within the period in review by this study is a very significant determinant of CO_2 emission in the country with an estimated Z-statistic which was found significant at $p<0.01$. This finding has equally vindicated FAO [9] who earlier noted that energy inputs (especially fossil fuel utilization) in the economies of many nations are partly and largely responsible for pollution or CO_2 emissions in developing and developed countries as well. There are policy implications for this which will be discussed later in our conclusion. The second equation's parameter estimates justifies the significance of including fossil fuel energy demand in the economy as a major variable in the emission of GHG determination as well its classification as an endogenous variable. As we earlier noted, the exogenous variables in this equation exhibited a fairly high coefficient of variation and in addition two out of its explanatory variables were found to be significant determinants of fossil fuel energy demand, thus enabling these factors to be regarded as indirect contributors to the CO_2 emission level in the nation's environment. It would be observed that through this factor for instance, economic growth rate (which is a product of all commercial activities growth, exports and imports of both oil and non-oil products, mining and manufacturing) indicated a significant effect on the level of fossil fuel demand in the economy over the period in review. This variable has an estimated Z-statistic of 3.470 and is statistically significant at $p<0.01$. The findings affirms the fears of environmental scientists [16] and other institutions/stakeholders such as World Bank [2], IPCC [4,17,14] who expressed worries over the possible effects of economic growth on energy demands and global warming.

4. CONCLUSION

Through the chosen econometric approach of this study it has been shown that agricultural land area expansion in various forms, be it through land grabbing by foreign investors or by internal policies of the nation's agricultural policy, along side other factors such as farm technology based on increasing use of farm machineries and tractors; deforestation (forestry commercial activities) and fossil fuel energy demand all contribute significantly towards the level of GHG emission (CO_2) levels in Nigerian environment. Besides these factors there are other factors which influence pollution or GHG emissions indirectly. These enter the system through the effects of economic activities that promote GDP growth rate as well as the chosen technology for agricultural production (given that agriculture is a major employer of Nigerian burgeoning population) via the use of fossil fuel energy. The demand for fossill energy thus appears to be one of the most significant issues to tackle if the problem of climate change mitigation in Nigeria has to be given the seriousness it deserves. In light of the foregoing findings we recommend that Nigeria should invest in energy efficient technologies and should utilize less of fossil fuels. Agricultural land expansion programmes and land grabbing should be moderated by the governments to check excessive opening and depletion of forestry resources in Nigeria. Since agriculture engage more than 65 percent of Nigerians, efforts should be made by the various governments at different levels to assist farmers adopt climate resilient technologies which will also ensure sustainable agricultural production. They need to be encouraged to adapt to the looming dangers of climate change now. Nigeria should put in place policies that will tax companies or firms emitting GHGs and utilize such tax proceeds for research and building the capacities of farmers to adapt to deleterious effect of climate change in the country and continent. The development of existing and new technologies for adapting to climate change and variability, building of environmental consciousness of Nigerians through curriculum restructuring and provision of weather information services by the governments to enable farmers plan against weather uncertainty and risks are hereby recommended.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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