EFFECTS OF LAND USE CHANGE AND CLIMATE CHANGE ON PLANT SPECIES

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ABSTRACT

The study examined the impact of land use and climate change on plant species in Nigeria from 1981 to 2022 using a historical survey design with time series data. Data were sourced from the National Bureau of Statistics, NIMET, FAO, and Nigeria's National Biodiversity Reports. Analysis was conducted using descriptive statistics and the Autoregressive Distributed Lag (ARDL) Model, with t-tests used to test hypotheses. Findings revealed mean values of 161,334.6 sq/km for land use change, 1266.28 mm for rainfall, 27.24°C for temperature, 81.3% for relative humidity, and 7,305.5 for plant species count. The Augmented Dickey-Fuller (ADF) test showed that all variables, except temperature, were stationary at the level; temperature became stationary after first differencing. The co-integration test confirmed a long-run relationship among land use change, climate variables, and plant species. ARDL results further indicated both short-term and long-term effects of land use and climate change on plant species. The study recommends that farming households adopt sustainable practices and afforestation to restore degraded ecosystems. Additionally, governments at all levels should enforce laws against harmful environmental practices such as indiscriminate hunting, bush burning, and habitat destruction, which contribute to climate change and negatively affect plant biodiversity in both the short and long term.

Keywords: Land, Biodiversity, Climate, Humidity, Greenhouse and Species

INTRODUCTION

Plant species form the backbone of terrestrial ecosystems, playing critical roles in maintaining ecological balance, supporting livelihoods, and sustaining biodiversity across nations. Each country hosts a unique array of plant species with profound biological, ecological, and cultural significance, underscoring the urgent need for their conservation. However, the comprehensive protection of global plant biodiversity demands substantial time, land, and financial investment—resources that are often limited. In Nigeria, plant species face mounting threats from both land use change and climate change. A significant portion of Nigeria's terrestrial ecosystems lies in dryland areas that are increasingly vulnerable to desertification, sheet erosion, and prolonged droughts—phenomena exacerbated by climate change (Abdallah and Rusea, 2020; Borokini, 2014). These climatic pressures not only degrade habitats but also interact with unsustainable land use practices such as deforestation, agricultural expansion, and urban development, accelerating the loss of native plant species. Recent shifts in climatic conditions have intensified these challenges, resulting in adverse impacts on both land use patterns and the health of plant communities (Borokini, 2014). As such, understanding and addressing the intertwined effects of land use and climate change is vital for the conservation of plant biodiversity in Nigeria and beyond.

Unfortunately, Nigeria has very weak adaptive strategies and capacity to mitigate the effects of a changing climate. Presently, the impacts of rising temperatures and rainfall variability on plant species are being felt across major agro-ecological zones in Nigeria (Ayanlade *et al.,* 2018). In addition, the highest rates of decline in plant species in the world are found in tropical regions populated by developing countries, including Nigeria, which do not have adequate technical and financial resources to manage all these species, thereby making these species to be threatened by various factors such as land use and climate change.

The pattern of land use in Nigeria has changed significantly in recent years as a result of the country's increasing urbanization, industrialization, and population increase. Majority of the nation's land is now used for urban and industrial purposes rather than for agriculture (Froeser and Schilling, 2019). Increasing temperatures, higher precipitation variability, weather extremes, or sea-level rise due to climate changes are considered to affect plant species through a variety of interconnections in the coming decades (Barros *et al.*, 2014; Ringim and Aliyu, 2018). One of the interconnections is land use and land use change which are expected to be strongly influenced not only through the changing climatic conditions but also through human interference due to population growth, rapid urbanization, and consequent increasing pressure on ecosystem resources (Froeser and Schilling, 2019).

In Nigeria, there are about 7,895 plant species identified in 338 families and 2,215 genera, and of these, about 0.4% are threatened and 8.5% endangered (FRN, 2015). These plants include 1335 algae, 17 lichens, 134 fungi (mushroom), 16 mosses, 6 liverworts, 165 pteridophytes, 5 gymnosperms, 6 chlamydosperms, 1575 monocotyledons and 4636 dicotyledons species (Emma–Okafor, Ibeawuchi and Obiefuna, 2010). Typically, plant uses and threatened depends on the region and locality as well as its availability.

Therefore, there is the need for setting priorities for conservation efforts for these plant species, with more attention to the ones whose biodiversity has reduced drastically, species with narrow range of bio-geographical distribution, endemic species and those who belong to mono-specific genera. Thus, the need to find the effect of land use and climate changes on plant species threatened in developing countries especially Nigeria.

2.0 METHODOLOGY

2.1. Study Area

The study was carried out in Nigeria. Nigeria is located on the Gulf of the Guinea in West Africa with a geographical area of 923,768 square kilometers. It is one of the eight most populous countries in the world with a population of about 140 million (NPC, 2006). With a population growth rate of 2.6%, Nigeria has an estimated population of about 210.87 million in 2021 (www.statista.com). Nigeria lies wholly within the tropics along the Gulf of Guinea on the western coast of Africa. The topography ranges from mangrove swampland along the coast to tropical rain forest and savannah to the north. Nigeria is located between latitude 4°16 and 13°53 north and longitude 2°40 and 14°41 east (CIA Fact Book, 2009).

Because Nigeria has a highly diversified agro-ecological climate, agriculture is one of the most important sectors of the Nigeria economy. The climate varies with Equatorial in South, Tropical in Centre and in the North. In the North, the vegetation is grassland savannah and in the south, forest. Because of this vegetation, agriculture is the major employer of labour in the country. In terms of employment, at least 60% of Nigeria's projected population of 210.87 million, is estimated to be engaged or employed in agriculture (mainly smallholders). Women make up to 60-80 percent of work or labour and produce two thirds of food crops.

2.2 Data Collection and Data Analysis Techniques

The study relied on the use of time series data spanning from 1981 to 2022. Data on rainfall and temperature was collected from the National Bureau of Statistics (NBS), data on humidity were collected from NIMET, data on land use were collected from the records of the Food and Agriculture Organization (FAO), while data on plant species were collected from various editions of the Nigeria National Biodiversity Report. Data for the study were analyzed using both descriptive and inferential statistics. Specifically, descriptive statistics such as mean, maximum and minimum was used for the mean of the variables, Bounds Tests from Autoregressive distributed lag model (ARDL) was used to test the existence of relationship between the variables while Autoregressive distributed lag model (ARDL) was used to achieved the effects of land use change and climate change on mammal species.

2.3. Model Specification

2.3.1 Autoregressive Distributed Lag (ARDL) Model

To find the relationship between plant species and independent variables (land use change, temperature, rainfall and relative humidity) ARDL model was employed. This model was constructed as:

$$\mathrm{PLTt¼} = \alpha_0 + \alpha_1\mathrm{LUC} + \alpha_2\mathrm{RAF} + \alpha_3\mathrm{TMP} + \alpha_4 RHD + E_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

By converting all variables of Equation (1) into the natural log, the model is designed below:

$$\mathrm{lnPLTt¼} = \alpha_0 + \alpha_1\mathrm{lnLUC} + \alpha_2\mathrm{lnRAF} + \alpha_3\mathrm{lnTMP} + \alpha_4\mathrm{lnRHD} + \mathrm{E_t} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Equation (2) can be written in ARDL and ECM general form as follows:

$$\Delta\mathrm{lnPLT_t} = \alpha_0\sum_{k=1}^{n} a_1\Delta\mathrm{lnLUC}_{t-k} + \alpha_0\sum_{k=1}^{n} a_2\Delta\mathrm{lnRAF}_{t-k} + \alpha_0\sum_{k=1}^{n} a_3\Delta\mathrm{lnTMP}_{t-k} + \alpha_0\sum_{k=1}^{n} a_4\Delta\mathrm{lnRHD}_{t-k} + \emptyset\mathrm{ECM}_{t-1} + \mathrm{E_t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where: PLT are the values of plant species, LUC, RAF, TMP and RHD are the values of land use change, rainfall, temperature and relative humidity which were used to estimate the values of the dependent variables, Et is the error term, α_0 represent the drift component, Δ shows the first difference while $\emptyset$ shows the coefficient of ECM for short run dynamics. ECM shows the speed of adjustment in the long-run equilibrium after a shock in the short run.

3.0 RESULTS AND DISCUSSION

3.1 Mean of Land Use Change, Climate Change and plant species in Nigeria

The mean of land use change, climate change and plant species is presented in Table 1. The result showed that land use change range between 139975.2 and 171421 square kilometers within 1981-2022 in Nigeria with a mean of 161334.6 square kilometers. The high diversity between the maximum and minimum land use change and high mean may be attributed to urbanization and an increase in agricultural activities, which put Nigerian land into several uses to meet human wants.

Furthermore, the result revealed that climate change indicators specifically rainfall was at it maximum at 1596mm and minimum of 1046mm with a mean of 1266.28 millimeter, temperature has a maximum of 27.8575°C and a minimum of 26.1882°C with a mean of 27.23515°C and relative humidity have a maximum of 85.0% and a minimum of 78.4% with a mean value of 81.3% during the period under study. This indicated that there is a high mean for climate change in Nigeria during the period under study. This high change is climate may be considered a global phenomenon due to high industrialization leading to accumulation or inorganic substances into the atmosphere.

More so, plants have a maximum of 7956.00 and a minimum of 6000.00 with a mean of 7305.50 species during the period under review. FRN (2015) reported a similar value 7,895 for plant species in Nigeria. This revealed that there is a great decline in plant species in Nigeria during the period under review. This could be attributed to several human activities such as, farming activities, bush burning, deforestation, among others, which lead to encroachment into the natural habitat of several plant causing displacement, reduction and even extinction of several plant species in the country. This is consistent with the report of FRN (2015) that Nigeria's wildlife is rapidly declining due to habitat loss and increased pressure from hunters, poachers, and bush burning.

3.2 Unit Root Test

As shown in Table 2, a necessary preliminary test, the Augmented Dickey Fuller (ADF) test for unit root was employed to test whether or not a variable is stationary and also determine the order of integration of the variable. The result indicated that all the variables (plant, land use change, relative humidity and rainfall) were found to be integrated of order zero, except temperature, which was found to be integrated of order one and became stationary on first differencing. This indicates that the variables exhibit random walk (unit roots) or the future values of these variables do not converge from their past values.

Bounds Test for Long Run Relationship

In the first step of the ARDL analysis, the presence of long-run relationships was tested as stated in the methodology. The bounds test was used to determine whether a linear combination of non-stationary variables is stationary. Regressing a non-stationary series on another non-stationary series yields spurious regression, but if a linear combination of the series is stationary, the variables are said to be co-integrated and the regression is no longer spurious. The result of the bounds test for plant species (Table 3) shows that the computed statistics 8.434847 is greater than the upper bound critical value, 4.35 at 0.05 level. Therefore, co-integration exists among the variables.

This implies that a long run relationship exists among plant species, land use change, temperature, humidity and rainfall. This is in line with Obayelu (2014) who reported climate change is affecting all aspects of biodiversity from individual organisms, within populations and species both in the short and long-run.

Table 1: Summary of Statistics of Variables

	PLANT	LUC	RHD	RAF	TMP
Mean	7305.50	161334.6	81.3	1266.28	27.23515
Maximum	7956.00	139975.2	85.0	1596	27.8575
Minimum	6000.00	171421	78.4	1046	26.1882
Std. Dev.	735.50	10917.14	1.746137	103.4055	0.432165
Skewness	-0.841	-0.844569	0.079407	0.412105	-0.747655
Kurtosis	-0.609	2.104901	2.076191	4.348147	2.771644
Jarque-Bera	17.52652	6.242918	1.501017	4.265404	3.908834
Probability	0.000156	0.044093	0.472126	0.118517	0.141647
Sum	58444	6614720	3334.732	51917.5	1116.641
Sum Sq.	430749398	4.77E+09	121.9597	427707.5	7.470649
Observations	41	41	41	41	41

RMD = relative humidity; LUC = Land use change; RAF= Rainfall; TMP = Temperature.

Source: Data Analysis, 2023

Table 2. Results of Augmented Dickey-Fuller (ADF) Test

Variable	Level				First Difference				
	ADF	1%	5%	10%	ADF	1%	5%	10%	Inference
PLANT	-6.0347***	-3.6056	-2.9370	-2.6069					I(0)
RAINFALL	-4.6640***	-3.6056	-2.9370	-2.6069					I(0)
HUMIDITY	-3.5308***	-3.6056	-2.9370	-2.6069					I(0)
TMP	-2.5813	-3.6105	-2.9390	-2.6080	-8.5498***	-3.6105	-2.9390	-2.6080	I(1)
LUC	-4.8268***	-3.6056	-2.9370	-2.6069					I(0)

TMP = Temperature; LUC = Land use change;

*** Significant at 1%

Source: Data Analysis, 2023.

Table 3. Bounds Test for Co-integration between Land Use Change, Climate Change and Plant Species

Test statistics	Value	Significance (%)	1(0)	1(1)
F	8.434847	10	2.72	3.77
K	3	5	3.23	4.35
		2.5	3.69	4.89
		1	4.29	5.61

Source: Data Analysis, 2023.

3.3 Effects of Land Use Change and Climate Change on Plant Species in the Short and Long Run

Having verified the existence of long run relationship between land use change and climate change on plant species, the ARDL approach was estimated. The result (table 4) indicated that in a long run, the coefficient of land use change (-1008.185608) was negative and statistically significant at 1% probability level. This implies that a unit change in land use will decrease plant species by 1008.185608 units in the long run *ceteris paribus*. More so, the coefficient of rainfall (16419.0662) was positive and statistically significant at 5% probability level. This implies that a unit increase in rainfall will increase plant species by 16419.0662 units in the long run *ceteris paribus*. Similarly, the coefficient of relative humidity (174107.7347) was positive and statistically significant at 5% probability level. This implies that a unit increase in relative humidity will increase plant species by 174107.7347 units in the long run *ceteris paribus*. Therefore, there is long run effect of land use and climate change on plant species in Nigeria. This may be attributed to the fact that several activities on land leading to changes in land use and climate may affect the welfare of plant species through deforestation leading to extinction among others. This is line with Unanaonwi and Amonum (2014) who posited that the impacts of land use change is usually long-term causing poverty, hunger, environmental degradation, climate change and loss of valuable biodiversity including medicinal plants and wildlife of ecological importance.

The short run result indicated that the conditional error correction term or speed of adjustment, ECM (-1) is negative (-1.356082) and statistically significant. The result implies that 135.61% of the deviation from the long run equilibrium position is corrected within the year. This indicates a quick speed of adjustment (that is, the speed at which the deviation from long run equilibrium is adjusted quickly where 1.356082 of the disequilibrium is removed immediately in each period). The coefficients of land use change (-2090.202) was negative and statistically significant at 5% probability level during the third lagged period respectively. This implies that a change in land use will decrease plant species by 2090.202 units in the third *ceteris paribus*.

Similarly, the coefficient of rainfall (18484.87) and (22097.17) were positive and statistically significant at 5% and 1% probability level during the base year and the fourth lagged period. This implies that a unit increase in rainfall will increase plant species by 18484.87 and 22097.17 units in the base year and the fourth lag period *ceteris paribus*. More so, the coefficient of temperature (129029.9) and (-113822.5) were positive and negative and statistically significant at 1% probability level during the base year and the fourth lagged period. This implies that a unit increase in temperature will increase plant species by 129029.9 units in the base year while an increase in temperature decrease plant species by 113822.5 units in the fourth lag period *ceteris paribus*. Furthermore, the coefficient of relative humidity (-58683.18) was negative and statistically significant at 5% probability level. This implies that a unit increase in relative humidity will decrease plant species by 58683.18 units *ceteris paribus*. This shows the existence of short run effect of land use change and climate change on plant species in Nigeria. This is consistent with the findings by Ayanlade *et al.* (2018) land use changes has distorted the ecosystem equilibrium and led to loss of ecological integrity, land degradation, and loss of environmental services provided by the plants.

4.0 CONCLUSION AND RECOMMENDATIONS

The study analyzed the effects of land use change, climate change on plant species in Nigeria from 1981 to 2022. The study confirms the existence of co-integration among land use change, climate change, and plant species, indicating a long-run relationship between these variables. Given this long-run association, a conditional error correction model based on the ARDL approach was estimated, revealing both long- and short-run impacts of land use and climate change on plant species.

The study therefore recommended that:

i. Farming households should adopt better farming practices that will protect plant existence and afforestation of already deforested areas, as these will help conserve ecosystem habitat, therefore encouraging the increase in plant species.

ii. The should be more public enlightenment campaign on the importance of plants as this will enlighten most citizens especially the rural dwellers on the need to protect their habitat

iii. Government at both the local, state and federal level should enact strong laws against activities such as indiscriminate hunting, bush burning and habitat destruction/degradation that leads to climate change which virtually has short and long run effect on plants' species.

Table 4. Short and long run effects of land use change and climate change on plant species

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
Short run estimates				
PLANT_SP(-1)	0.136691	0.245861	0.555969	0.6079
PLANT_SP(-2)	0.226789	0.213152	1.063975	0.3473
PLANT_SP(-3)	-0.719562	0.197223	-3.648472***	0.0218
LNLUC	1319.237	532.9985	2.475124**	0.0686
LNLUC(-1)	449.1902	578.0068	0.777137	0.4805
LNLUC(-2)	495.71	717.713	0.69068	0.5278
LNLUC(-3)	-2090.202	833.1996	-2.508645**	0.0662
LNLUC(-4)	-1541.117	792.8223	-1.943837	0.1238
LNRAINFALL	18484.87	6857.524	2.69556**	0.0543
LNRAINFALL(-1)	-25414.84	7183.883	-1.537754	0.224
LNRAINFALL(-2)	-1062.989	8984.062	-0.118319	0.9115
LNRAINFALL(-3)	8161.382	5481.236	1.488967	0.2107
LNRAINFALL(-4)	22097.17	5867.925	3.765755***	0.0197
LNTEMP	129029.9	35023.31	3.684116***	0.0211
LNTEMP(-1)	58629.88	56930.19	1.029856	0.3613
LNTEMP(-2)	-6816.385	44263.89	-0.153994	0.8851
LNTEMP(-3)	16230.43	40153.9	0.404205	0.7067
LNTEMP(-4)	-113822.5	47111.98	-2.416**	0.0731
LNHUMIDITY	115138.9	31605.7	3.642978***	0.0219
LNHUMIDITY(-1)	24319.46	31482.24	0.772482	0.4829
LNHUMIDITY(-2)	-58683.18	26281.35	-2.232883**	0.0893
LNHUMIDITY(-3)	104720.1	38382.2	1.728335	0.1916
LNHUMIDITY(-4)	50609.02	33024.29	1.532479	0.2002
CointEq	-1.356082	0.345581	-3.924058***	0.0172
Long run estimates				
LNRAINFALL	16419.0662	10845.83517	2.513858**	0.0694
LNHUMIDITY	174107.7347	55630.40637	3.129723***	0.0352
LNTEMP	61391.07798	54288.67339	1.130827	0.3213
LNLUC	-1008.185608	955.173474	-3.055504***	0.0272
C	-1079700.56	291729.9846	-3.701027	0.0208
R-squared	0.968944	Mean dependent var		1024.679
Adjusted R-squared	0.790373	S.D. dependent var		2562.405
S.E. of regression	1173.199	Akaike info criterion		16.74123
Sum squared resid	5505581	Schwarz criterion		17.88312
Log likelihood	-210.3772	Hannan-Quinn criter.		17.09032
F-statistic	5.426089***	Durbin-Watson stat		1.992511
Prob(F-statistic)	0.055807			

* = Significant at 10%, ** = Significant at 5%, *** = Significant at 1%

Source: Data Analysis, 2023.

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