NEXUS OF LAND USE CHANGE, CLIMATE CHANGE, AND MAMMALS' SPECIES IN NIGERIA (1981-2022)

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ABSTRACT
The study analyzed the nexus of land use change, climate change and mammal species in Nigeria. The study adopted a historical survey design using time series data from 1981 to 2022. Data for the study were collected from the archive of the National Bureau of Statistics (NBS), NIMET, Food and Agriculture Organization (FAO) and various editions of the Nigeria National Biodiversity Report. Data for the study were analyzed using descriptive statistics and the Autoregressive Distributed Lag Model (ARDL). The result of the analysis revealed that the mean of land use change, rainfall, temperature and relative humidity were 161334.6sq/km, 1266.28mm, 27.23515^{o}C and 81.3%, respectively, while mammals had a mean value of 262.38 during the period under review. The result of the Augmented Dickey-Fuller (ADF) test for unit root indicated that all the variables were found to be integrated of order zero except temperature which was found to be integrated one and became stationary on first differencing. The result further shows that the mammal species (4.136070) was greater than the upper bound critical value at 0.05 level. Therefore, co-integration exists among the variables which implies a long-run relationship exists among land use change, climate change and mammal species in Nigeria. Based on the confirmation of the long-run relationship among land use change, climate change and mammal species, the ARDL approach was further applied. The result of the ARDL revealed that there is a short and long-run effect of land use change and climate change on mammal species in Nigeria. The study, therefore, recommends that individuals and farming households should adopt better farming practices and afforestation of already deforested areas as these will help conserve ecosystem habitat. Government at both the local, state and federal levels should enact strong laws against activities such as indiscriminate hunting, bush burning and habitat destruction/degradation that lead to climate change which has short and long-run effects on mammal species.

Keywords: Land, biodiversity, climate, humidity, greenhouse and species

INTRODUCTION
Nigeria's economy and society are heavily dependent on land, with agriculture constituting the largest industry and the main source of employment, over 35% of the workforce in Nigeria is employed in the agricultural sector (World Bank, 2024). 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. The majority of the nation's land is now used for urban and industrial purposes rather than for agriculture (Froeser and Schilling, 2019). Olayemi and Adewole (2020) estimate Nigeria's total land area of 923,768 km^2 of which agriculture makes up 42% of the country's total land area. The remaining 58% of the land area is utilized for non-agricultural activities, including urbanization, industry and mining. The overall amount of agricultural land in Nigeria declined from around 38.7 million hectares in 1990 to approximately 35.9 million hectares in 2019; this indicates a loss of roughly 7.2% for the time frame (Food and Agriculture Organization, 2020).

These changes in land use patterns have led to several environmental issues, including climate change and biodiversity in Nigeria (Lutz and Samir 2010; World Bank 2011).
There are about 4600 species of animals today called mammals in the world; despite an astonishing diversity of form and habitat, they all share a long list of characteristics not found in any other organisms (Fadairo *et al.,* 2021). The diversity of Nigeria's wild animals can be attributed to its tropical location, size, and ecosystems (Food and Agriculture Organisation, 2000). Mammals are good bio-indicators of environmental conditions due to their rapid turnover rate, high biotic potential, ability to invade reclaimed areas, and sensitivity to ecological disturbance (Ijeomah *et al.,* 2015).

Nigeria has about 22,000 vertebrate and invertebrate species, and of these, about 0.14% are threatened and 0.22% are endangered (Federal Republic of Nigeria, 2010). The country is one of the global hotspots of primate species, and several of them are found in the Gulf of Guinea forests of Cross River State including three species of monkeys viz: white-throated monkey (*Cercopithecus erythrogaster*), Sclater's guenon (*Cercopithecus sclateri*) and the Niger Delta red colobus (*Procolobus pennantii epieni*), and Cross River gorilla (*Gorilla gorilla diehli*); one of the most endangered gorilla subspecies on earth, with an estimated population of greater than 250 individuals found in protected areas in Cross-River State alone (Emma–Okafor, Ibeawuchi and Obiefuna, 2010).

According to the Federal Republic of Nigeria (2015) Nigeria's wildlife is rapidly declining due to habitat loss and increased pressure from hunters, poachers, and bush burning, and animals such as Giant Eland (*Taurotragus derbianus*), the Giraffe (*Giraffa camelopardalis*), Black Rhino (*Diceros bicornis*), Cheetah (*Acinonyx jubatus*) and Pygmy hippopotamus (*Choeropsis liberiensis*) have disappeared. They further reported that about 10-12 species of primates, such as the white-throated guenon and sclater's guenon, are under serious threat of extinction. Ohimain *et al.* (2014) reported a total of 45 mammalian species belonging to 21 families in Wilberforce Island, Bayelsa state, after the 2012 water flooding events using a questionnaire and survey assessment. Lameed (2009) reported a total of 47 mammalian species in the Kwale forest reserve and the Okpai ecosystem (transit pipeline to Onitsha), Delta state.

Globally, wildlife is faced with severe challenges of endangerment as well as extinction due to habitat destruction and over-exploitation as a result of vast growth in human population and its significant rise in urbanization and high demand for food, especially in the rural areas where the primary source of protein remains animal (Ijeomah *et al.,* 2015). Activities such as excessive hunting and habitat destruction/degradation explain virtually all the impact of humans on endangerment and extinction (Ogundele *et al.,* 2012). Thus, there is a need to study the link between land use change, climate change and mammal species in Nigeria.

METHODOLOGY

Study Area

The study was carried out in Nigeria. Nigeria is located on the Gulf of Guinea in West Africa with a geographical area of 923,768 square kilometers. As of 2024, Nigeria's population is estimated at approximately 219 million people, making it the most populous country in Africa and the seventh most populous globally. This significant increase from the 140 million recorded in the 2006 census is primarily due to a high population growth rate, with projections indicating that Nigeria's population could reach 477 million by 2100. (www.statista.com). Nigeria lies 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 rainforest 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 Nigerian economy. The climate varies with Equatorial in the South, and Tropical in the 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 smallholder). Women make up 60-80 percent of the 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 were 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) and data on mammal 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 were used for the mean of the variables, Bounds Tests from the Autoregressive distributed lag model (ARDL) was used to test the existence of a relationship between the variables while Autoregressive distributed lag model (ARDL) was used to realize 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 mammal species and independent variables (land use change, temperature, rainfall and relative humidity), the ARDL model was employed. This model was constructed as:

$$\text{MAMt¼} = \alpha_0 + \alpha_1\text{LUC} + \alpha_2\text{RAF} + \alpha_3\text{TMP} + \alpha_4 RHD + E_t \dots\dots\dots\dots\dots\dots\dots\dots (1)$$

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

$$\ln\text{MAMt¼} = \alpha_0 + \alpha_{1\ln}\text{LUC} + \alpha_2\ln\text{RAF} + \alpha_3\ln\text{TMP} + \alpha_4\ln\text{THD} + \text{E}_\text{t} \dots\dots\dots\dots\dots (2)$$

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

$$\Delta\ln\mathrm{MAM_t} = \alpha_0 \sum_{k=1}^{n} a_1 \Delta\ln\mathrm{LUC}_{t-k} + \alpha_0 \sum_{k=1}^{n} a_2 \Delta\ln\mathrm{RAF}_{t-k} + \alpha_0 \sum_{k=1}^{n} a_3 \Delta\ln\mathrm{TMP}_{t-k} + \alpha_0 \sum_{k=1}^{n} a_4 \Delta\ln\mathrm{RHD}_{t-k} + \emptyset\mathrm{ECM}_{t-1} + \mathrm{E}_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where: MAM is the values of mammal species, LUC, RAF, TMP and RHD are the values of land use change, rainfall, temperature and relative humidity which will be 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 ∅ 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

3.1.1 Mean of Land Use Change, Climate Change and Mammal Species in Nigeria

The mean of land use change, climate change and mammal species in Nigeria is presented in Table 1. The result showed that land use change ranged between 139975.2 and 171421 square kilometres between 1981-2022 in Nigeria, with a mean of 161334.6 square kilometres. The high diversity between the maximum and minimum land use change and high mean may be attributed to urbanization and increase in agricultural activities which put Nigeria's land into several uses to meet human wants. Furthermore, the result revealed that climate change indicators specifically rainfall at it maximum of 1596mm and a minimum of 1046mm with a mean of 1266.28 millimetres, the temperature had a maximum of 27.8575^{o}C and a minimum of 26.1882^{o}C with a mean of 27.23515^{o}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 the accumulation of inorganic substances in the atmosphere.

More so, the result further shows that mammal species have a maximum of 294.00 and a minimum of 238.00 with a mean of 262.38 species during the period under review. This revealed that there is a great decline in the mean of mammal species in Nigeria during the period under study. This could be attributed to several human activities such as hunting, fishing, bush burning, and deforestation among others, which leads to encroachment into the natural habitat of several biodiversity causing displacement, reduction and even extinction of several mammal species in the country. This is implied by 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.

Table 1: Summary of Statistics of Variables

	MAM	LUC	RHD	RAF	TMP
Mean	262.38	161334.6	81.3	1266.28	27.23515
Maximum	294.00	139975.2	85.0	1596	27.8575
Minimum	238.00	171421	78.4	1046	26.1882
Std. Dev.	22.98	10917.14	1.746137	103.4055	0.432165
Skewness	0.594	-0.844569	0.079407	0.412105	-0.747655
Kurtosis	-1.987	2.104901	2.076191	4.348147	2.771644
Jarque-Bera	17.32195	6.242918	1.501017	4.265404	3.908834
Probability	0.000173	0.044093	0.472126	0.118517	0.141647
Sum	2099	6614720	3334.732	51917.5	1116.641
Sum Sq.	554423	4.77E+09	121.9597	427707.5	7.470649
Observations	41	41	41	41	41

RMD = relative humidity; LUC = Land use change; MAM = Mammal species; RAF= Rainfall; TMP = Temperature.
Source: Data Analysis, 2023

3.1.2 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 (mammal, land use change and rainfall) were found to be integrated of order zero except temperature, which was 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.

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

Variable	Level				First Difference				
	ADF	1%	5%	10%	ADF	1%	5%	10%	Inference
MAMMAL	-6.0110***	-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

3.1.3 Bounds Test for Long-Run Relationship between Land Use Change, Climate Change and Mammal Species

In the first step of the ARDL analysis, the presence of long-run relationships was tested as stated in the methodology. A 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 cointegrated, and the regression is no longer spurious. The result of the bounds test for mammal species (Table 3) shows that the computed statistics 4.136070 is greater than the upper bound critical value, 4.01 at 0.05 level. Therefore, co-integration exists among the variables. This implies that a long-run relationship exists among mammal species, land use change, temperature, humidity and rainfall. This agrees 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 5. Bounds Test for Co-integration between Land Use Change, Climate Change and Mammal Species

Test statistics	Value	Significance (%)	1(0)	1(1)
F	4.136070	10	2.45	3.52
K	4	5	2.86	4.01
		2.5	3.25	4.49
		1	3.74	5.06

Source: Data Analysis, 2023.

3.1.4 Effects of Land Use Change and Climate Change on Mammal Species in the Short and Long Run

Based on the confirmation of the long-run relationship among land use change, climate change and mammal species, the ARDL approach was further applied. The result of the ARDL as shown in Table 4 indicated that in the long run, the coefficient of land use change (-60.810337) was negative and statistically significant at 1% significance level. This implies that a unit change in land use will decrease mammal species by 60.810337 units in the long run *ceteris paribus*. More so, the coefficient of rainfall (1281.210806) was positive and statistically significant at a 5% probability level. This implies that a unit increase in rainfall will increase mammal species by 1281.210806 units in the long run *ceteris paribus*. Therefore, there is a long-run effect of land use and climate change on mammal species in Nigeria. The short-run result indicated that the conditional error correction term or speed of adjustment, ECM (-1) is negative (-1.736945) and statistically significant. The result implies that 173.69% 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 1.736945 of the disequilibrium is removed immediately in each period).

Table 4. Short and Long Run effects of land use change and climate change on mammal's species in Nigeria

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
Short run estimates				
MAMMALS_SP(-1)	0.255256	0.487923	0.523149	0.6285
MAMMALS_SP(-2)	-0.274811	0.454023	-0.605281	0.5777
MAMMALS_SP(-3)	0.081167	0.466103	0.174139	0.8702
MAMMALS_SP(-4)	-0.798557	0.469871	-1.699525	0.1644
LNLUC	30.82425	27.83746	1.107294	0.3303
LNLUC(-1)	-53.6559	46.64204	-1.150376	0.3141
LNLUC(-2)	-53.04511	48.89319	-1.084918	0.339
LNLUC(-3)	-92.61276	48.9465	-2.892144***	0.0479
LNLUC(-4)	62.8653	41.23016	1.524741	0.202
LNRAINFALL	215.8268	387.8658	0.556447	0.6076
LNRAINFALL(-1)	-21.06422	454.1369	-0.046383	0.9652
LNRAINFALL(-2)	680.3137	520.8962	1.306045	0.2616
LNRAINFALL(-3)	742.4084	460.7005	1.611477	0.1824
LNRAINFALL(-4)	607.9081	315.4182	1.927308*	0.1262
LNTEMP	3553.236	2197.146	1.617205	0.1811
LNTEMP(-1)	-975.8679	2396.927	-0.407133	0.7048
LNTEMP(-2)	-2709.907	1929.592	-1.404394	0.2329
LNTEMP(-3)	743.2568	2412.354	0.308104	0.7734
LNTEMP(-4)	-1731.982	2072.792	-0.835579	0.4504
LNHUMIDITY	4275.529	1926.694	2.219102**	0.0907
LNHUMIDITY(-1)	1219.008	1522.244	0.800797	0.4681
LNHUMIDITY(-2)	-1221.814	1608.023	-0.759824	0.4897
LNHUMIDITY(-3)	1153.372	2109.897	0.546649	0.6137
Coint Eq	-1.736945	0.860866	-2.517673**	0.0895
Long run estimates				
LNLUC	-60.810337	44.363697	-3.370384***	0.0245
LNRAINFALL	1281.210806	530.313372	2.41595**	0.0731
LNTEMP	-645.538337	2327.401953	-0.277364	0.7952
LNHUMIDITY	3123.930348	2064.530124	1.513144	0.2048
C	-20387.48629	10781.91016	-1.890897	0.1316

R-squared	0.912904	Mean dependent var	35.42857
Adjusted R-squared	0.712103	S.D. dependent var	88.3748
S.E. of regression	67.76087	Akaike info criterion	11.03822
Sum squared resid	18366.14	Schwarz criterion	12.18011
Log likelihood	-130.5351	Hannan-Quinn criter.	11.38731
F-statistic	2.822237***	Durbin-Watson stat	2.069801
Prob(F-statistic)	0.529818		

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

Source: Data Analysis, 2023

This implies that a change in land use will decrease mammal species by 92.61276 units *ceteris paribus*. Similarly, the coefficient of rainfall (607.9081) was positive and statistically significant at a 10% likelihood level during the fourth lagged period. By implication, a unit increase in rainfall will increase mammal species by 607.9081 units in the short run *ceteris paribus*. Furthermore, the coefficient of relative humidity (4275.529) was positive and statistically significant at a 5% probability level. This implies that a unit increase in relative humidity will increase fish species by 4275.529 units *ceteris paribus*. This shows the existence of the short run effect of land use change and climate change on fish species in Nigeria. This could be attributed to some human activities that lead to the accumulation of greenhouse gases in the short run which destroys the ecosystem in the long run leading to the destruction of habitat and extinction. This gives credence to the study by Akpan *et al.* (2015) reported that globally, mammals are faced with severe challenges of endangerment as well as extinction due to habitat destruction and over-exploitation; Ayanlade *et al.* (2018) opined that human activities such as excessive hunting and habitat destruction/degradation are leading to climate change which impacts endangerment and extinction of mammals in the long run.

4.0 CONCLUSION AND RECOMMENDATIONS

The study analyzed the nexus of land use change, climate change and mammal species in Nigeria (1981-2022). The study identified a co-integration between land use change, climate change, and mammal species, suggesting a long-run relationship among these variables. As a result, the conditional error correction model, utilizing the ARDL approach, was estimated, revealing both long-run and short-run effects of land use and climate change on mammal species. The study therefore recommended that:

i. Individuals and farming households should adopt better farming practices and afforestation of already deforested areas as these will help conserve ecosystem habitat.

ii. 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 mammals' species.

iii. There should be increased public awaresness campaigns highlighting the importance of mammals, as this would educate citizens, particularly those in rural areas, on the necessity of protecting their habitats.

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