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Vulnerability analysis of Nigeria's agricultural output growth and climate change

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Abstract

Purpose – Aside from oil, the Nigerian economy is largely agrarian, which is rain-fed. Hence the criticality of understanding climate change and its impact on agricultural output is more pressing than ever. This is in line with Sustainable Development Goal 13 which is to take urgent action to combat climate change and its impacts. Regardless, Nigeria has in the past five decades experienced a significant increase in temperature, in the range of 10 to over 30 degree Celsius. Therefore, managing the effect of climate change on agricultural output now has the colouration of a developmental challenge.

Design/methodology/approach – In light of this, this study gives due consideration to the impact of climate change on agricultural output between the years 1986 and 2015. For the purpose of analysis, descriptive statistics, unit root test and the ordinary least square (OLS) estimation technique were employed.

Findings – Findings from the study reveal that the average annual rainfall, temperature and forest area positively influence agricultural output, whereas drought, floods and agricultural nitrous oxide (N_2O) emissions have negative impact on agricultural output. The study suggests the need for a regulatory framework and also an explicit national agricultural policy essential to offset the negative effects of climate change especially on agricultural output.

Originality/value – As Nigeria look to diversify her economy which relied on oil, agriculture is among the alternative sector hoping to drive her economic growth, therefore, it is pertinent to examine the current output in the sector given the effects of climate change.

Keywords Agricultural output, Climate change, Economic growth, Vulnerability, Weather

Paper type Research paper

Introduction

Of the mammoth of challenges faced by the world in recent decades, climate change is the most challenging (Shabbir, 2015; Sarkar, 2017; Letcher, 2021). The climate change situation is even more daunting in emerging countries. This is as a result of the geographical positioning of these nations, coupled with meagre revenues, excessive dependence on climate-sensitive sectors and a feeble ability to cope and conform to modifications in climatic conditions (Rasul and Sharma, 2016; Abid *et al.*, 2016; Morton *et al.*, 2015). Climate change is the consistent average level of fluctuations in weather output that exists over a sustained period. It is

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worthy of note that climate change and weather variation are two distinct but related issues. Climate change is known for its peculiar characteristics which are the increased frequency of weather shocks (Apata *et al.*, 2009; Kaczan and Orgill-Meyer, 2020).

The economic landscape of most African nations is dependent majorly on climate change dynamics (Oluwatayo, 2017; Batten *et al.*, 2020). Also, the vulnerability of the entire African economies especially key sectors like agriculture, water resources, forestry, tourism and energy are exacerbated by climate change (Masih *et al.*, 2014; Ouedraogo *et al.*, 2016; Erkan and Diken, 2020). In the Nigerian context, heightened rainfall, rising sea level, large runoffs, several waterlogged areas, floods and the overflow of coastal land by seawater (Okpara *et al.*, 2013; Munonye, 2017; Sholanke *et al.*, 2021) and high frequencies of floods, sturdy storms and temperature beyond the average daily minimum and maximum (Dike and Dike, 2018) are indicative of climate change.

Closely following this is the indirect effect of climate change on agriculture which has a far-reaching implication on the incomes of farmers, the agricultural market growth, the environment and especially on food security both on domestic and international scales (Ebele and Emodi, 2016; Tsojon, 2017; Ikhuoso *et al.*, 2020). The availability of productive agriculture is necessary to keep the growing population fed and to sustain modern civilisation. In most stations situated in Nigeria, there has been an increase in temperature by 0.2–0.3°C per decade (Ibitoye *et al.*, 2017). The yearly difference in recorded harvest is the result of the unusual rainfall and temperature. The unusual condition of the rainfall and temperature are responsible for the differences between ample “bumper” crops and economic wreck. Instances include the continuous Sahelian drought of 1969–1973, followed by the second occurrence that occurred between 1979 and 1983.

In many African nations, their economies to a large extent are based on climate-sensitive agricultural productions. The nations in this category, for instance, Nigeria, are especially vulnerable to climate change (Salahuddin *et al.*, 2020). Instances of this vulnerability are being witnessed in the Niger Delta region where flooding and long-term droughts are the order of the day (Week and Wizor, 2020). The flood and drought conditions are also applicable in the Northern region (Oyerinde, 2018; Abdulrashid, 2020). Therefore, for developing countries such as Nigeria, their vulnerability to the impacts of climate change makes it pertinent to seek and understand the responses of farmers to climatic differences. The knowledge of climatic differences or variation will make it easier to design the ideal coping techniques (Susskind and Kim, 2021).

The conclusions reached by past studies show that climate change influences agricultural productivity, which ultimately leads to a fall in food production (Kurukulasuriya and Mendelsohn, 2006; Lobell *et al.*, 2008; Nightingale *et al.*, 2020). Declining agricultural production will have serious implications on African economies including Nigeria, where agriculture is the highest employer of labour. To a larger extent, the ability of Nigeria to enhance its development and contribute to global sustainable development will be hampered by climate change (Aryal and Marenya, 2021). More so, malnutrition and its related challenges are likely to exacerbate as vulnerable economies and communities grapple with food insecurity. Each literature that is centred on climate change examines the effects of the changes using diverse approaches (Toll, 2009; Talanow *et al.*, 2021). Uniting the incidence and key drivers of climate change is especially important when trying to reach an analysis on the diverse approaches using a harmonised method. It is important to give due focus to the differences existing in the diverse model specifications and the behavioural assumptions. This method should be applied instead of considering the variation in the definition of highlighted variables, incidences and key drivers. If this pattern is used for analysis, reaching an accurate analysis of the effects of climate change will be possible. In this light, this study seeks to re-evaluate the implications which climate changes have on Nigeria’s agricultural output.

Theoretical review

Production function approach

This theory specifies the production function and ensures the outputs of different varieties of crops are investigated under varying climate (Reinsborough, 2003; Singh *et al.*, 2019). This model assumes that varieties of crops cannot adapt to the evolving climate condition. Furthermore, the assumption is that land used year on year for the same specific crop type. The drawback of this theory is that the model underestimates the agricultural benefits of the evolving climate.

The agronomic-economic models (AEM)

This model carries out its analysis with a medley of controlled experiments on certain crops which are field, and laboratory-grown. Likewise, climatic events such as agronomic modelling, carbon dioxide, precipitations, temperatures and economic modelling are used to gain prediction of the climatic impacts on the crops considered (Adams and McCarl, 2001; Al-Juaidi, 2019). They evaluated changes on experimental crops in the context of the AEM are subsequently imputed into an economic model. This is to predict market prices, crop choice and production (Seo *et al.*, 2005; Lionboui *et al.*, 2018). The outstanding merit of the AEM is its ability to give direct prediction to how climate changes affect the yield of crops, seeing that it requires properly calibrated controlled experiments. On the other hand, it has the disadvantage of not applying to developing nations, provide control for the adaptation to the changing climates, amongst its other disadvantages (Mendelsohn and Dinar, 1999). The absence of adequate controlled experiments does not ascertain the agronomic responses in the various less-developed nations (Seo *et al.*, 2005).

Agro-ecological zone models (AEZM)

Contrarily, the AEZM allots crops to available agro-ecological zones as contained in the name and crop output prediction (FAO, 1996). At the core of this model lies the simple fact that with climate changes comes agro-ecological zones and crop changes. This makes predicting the impact of alternative climate conditions on crop yields feasible (Mendelsohn and Dinar, 1999; Ampofo *et al.*, 2020). Nevertheless, as in the case of AEM, the variations in the experimental crops gotten from the numerous agro-ecological zones are imputed into an economic model. This is done to predict the entire supply and market impacts (Darwin *et al.*, 1995; Shukla *et al.*, 2017). The key strength of the AEZM lies in the ease with which it can be applied to developing countries. This is because there is a geographical distribution of zones in developing countries (Mendelsohn, 2000; Farida *et al.*, 2017). The disadvantage of the AEZM is visible in its lack of clarity, and how rarely climate zones can make a prediction of the crops to grow and the level of yield to anticipate (Mendelsohn, 2000). Further, the estimates do not provide for adaptation to changes in climatic condition, which is also the case with AEM.

The Ricardian cross-sectional model (RM)

This theory leverages on the earlier works of David Ricardo (1815) which is around the popular theory of economic rents and adapted to climate-land value analysis, by the works of Mendelsohn *et al.* (1994). The Ricardian model (RM) evaluates how changes in climatic conditions in different locations impact the net revenue or the value of the land. Seo *et al.* (2005) noted that by so doing, the RM gives accounts of the direct effects of the climate on the yields of various crops. Coupled with the indirect alternative of various inputs, an introduction to different events, and other undiscovered adaptation by farmers to the different climatic conditions (Antle and Stöckle, 2017; Hossain *et al.*, 2019). Therefore, the key strength of this model lies in its ability to integrate the changes made by farmers, to adapt their activities to climate change (Mendelsohn and Dinar, 1999; Farida *et al.*, 2017).

Although despite this great advantage of the RM over other models, such as (1) AEM and AEZM, it still receives criticisms on the basis that crops are not prone to controlled experiments on farms, which is the case with the AEM and the AEZM, (2) also, the RM does not provide any account for technological changes, rules and establishments, it holds on to an assumption of constant price. This however is the case with agricultural items because other variables are the price determinants (Onyekuru and Marchant, 2016). Finally, the RM also fails to give account for the impact of factors that do not conform across the board. An instance is a CO_2 concentration, which is of benefit to crops (Hassan, 2008; Fonta *et al.*, 2010; Gedik and Günel, 2021). Despite its highlighted shortfalls, the RM has been well applied in developed and developing countries alike and is adopted for this paper.

Empirical literature

A study conducted by Jacques *et al.* (2018) aimed at discovering the long-term global effects of climate change on the productivity of crops under diverse climatic conditions using AgMIP approach (Agricultural Model Inter-comparison and Improvement Project). The outcome shows that at the global level, climate change will result in about a 2%–15% fall in productivity agricultural by 2050, leading to a 1.3%–56% increase in food prices and 1 and 4% extensification of cultivated area.

The result derived from the study of the effect of climate change on agricultural output in China revealed the negative impact of climate change in crop production. The CAPRI-induced impacts entirely tilt to the median in every AgMIP models. The model inter-comparison analysis indicates consistency in the area of the direction of climate change with relatively large heterogeneity in terms of the magnitude of the impacts on the models.

Wang *et al.* (2017) used a stochastic frontier approach to determine how changes in climate and severe weather affect agricultural productivity in the United States. This study was conducted with the use of historical weather data (mean and variation) between the years 1940 and 1970. Findings from the study showed that with the use of temperature-humidity index (THI) load and the Oury index between the years 1960 and 2010, the climate pattern in the last half-century has varied. Some years within the study period experienced drier and warmer conditions when compared to others.

When the THI load is high (above heat waves), the Oury index becomes low (very dry). The effect of this is lesser productivity in the country. Next is the impact of THI load shock and the Oury index shock variables (a deviation from the historical norm fluctuations) on productivity are larger than the magnitude of THI and Oury index variables across specifications. There is also the project potential effect of climate change and severe weather on US regional productivity. This was derived through estimates. Findings revealed that an equal degree of changes in rain or temperature will give an uneven impact on the productivity experienced in regions. From years 2000–2010, it was discovered that Delta, Northeast and Southeast regions amassed larger effects, in comparison to other regions.

Apata (2014) studied the impacts of global warming on Nigerian agriculture and estimated the determinants of adaptation to climate change. The multi-nominal choice and stochastic-stimulation model were employed to determine the impact of the continuously increasing climate change on the production of grain and the human population in Nigeria (Durodola, 2019). The production, consumption and storage of grains were calculated in the context of varying climate condition throughout 10-years. In many cases, there is either an optimistic baseline yearly rises in agricultural output of 1.85% or the use of a pessimistic analysis of 0.75%. The level of natural rise of the human population, excluding high hunger-induced deaths could rise if the production of grain does not match the population growth. This will most likely be the case if the climatic conditions are unfavourable. Nevertheless, climate change adaptations have a huge effect on farm productivity.

Enete' (2014) study also reflects the effect of climate change on agricultural productivity in Enugu State in Nigeria using 30-year rainfall data from 1981 to 2010 derived from the Nigeria Meteorological Agency. The data were analysed using descriptive and correlation statistics. Findings from the study revealed a general alteration in the occurrence of seasonal rainfall regime. The rainfall regime in Enugu occurs during a recognised seasonal regime which gives rise to a prolonged dry season (Ogunrinde *et al.*, 2019). A reliable rainfall regime is characterised by a significant variation in the months wherein maximum rainfall occurs. The climate changes witnessed are remarkable pointers of climate changes. Further, the study revealed that every traditional crop, excluding cassava and pepper, are experiencing a huge field decline due to the rise in rainfall. The literature review showed that climate change and agriculture possess a double-barrel impact on one another.

Also, in another similar study carried out in Sokota state, Nigeria by Atedhor (2015) where he said persistent unreliable rainfall is a proof of climate change in the semi-arid zone. His results show that the local farmers know the importance of rainfall to their agricultural activities and are very conversant with rainfall pattern in Sokoto since their agricultural activities and that inconsistent rainfall or absence of it has been a major barrier to their agricultural activities causing that area to be desert. The literature review showed that climate change and agriculture possess a double-barrel impact on one another.

Theoretical framework

This study adopted the RM as its theoretical framework. The RM employs a cross-sectional approach while evaluating agricultural production. Mendelsohn *et al.* (1994) while trying to evaluate the effect of climate change on agriculture, introduced the RM. The RM has been applied in some continents such as Africa, Europe and Asia. The outcome reached from the areas wherein it has been applied shows that the net agricultural revenue or land value is based on climate, economic condition and soils. The equation below gives a summary of the principle behind the RM.

$$V = \sum P_i \; Q_i \,(X, C, S, G, H) - \sum P_X \; \mathrm{X} \tag{1}$$

where P_i represents the market price of crops i, Q_i represents the yield of crops i, X is a vector of the inputs purchased (besides land), C is a vector of climate variables, S is a vector of soil variables, G is a vector of economic variables, H represents the flow of water and P_x is a vector of input prices.

The RM depends on a quadratic formulation of climate. Therefore, the net value of the land can be expressed thus:

$$V = \beta_0 \, C + \beta_1 \, C^2 + \beta_2 \, S + \beta_3 \, G + \beta_4 \, H + \mu_i \tag{2}$$

In the above equation, V represents land, C serves as the vector of climate variables, S is the group of soil variables, G is the group of household's socioeconomic factors, H represents the set of water flow and both the b and the coefficient of the variables are error terms. The net revenue climate response function (Eq. 2) is shown with the use of quadratic terms. The quadratic terms reveal the nonlinear shape which shows how the marginal impact will be changed the moment movement is made from the mean (Mendelsohn *et al.*, 1994). If the quadratic term is positive, the net revenue function will be U-shaped. However, if the quadratic term is negative, the net revenue function will be U-shaped. Prior cross-sectional analyses revealed that farm net value is meant to have a hill-shaped correlation with temperature.

There is an appropriate temperature that suits each crop for it to be well grown in its season. However, the correlation of seasonal climate factors may accommodate a medley of positive and negative coefficients, which makes the variables more complex. The RM was introduced to show the differences in land value for each hectare of cropland across climate zones (Mendelsohn *et al.*, 1994; Seo and Mendelsohn, 2007; Farida *et al.*, 2017). Therefore, the RM considers climate changes by weighing economic ruins such as a fall in net income or a fall in land value as a result of environmental factors. The collection of secondary data, on the other hand, is much easier with the use of cross-sectional climatic variables.

It is general knowledge therefore that this method minimises the cost of data collection. However, the use of the RM is not void of drawbacks. First, this model does not take the impact of price into account. There is an assumption of price equilibrium. Next is the over or underestimation of the climate change effect. In cases of significant climate change, the price of crops could be affected for a protracted-time period (Batieno *et al.*, 2016; Mendelsohn and Tiwari, 2000). Mendelsohn and Tiwari (2000) however argue that constant price is permissible due to the tedious process of predicting the global crop model, the pattern of warming anticipated for the coming century and the change in total supply which does not give rise to challenges in the course of using the model.

There are non-climatic factors such as the socio-economic conditions, access to the market and the impact of fertilization in the form of carbon dioxide concentrations. Unfortunately, these non-climatic factors are minimal or not considered at all in the full model (Mendelsohn *et al.*, 1994). However, these factors have a definite impact on crop yield, and the adaptation of farmers both directly and indirectly. Despite these shortfalls, the non-climatic factors can be used to evaluate the impact of climate change on agriculture. In fact, there is a recent surge in its worldwide use (Mendelsohn and Dinar, 2009).

Methodology

This research is conducted using secondary data with the analysis of multiplicative reactions of agricultural output to climate change between 1986 and 2015. Average annual rainfall and temperature, droughts and floods, agricultural nitrous oxide (N_2O) emissions and forest area as proxies for climate change, while agricultural output was proxied by agriculture value-added. Also, total population and economic growth were included in the model with economic growth being proxied by real gross domestic product. The model can therefore be specified as,

$$\mathrm{AV} = \propto_0 + \propto_1 \mathrm{ART} + \propto_2 \mathrm{DF} + \propto_3 \mathrm{AE} + \propto_4 \mathrm{FA} + \propto_5 \mathrm{POP} + \propto_6 \mathrm{RGDP} + \cup_t$$

where

AV = Agriculture Value Added

ART = Average Annual Rainfall and Temperature

DF = Droughts and Floods

AE = Agricultural Nitrous Oxide (N_2O) Emissions

FA = Forest Area

POP = Total Population

RGDP = Real Gross Domestic Product

The term is a general error term, which represents the entire variables not identified in the model. The technique for reaching an estimate in this study is the ordinary least squares (OLS) method, which is applicable in a single equation model. The choice of the OLS method is due to its significant advantage, which includes Best Linear Unbiasedness (BLU), minimal variance, efficiency, least mean square-error (MSE) and sufficiency (Wallace and Silver, 1988;

Pandey *et al.*, 2017). Summarily, the statistics such as R^2, t-value, F-statistics, DW-statistics and many others are computed to allow for testing of the statistical and econometric reliance of the derived regression results.

Empirical results and discussions

Descriptive statistics

Table 1 shows the results of the time series attributes of variables highlighted in the model. These variables that were analysed using descriptive statistics are average annual rainfall and temperature (ART), droughts and flood (DF), agricultural nitrous oxide (N_2O) emission (AE), forest area (FA), agriculture value-added (AV), total population (POP) and real gross domestic product (RGDP) from 1986 to 2015. As shown in Table 1, whilst the average annual rainfall and temperature (4.48E+12) have the highest standard deviation, agricultural nitrous oxide emission (1.52) has the lowest. This implies that average annual rainfall and temperature is the variable with the largest variability. The degree of variability in agricultural nitrous oxide emission is low and hence can be much relied on than rainfall and temperature. Also, apart from the variable, droughts and flood which is negatively skewed, the rest are positively skewed.

Unit root test

The conclusion from the literature reveals that many time series variables are not fixed. Therefore, the use of variables that are non-stationery in the model might give rise to the derivation of regression filled with error, and thus cannot be used to make an accurate prediction (Gujarati, 2003; Enders and Lee, 2012). In light of this, the first step is the examination of the integration of the series using the Augmented Dickey-Fuller (ADF) and Phillips–Perron (PP) test. The rule of thumb here is that if the ADF and PP value is above the critical values at the 5% level, we then conclude that the variable has a unit root.

Table 2 showed that all the variables were stationary at a 5% significant level. This can be seen by comparing the test statistics (in absolute terms) of the ADF test and PP test statistics with the critical values (also in absolute terms) at a 5% level of significance. This implies that a long-run relationship does not exist among the variables which satisfy the condition for fitting the ordinary least square model.

Ordinary least square regression result

From the result below, average annual rainfall and temperature (ART), forest area (FA) and real gross domestic product (RGDP) revealed a positive and significant effect on agriculture value-added (AV). This implies that during the rainy season and the availability of forest area, agricultural productivity (proxied by agriculture value-added) tends to increase. Similarly, a higher level of economic growth (proxied by real gross domestic product) increases agricultural productivity. However, droughts and flood (DF), agricultural nitrous oxide (N_2O) emission (AE) and total population (POP) revealed a negative and significant effect on agriculture value-added (AV). This implies that the level of droughts and flood and the agricultural nitrous oxide (N_2O) emission reduces the level of agricultural productivity. Therefore, irrigation is usually put in place to prevent erosion caused by droughts and flood. Furthermore, an increase in the total population does not necessarily increase the level of productivity. This is because a larger percentage of the population is not into agricultural production and with the rate of population increases every day, agricultural products available may not meet their demands.

The coefficient of adjusted R-squared of 0.79 indicated that 79% of the entire difference in agriculture value-added is made clear by the variables employed in the study. Also, the

Table 1.
Empirical result of the statistics

Statistics	AE	ART	AV	DF	FA	POP	RGDP
Mean	78.58744	7.62E+12	6.426551	32.28887	12.92513	1.28E+08	4.713998
Median	78.14492	4.94E+12	4.287359	32.73480	12.62514	1.24E+08	4.649226
Maximum	82.11004	1.60E+13	55.18264	48.56594	18.47261	1.82E+08	33.73578
Minimum	75.95826	2.86E+12	−3.503378	20.23572	7.678119	86118043	−10.75170
Std. Dev	1.518517	4.48E+12	9.570074	7.019258	3.042061	28881298	7.272567
Skewness	0.607911	0.540405	4.581029	−0.007668	0.139336	0.299765	1.696018
Kurtosis	2.903931	1.745261	24.08273	2.667257	2.088541	1.910575	10.29744
Jarque–Bera	1.859313	3.428153	660.5313	0.138692	1.135519	1.932854	80.94812
Probability	0.394689	0.180130	0.000000	0.933004	0.566794	0.380440	0.000000
Sum	2357.623	2.29E+14	192.7965	968.6662	387.7538	3.84E+09	141.4199
Sum sq. dev	66.87092	5.81E+26	2656.003	1428.829	268.3699	2.42E+16	1533.817
Observations	30	30	30	30	30	30	30

Source(s): Authors’ computation, 2020

Table 2.
Co-integration result

Variables	ADF statistics	5% Critical values	Phillips–Perron statistics	5% Critical values	Order of integration	Remarks
AE	/4.385590/	/2.963972/	/4.347888/	/2.963972/	*I*(0)	Significant
ART	/5.809283/	/2.967767/	/5.938318/	/2.967767/	*I*(0)	Significant
AV	/6.065123/	/2.967767/	/6.034602/	/2.967767/	*I*(0)	Significant
DF	/5.783085/	/2.967767/	/5.15366/	/2.967767/	*I*(0)	Significant
FA	/5.783085/	/2.967767/	/5.15366/	/2.967767/	*I*(0)	Significant
POP	/3.809283/	/2.967767/	/3.938318/	/2.967767/	*I*(0)	Significant
RGDP	/4.065123/	/2.967767/	/4.034602/	/2.967767/	*I*(0)	Significant

Source(s): Authors' computation, 2020

Durbin–Watson (DW) statistic of approximately 2.00 shows no presence of serial correlation, while the Probability of *F* statistic of 0.00 indicates that the overall independent variables are statistically significant.

Findings from the study show that a long-run relationship does not exist among the variables which satisfy the condition for fitting the ordinary least square model. Furthermore, the result shows that average annual rainfall and temperature (ART), forest area (FA) and real gross domestic product (RGDP) have positive and significant effects on agriculture value-added (AV). Drought, floods and agricultural nitrous oxide (N_2O) emissions have negative impacts on agricultural output. This implies that the level of drought, flood and agricultural nitrous oxide (N_2O) emission reduces the level of agricultural productivity.

As shown in Table 3, the adjusted *R*-square which measures the goodness of fit is as high as 79.3%. Overall, the dependent variables namely average annual rainfall and temperature (ART), droughts and flood (DF), agricultural nitrous oxide (N_2O) emission (AE), forest area (FA), agriculture value-added (AV), total population (POP) and real gross domestic product (RGDP) account for 79% of the variation in agriculture value-added during the period under study. For specifics, droughts and flood (DF) have the highest negative effects on agriculture value-added. As shown in Table 3, if the droughts and flood (DF) increases by 1 unit, agriculture value-added will decrease as much as 47.8%. Conversely, if the real domestic product growth increases by 1 unit, the agriculture value added will increase by 79.9% representing the highest positive impact. Forest area is the variable with the second-highest impact on agriculture value-added. This is the multifaceted effects on the forest on agriculture production. The negative magnitude of effects of droughts and flood (DF),

Table 3.
Dependent variable: AV

Variables	Coefficient	Standard error	*T*- statistics	Probability
C	0.282579	3.537362	1.341457	0.4287
AE	−0.170043	−0.002944	−4.440436	0.0001
ART	0.182568	0.083214	2.193956	0.0364
DF	−0.478276	0.016121	4.855702	0.0000
FA	0.658706	0.007783	2.412262	0.0181
POP	−0.35226	−0.004425	−7.960437	0.0000
RGDP	0.789676	0.333165	2.370225	0.0307
R- squared	0.869335			
Adjusted R^2	0.792521			
Durbin–Watson stat	1.982092			
F-statistic	142.2478			
Prob (*F*-statistic)	0.000000			

Source(s): Author's computation, 2020 agricultural nitrous oxide (N_2O) emission (AE) and total population (POP) on agriculture added are 47.8%, 17.0 and 35.2% respectively.

The positive impact of forest cover on agricultural value-added stems from the fact that as more of the land area is covered by forest trees, less of the ground and surface water is lost into the atmosphere in the form of evapotranspiration. As noted by Ellison *et al.* (2017), the forest is a regulator of water supply. It provides cover for excessive rainwater storage under the ground. Through rainfall effects, agricultural productivity is expected to increase thereby increasing agriculture value-added. Also, some of the fruits and nuts are obtained from the forest which goes a long way to increase agriculture value addition.

With the drought, the moisture in the soil is not enough to support crops leading to low productivity. Sometimes drought results in total crop failure thereby affecting the amount of value-added agricultural products in the country. The findings of the current study support the work of Leclerc *et al.* (2014) that crop yields especially cereals are likely to decrease substantially when exposed to drought because of their sensitivity to heat and drought stress. This according to Junaidu *et al.* (2017) has resulted in a sharp decline in agricultural productivity of smallholder farmers and pastoralists in sub-Saharan Africa. Ironically, drought and floods are on the opposite side of the coin, they are both detrimental to agricultural production. This necessitates the call for irrigation to be put in place to prevent erosion caused by droughts and flood.

The flood which is caused by excessive rainfall leading to an overflow of rivers sometimes washes some of the field crops away. Flooding also causes the leaching of soil nutrient deep outside the reach of crop roots. This affects the growth and productivity of crops. Also, excessive rainfall resulting in flooding destroys roads thereby affecting the carting of foodstuffs and animals from the rural production areas to market centres. Likewise, the supply of agricultural inputs such as fertilizer, seeds, medications for farm animals from the city centres to rural agricultural growth poles is affected by flooding. As noted by Bendito and Twomlow (2014), postharvest storage facilities are not spared from floods. Therefore, flooding has devastating effects on agricultural value addition and hence the observation in this study.

According to Fowler *et al.* (2015), nitrous oxide (N_2O) is an anthropogenic greenhouse gas with agriculture activities contributing about two-third globally. This happens when organic matter and fertilizer combine with water. This nitrous oxide (N_2O) gas when emitted into the atmosphere adds to the greenhouse gas which results in acid rains. It has been long established by Valasai *et al.* (2005) that greenhouse gasses including N_2O cause acid rain and global warming which intend destabilises the natural ecosystem and increases natural disasters, such as heavy storms, floods, droughts, etc. with their associated effects on agricultural productivity. This implies that heavy usage of agrochemicals has detrimental effects on agriculture productivity as agrochemicals release N_2O emission which intends causes acid rain and global warming with their attendant problems.

Conclusion and recommendation

This study examines the impact of climate change on agricultural output in Nigeria. The results suggest a mix finding where ART, FA and RGDP have a positive relationship with agricultural output. However, drought, floods and agricultural nitrous oxide (N_2O) emissions negatively affect agricultural output.

The reduction in the rate of precipitation could have a negative impact on the agriculture of farmers who do not use irrigation techniques. The increase in drought events might also lead to a decline in yields, which will inevitably result in a shortage of food, rising prices of food commodity and poverty among farmers (IPCC, 2018). However, a larger forest area will provide more arable land for farming purpose which positively contributes to agricultural output. Rising temperature and low rainfall immensely affect agricultural activities through a reduction in water for agriculture. Moreover, the study found that a higher level of economic growth and population control could increase the level of agricultural productivity. Thus, an increase in the real GDP of the country and control of the population positively influence the output of agricultural products.

Based on the findings, it is imperative for the country as a whole and government, in particular, to strengthen the national agricultural policy framework, by formulating and implementing policies and programmes that embrace technology and innovation in agriculture, thereby increasing yields and minimizing the adverse impact of climate change on the sector. The need to minimise CO_2 emissions is very essential if the country wants to increase agricultural production and achieve food security and food self-sufficiency. Hence legislations, innovations and practices that contribute to the reduction of greenhouse emission should be promoted. Improving and strengthening the adaptive capacity of vulnerable smallholder farmers engaged in agriculture should be a priority of the government and its development partners. This is necessary to improve their adaptation to climate change, increase agricultural production and income and reduce poverty. Such strategy should involve education, diffusion of innovation, technology and improved management practices, and provision of socioeconomic resources needed by smallholder farmers and vulnerable communities.

Our study is without limitations, we examined the aggregate agricultural output in the county and did not look at the relationship between climate change and major agricultural products in the country. Therefore, we suggest that future study can look at the impact of climate change on selected agricultural produce in the country most importantly those that positively drive the economy.

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