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# An Econometric Analysis of Wood Charcoal Production in Nigeria (1961-2021)

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**Abstract:** The high rate of charcoal production in Nigeria is a major concern to environmentalists because of its short and long term implications, some of which are clearly evident in greenhouse gas emission, deforestation, soil quality degradation and biodiversity loss. This study assesses the trend of charcoal production in Nigeria from 1961 to 2021, with the aim of highlighting its implications for sustainable forest management among others both now and in the far future. Also predicts future movement in production volume of wood charcoal in Nigeria up to 2050. Data was time series data on quantity of wood charcoal produced in Nigeria obtained from FAOSTAT database. The result of the analysis shows that there was an increase of 30.69% in production from 1961 to 1970. The increasing rate of production continued by 1993, the rate of production of charcoal in Nigeria rose to 200.13% from what it was in 1961. The rapid rise in production could be attributed to rise in population and expansion of industrial enterprises, like bakeries, which use charcoal as source of energy. By 2020, the production of charcoal in Nigeria increased by more than five hundred percent (515.97%) from the 1961 base year. This may be attributed to high cost of cooking fuels coupled with the incessant scarcity of the product which makes it become important to provide an alternative means of energy for the sustenance of the people.

**Keywords:** Charcoal, Environment, Deforestation, Production, Sustainability.

## Introduction

Inadequate energy production and supply is one of the many problems facing the developing countries. In order to meet their energy need, rural and some peri-urban people in these countries usually resort to the use of biomass especially charcoal to generate energy for domestic and commercial uses. Nigeria is one of the major producers of charcoal in Africa (Lansu *et al*., 2020). According to FAO (2022), about forty million Nigerians are engaged directly in fuel wood collection and charcoal production, thereby providing an estimated 530,000 full-time equivalent direct jobs for the citizens. It was also reported that additional 200,000 people, mostly also full-time, provided transport services for retail and wholesale trade in the fuelwood and charcoal production value chain in the country.

The high rate of charcoal production in Nigeria is a major concern to environmentalists because of its short and long term implications some of which are clearly evident in greenhouse gas emission, soil quality degradation and biodiversity loss. Ajadi *et al.* (2012) posited that charcoal production in Nigeria results in different forms of problems some of which are environmental pollution arising from smoke, deforestation as a result of tree harvest and erosion which exposes the soil to direct sunshine. It also leads to reduction in the soil fertility and health problems to people around the production site. Several factors contribute to the increase in charcoal production in Nigeria namely: ease of transportation compared to fuelwood (which is another form of bio-energy) little space that is required for storage and its non-susceptibility to insect or fungi attack (Kaale, 2005). Besides, charcoal is known to generate more heat and

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to contain twice the energy of ordinary fuelwood which makes it cook faster than most other biomass fuel such as kerozene. FOSA (2001) noted that charcoal is energy-dense light-weight (on energy value per weight), easy-to-handle, and convenient fuel, which burns without producing much smoke other than during lighting. These attributes make it a desired fuel especially in urban and peri-urban areas. According to Kambewa *et al.* (2007), charcoal consumption is higher among individuals and families that have low income, with charcoal and fuel wood accounting for three-quarters of their total household energy expenditure.

Charcoal and fuelwood have been identified as major sources of cooking energy by households in both rural and urban areas of Nigeria. Wood charcoal enterprise is one of the major components of the wood fuel industry and it is the main source of domestic fuel in urban areas, accounting for more than half of the domestic energy consumption (Sasu, 2022; Foley, 2022). Due to the steady increase in the demand for charcoal as a result of different industrial revolutions and urbanization, production of charcoal has been largely carried out with an unsustainable approach. A large percentage of charcoal produced in Nigeria finds its way to the European market serving countries like UK, Germany, Spain. Denmark, France etc (UN, 2005).

Charcoal is mostly produced in rural areas as an income generating activity and usually sold into the more urban areas where firewood collection is less feasible and people have more purchasing power to buy fuel.  In Nigeria, charcoal is available in all the geopolitical zones of the country as many local communities have perfected the technology of charcoal production. Charcoal production normally involves the cutting down of trees which are later subjected to the technology of its production. Some of the tree species that are commonly used for charcoal production in Nigeria are Prosopis *africana*, *Anogeissus leiocarpus*,*Vitellaria paradoxa*, *Burkia africana*,*Pterocarpus erinaceus*, *Khaya senegalensis*, *Parkia biglobosa*, *Isober linadoka*,, *Afzelia africana*, *Pericopsis laxiflora*, *Khaya senegalensis*, *Isober linadoka* , *Parkia biglobosa*, *Afzelia africana*, *Pericopsis laxiflora*, and *Terminalia aglaucoscens.* Usually hardwood species like Acacia, Mangroves, Oaks and Prosopis are preferred for Charcoal production (Ogara, 2011).

According to Awoyemi *et al.* (2006), some known charcoal depots  are found in places like Oyo, Nassarawa, (Kwara ,Kogi Niger, Plateau and Kaduna States and several others, as shown in Fig.1, where quality charcoal are produced.

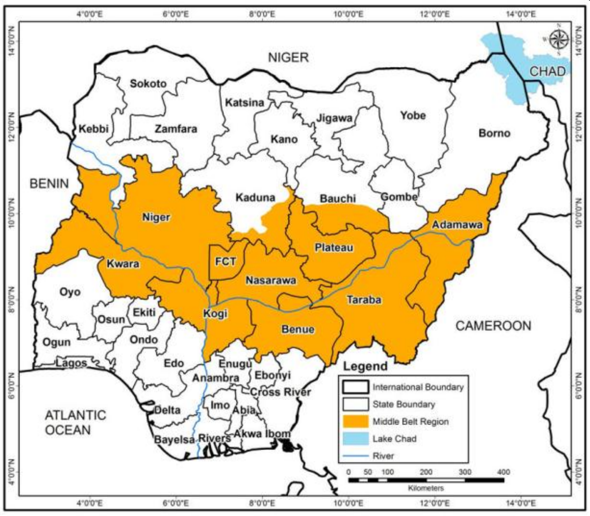


**Figure1:** Map of Nigeria showing regions where charcoal is produced.

Data on charcoal production in Nigeria shows a steady increase. This study takes a critical look at the trend of charcoal production in Nigeria with the aim of highlighting its implications for sustainable forest management among others both now and in the far future. In view of this, the study was designed to examine the trend in wood charcoal production in Nigeria from 1961 to 2021 and to also predict future movement in production volume of wood charcoal in Nigeria up to 2050.

This study is divided into three sections namely: introduction followed by research methodology, results and discussions and finally by conclusion and recommendations.

## Materials and methods

Data for this study are time series data on quantity of wood charcoal produced in Nigeria which were obtained from FAOSTAT database and covered from 1961 to 2021. Time series model is commonly used when using past movement of variables to predict future values. Away from structural models that use model at hand to forecast, time series models are not necessarily rooted on economic theory. The reliability of the estimated equation is normally based on out-of-sample forecast performance as first observed by Stock & Watson (2003). Times series are mostly expressed by Autoregressive Moving Average (ARMA) models which were first produced by Slutsky (1927) and Wold (1938) as expressed in the following equation:

$$Y_t = e_t - \theta_1 e_{t-1} - \theta_2 e_{t-2} - \theta_3 e_{t-3} \ldots\ldots - \theta_q e_{t-q} \qquad (1)$$

Such a series is referred to as a moving average of order q, with the nomenclature MA (q); where Yt is the original series and “et” as error term in the series. As Yule (1926) suggested, the autoregressive process of the moving average series can be expressed as:

$Y_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \phi_3 Y_{t-3} + \ldots\ldots + \phi_p Y_{t-p} + e_t$ (2)

It is assumed that t, is independent of $Y_{t-1}$, $Y_{t-2}$, $Y_{t-3}$, ..$Y_{t-q}$.

Here, we are trying to fit the Box-Jenkins Autoregressive Integrated Moving Average (ARIMA) model, which is the generalized model of the non-stationary ARMA model represented by ARMA (p, q) and this can be written as:

$Y_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \phi_3 Y_{t-3} + \ldots + \phi_p Y_{t-p} + e_t - \theta_1 e_{t-1} - \theta_2 e_{t-2} \ldots.. - \theta p e t - p$ (3)

Where, Yt is the original series, for every t, we assume that is independent of: Yt−1, Yt−2, Yt−3, …Yt−p.

Forecasts from Autoregressive Integrated Moving Average (ARIMA) models are optimal forecasts. This means that no other univariate forecasts have a smaller mean-squared forecasts error (Shumway & Stoffer, 2010). ARIMA model was popularized in the landmark work by Box & Jenkins (1976). Therefore, the Autoregressive Integrated Moving Average (ARIMA) models which is usually known as the Box-Jenkins approach has become popular, especially with the advent of computer (Gooijer *et al*., 2006). ARIMA models are useful in building sufficient number of samples which Box and Jenkins suggested that the minimum sample size should be 50 observational data points. The first step to using the Box-Jenkins model is to determine whether the time series data used are stationary or not stationary.

Test for data stationarity was performed using a unit root test by Phillips-Perron (PP) approach. Data is stationary if the absolute value of the PP Test Statistic is greater than absolute value of t statistic with the critical value at $\alpha = 1\%$. If the data is not stationary, it is made stationary by doing logarithm transformation and differencing. The model is then estimated when the data is stationary. Data were analyzed using Autoregressive Integrated Moving Average (ARIMA) method, popularly known as the Box-Jenkins Approach and the statistical package used in the analysis was Eviews12 (Student Lite Version). The best ARIMA model was then used to predict the quantity of wood charcoal production up to year 2050.

## Results

### Result of the Unit Root Test

Stationarity or unit root test was performed using Phillips-Perron unit root test approach. This test was used to ascertain whether a time series is stationary or not. The null hypothesis is that the observed variable is non-stationary, relative to the alternative that states that the variable is stationary. The tests results are shown in Table 1 in logarithm form. From the results, it can be observed that the series has unit root at its level form but became stationary after second differencing. Therefore, the order of integration is two and the variable is said to be integrated of the second order. That is I (2). This, therefore, indicates that ARIMA is the appropriate methodology to be applied as opposed to ARMA. The result is therefore in line with earlier studies by Idumah & Awe (2017) and Idumah *et al*. (2020) where time series data had unit roots and became stationary after differencing.

**Table1:** Phillips-Perron Unit Root Test

| Variable | Coefficient (Level form) | Decision | Coefficient at Second Differencing) | Decision |
|---|---|---|---|---|
| LCharcoal Prod. | 3.073947 | Non-stationary | -3.773929 | Stationary |

Eviews 12 statistical package output; critical value at 1% is -3.546099

### Result of the ARIMA Estimation

The study employed Automated ARIMA forecast process in selecting the best model for the data and the model (1, 2, 1) was selected as the best model, as depicted in Table 2. The approach for this analysis is uni-variate, since there is a single variable (wood charcoal production). Therefore the lag of this variable can be used to determine future occurrences. After series of iterations, the estimation output in Table 2 is considered the best, with the lowest AIC value. It can also be seen from the table that the first lag of Autoregressive model (AR (-1)) is significant. This is an indication that the future production volume of wood charcoal from Nigeria can be determined by its first lagged value. This implies that any quantity of wood charcoal that needs to be produced this year will be dependent on the quantity that was produced the previous year.

**Table 2:** Automatic ARIMA output for wood charcoal production data series.

| Type | Coefficient | SE of Coefficient | T | P-value |
|---|---|---|---|---|
| AR (1) | 0.999162 | 0.010000 | 99.91965 | 0.0000 |
| MA (1) | 0.866314 | 0.070277 | 12.32715 | 0.0000 |
| SIGMASQ | 1.97E+09 | 5.47E+08 | 3.609104 | 0.0006 |
| C | 2804789 | 2002026 | 1.400975 | 0.1666 |

*$R^2$ = 0.998836* *Adjusted R2 = 0.998775*

*Source: Eviews 12*

## Discussion

Figure 2 and Table1 show the trend in wood charcoal production in Nigeria from 1961 to 2021 as well as the forecast from moving average up till the year 2050. From the graph, an upward trend can be observed throughout the period. From Table1, it can be observed that there was an increase of 30.69% in production from 1961 to 1970. The increasing rate of production continued and by 1993, the rate of production of charcoal in Nigeria had risen to 200.13% from what it was in 1961. This rapid rise in production could be attributed to a number of factors which include arise in population and expansion of industrial enterprises, like bakeries, which use charcoal as source of energy. This, therefore, corroborates the study by Jamala *et al*., (2013) where it was reported that half of the world's population use biomass fuel for cooking and that in 1992, over 24 million tonnes of charcoal were consumed worldwide, with developing countries accounting for nearly all the consumption while Africa alone accounted for 50 per cent. By 2020, the production of charcoal in Nigeria had increased by more than five hundred percent (515.97%) from the 1961 base year. This may be attributed to high cost of cooking fuels coupled with the incessant scarcity of the product which makes it become important to provide an alternative means of energy for the sustenance of the people. Therefore, charcoal production has been adopted to meet some socio-economic benefits and energy needs of the people. This is because, for many rural people and urban poor, charcoal provides a reliable, convenient and accessible source of energy for cooking at a stable cost.

However, it is estimated that from 2020 to 2030, the production of charcoal in Nigeria would have declined from 515.97% to 280.40%. This decline may not be unconnected with scarcity of mature timber species suitable for charcoal production. This is because most mature tree species in Nigerian forests would have been grossly depleted.

It has also been projected that by 2050, the production would have risen to 486% on the assumption that more trees would have been planted through massive mobilization of people to plant trees during the intervening period thereby increasing the wood stock available. This increase may be achieved through the mobilization of charcoal producers to plant trees, especially fast maturing species like eucalyptus, for the production of charcoal. Such planted species would have attained maturity size between 2030 and 2050, making them available for charcoal production.

## Conclusion

This paper assessed the trend and movements in the production of wood charcoal in Nigeria from 1961 to 2021, making projection of the trend up to year 2050 through the use of moving average. Phillips-Perron unit root test was used to test for stationarity of the series. From the result, it was discovered that the series was not stationary at its level form. It however became stationary after second differencing. Furthermore, automatic ARIMA modelling technique was employed to model the wood charcoal production series. The modelling therefore produced ARIMA (1, 2, 1) as the best model. The result also revealed that future production of wood charcoal is significantly determined by its previous lagged value. It has also been estimated that from 2022, charcoal would be produced in Nigeria at a declining rate. This can be attributed to declining availability of wood in Nigerian forests, resulting from unsustainable exploitation. In view of this, it is recommended that government agencies, like Forestry Research Institute of Nigeria, should train and enlighten charcoal producers on the establishment of woodlots and plantations in order to increase supply of wood for charcoal production. In addition, seedlings of fast growing tree species, such as eucalyptus spp, should be made readily available to producers of wood charcoal and they should be mandated to plant trees if they want to continue with the business of charcoal production. In addition, adequate and strict mechanism should be put in place by governments at various levels so as to ensure that the remaining natural forest resources are protected and conserved to ensure sustainability.

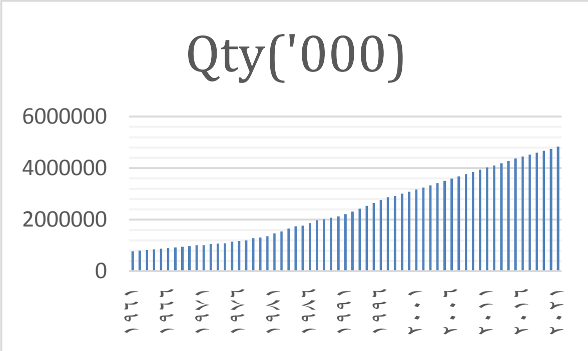


**Figure 2:** Graph showing trend in charcoal production in Nigeria (1961-2021)

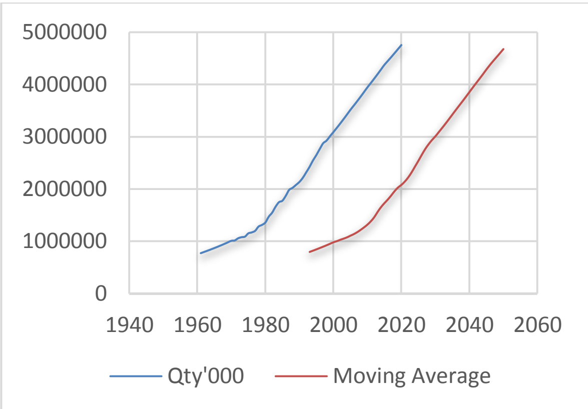


**Figure 3:** Graph showing moving average for charcoal production in Nigeria from 1961 to 2021.

# Appendix

**Table1:** Table1: Quantity of charcoal produced in Nigeria (1961-2021)

| Number | Year | Quantity ('000) | Percentage Change (%) |
|---|---|---|---|
| 1 | 1961 | 771261 | |
| 2 | 1962 | 794540 | 3.01 |
| 3 | 1963 | 818523 | 6.12 |
| 4 | 1964 | 843229 | 9.33 |
| 5 | 1965 | 868680 | 12.61 |
| 6 | 1966 | 894900 | 16.03 |
| 7 | 1967 | 921912 | 19.53 |
| 8 | 1968 | 949739 | 23.14 |
| 9 | 1969 | 978405 | 26.85 |
| 10 | 1970 | 1007937 | 30.69 |
| 11 | 1971 | 1014300 | 31.51 |
| 12 | 1972 | 1055688 | 36.87 |
| 13 | 1973 | 1076642 | 39.59 |
| 14 | 1974 | 1087104 | 40.95 |
| 15 | 1975 | 1149970 | 49.10 |
| 16 | 1976 | 1168026 | 51.44 |
| 17 | 1977 | 1198482 | 55.39 |
| 18 | 1978 | 1279394 | 65.88 |
| 19 | 1979 | 1311257 | 70.01 |
| 20 | 1980 | 1357001 | 75.94 |
| 21 | 1981 | 1469004 | 90.46 |
| 22 | 1982 | 1545258 | 100.35 |
| 23 | 1983 | 1658896 | 115.08 |
| 24 | 1984 | 1745863 | 126.36 |
| 25 | 1985 | 1773315 | 129.92 |
| 26 | 1986 | 1867006 | 142.07 |
| 27 | 1987 | 1980778 | 156.82 |
| 28 | 1988 | 2020427 | 161.96 |
| 29 | 1989 | 2075513 | 169.10 |
| 30 | 1990 | 2131778 | 176.40 |
| 31 | 1991 | 2210445 | 186.60 |
| 32 | 1992 | 2314797 | 200.13 |
| 33 | 1993 | 2420873 | 213.88 |
| 34 | 1994 | 2542902 | 229.70 |
| 35 | 1995 | 2646794 | 243.17 |
| 36 | 1996 | 2763475 | 258.30 |
| 37 | 1997 | 2872535 | 272.44 |
| 38 | 1998 | 2922971 | 278.98 |
| 39 | 1999 | 3006209 | 289.77 |
| 40 | 2000 | 3085072 | 300.00 |
| 41 | 2001 | 3165781 | 310.46 |
| 42 | 2002 | 3248602 | 321.20 |
| 43 | 2003 | 3333589 | 332.22 |
| 44 | 2004 | 3420800 | 343.53 |
| 45 | 2005 | 3510292 | 355.13 |
| 46 | 2006 | 3592327 | 365.77 |
| 47 | 2007 | 3676300 | 376.66 |
| 48 | 2008 | 3762200 | 387.79 |
| 49 | 2009 | 3850113 | 399.19 |
| 50 | 2010 | 3940089 | 410.86 |
| 51 | 2011 | 4022763 | 421.56 |
| 52 | 2012 | 4107172 | 432.52 |
| 53 | 2013 | 4193352 | 443.70 |
| 54 | 2014 | 4281341 | 455.10 |
| 55 | 2015 | 4371175 | 466.75 |
| 56 | 2016 | 4444581 | 476.27 |
| 57 | 2017 | 4519220 | 485.95 |
| 58 | 2018 | 4595112 | 495.79 |
| 59 | 2019 | 4672279 | 505.79 |
| 60 | 2020 | 4750741 | 515.97 |
| 61 | 2021 | 4828689 | 526.07 |
| 62 | 2022 | *2139245 | 177.36 |
| 63 | 2023 | *2219007 | 187.71 |
| 64 | 2024 | *2315372 | 200.20 |
| 65 | 2025 | *2426191 | 214.57 |
| 66 | 2026 | *2536856 | 228.92 |
| 67 | 2027 | *2651057 | 243.73 |
| 68 | 2030 | *2933905 | 280.40 |
| 69 | 2040 | *3676942 | 376.74 |
| 70 | 2050 | *4519638 | 486.00 |

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