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WOOD CHARCOAL PRODUCTION, CARBON EMISSION, AND POVERTY ALLEVIATION IN NIGERIA

[A]Shaibu, U.M., [B]Sale, F.A. and [C]Adejoh, E.

[a]Department of Agricultural Economics and Extension, Faculty of Agriculture, Prince Abubakar Audu University, Anyigba, Nigeria & Department of Agricultural Economics and Agribusiness, University of Ghana, Accra-Ghana
[b]Department of Forestry and Wildlife, Faculty of Agriculture, Prince Abubakar Audu University, Anyigba, Nigeria
[c]Department of Public Administration, Salem University, Lokoja, Nigeria
Corresponding E-mail: shaibu.um@ksu.edu.ng

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Abstract: This study applied an econometric technique to establish the nexus of charcoal production, carbon emission, and poverty alleviation in Nigeria. The data sources include the World Development Indicators (World Bank's WDI), the FAOSTAT, and the AFDB Socioeconomic Profile Database from 1990-2022. The data obtained were analysed using descriptive statistics and the Autoregressive Distributed Lags (ARDL) Bounds Testing Approach. The result shows that the variables have a normal distribution. The country's forest area has declined during the period under study. Wood charcoal production showed an increasing trend over the same period. The ADF test suggests that the variables have stable statistical properties over time.

The ardl bound test for cointegration confirmed a long-run economic association between foresty, climate change, and poverty. The result further shows a long-lasting impact of past extreme poverty levels on current extreme poverty. The quantity of wood charcoal produced in the current year, when lagged by one, two and three years was found to decrease the number of persons in extreme poverty. In the long run, increased carbon emissions and poverty were directly related. The coefficient on inflation in both short and long-run models suggests that inflation exacerbates extreme poverty. The coefficient of error correction model (ECM) was found to be less than 1, highly significant and negatively signed as expected (-0.750233). The

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post-estimation tests validated and verified the estimates obtained from the ARDL model. The study recommended that the government should promote clean energy adoption, ensure controlled deforestation through reforestation, stabilize prices, and integrate poverty-environment-climate efforts to foster inclusive sustainable development in Nigeria.

Keywords: ARDL, Climate Change, Forestry, Poverty, Wood Charcoal Production, SDGs

INTRODUCTION

Wood charcoal production is a major source of carbon emissions and deforestation, leading to environmental degradation and climate change [1]. It is however a primary means of energy for both household and industrial use in many developing countries, including Nigeria [2,3,4]. Its production and consumption patterns directly affect household welfare, livelihoods, and socio-economic development.

Nigeria's continued reliance on wood charcoal as a primary source of household energy has implications for both environmental sustainability and poverty alleviation efforts [5,6]. Despite its widespread use, limited empirical research exists on the effects of wood charcoal production and carbon emissions on the socio-economic well-being of individuals. This study seeks to move the knowledge frontier by examining the relationship between wood charcoal production, carbon emissions, and poverty alleviation outcomes in Nigeria. Specifically, it aims to investigate how variations in wood charcoal production levels and associated carbon emissions impact poverty at the macro level. The use of econometric analysis techniques such as the Autoregressive Distributed Lags (ARDL) model, and leveraging available data sources, makes this study stand out.

The outcome of this study provides evidence-based facts for policymakers and stakeholders seeking to promote sustainable energy practices, mitigate environmental degradation, and alleviate poverty in Nigeria. Additionally, this study addresses multiple UN SDGs, including Goal 1 (No Poverty), Goal 7 (Affordable and Clean Energy), and Goal 13 (Climate Action) [7].

METHODOLOGY

This study covered Nigeria, a sub-Sahara African country located between 3^0 and 14^0E latitudes and 4^0 and 14^0N Latitudes. This study adopted the longitudinal research research design. Time series data type (1990-2022) on relevant variables of interest were obtained through the databases of the World Bank, Food and Agriculture Organization Statistics (FAOSTAT), and the Africa Development Bank (AfDB). The data were described using charts and simple statistics. The null hypothesis of the autoregressive unit root was tested using equation (1).

$$S_t = \alpha_0 + \beta_1 S_{t-1} + \Sigma_{i=1}^{k} \lambda_i \Delta S_{t-1} + \varepsilon i \tag{1}$$

Where;

Δ = the first–difference operator; S = the series under consideration, $\alpha_{0,}$ β_s and λ1 are parameters to be estimated, ε_i = the error term.

The "Autoregressive Distributed Lags" (ARDL) Bounds Testing model was used to determine the effect of forestry and climate change on poverty as specific in equation (2). Relevant post-estimation tests were conducted.

$$POV_t = f(FOR, CLC, PGR, INF)] \tag{2}$$

$$\Delta \ln POV_t = \beta_0 + \beta_1 \ln FOR_{t-1} + \beta_2 \ln CLC_1 t_1 + \beta_3 \ln PGRt_1 + \beta_4 \ln INFt_1 + + \Sigma_{i=1}^{k} \alpha \Delta \ln POV_{t-1}$$
$$+ \Sigma_{i=1}^{k} \alpha_2 \Delta \ln FOR_1 t_1 + \Sigma_{i=1}^{k} \alpha_3 \Delta \ln CLCt_1 + \Sigma_{i=1}^{k} \alpha_4 \Delta \ln PGRt_1 + \Sigma_{i=1}^{k} \alpha_5 \Delta \ln INFt_1 + \mu_{it} \tag{3}$$

Where:

POV_t = Poverty rate - measured as the headcount ratio below the international poverty line (number)

FOR_t = Forestry, proxied as wood charcoal production (t)

CLC_t = Climate change, proxied as CO_2 emission (mt)

PGR_t = Population growth rate

INF_t = Inflation rate

The first part of the right-hand side of equation (2) with parameters β_1 to β_5 represents the long-run parameters of the model and the second part with parameters α_1 to α_6 represents the short-run dynamics of the model.

The series in equation (3) underwent a bound co-integration test using the ARDL method as in equation (4):

$$\Delta \ln y_{it} = \lambda_0 + \sum_{i=1}^{n} \lambda_i \Delta \ln y_{it-1} + \sum_{j-1}^{p} \beta_j \ln\, y_{it-1} + \varepsilon_{it} \tag{4}$$

Acceptance Principle: F-statistic should exceed the critical values at both the lower and upper bounds. This indicates the presence of co-integration (long-run relationship) among the variables.

RESULTS AND DISCUSSION

Descriptive Statistics of the Series

The descriptive statistics of the series used in this study are presented in Table 1.

Table 1: Descriptive Statistics

	FOR (tons)	*POV (number)*	*CLC (mt)*	*PGR (%)*	*INF (%)*
Mean	3579160	61876411	97503036	2.597366	16.61206
Std. Dev.	832331.1	6354757	13384781	0.106715	0.106715
Kurtosis	1.842915	1.892822	2.073181	1.980758	1.980758
Skewness	-0.087256	-0.225616	0.158023	-0.169094	-0.169094
Jarque-Bera	1.882787	1.965498	1.318460	1.585684	1.585684
Probability	0.390084	0.374281	0.517250	0.452557	0.452557

Source: Author's Computation from Secondary Data Number of Obs. = 33
FOR = wood charcoal production, POV = population of individuals in extreme poverty, CLC = CO_2 emission, PGR = population growth rate, INF = inflation. rate

From Table 1, the average values show the central tendency of each variable, while the standard deviation measures the variation in data points around the mean. Wood charcoal production, poverty, population growth rate, and inflation are slightly left-skewed distribution, while carbon emission's skewness value indicate a slightly right-skewed distribution. The Jarque-Bera test confirms the series' normal distribution based on skewness and kurtosis. The reported probabilities (p-values) indicate whether the null hypothesis of normality is rejected or not. From Table 1, the p-values are relatively high ($p>0.05$), suggesting that the variables do not significantly depart from normality at the conventional significance level of 0.05, hence, the included variables have a normal distribution.

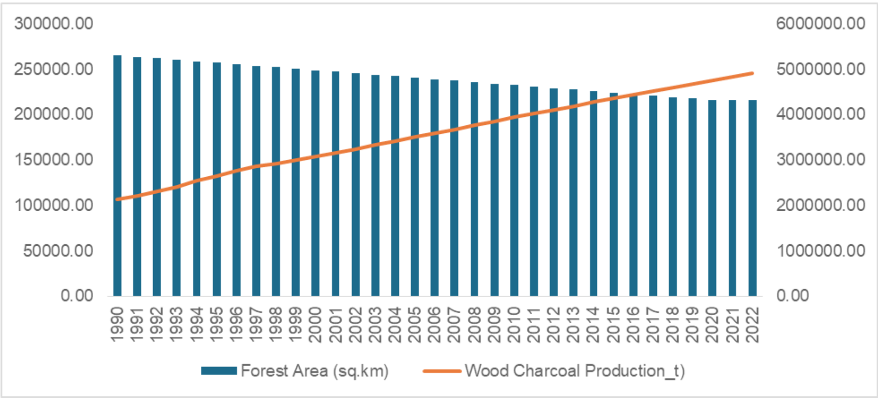
Trend of Nigeria's Forest Area and Wood Charcoal Production, 1990-2022

The trend of forest area and wood charcoal production in Nigeria is shown in Figure 1. The result shows that the country's forest area has declined during the period under study. This trend suggests potential deforestation or degradation of forested areas over time. The result of forest area may indicate environmental challenges such as urbanization, agricultural expansion, or unsustainable logging practices. The result agrees with a study by the FAO [8] on the global forest assessment where it reported a 5% annual rate of deforestation. The United

Nations [9] attributed Nigeria's declining forest resources to deforestation from agriculture, industrial development, and overexploitation.

Wood charcoal production (Figure 1) shows an increasing trend over the same period. Despite the noticeable decline in forest area, the production of wood charcoal has steadily risen, this could be due to factors such as increased demand for charcoal as a fuel source, advancements in charcoal production technology, or the utilization of alternative sources of wood for charcoal production.

Figure 1: Trend of Nigeria's forest area and wood charcoal production, 1990-2022



Unit Root Test

The presence of unit root in the series was assessed using the ADF statistics. The presence of a unit root is an indication that a time series is non-stationary; its statistical properties such as the mean and variance change over time [10]. Table 2 shows that all the included series (variables) exhibit statistically significant ADF test results after the first differencing (Δ). This suggests that the variables have stable statistical properties over time, which is important for further time series analysis and modelling.

Table 2: Outcome of the ADF Test

Variables	*Augmented Dickey-Fuller Test*				*Decision*
	ADF stat	*Prob.*	*Critical value @ 5%*	*Order*	
POV	-5.749029	0.0000**	-2.960411	I(1)	Stationary
FOR	-3.308023	0.0231**	-2.960411	I(1)	Stationary
CLC	-5.805876	0. 0000**	-2. 960411	I(1)	Stationary
PGR	-8.091523	0.0000**	-2.641672	I(1)	Stationary
INF	-4.385196	0.0024**	-2.998064	I(1)	Stationary

Source: Authors' Computation, 2024 using E-Views 11 ** ➔ figures are significant at 5%.

Effects of Wood Charcoal Production and Carbon Emission on Poverty Alleviation

According to Shrestha and Chowdhury [11], the ARDL bounds testing procedure does not necessitate testing for unit roots because it is applicable irrespective of the level of stationarity of the series - purely integrated of order zero (I(0)), order one (I(1)), or both. However, the Augmented Dickey-Fuller (ADF) statistic was adopted in this study to ensure the series are integrated at orders zero and/or one, and none of them are integrated at orders two or beyond. According to Pesaran *et al.* and Shaibu *et al.* [12,13], the computed F-statistics are acceptable and valid only for series that are I(0) or I(1). As shown in Table 2, none of the variables were integrated.

Cointegration Analysis

The ARDL Bound Cointegration test was used to test the long-run relationship among poverty, wood charcoal production, and carbon emissions, as presented in Table 3.

Table 3: Outcome of ARDL bound test

Critical Value Bounds	*I(0) Bound*	***I(1) Bound***	***K***
10%	2.2	3.09	4
5%	2.56	3.49	4
1%	3.29	4.37	4
F-statistic = 6.611417			

Source: Authors' Computation, 2024

The calculated F-value (Table 3) exceeds the critical value at the upper bound, indicating co-integration among the series. This suggests a cointegration or long-run association between the series. Based on Table 3, the outcome of the short-run and the long-run relationship between poverty, forestry, and climate change are presented in Table 4. The depth of poverty in the current year adjusted significantly with poverty in the previous two years. This suggests a long-lasting impact of past extreme poverty levels on current extreme poverty. This finding is in tandem with Yoshida *et al.* [14] who reported that the end of global extreme poverty is not in sight, and ending it in 2030 is very challenging. The negative coefficient suggests that extreme poverty tends to exhibit persistence over time, with past levels influencing current outcomes. This phenomenon aligns with the concept of poverty traps, where individuals or regions find it difficult to escape poverty due to various socioeconomic factors.

The coefficient of wood charcoal production was negatively signed and significant at 5% and 10% levels of significance in the current year and when lagged by one, two, and three years. The negative sign is in line with the *a priori* expectation. It implies an inverse relationship between the quantity of wood charcoal produced in the current year, when lagged by one, two and three years and the number of persons in extreme poverty in the country. The short-run model also shows that the coefficient of carbon emission is negatively signed and significant at the 1 per cent level of significance. This implies that carbon emissions and poverty in the country are inversely related in the short run. The negative coefficient on CO_2 emissions in the short run suggests that higher emissions are associated with lower extreme poverty. This might seem counterintuitive, as increased emissions should increase poverty levels. However, the long-run equation shows that increased carbon emission will increase the number of persons in extreme poverty.

The inflation coefficient was positively signed and significant at 1% and 5% significance levels during the short-run and long-run. This implies that inflation and the number of individuals in extreme poverty in both the short and long run are directly related. The positive coefficients on inflation suggest that inflation exacerbates extreme poverty, which aligns with economic theory indicating that high inflation erodes purchasing power, particularly affecting the poor. As prices rise faster than incomes, vulnerable population, particularly those reliant on fixed incomes or social welfare programs, experience a decline in real purchasing power, pushing them deeper into poverty.

Table 4: Estimates of the short-run and long-run relationships

Variables	*Coeff.*	*Std. Error*	*Prob.*
Short-run			
D(LN_POV_POP(-1))	-0.082716	0.129426	0.5339
D(LN_POV_POP(-2))	-0.461271	0.134966	0.0046***
D(LN_WOOD_CHARCOAL)	-5.717703	2.104187	0.0176**
D(LN_WOOD_CHARCOAL(-1))	-4.223409	1.981490	0.0527*
D(LN_WOOD_CHARCOAL(-2))	-3.780817	1.947960	0.0743*
D(LN_WOOD_CHARCOAL(-3))	4.710206	1.683771	0.0151**
D(LN_CO2_EMISSION)	-0.389467	0.119139	0.0061***
D(LN_INFLATION)	0.037970	0.010350	0.0028***
D(LN_POP_GROWTH)	-1.510290	0.872451	0.1071

D(LN_POP_GROWTH(-1))	-1.829737	0.874836	0.0567
CointEq(-1)	-0.750233	0.101230	0.0000***
Cointeq = LN_POV_POP - (-0.4252*LN_WOOD_CHARCOAL + 0.0395*LN_CO2_EMISSION + 0.1320*LN_INFLATION -1.0613*LN_POP_GROWTH + 24.6495)			
Long Run Coefficients			
LN_WOOD_CHARCOAL	-0.425228	0.286771	0.1620
LN_CO2_EMISSION	0.039549	0.248539	0.8760
LN_INFLATION	0.131980	0.047129	0.0150**
LN_POP_GROWTH	-1.061272	0.502790	0.0547*
C	24.649466	7.793047	0.0075***

Source: Authors' Computation, 2024. ***, **, and * = coefficient significant at 1%, 5%, and 10% level of significance respectively.

The coefficient of error correction model (ECM) was found to be less than 1, highly significant and negatively signed as expected (-0.750233); satisfying the condition of being negative and less than 1. The value of the ECM implies that any distortion of the series in the short run will be restored at the speed of 75% per annum.

Post-estimation tests (diagnostic and stability tests of the ARDL model)

Post-estimation tests, including heteroskedasticity and Jarque-Bera tests as shown in Table 5, were conducted. The findings indicate that the probability value exceeds 5% ($p > 0.05$), supporting the acceptance of the null hypothesis of no heteroskedasticity. Additionally, Table 5 reveals that the null hypothesis of multivariate normal distribution was accepted at the 5% significance level ($p > 0.05$), indicating that the ARDL residuals demonstrated normal distribution.

Table 5: Diagnostic tests of the ARDL models

Diagnostic	*F – stat.*	*P – value*
Breusch -Godfrey (Serial Correlation LM test)	0.789552	0.4782
Breusch-Pagan-Godfrey (Heteroskedasticity test)	0.987808	0.5141
Jarque-Bera (Normality test)	2.527198	0.282635

Source: Author's Computation using E-Views 11

The structural stability of the model was assessed using the CUSUM (Cumulative Sum test) and CUSUM squares (Cumulative Sum of Squares residual) tests, as recommended by Brown *et al.* [15]. Essentially, if the cumulative sum plot exceeds the 5% critical lines, it indicates instability in the parameter estimates. Figures 3 and 4 display the CUSUM and CUSUM of Squares residual tests for the ARDL model, respectively. The findings reveal that the estimated parameters of the equation in the ARDL model remain constant and stable

Figure 2: CUSUM Stability Test for the Model

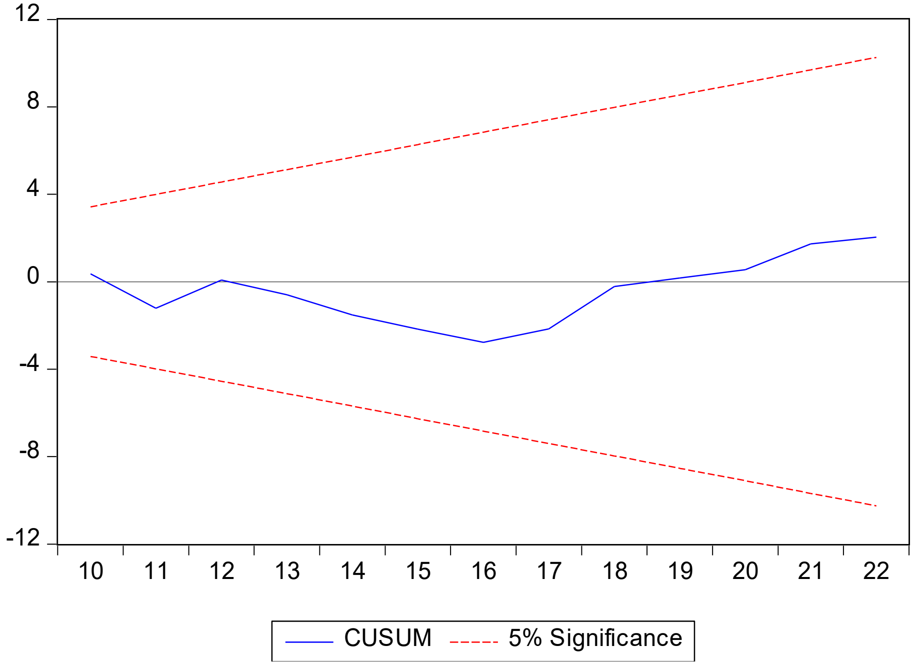
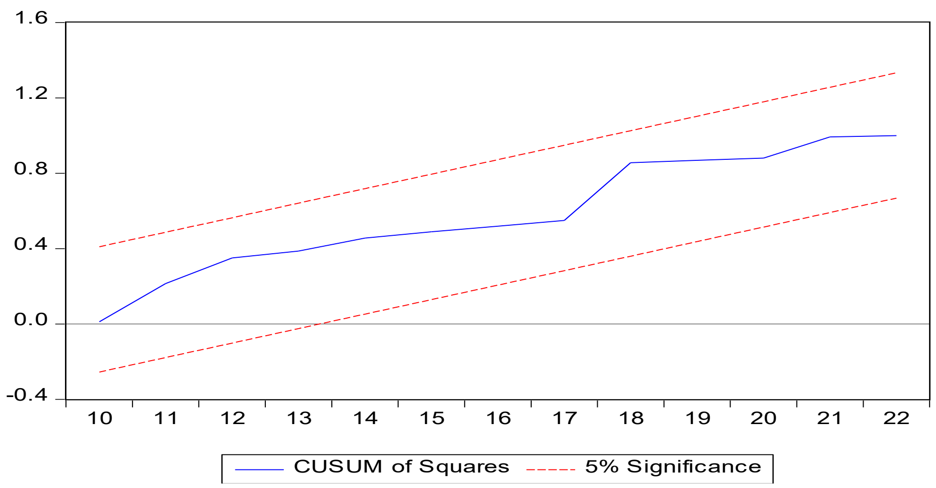


Figure 3: CUSUM-SQ Stability Test for the Model



CONCLUSION

The analysis reveals a significant long-run economic association between wood charcoal production, carbon emissions, and poverty. While short-term increases in wood charcoal production and carbon emissions appear to correlate with reductions in extreme poverty, sustained carbon emissions may exacerbate poverty over time. Furthermore, the study underscores the negative consequences of inflation on poverty in both the short and long run. The outcome of the post-estimation tests lend credibility to the study's findings.

The policy recommendations are:

1. The government or relevant stakeholders should implement policies to incentivize the adoption of clean and renewable energy sources, reducing reliance on wood charcoal production for cooking and heating.
2. The government and relevant stakeholders should implement measures to mitigate deforestation and carbon emissions, such as sustainable forest management practices and reforestation efforts.
3. The government should prioritise policies aimed at maintaining price stability and controlling inflation to mitigate its adverse effects on poverty.
4. Stakeholders should adopt integrated approaches that address the interconnected challenges of poverty, environmental degradation, and climate change, aligning with the Sustainable Development Goals (SDGs) to promote inclusive and sustainable development in Nigeria.

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