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Deforestation, Sectoral co_2 emissions and climate change nexus: Fresh evidence from Nigeria

Auwal Garba[1], Usman Abubakar Tama[2], Ahmad Isah Ammani[3]

[1] Department of Environmental Technology, Faculty of Environmental Technology, Abubakar Tafawa Balewa University Bauchi, Nigeria

[2] Directorate of Basic and Remedial Studies (DBRS), Abubakar Tafawa Balewa University Bauchi, Nigeria.

[2, 3] Department of Economics, Faculty of Social and Management Sciences, Bauchi State University Gadau, Yuli Campus, Bauchi, Nigeria

Corresponding Author: **Auwal Garba**

Abstract

This study examines the impact of deforestation and sectoral CO_2 emissions on climate change in Nigeria using an autoregressive distributed lag model covering the period 1972-2012. The results indicated that deforestation, transport sector CO_2 emission and other sectors CO_2 emissions have significant impact on climate change in both the long run and the short run periods. The findings suggested that deforestation, transport sector CO_2 emission and other sectors CO_2 emissions which are the focal variables, could affect climate change in the both the long run and the short run periods. Therefore, government should provide affordable and subsidized modern fuels for cooking in order to reduce higher demand for woods fuel, embark on awareness campaign on the danger of desertification as it is associated with deforestation, encourage reforestation among rural dwellers and adopts sustainable farming practices or employed new farming technologies and crops in order to reduce the need for more land. Policy on the reduction of carbon emission in the country should be a long time one.

Keywords: Deforestation, Sectoral CO_2 Emission, Climate Change, ARDL Approach and VECM Granger Causality

Introduction

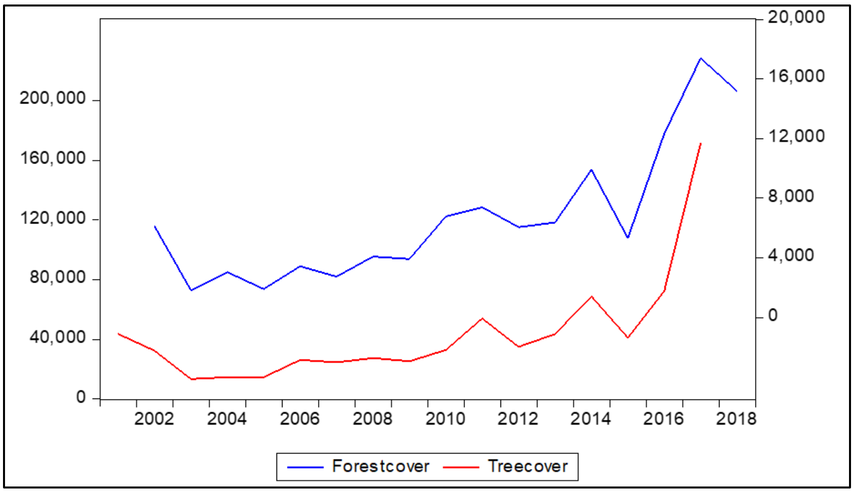
Deforestation is the long term or permanent conversion of forest to other land uses, such as agriculture, pasture, water reservoirs, infrastructure and urban areas. The term deforestation does not apply to areas where the trees have been removed as a result of harvesting or logging and the forest is expected to regenerate (either naturally or with the aid of silvicultural measures), but it does apply to situations in which logging is followed by the conversion of the logged over forest to other land uses [1]. According to [2] deforestation and forest degradation contribute about one-fifth of total greenhouse gas emissions globally. Other environmental impacts of deforestation include damage to and the fragmentation of habitat and the resultant loss of biodiversity; the disruption of water cycles; soil erosion; and desertification. Again [2] indicates that between 1990 and 2015, the world's forests decreased from 31.6 percent of the world's land areas to 30.6 percent, although the rate of loss has slowed down in recent years. This loss occurred mainly in developing countries, in sub-Saharan Africa, Latin America and Southeast Asia. Deforestation is the second leading cause of climate change after the burning of fossil fuels and accounts for almost 20 percent of all greenhouse gas emissions. This is more than the entire transport sector. Between 24 percent and 30 percent of the total mitigation potential can be obtained by stopping and reducing tropical deforestation. In places where the demand for charcoal is high, especially in sub-Saharan Africa, South East Asia and South America, its production puts pressure on forest resources and contributes to degradation and deforestation, especially when access to these forests is not regulated. The proportion of people who depend on firewood varies from 63 percent in Africa to 38 percent in Asia, and 16 percent in Latin America [2].

Deforestation has negative implications on the environment in terms of wildlife and increased desertification among many other reasons. According to data taken over a period of five years from 2000 to 2005, Nigeria has the largest desertification rates in the world with loss of 55.7 percent of its primary forest. The annual rate of deforestation in Nigeria is approximately 3.5 percent, which is between 350,000 and 400,000 hectares per year. In Nigeria forest has been cleared for logging, timber export, subsistence agriculture and notably the collection of wood for fuel which remains problematic in West Africa. A lot of damage has been done to Nigeria's land through the process of deforestation, notably contributing to the overwhelming trend of desertification. Desertification is the encroachment of the desert on land that was once fertile. A study conducted from 1901 to 2005 gathered that there was a temperature increase in Nigeria of 1.10c, while the global mean temperature increase was only

0740c and decrease in the amount of rainfall by 81mm. It was noticed that both trends simultaneously had sharp changes in the 1970. From 1990 to 2010 Nigeria nearly halved their amount of forest cover moving from 17,234 to 9,041 hectares. The combination of extremely high deforestation rates, increased temperature and decreasing rainfall are all contributing to desertification in the country [3].

Trends in primary forest loss and tree cover loss for the periods of 2001 to 2018 in Nigeria

The nature of primary forest loss and tree cover have been experiencing fluctuations in Nigeria due to higher demand for wood fuels and timber for human purposes as shown by the data obtained from [4]. Figure 1 revealed the trends of primary forest loss and tree cover loss for the periods of 2001-2018. Within this period the trend indicates that there has been a continuous downward trend in the primary forest loss due to tree cover loss since from around 2001. This in turn calls for the urgent policy on deforestation in order to prevent desertification and environmental degradation in the country.

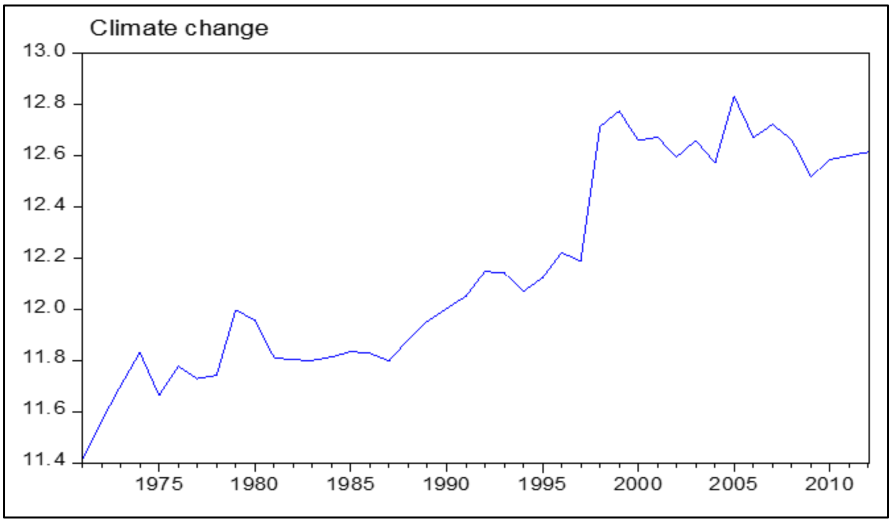


***Source*:** Author's calculation based on the data from Deforestation Statistics for Nigeria.

Fig 1: Trend of primary forest loss and tree cover loss from 2001-2018.

Trends of climate change for the periods of 1971 to 2012 in Nigeria

Climate has been changing in Nigeria at an increasing rate as a result of massive deforestation, carbon emissions and environmental degradation. Figure 2 revealed that change in climate condition has been on increasing rate for entire periods under study. The trend of climate change maintained a constant upward movement from 2000 up to 2010. This situation calls for workable measures to reduce CO_2 emissions and deforestation as they are among the major drivers of climate change in the country.

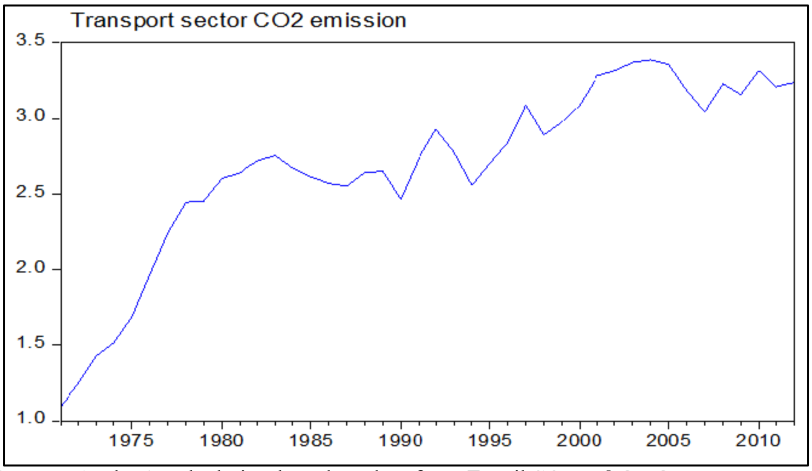


***Source*:** Author's calculation based on data from World Development Indicators.

Fig 2: Trend of logarithm of climate change from 1971 to 2012.

Trends of transport sector CO_2 emission in Nigeria

CO_2 emission from the transport sector in Nigeria has been increasing at an increasing rate and this entails that transport sector is among the leading emitters of CO_2 and causing environmental pollution in Nigeria. Figure 3 revealed that transport sector CO_2 emission has been on increasing trend throughout the periods of 1975 to 2010. This situation calls for workable measures to reduce CO_2 emissions form transport sector to reduce environmental pollution and achieve environmental quality in the country.



***Source*:** Author's calculation based on data from Fossil CO_2 and GHG emissions of all world countries, 2019 report.

Figure 3 Trend of natural logarithm of transport sector CO_2 emission from 1971-2012.

Many research papers were written in the past in this area in Nigeria concentrated on either the relationship between of CO_2 emission and energy consumption or assessing the drivers of deforestation with the highest sample year of 2016. Therefore, in line with this, study will combine the effects of deforestation and that of CO_2 emission but this time around is going to be on sectoral CO_2 emission on climate change. The study will empirically investigate the effects of deforestation and sectoral CO_2 emissions on climate change in Nigeria by means of autoregressive distributed lag (ARDL) model advanced by Pesaran et al. (2001).

The first section contains introduction, research problem statement, significance of the research paper, objective of the research paper and the organization of the research paper. The second section contains the review of related literatures. Third section contains the methodology and which contains data and model specification. The fourth section presents results and discussions of findings and lastly, fifth section offers discussions on the conclusion and policy recommendations.

2. Review of related literatures

[5] studied the impact of human capital on carbon emissions in Pakistan and find out that human capital positively effects quality of the environment and this finding implies that human capital improvement helps in decreased the level of carbon emissions with no effect on economic growth and the author conclude that unidirectional hypothesis exists for human capital to environmental degradation and economic growth.

[6] examined the three-way linkage relationship between CO_2 emissions, energy consumption and economic growth in Malaysia spanning the period 1975 to 2015. The outcomes of the study revealed that economic growth is affected by CO_2 emissions and energy consumption while CO_2 emission is shown to increase with increase in economic growth and energy consumption.

[7] analyzed the factors that are responsible for deforestation activities in Anambra state of Nigeria by means of primary data through questionnaire survey and 30 households were sampled from 20 communities which were randomly selected from four agro ecological zones of the state. The outcome from the analysis revealed that the immediate and remote causes of deforestation in the state consist of farming activities, rural poverty, construction work, population growth, fuel wood collection, government sponsored projects and hunting activities.

[8] examines the trends and status of deforestation as well as how it can be lessen in Nigeria and the result of the examination revealed that there is an existing pressure on the forest communities in the country and these pressures are largely associated with urbanization, overpopulation, development projects execution, expansion of land for agricultural purposes, mining activities, bush burning, logging and wood fuel collection among other factors. It is recommended that effort should be put in place to guide against human actions that promote forest exhaustion.

[9] studied the relationship between energy consumption, CO_2 emissions and economic growth in Malaysia for the period of 1965 to 2015. The outcome of the study indicates that decrease in CO_2 emissions is associated with an increase in income and also increase in CO_2 emissions is associated with an increase in trade openness given that environment kuznet curve does not hold.

[10] analyzed the determinants of energy demand in morocco using time series data for the period of 1990 to 2016. The data were analyze using vector error correction model (VECM) and the results revealed that energy demand in morocco is associated with real cause such as GDP, foreign direct investment and the access to electricity.

[11] studied the relationship among energy consumption, carbon dioxide emission, economic growth, trade openness and urbanization for South Africa for the period spanning 1970-2013. By means of Johansen test for cointegration and vector error correction model Granger causality, the outcomes revealed that they variables are cointegrated and there is existence of bidirectional causality running among energy use and GDP in the long. It is recommended that South African government should enforce energy policies for the enhancement of economic growth.

[12] in their study indicates that road transport affects the quality of air in Nigeria and this relates to the metropolises (particularly the densely populated municipalities) where there is a huge movement of cars, which are frequently old and do not meet recent environmental principles. The noise and CO_2 emissions from the road transportation sector produce direct and harmful effects on the environment, along with indirect impacts.

[13] is of the view that road transportation contributes significantly to the socioeconomic development in Nigeria as

it makes fresh lands for agricultural, industrial and housing development. Nevertheless, in spite of the fact that roads altered the positioning of the internal areas of the country from the waterways and the railways to the road network, and its flexibility creates accessibility to the interior parts of the country, as well as employment opportunities to drivers, mechanics thus raising economic standards, its resultant effects in the emission of GHGs cannot be overemphasized

[14] examined the potential contribution of sustainable urban transportation in the reduction of Green House Gases emissions in Nigeria and recommended the use of the methods of sustainable transport defined as all forms of transport which minimize fuel consumptions and emissions of CO_2 and pollutants. These methods can reduce traffic congestion and volume of vehicles on the roads.

[15] investigate the impact of energy consumption on poverty reduction in a panel of 12 African countries over a period of 1981 to 2014. Using the fully modified ordinary least squares (FMOLS) method, the result shows that there is a long run negative relationship between energy consumption and poverty level. The result also indicates that other variables such as capital stock and political stability have significant effect on poverty implying that these factors play critical role in reducing poverty. The granger causality test shows that a short-run unidirectional causality runs from energy consumption to poverty. It is concluded that increasing energy consumption leads to decline in poverty level.

[16] investigates the interplay between energy demand and its determinants notably world oil price, economic growth, population, urbanization and energy access in the Association of Southeast Asian Nations (ASEAN)-5 over the 2000 to 2016 period. At the aggregated level, the long run results reveal that economic growth, energy access and urbanization have significant effects on energy demand. However, the results vary by the disaggregated fuel type, respectively.

[17] analyzed the determinants of energy demands in morocco during the period of 1990 to 2016. Using Error Correction (ECM) Model, the results show that energy demand in morocco is linked to real causes, which are gross domestic products (GDP), access to electricity and foreign direct investment.

[18] investigate the impact of renewable energy consumption on economic growth in Cote d'Ivoire by using autoregressive distributed lag (ARDL) model. Using data covering the period of 1991 to 2015. The results suggest that in the short run, the impact of renewable energy consumption on economic growth is mixed while in the long run, the impact is not significant. The results also provide empirical evidence that the non-renewable energy/renewable energy transition is not yet effective but is under process in Cote d'Ivoire.

[19] examined the causal nexus between renewable energy consumption and economic growth for some European Union nations for the period of 1990 to 2009. By means of ARDL approach, the outcomes indicate evidence in favor of a positive effect of renewable energy consumption on economic growth. Though, this effect is not statistically significant for all the nations. The significant positive effect was only shown for Bulgaria, Estonia, Poland, and Slovenia. Moreover, no causality evidence was found for Cyprus, Estonia, Hungary, Poland and Slovenia.

[20] disclosed that there is a unidirectional causality running from woody biomass energy consumption to economic growth in Angola, Guinea-Bissau and Niger. The outcomes also indicate a causality from economic growth to woody biomass energy consumption in Seychelles and a bidirectional connection between biomass energy consumption and economic growth in Benin, Mauritania, Nigeria and South Africa.

[21] indicated that there is a long-run unidirectional causality running from hydroelectricity consumption to economic growth in Brazil, Chile, Colombia, Ecuador and Peru. Their outcomes also recommended that there is a long-run bidirectional causality between hydroelectricity consumption and economic growth for Argentina and Venezuela. On the other hand, in the short run, the causality mechanism between the variables was not shown by the authors.

by means of ARDL model on the time series data for the period spanning 1979 to 2014, [22] studied the relationship between renewable energy consumption and economic growth in Iran. The outcome revealed that renewable energy consumption affects economic growth negatively in both the long run and short run period.

[23] in their analysis found that non-renewable energy increases economic growth in Algeria and that there is a long-run unidirectional causality from renewable energy to economic growth equation. The result further confirmed the existence of a short-run causality running from non-renewable energy to renewable energy equation.

By means of the ARDL approach, [24] revealed an evidence of a positive effect of biomass energy consumption on economic growth in the United States in both short and long run periods. Moreover, by applying the Toda-Yamamoto causality test, the outcome revealed a unidirectional significant causality running from biomass consumption to economic growth.

By the same means of ARDL approach to cointegration, [25] analyzed the influence of price of crude oil and urbanization on the level of environmental pollution for the 1981-2016 periods. The outcome of the analysis revealed that all the series are cointegrated and that price of crude oil and foreign direct investment have significantly influenced environmental pollution negatively in both the short run and the long run periods. But significant positive influenced was witnessed from the urbanization on the level of environmental pollution.

Again, in a similar line of action, [26] applied ARDL procedures on the time series data spanning the period 1981 to 2014 in the case of the Nigeria economy in their determination for the influence of economic growth and consumption of energy on environmental pollution. Their outcome from the ARDL procedure indicate that all the series are cointegrated and consumption of energy and economic growth have significantly signed positively with the environmental pollution whereas negative and significant signed was witness from the price of crude oil and the long run outcomes are the same with that of the short run.

From the related literature reviewed and to the best of our abilities, the review revealed that majority of the literature reviewed centered on the relationship between energy consumption and economic growth, assessing the determinants of deforestation and determinants of energy demand in different countries using different time series and panel methodologies. Therefore, this study will contribute to the existing literatures by investigating the joints impacts of deforestation and sectoral CO_2 emission on climate change in Nigeria for the sample period of 1971 to 2012 using ARDL approach.

3. Methodology and model specification

3.1. Empirical model

The research study involved five variables namely climate change, deforestation, transport sector Co_2 emission, other sectors Co_2 emissions and urbanization. Given that the research paper is trying to investigate the impact of sectoral Co_2 emission and deforestation on climate change in the case of Nigerian economy for the period under study, we have restricted the amount of variables to deforestation, transport sector Co_2 emission, other sectors Co_2 emissions, climate change and urbanization if not adding any variable may change the result of the analysis.

The study will adapt and modify the model of [27] who study the key drivers of energy demand in Nigeria. The model can be finally written as.

$$CMC_t = F(DFT_t, TCO_{2t}, OCO_{2t}, URB_t) \quad ...\ (1)$$

The econometric form of the model can be written in equation 2 below.

$$CMC_t = \beta_0 + \beta_1 DFT_t + \beta_2 TCO_{2t} + \beta_3 OCO_{2t} + \beta_4 URB_t + \varepsilon_t$$
…. (2)

where CMC_t represents Climate change, DFT_t represents deforestation, TCO_{2t} represents transport sector emission, OCO_{2t} represents other sectors CO_2 emission, URB_t represents urbanization, β_1-β_4 are the coefficients of explanatory variables, ε_t is the error term and t is the time trend. Data on all the variables for 41 years were sourced from [28] and [29] respectively.

Introducing natural logarithmic function in the model will help to improve the assumption of linearity, eliminates the problems of multicollinearity, heteroscedasticity and provides easy way of interpreting the coefficients in terms of elasticity [30]. Therefore, the model equation written in natural logarithmic form is given in Equation 3.

$$\ln CMC_t = \beta_0 + \beta_1 \ln DFT_t + \beta_2 \ln TCO_{2t} + \beta_3 \ln OCO_{2t} + \beta_4 \ln URB_t + \varepsilon_t$$
……………. (3)

where $\ln$ is the natural log sign, $\ln CMC_t$ is the natural log of climate change, $\ln DFT_t$ is the natural log of deforestation, $\ln TCO_{2t}$ is the natural log of transport sector emission, $\ln OCO_{2t}$ is the natural log of other sectors CO_2 emission, $\ln URB_t$ stand in for the natural log of urbanization, ε_t is the error term and t is the time trend.

3.2 Description of the variables in the model

Climate change was measured using total greenhouse gas emissions (kt of CO_2 equivalent) and is the dependent variable. Deforestation was measured using agricultural land (% of land area) following the work of researchers such as [31], transport sector CO_2 emission was measured using fossil CO_2 by sector expressed in Mt CO_2/yr, other sectors CO_2 emissions was also measured using fossil CO_2 by sector expressed in Mt CO_2/yr and urbanization was measured using urban population and they are explanatory variables.

3.3. Unit root and cointegration tests

Before going into the main estimation of the ARDL model estimators, unit root test and cointegration test would be conducted to ascertain the order of integration of the variables and the probable existence of cointegration relationship among the variables respectively. Augmented dickey fuller (ADF), Philip Perron (PP) and breakpoint unit roots tests will be utilized to determine the order of integration of the variables under study. ADF and PP were choosing due to their power in detecting the order of integration of the variables in time series analysis and breakpoint unit root test is choosing owing to its ability to tackled structural breaks, drift and trend issues in the series, while the cointegration relationship among the variables will be tested using ARDL bound test and Johansen Juselius test for cointegration.

3.4 Method of estimation

To test for the existence of long run relationship among deforestation sectoral CO_2 emission and climate change the model equation 4 is specified and estimated using ARDL bound test. The model contained the null and alternative hypotheses which may be accepted or rejected and this stand a decision point when the null hypothesis of no long run relationship between variables is accepted as against the alternative hypothesis of long run relationship, and then some methods which include VECM among others can be amply applied. If on the other hand there is an existence of long run relationship resulting from the rejection of the null hypothesis, then long run and short run coefficients can be calculated respectively. Therefore, the specified model for long run relationship is given in the equation below:

$$\Delta \ln CMC_t = \beta_1 + \sum_{i=1}^{k} \phi_{1i} \Delta \ln CMC_{t-i} + \sum_{i=0}^{P} \chi_{1i} \Delta \ln DFT_{t-i} + \sum_{i=0}^{Q} \varphi_{1i} \Delta \ln TCO_{2t-i} + \sum_{i=0}^{N} \delta_{1i} \Delta \ln OCO_{2t-i} + \sum_{i=0}^{M} \vartheta_{1i} \Delta \ln URB_{t-i} + \alpha_1 \ln CMC_{t-i} + \alpha_2 \ln DFT_{t-i} + \alpha_3 \ln TCO_{2t-i} + \alpha_4 \ln OCO_{2t-i} + \alpha_5 \ln URB_{t-i} + \varepsilon_{2t}$$
(4)

To estimate the long run equilibrium association among the series, we test the combine null hypothesis of no cointegration relationship on the level variables against its alternative hypothesis that proposes the presence of cointegration relationship. The null hypothesis is $H_0: \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0$ while the alternative hypothesis is given by $H_1: \alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq \alpha_5 \neq 0$.

The presence of cointegration or its absence depend largely on the outcome of the calculated F-statistics value. If the calculated F-statistics value is greater than the upper bound critical value, then cointegration relationship exist. But if the calculated F-statistics value is less than the lower bound critical value, then there is an absence of cointegration relationship. On the other hand, if the F-statistics value is in between the upper and the lower bound critical values, the outcome is said to be inconclusive.

To get the short-run coefficients and the coefficient of error correction term that measure the speed of adjustment or convergence back to the equilibrium position from the position of disequilibrium, the Equation 5 is properly specified and estimated to gets these coefficients.

$$\Delta \ln CMC_t = \beta_5 + \sum_{i=1}^{k} \phi_{4i} \Delta \ln CMC_{t-i} + \sum_{i=0}^{P} \chi_{2i} \Delta \ln DFT_{t-i} + \sum_{i=0}^{Q} \varphi_{2i} \Delta \ln TCO_{2t-i} + \sum_{i=0}^{N} \delta_{2i} \Delta \ln OCO_{2t-i} + \sum_{i=0}^{M} \vartheta_{2i} \Delta \ln URB_{t-i} + \Omega ECT_{t-1} + \varepsilon_{5t}$$
(5)

3.5 Vector error correction model granger causality

The determination of the direction of causality between sectoral CO_2 emissions, deforestation and climate change is done by VECM granger causality in order to determine the long run and short run dynamic relationship between these variables. Again, the VECM granger causality is considered of paramount for testing causality between variables of the same level of stationarity or order of integration, that is, when all the variables are stationary at first difference or I(1) and they must be cointegrated. The vector error correction model (VECM) has some advantage over the granger causality test such as ability to provide short run and long run causalities and it is also base on system of equations. The vector error correction model (VECM) modeling equation contained by a system of error correction model (ECM) for this study is given in a matrix form below in Equation 7.

$$\begin{bmatrix}\Delta\ln CMC_t\\ \Delta\ln DFT_t\\ \Delta\ln TCO_{2t}\\ \Delta\ln OCO_{2t}\\ \Delta\ln URB_t\end{bmatrix}=\begin{bmatrix}\chi_0\\ \beta_0\\ \lambda_0\\ \varphi_0\\ \theta_0\end{bmatrix}+\sum_{i=1}^{k}\begin{bmatrix}\phi_{11,i}&\phi_{12,i}&\phi_{13,i}&\phi_{14,i}\\ \phi_{21,i}&\phi_{22,i}&\phi_{23,i}&\phi_{24,i}\\ \phi_{31,i}&\phi_{32,i}&\phi_{33,i}&\phi_{34,i}\\ \phi_{41,i}&\phi_{42,i}&\phi_{43,i}&\phi_{44,i}\\ \phi_{51,i}&\phi_{52,i}&\phi_{53,i}&\phi_{54,i}\end{bmatrix}\times\begin{bmatrix}\Delta\ln CMC_{t-1}\\ \Delta\ln DFT_{t-1}\\ \Delta\ln TCO_{2t-1}\\ \Delta\ln OCO_{2t-1}\\ \Delta\ln URB_{t-1}\end{bmatrix}+\begin{bmatrix}\pi_1\\ \pi_2\\ \pi_3\\ \pi_4\\ \pi_5\end{bmatrix}(ECT_{t-1})+\begin{bmatrix}\varepsilon_{1t}\\ \varepsilon_{2t}\\ \varepsilon_{3t}\\ \varepsilon_{4t}\\ \varepsilon_{5t}\end{bmatrix} \quad (7)$$

3.6 Robustness test

As a test for robustness, time series dynamic ordinary least squares (DOLS), fully modified ordinary least squares (FMOLS) and canonical cointegration regression (CCR) would be conducted to affirm the results of ARDL long run estimates as against the suspected endogeneity and serial correlation problems in the model. Time series DOLS is popularly known for its power to deal with the problems of simultaneity bias, small sample bias, endogeneity and serial correlation in the model. Therefore, these estimators would serve as a validation tests for the long-run ARDL estimator discussed earlier. The following model Equation will be estimated:

$$Y_t = \beta_t + \phi X_t + \mu_t \quad (8)$$

Where: X_t means the $m \times n$ matrix of climate change, deforestation, transport sector Co_2 emission, other sectors Co_2 emissions and urbanization. While ϕ is the $m \times 1$ vector of all the coefficients of the regressors.

The DOLS regressors correct for endogeneity and serial correlation that is associated with ordinary least squares (OLS) estimator through differenced leads and lags. This could be represented in the following Equation 9.

$$Y_t = \beta_1 + X_t'\phi + \sum_{j=n}^{k}\partial_i \Delta X_{t+k} + \mu_t \quad (9)$$

If Y_t and X_t are integrated of order I(0), I(1) or combination of I(0) and I(1), ADRL bound test and Johansen Juselius tests for cointegration can be applied to determine the long run coefficients of DOLS, FMOLS and CCR respectively.

4. Results and discussions

The estimation procedure begins with the preliminary tests to check the normality of the variables and also to ensure that there is no multicollinearity among the independent variables. The descriptive statistics for each of the variables are presented in Table 1 and the results revealed that all the variables employed are normally distributed. The descriptive statistics results revealed that the observations are equal meaning there are 42 numbers of observations. The approximated mean values are; CMC_t (207297.1), DFT_t (68.769), TCO_{2t} (16.716), OCO_{2t} (8.260) and URB_t (337). The analysis further indicates that all the variables are positively skewed as indicated by the skewness coefficients. The variability returned indicated by the standard deviation statistics showed that CMC_t (85804.27), DFT_t (9.425), TCO_{2t} (7.508), OCO_{2t} (4.324) and URB_t (190). Comparatively, these values indicate that the variables are clearly dispersed far below their mean and median values except for variable URB_t.

Table 1: Descriptive analysis of the variables

Variables	Obs	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Prob.
CMC_t	41	207297.1	172910.6	374421.7	90499.95	85804.27	0.491	1.653	0.087
DFT_t	41	68.769	70.476	80.920	51.845	9.425	-0.397	1.769	0.153
TCO_{2t}	41	16.716	15.235	29.590	2.980	7.508	0.001	2.155	0.535
OCO_{2t}	41	8.260	8.365	18.400	1.230	4.324	0.396	2.646	0.517
URB_t	41	337	300	756	103	190	0.618	2.274	0.165

Prob. means Jarque-Bera P-Values.

Coming down to correlation analysis as reported in Table 2, all the variables are in natural logarithmic form. The result indicates that transport sector CO_2 emission, other sectors CO_2 emission, urbanization and deforestation have positive correlation with climate change. This means that increase in any of the transport sector CO_2 emission, other sectors CO_2 emission, urbanization and deforestation will influence climate change. The result further indicates that considering approximated absolute values (0.820- 0.913) indicates that there is a problem of multicollinearity among the independent variables. This is because the values are above the benchmark of 0.80 [32].

Table 2: Correlation matrix

Variables	Climate change	Transport Co_2 emission	Other sectors CO_2 emission	Urbanization	Deforestation
Climate change	1.000				
Transport CO_2 emission	0.823	1.000			
Other sectors CO_2 emission	0.835	0.954	1.000		
Urbanization	0.913	0.881	0.934	1.000	
Deforestation	0.820	0.576	0.688	0.846	1.000

To inspect the property of the data before estimating the long run equilibrium relationship, the following are required. At first, we check for the stationarity or integration properties of the data, by means of the widely used Augmented Dickey-Fuller (ADF) and Philip-Perron (PP) unit root tests, while breakpoint unit root test will serve as robustness check to

ADF and PP results given that the variables are non-stationary. Table 3a reported the results of ADF and PP unit root tests. The results for ADF test revealed that all the variables were not stationary at level values but became stationary after first differencing and they are said to be integrated of order I(1). But Philip-Perron (PP) unit root test result also reported in Table 3a revealed that only OCO_{2t} is stationary at level value and is said to be integrated of order I(0) whereas the four other variables are stationary at first difference and they are said to be integrated of order I(1). Therefore, since there is a mixture of order of integration in both ADF and PP unit root tests i.e. all variables are I(1) in ADF, while in PP one variables is I(0) and four variables are I(1), then Autoregressive Distributed lag (ARDL) model is more efficient to be utilize as an analytical tool for this research work.

Table 3a: Augmented Dickey Fuller unit root test result (ADF)

Level Values			First Difference		
Variables	Constant	Constant & Trend	Constant	Constant & Trend	Order of Integration
$lnCMC_t$	-1.555 (0.495)	-2.603 (0.280)	-7.415* (0.000)	-7.355*** (0.000)	I (1)
$lnTCO_{2t}$	-3.294** (0.021)	-2.680 (0.249)	-5.331*** (0.000)	-5.747*** (0.000)	I (1)
$lnOCO_{2t}$	-2.611* (0.098)	-3.488*(0.054)	-5.898*** (0.000)	-6.096*** (0.000)	I (1)
$lnURB_t$	-1.309 (0.615)	-2.599 (0.282)	-1.686 (0.430)	-4.592*** (0.004)	I (1)
$lnDFT_t$	-0.538 (0.873)	-2.351 (0.398)	-7.093*** (0.000)	-2.597 (0.283)	I (1)

Philip Perron unit root test result (PP).

Variables	Constant	Constant & Trend	Constant	Constant & Trend	Order of Integration
$lnCMC_t$	-1.555 (0.495)	-2.648 (0.262)	-7.496*** (0.000)	-7.427*** (0.000)	I (1)
$lnTCO_{2t}$	-3.839*** (0.005)	-2.739 (0.227)	-5.315*** (0.000)	-5.719*** (0.000)	I (1)
$lnOCO_{2t}$	-3.372** (0.017)	-3.537** (0.048)	-6.838*** (0.000)	-7.249*** (0.000)	I (0)
$lnURB_t$	-1.234 (0.650)	-1.210 (0.895)	-1.786 (0.530)	-4.392*** (0.001)	I (1)
$lnDFT_t$	-0.659 (0.845)	-2.445 (0.352)	-7.000*** (0.000)	-6.923*** (0.000)	I (1)

Values in parentheses are the P-values and ***, ** & * represents statistically significant at 1, 5 & 10% levels respectively.

However, at times, ADF and PP unit root tests may not produce dependable estimates if there is an existence of structural break in the variables and as such, they could generate a biased result. To clear such doubt, we have equally utilized breakpoint unit root test and the result is reported in Table 3b. The breakpoint unit root test result indicates that, CMC and URB are stationary at level values and they are said to be integrated of order I(0) while three other variables are stationary at first difference and they are said to be integrated of order I(1). In summary, the breakpoint unit root test result also indicates the combination of I(1) and I(0) variables. For this reason, the result of breakpoint unit root test too supports the application of Autoregressive Distributed Lag (ARDL) model.

Table 3b: Breakpoint unit root test result

Level value					First difference				
Variables	Constant	Break Point	Constant & trend	Break point	Constant	Break point	Constant & trend	Break point	I(d)
$lnCMC_t$	-4.148 (0)	1997	-7.060 (0)***	1997	-9.063 (0)***	1998	-8.502 (0)***	1998	I (0)
$lnTCO_{2t}$	-3.895 (0)	1995	-3.075 (1)	1998	-6.071 (0)***	1984	-6.676 (0)***	1994	I (1)
$lnOCO_{2t}$	-3.481 (0)	2010	-5.431 (5)**	1984	-6.921 (1)***	1986	-7.629 (0)***	1992	I (1)
$lnURB_t$	-2.847 (1)	2000	-9.756 (9)***	1989	-14.580 (9)***	1990	-13.393 (9)***	1990	I (0)
$lnDFT_t$	-4.124 (1)	1983	-4.185 (7)	2001	-8.084 (0)***	1984	-6.634 (9)***	1985	I (1)

***, ** & * stands for 1%, 5% & 10% levels of significance and values in brackets are the lag lengths, while I(d) stands for the interpretation of the results.

From the results of the unrestricted vector autoregression (VAR) reported in Table 4 below, using sequential modified LR test statistic, Final Prediction Error, Akaike Information Criterion (AIC) and Hannan-Quinn criteria (HQ) each test at 5 percent level indicates that lag 2 should be selected while Schwarz criterion (SC) indicated that lag 1 should be selected. Therefore, in line with the Akaike Information Criterion (AIC), lag 2 is the maximum lags length for this study.

Table 4: VAR lag order selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	73.86596	NA	2.01e-08	-3.531588	-3.318310	-3.455066
1	345.0329	458.8979	6.71e-14	-16.15553	-14.87587*	-15.69640
2	387.5327	61.02535*	2.92e-14*	-17.05296*	-14.70691	-16.21122k
3	411.0484	27.73650	3.77e-14	-16.97684	-13.56441	-15.75249

* refers to the lag selected by different information criterions.

Having obtained the maximum lag length, the next step is to determine the long run relationship among the variables by employing ARDL bounds test. The null hypothesis of no long run relationship H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0$ was tested along with the alternative hypothesis of long run relationship Ha: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq \alpha_5 \neq 0$. The result of this test reported in Table 5 and the result revealed that the null hypothesis of no long run relationship among the variables was rejected for the entire period under study (i.e. 1971 to 2012), at 5 percent level of significance. Because the estimated F-statistics value of 4.727 exceeded the lower bound critical value of 2.86 and the upper bound critical of value of 4.01 at the abovementioned level of significance. As such, existence of long run relationship is established in this respect. Meaning that the variables are moving together in the long run.

Table 5: Bounds test result for ARDL (1, 1, 2, 2, 1) using AIC Bound test critical values

Model	F-stat.	Lag	Level of sign.	I (0)	I (1)
1971- 2012	4.727^{**}	2	1%	3.74	5.06
F ($lnCMC_t$ /$lnDFT_t$, $lnTCO_{2t}$, $lnOCO_{2t}$, lnURBt)			5%	2.86	4.01
K = 4 & n = 41			10%	2.45	3.52

The Johansen Juselius test for cointegration relationship using model with Trace statistic and model with Max-Eigen value statistic as reported in Table 6 revealed the existence of 2 cointegration equations in the trace statistic model and 2 cointegration equations in the max-eigen statistic model. Therefore, we bring to a conclusion that there is an existence long run relationship among variables and that all the variables moved jointly in the long run. The Johansen Juselius test for cointegration result corroborates the ARDL bounds test result.

Table 6: Johansen Juselius test for cointegration result

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Max-Eigen Statistic	0.05 Critical Value
$C \leq 0$	0.676242	108.593^{***} (0.000)	69.81889	43.982^{***} (0.002)	33.87687
$C \leq 1$	0.595794	64.611^{***} (0.000)	47.85613	35.327^{***} (0.004)	27.58434
$C \leq 2$	0.416640	29.283 (0.057)	29.79707	21.131 (0.051)	21.13162
$C \leq 3$	0.163947	8.264 (0.437)	15.49471	14.264 (0.491)	14.26460
$C \leq 4$	0.032317	1.281 (0.257)	3.841466	3.841 (0.257)	3.841466

Values in parentheses are the P-values and *** represent statistically significant at 1% level of significance.

Following the establishment of long run relationship among the variables, the long run and short run models were estimated and their coefficients are reported in Table 7. The results revealed that transport sector CO_2 emission has positive and significant impact on climate change in the long run, in the short run the coefficients of transport sector CO_2 emission is positively signed but insignificant. Meaning that increase in transport sector CO_2 emission causes increase in climate change in the long run and in the short run climate change is insensitive to increase in transport sector CO_2 emission. This is inconformity with the findings of [32] and [33].

Other sectors CO_2 emissions yielded a negative and significant coefficient with respect to climate change in the long run. In the short run, the coefficient turns to positive and significant in explaining changes in climate change. Specifically, this suggest that increase in other sectors CO_2 emissions lowers climate change in the long run since the contribution of other sectors CO_2 emission total CO_2 emission is lower and causes increase in climate change only in the short run period.

Urbanization is positively signed and significant with climate in the long run. Precisely, increase in urbanization causes increase in the rate of climate change in the long run but urbanization lower the rate of climate change in the short run. This corroborates the findings of [34] and [35].

Deforestation is positive and significantly associated with climate change in the long run and this indicates that increase in deforestation activities causes increase in the rate of climate change. But the coefficient appears to be positive and insignificant in the short run. This is in line with the work of [36] and [37].

The error correction term which measures the speed of adjustment, was -0.714 (71.4 percent). This means that the long run convergence among the variables would be at a speed of 71.4 percent and it further confirmed the long run relationship among the variables as established earlier by the bound test result.

R-square value of 0.953 implies that 95 percent changes or variation in climate change can be jointly accounted by the independent variables and only 5 percent changes in climate change is explained by the error term or other factors that are not captured in the model.

Durbin Watson (DW) statistic of 2.555 implies that the model is free from first order serial correlation as the value is out of 1.50 and 2.50 range. The test for the overall significant of the model depends on the significance of F-statistic and the F-statistic value of 52.527 is significant at 1 percent level of significance indicating that all the explanatory variables in the model are jointly significant in explaining the changes in the climate change.

Table 7: Long run and short run coefficients for ARDL (1, 1, 2, 2, 1) using AIC

Dependent Variable = $lnCMC_t$				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
$lnTCO_{2t}$	1.216^{***}	0.219	5.534	0.000
$lnOCO_{2t}$	-1.260^{***}	0.256	-4.919	0.000
$lnURB_t$	0.407^{*}	0.216	1.882	0.070
$lnDFT_t$	1.406^{***}	0.504	2.786	0.009

Constant	1.406***	0.504	2.786	0.009
Dependent Variable = Δ lnCMC_t				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
$\Delta lnTCO_{2t}$	0.011	0.153	0.073	0.941
$\Delta lnTCO_{2t-1}$	-0.455*	0.236	-1.923	0.064
$\Delta lnOCO_{2t}$	-0.219	0.161	-1.358	0.185
$\Delta lnOCO_{2t-1}$	0.351**	0.165	2.121	0.042
$\Delta lnURB_t$	-13.015***	4.626	-2.813	0.008
$\Delta lnDFT_t$	0.096	0.568	0.168	0.867
ECM (-1)	-0.714***	0.152	-4.693	0.000
$ecm = lnCMC_t - 1.216 \times lnTCO_{2t} + 1.260 \times lnOCO_{2t} - 0.407 \times lnURB_t - 1.406 \times lnDFT_t + 0.649$				
R^2: 0.953, Adjusted R-squared: 0.935, DW-statistic: 2.555, F-stat: 52.527^a (0.000), Akaike info criterion: -1.546, Schwarz criterion: -1.040.				

ECM = Error Correction Model. ***, ** & * and are significant at 1, 5 & 10% levels of significance respectively.

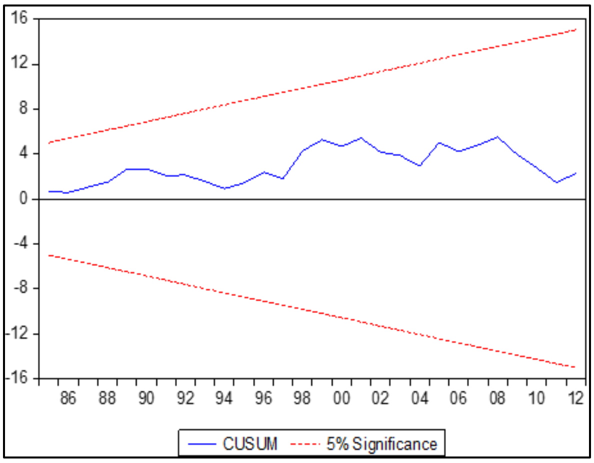
To guarantee the reliability of the estimated coefficients, the reliability tests of serial correlation using Breusch-Godfrey serial correlation LM test, functional form test using Ramsey RESET test, normality test using Jarque-Berra test and the heteroskedasticity using Autoregressive conditional heteroscedasticity (ARCH) test were applied and the results are reported in Table 8. The results showed that the null hypotheses for the serial correlation LM test, functional form, normality test and heteroskedasticity test could not be rejected for the model as their probability values were not significant. This shows that the model is reliable for policy making and statistical inferences.

Table 8: Diagnostic tests results for ARDL (1, 1, 2, 2, 1)

Test statistics	LM version	F-version
Serial correlation	CHQ (4) = 10.407 [0.034]	F (4,24) = 2.110 [0.110]
Functional form	Not applicable	F (1, 27) = 0.278 [0.602]
Normality	JB = 2.736 [0.254]	Not applicable
Heteroscedascity	CHQ (11) = 12.636 [0.317]	F (11,28) = 1.175 [0.346]
CUSUM	Stable	
CUSUMSQ	Stable	

Values in [] are the probability values. LM = langrange multiplier test, CHQ = chi-square.

In determining the stability of the estimated coefficients of climate change Equation for Nigeria, the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests were utilized as suggested by [38].
From figure 1 and 2 of CUSUM and CUSUMSQ, it can be noticed that both the CUSUM and CUSUMSQ plots do not pass through the 5 percent critical boundaries, indicating that over the entire study period of 1971 to 2012, there is an existence of stability among the estimated coefficients. Therefore, the estimated coefficients are reliable and suitable for policy making in Nigeria.



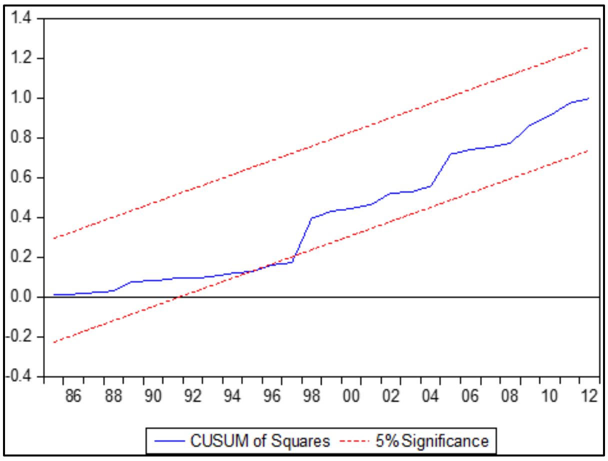


Fig 4: Stability test for the impacts of deforestation and sectoral CO_2 emissions on climate change in Nigeria

As strength checks to the ARDL results, we have employed time series dynamic OLS, fully modified OLS and Canonical CR, and their coefficients are reported in Table 9. The results demonstrate that all the variables corroborate the long run ARDL estimates except for urbanization under fully modified ordinary least squares and canonical cointegration regression estimators. The normality test results reported at the lower part of the Table 9 indicates that the models are normally distributed along the study period.

Table 9: Estimated results for Stability test for the impacts of sectoral CO_2 emissions and deforestation on climate change using time series DOLS, FMOLS and CCR

Dependent Variable = lnClimate Change :	**DOLS**		**FMOLS**		**CCR**	
Regressors	**Coefficients**	**SE**	**Coefficients**	**SE**	**Coefficients**	**SE**
Deforestation	1.036** (2.235)	0.463	1.440*** (3.031)	0.475	1.504*** (2.939)	0.511
Transport Sector CO_2	1.311** (6.596)	0.198	0.704*** (4.057)	0.173	0.755*** (3.855)	0.195
Other Sector CO_2	-1.377*** (-5.066)	0.271	-0.505*** (-2.699)	0.187	-0.546** (-2.702)	0.202
Urbanization	0.516** (2.391)	0.215	0.262 (1.207)	0.217	0.241 (1.003)	0.240
Constant	-0.933 (-0.418)	2.231	0.669*** (0.304)	2.199	0.702 (0.313)	2.238
R^2 & Adjusted R^2	0.958 & 0.927		0.860 & 0.844		0.857 & 0.841	0.975862 0.911493
Normality Test	0.080 [0.960]		0.304 [0.858]		0.358 [0.835]	

Numbers in brackets are the t-statistics and Numbers in [] are the Jarque-Bera P-Values. DV = Dependent variable, DOLS = dynamic ordinary least squares; FMOLS = fully modify ordinary least square; OLS = Ordinary Least Square; SE = standard error. *** & ** indicates significant at 1% and 5% levels of significance respectively.

Following the strength check of ARDL long run coefficients, then causal link between the variables was checked using VECM granger causality test in a system of vector autoregressive (VAR) model. The existence of long run relationship as represented in Table 5 and robust checked by Table 6 suggest the existence of causal relationship in at least one direction. The estimated short run and long run causality results are offered in Table 10 and the summary of causality results is presented in Table 11. The long run causality results reveal that ECT_{t-1} in climate change and other sectors CO_2 emission Equations have fulfilled the econometrics requirements of negative, less than one in value and statistically significant. These suggest that there is a long run causality running from urbanization, other sectors CO_2 emission, transport sector CO_2 emission and deforestation to climate change. Again, from urbanization, transport sector CO_2 emission, deforestation and climate change to other sectors CO_2 emissions.

Apart from the long run causality, the short run causality was also reported in Table 10. However, in the short run, there is unidirectional causality running from transport sector CO_2 emission to climate change, urbanization to climate change, transport sector CO_2 emission to deforestation, transport sector CO_2 emission to other sectors CO_2 emissions and urbanization to other sectors CO_2 emissions respectively.

The VECM diagnostic tests results are presented in the lower part of Table 10 which indicates that the model is steady and reliable as all the null hypotheses of the tests were accepted, and therefore its coefficients are acceptable for statistical reasoning.

Table 10: Vector error correction model granger causality test result

	Direction of VECM causality					
	Short run					**Long run**
Dependent Variables	$\sum\Delta lnCMC_t$	$\sum\Delta lnDFT_t$	$\sum\Delta lnTCO_{2t}$	$\sum\Delta lnOCO_{2t}$	$\sum\Delta lnURB_t$	ECT_{t-1}
$\Delta lnCMC_t$	-----	1.308 (0.252)	3.468* (0.062)	2.357 (0.124)	9.067*** (0.002)	-0.385*** (0.000)
$\Delta lnDFT_t$	0.083(0.772)	-----	9.003*** (0.002)	1.463 (0.226)	0.035 (0.850)	-0.046 (0.123)
$\Delta lnTCO_{2t}$	0.030 (0.861)	2.027 (0.154)	------	0.017 (0.894)	0.296 (0.586)	-0.029 (0.820)
$\Delta lnOCO_{2t}$	0.279 (0.597)	0.155 (0.693)	8.044*** (0.004)	------	5.002** (0.025)	-0.542*** (0.000)
$\Delta lnURB_t$	1.736 (0.187)	0.950 (0.329)	0.563 (0.453)	0.497 (0.480)	------	-0.000 (0.767)
Diagnostic tests: Akaike information criteria = -1.454, Schwarz criterion: -1.158, VEC residual Serial correlation LM test = 13.939 (0.962), VEC White heteroscedasticity test = 170.955 (0.673), VEC Jarque Bera normality test = 0.339 (0.843)						

Values in parentheses are the P-values. LM = langrange multiplier; Δ is the short run parameter; VEC = vector error correction ***, ** & * indicates significant at 1, 5 & 10% levels of significance respectively.

The remaining interpretations of the vector error correction model causality test results presented in Table 10 above are offered in Table 11.

Table 11: Summary of VECM granger causality test result

Direction of causality	**Short run (F-statistics)**	**Long run (ECT_{t-1})**
$lnDFT_t$ causes $lnCMC_t$	NO	At 1% level of significance
$lnTCO_{2t}$ causes $lnCMC_t$	At 10% level of significance	At 1% level of significance
$lnOCO_{2t}$ causes $lnCMC_t$	NO	At 1% level of significance
$lnURB_t$ causes $lnCMC_t$	At 1% level of significance	At 1% level of significance
$lnCMC_t$ causes $lnDFT_t$	NO	NO

$lnTCO_{2t}$ causes $lnDFT_t$	At 1% level of significance	NO
$lnOCO_{2t}$ causes $lnDFT_t$	NO	NO
$lnURB_t$ causes $lnDFT_t$	NO	NO
$lnCMC_t$ causes $lnTCO_{2t}$	NO	NO
$lnDFT_t$ causes $lnTCO_{2t}$	NO	NO
$lnOCO_{2t}$ causes $lnTCO_{2t}$	NO	NO
$lnURB_t$ causes $lnTCO_{2t}$	NO	NO
$lnCMC_t$ causes $lnOCO_{2t}$	At 5% level of significance	At 1% level of significance
$lnDFT_t$ causes $lnOCO_{2t}$	At 1% level of significance	At 1% level of significance
$lnTCO_{2t}$ causes $lnOCO_{2t}$	At 1% level of significance	At 1% level of significance
$lnURB_t$ causes $lnOCO_{2t}$	At 5% level of significance	At 1% level of significance
$lnCMC_t$ causes $lnURB_t$	NO	NO
$lnDFT_t$ causes $lnURB_t$	NO	NO
$lnTCO_{2t}$ causes $lnURB_t$	NO	NO
$lnOCO_{2t}$ causes $lnURB_t$	NO	NO

Note: ***, ** & * are the 1, 5 and 10 % significance levels

5. Conclusion and recommendations

The study investigated the impact of sectoral CO_2 emissions and deforestation on climate change in Nigeria for the sample period of 1971 to 2012. ARDL method was utilized in achieving the objective of the study. The ARDL bound test result revealed strong long run relationship among the variables. The ARDL long run model indicates that transports sector CO_2 emission, urbanization and deforestation were found to have positive and significant impact on climate change. But other sectors CO_2 emissions have significant negative impact on climate change. The short run coefficients indicated that transports sector CO_2 emission, other sectors CO_2 emissions and deforestation have significant negative impact on climate change. To ensure robustness and reliability of the ARDL long run coefficients we have equally employed dynamic OLS, Fully modified OLS and Canonical CR. The results obtained corroborate the results of the ARDL long run model.

Based on the findings of this study, we have made the following recommendations. Firstly, since deforestation activities is widely practice in the country for wood fuel, farming practice and timber purpose, government should provide affordable and subsidized modern fuels for cooking and provide awareness campaign on the danger of desertification as it is associated with deforestation and encouraged reforestation among rural dwellers. Secondly, people should also adopt sustainable farming practices or employed new farming technologies and crops in order to diminish the need for more land. Likewise, Forests can also be restored, through replanting trees in cleared areas or simply allowing the forest ecosystem to regenerate over time. Thirdly, strict workable measures should be taken by the government on illegal cutting down of trees without replacement in the forest in order to mitigate the impact of deforestation on the environmental quality and forest degradation.

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