academicresearchJournals

Vol. 6(3), pp. 43-56, October 2018
DOI: 10.14662/IJEBM2018.080

ISSN: 2384-6151
http://www.academicresearchjournals.org/IJEBM/Index.htm

International Journal of Economic and Business Management

Full Length Research

Modelling Annual Yield of Coffee in Nigeria Using ARIMA Time Series Model (2018 – 2050)

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Accepted 18 October 2018

Coffee represents the world's most valuable tropical agricultural commodity in the international commodity trade and it comes next to crude oil. A large proportion of growers in the major coffee - producing countries in Sub-Saharan Africa which accounts for about 12 percent of world coffee depends on coffee for their living. The paper employed the Autoregressive Integrated Moving Average (ARIMA) time series model to analse the behavior of Nigeria's annual coffee yield as well as make forecasts unto the year 2050. Annual coffee yield data from 1961 to 2016 was obtained from the online statistical database of the Food and Agricultural Organization of the United Nations (FAOSTAT) and analyzed using ARIMA. The results showed that coffee yield in Nigeria follow an upward and downward movement from 1961 to 2016. ARIMA (0, 1, 1) was selected as the best model for the forecast of cocoa yield in Nigeria after various diagnostics selection and evaluation criteria. In the end, the forecast figures base on Box- Jenkins forecast technique showed that Nigeria's annual coffee yield will increase continuously in the next thirty-four (34) years.

Keywords: Coffee, Yield, ARIMA, Box –Jenkins, Forecast, Time Series, Autocorrelation.

Cite This Article As: Binuomote, S.O. Lukman, A.F., Olumide, S.O., Adeleke O.A (2018). Modelling Annual Yield of Coffee in Nigeria Using ARIMA Time Series Model (2018 – 2050). Inter. J. Econ. Bus. Manage. 6(3): 43-56

INTRODUCTION

Coffee plant is an indigenous plant from Africa, which belongs to the botanical family *Rubiaceae.* It has two major botanical species, which are the *Arabica* and *Robusta*. *Coffee Arabica* has been traced to originate from Ethiopia, while Robusta coffee variety was believed to have come from Central to West Africa (Williams, 2008; Opeke, 2005; and Ngussie and Dererse, 2007). Robusta coffee is planted in lower plain fields while Arabica coffee is planted at higher plains and often on volcanic soils.

Globally, 80 countries produce coffee and it is exported by over 50 countries in Central and South America, Africa and Asia. More than 100 million people are engaged in producing and processing of coffee. Brazil is ranked the highest producing country (30.18%) followed by Vietnam (15.27%), other major producers include Colombia, Indonesia, Ethiopia, India, Guatemala, Honduras and Peru. Ethiopia being one of the major producer of the crop, but is not the only country producing coffee in Africa, some others are Uganda, Nicaragua, Ivory Coast, Tanzania, Malawi and Zambia, Kenya and Nigeria from whence a total number of farmers estimated at between

10 and 12 million are directly involved in coffee production activities (International Coffee Organization, 2015).

Coffee is an important foreign exchange earner, contributing in varying degrees to the national income of the producing countries. It guarantees a solid basis for the promotion of economic development (Cambrony, 1992). About 33 million people in 25 African countries as put by Surendra (2002) derived their livelihoods by growing coffee on their subsistence farms on about 4.5 million square kilometers of land. *Arabica coffee* for instance has become a major global commodity. Its cultivation, processing, trading, transportation, marketing provide employment for a lot of people in all producing countries (Muleta, 2007).

Over 80% of coffee from developing countries, particularly Nigeria, is produced by small scale farmers who lack adequate technical education and are faced with low market price leading to poor management, poor productivity and abandoned farms (Williams, 1989; Mutua, 2000; and Agbongiarhuoyi *et al*, 2006). In the world trade, *Arabica* coffee is of greatest economic importance which account for 4% of export in Nigeria. Although, Nigeria supplies less than 2% of world coffee, yet in terms of the national economy, its contribution in the non-oil sector is significant (Williams, 1989). Currently, coffee agriculture contributes about 34.5% to Nigeria GDP (FAO, 2007)

Coffee production in Nigeria on a large scale started as far back as the 1940s, but gained momentum in the early to mid 1950s. *C. arabica* is grown mainly by the small scale farmers in the highland area of Mambilla plateau in Taraba State as well as Nasarawa, Abia, Kogi, Kwara, Ondo, and Ogun States (Williams, 2008); and it used to be one of the major cash crops constituting the backbone of Nigerian economy before the emergence and predominance of oil. However, a recent analysis in the trends in coffee output in Nigeria has shown decline in the production over the period between 1960 and 2008 in Nigeria. Between these periods, production has ranged from 18,000 bags [of 60kg bag] in 1961 to 50,000 bags in 2008, with the highest production level of 95,000 bags in 1964, 1988 and 1990 (Williams, 2008).

The yield of Coffee is fast declining in Nigeria and the participation of farmers has become very low. However, the recent policy shift towards diversification of the national economy towards agriculture to cover for the consequences of shocks from volatility in world crude oil production and prices, especially coffee having played a very important economic role in the pre-oil era in Nigeria; the Presidential Initiative in Agriculture; provides an a good opportunity stop and consequently reverse the declining trend in coffee production in Nigeria and also employ it as one of the major drivers of foreign reserve in Nigeria given the economic importance of coffee and its capacity to boost the country's revenue, especially in the face of dwindling oil revenue. A resuscitations of the Nigeria coffee sector would also be consistent with the vision of the New Partnership for Africa's Development [NEPAD] that "Agriculture-led development is fundamental to cutting hunger, reducing of food imports and opening the way to an expansion of exports".

As the international market price is beyond the control of coffee growers, an increase in yield is expected to mitigate their cost of production, thus contributing to improving their income. High yields are therefore an important factor in achieving a sustainable coffee production. Being a major cash crop and with the capacity of contributing significantly in the agricultural economy of the country, it is worthwhile to know about the yield status of coffee in the near future. If past values of the crop's yield are given, one can use past pattern of the data to forecast coffee yield. This paper therefore forecasts the annual yield of coffee in Nigeria using Auto Regressive Integrated Approach. The remaining part of this paper is organized as follows: Section two is the methodology of the research work, section three deals with the presentation and discussion of obtained results while section four is the conclusion and policy recommendation from the study.

DATA AND METHODOLOGY

Data and Data Source

This study is based secondary data pertaining to annual coffee yield for Nigeria. The coffee yield data from 1961 to 2016 was obtained from Food and Agriculture Organization of the United Nations online statistical database (FAOSTAT).

Analytical Techniques

Both inferential and descriptive statistics were used to analyse this study. While the descriptive statistics involved the use of graph to examine the trend in coffee yield in Nigeria, as well as some time series properties of the data, the ARIMA model was used to forecast the yield of cocoa in Nigeria.

ARIMA modelling

This study applied ARIMA modelling also known as Box-Jenkins Methodology of forecasting to analyze coffee yield forecast in Nigeria. ARIMA is the method first introduced by Box and Jenkins (1976) and until now has become the most popular models for forecasting univariate time series data (Harris *et al*, 2012). The basic principle of methodology involves forecasting the future values of a particular variable using the past or lagged values of the same variable. The ideology is termed “let the data speak for themselves” (Gujarati, 2004). The various steps and procedure involved in ARIMA modeling is explained below.

The Box-Jenkins ARIMA model has evolved from the combination of AR (Autoregressive) and MA (Moving Average), the ARMA models.

The methodology of Chandra (2012) as contained in Gathondu (2012) is specifically applied in this study. According to Gathondu (2012), let Y_t be a discrete time series variable which takes different variable over a period of time. the corresponding AR (p) model of *Yt* series, which is the generalizations of the autoregressive model, is expressed as;

$$AR(p); Y_t = \theta_0 + \theta_1 Y_{t-1} + \theta_2 Y_{t-2} + ... + \theta_p Y_{t-p} + \varepsilon_t \quad ... \quad (1)$$

Where Y_t is the response variable at time t, Y_{t-1}, Y_{t-2}, Y_{t-p}, *are* the respective variables at different time lags; θ_0, θ_1, …. θ_p are the coefficients and ε_t is the error factor.

Similarly, the MA(q) model which is the generalization of the moving average model is specified as;

$$MA(q); Y_t = \mu_t + \varepsilon_t + \sigma_1 \varepsilon_{t-1} + ... \sigma_q \varepsilon_{t-q} \qquad \varepsilon_t \sim WN(0, \sigma^2_t) \quad (2)$$

Where, μ_t is the constant mean of the, series, σ_1, σ_2, …. σ_q, *are* the coefficients of the estimated term and ε_t is the error term.

When (Y_t) in the data is replaced with ($\Delta Y_t = Y_t - Y_{t-1}$), then the ARMA models become the **ARIMA (*p,d,q*)** models, where ***p*** is order of autocorrelation (indicates weighted moving average over past observations), ***d*** is order of integration (differencing) and ***q*** is order of moving averaging. By combining the models in (1) and (2), this resulting model is referred to as ARIMA model, which have the general form of;

$$Y_t = \theta_0 + \theta_1 Y_{t-1} + \theta_2 Y_{t-2} + ... \theta_p Y_{t-p} + \varepsilon + \sigma_1 \varepsilon_{-1} + ... + \sigma_q \varepsilon_{-q} \quad (3)$$

If Y_t is stationary at level or I(0) or at first difference I(1) then this determines the order of integration. To identify the order of p and q the ACF and PCF is applied.

Test of Stationarity of Time Series Data

ARIMA model is generally applied for stationary time series data. A time series is said to be stationary if both the mean and the variance are constant over time. A time plot of the data can suggests whether the time series needs any differencing before performing formal tests. Also, the stationarity and non-stationarity properties are checked by applying ADF. The ADF statistic is a negative number and the more negative it is, the stronger the rejection of the hypothesis that there *is* a unit root at some level of confidence i.e., the time series is non-stationary. If the time series is non-stationary, we do the first differencing or a higher order differencing till the time series becomes stationary. The times of differencing the series is indicated by the parameter *d* in the ARIMA(*p,d,q*) model.

ARIMA model Selection

The Box-Jenkins methodology employed a three stage method for selection of appropriate ARIMA model for the purpose of estimating and forecasting univariate time series. These include; i) Identification, ii) Model estimation, and iii) Diagnostic Checking. After these stages, the selected models can now be used for forecasting.

Model Identification

The first step of applying the model is to identify appropriate order of ARIMA (*p,d,q*) model. Identification of ARIMA model involves selection of order of AR(*p*), MA(*q*) and I(*d*). The order of *d* is estimated through I(I) or I(0) process.

The model specification and selection of order *p* and *q* involves plotting of ACF and partial PACF or correlogram of variable at different lag length after stationarity. The plotted ACF and PACF of the variable were observed to determine which correlations were statistically significant at 95% confidence interval. The principle of parsimony was adhered to, in which a model is expected to have as small parameters as possible yet still be capable of explaining the series, that is if two or three explanatory variables can explain the behavior of a model we do not need to add more variables.

Model estimation

Once the order of p, d and q are identified, the next step is to specify appropriate regression model and estimate. With the help of R software various orders of ARIMA model were estimated to arrive at the optimal model. For instance, by ARIMA (2, 1, 1), it means the series is stationary at first difference and follows AR (2) and MA (I) process. The estimated models are compared using AIC and BIC, the one with smallest AIC and BIC values is then selected.

Diagnostic Checking

After selecting an ARIMA model and having estimated its parameters, diagnostic check was done to assess whether the chosen model fits the data reasonably well.This was done by checking on the residual term obtained from ARIMA model by applying ACF and PACF functions, to know if residuals are not auto correlated and follow normal distribution. The Q statistic of Ljung-Box (1978) was used to test for auto-correlation.

Forecasting

After the Box-Jenkins three stage methodology of forecasting was carried out, then the selected model was used in forecasting the future values of the variable.

RESULT AND DISCUSSION

This chapter looks at the analysis and extraction of information from the data collected and to make inferences based on this information to produce solid and sound conclusions and recommendations. The analysis employs Box-Jenkins method of analyzing time series data.

Descriptive Statistics

The fifty-six year's data of the average yearly coffee yield in Nigeria is purely secondary and was obtained from FAOSTAT database. The data of the coffee yield spans from 1961 to 2016.
From, the table above, the results show that the mean of the Nigeria coffee yield is 824.7Kg/ha with a standard error of 50.1Kg/ha and a standard deviation of the coffee yield 374.8Kg/ha. The maximum coffee yield ever recorded was 1439.4Kg/ha in year 2006 and the minimum yield was also recorded in 1961.

Table 1: Descriptive statistics of the Nigeria coffee yield

	Coffee Yield
Count	56
Mean	824.7
Standard Error	50.1
Std. Deviation	374.8
Median	776
Minimum	183.3
Maximum	1439.4

Source; *Data Analysis, 2018*

Box-Jenkins (ARIMA) Methodology

A dimension of the preliminary analysis for examining non-stationarity of the data is by considering the time series plot, correlogram and partial correlogram of the coffee yield from 1961 to 2016 as shown in Figure 2.
The time series plot above has shown how the coffee yield dataset behaves through equally spaced time interval. It can be observed that the coffee yield does exhibit a form of upward trend. Therefore, there may be need for differencing in order to attain stationarity. The also depicts that the coffee yield dataset does not have a constant mean and variance over time. Therefore, there is need to adjust them to form a stationary series, so that the values vary more or less uniformly about a fixed level over time. This can also be seen through the ACF plot of the series in figure above, which shows a slow decline, the Partial ACF plot has a significant spike at lag 1.

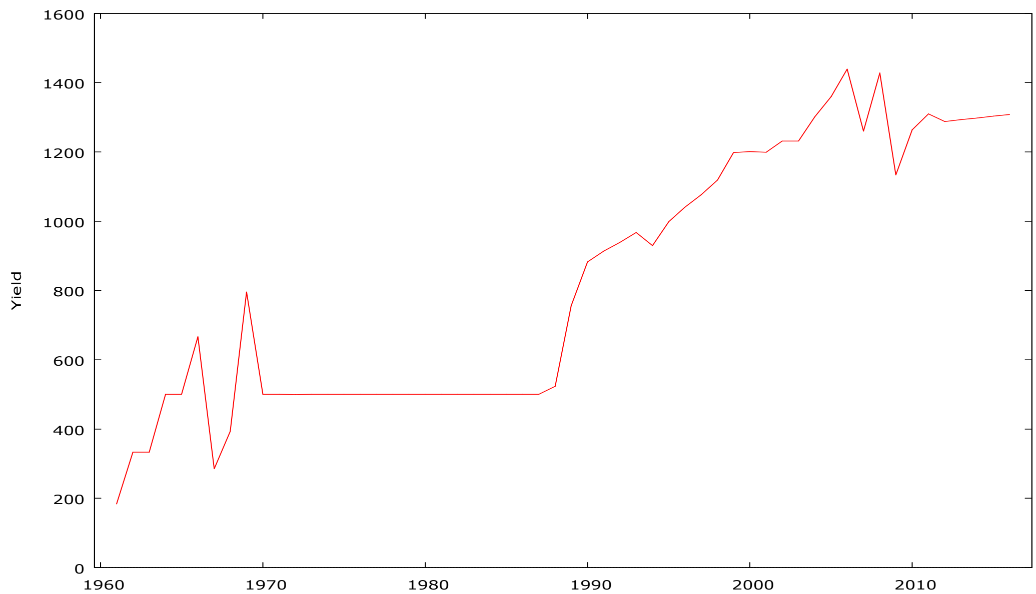

Figure 1: Time series plot of the coffee yield data

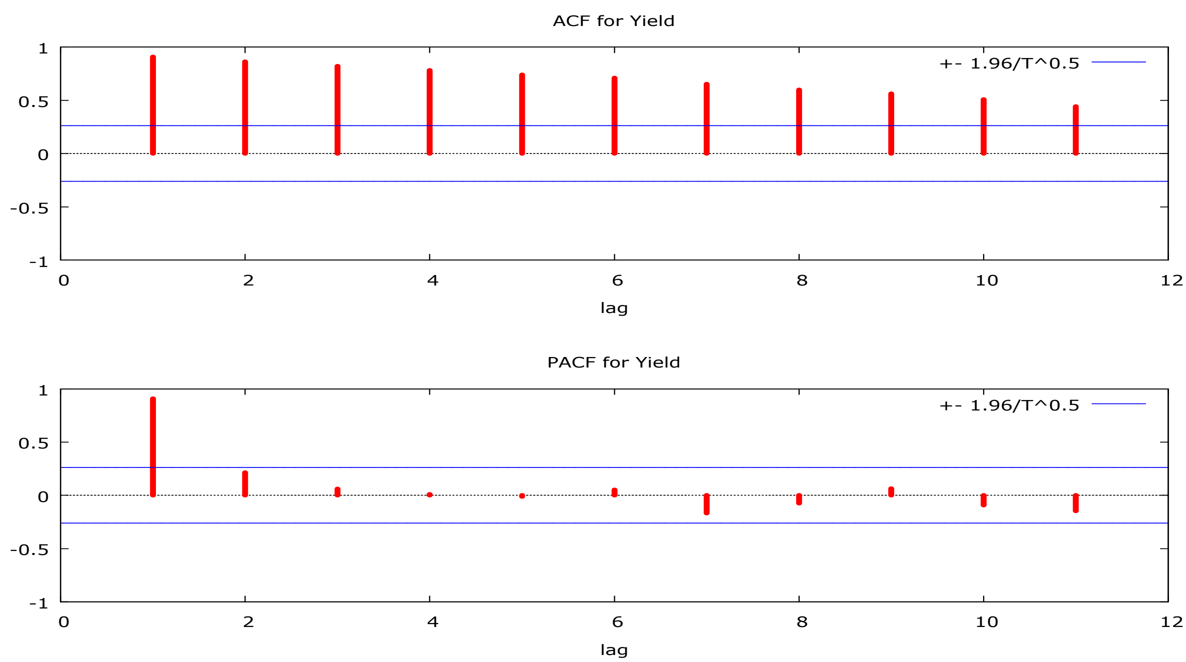

Figure 2: ACF and PACF plot of coffee yield data

Test for stationary of coffee yield data

Furthermore, Dickey-Fuller test shown in Table 1 shows that the series was not stationary. Thus, the data was differenced and tested. As shown in Table 2, the Dickey-Fuller test reveals that the data was stationary after the non-seasonal first difference and therefore further and precise analysis can be carried out on the dataset.

Table 2: Augmented Dickey-Fuller (ADF) Test of Coffee yield

Dickey-Fuller	Lag order	p-value
-1.7066	3	0.6929

Source; *Data Analysis, 2018*

Table 3: Augmented Dickey-Fuller (ADF) Test of differenced Coffee yield

Dickey-Fuller	Lag order	p-value
-4.2042	3	0.0100

Source; *Data Analysis, 2018*

Figure 4 shows the movement of the stationary differenced coffee yield dataset. It follows the pattern of a random sequence although it stabilized between 1971 -1987 where it continued it random movement. Here we observed a stable linear trend. Since the data was nonstationary the differencing has made it stationary and therefore further and precise analysis can be carried out on the datasets. The series moves around a fixed point and it shows that the coffee data has an integration order of one (1) which implies that differencing this data once makes the coffee yield data stationary.

Figure 3: Time series plot of the differenced coffee yield data

Identification of Model

The next step is the identification of model, which is determined by the order of AR and MA. The order of AR and MA component is suggested by the sample ACF and PACF plots based on the Box-Jenkins approach. The significant lag of the PACF suggests the order of AR while the significant lag of the ACF suggest the order of MA.
Now from Figure 5, The ACF and PACF plots respectively suggest that p=1, d=1 *and* q=1was needed to describe this data set autoregressive, integration orderand moving average process respectively. The principle of parsimony was at adhere.

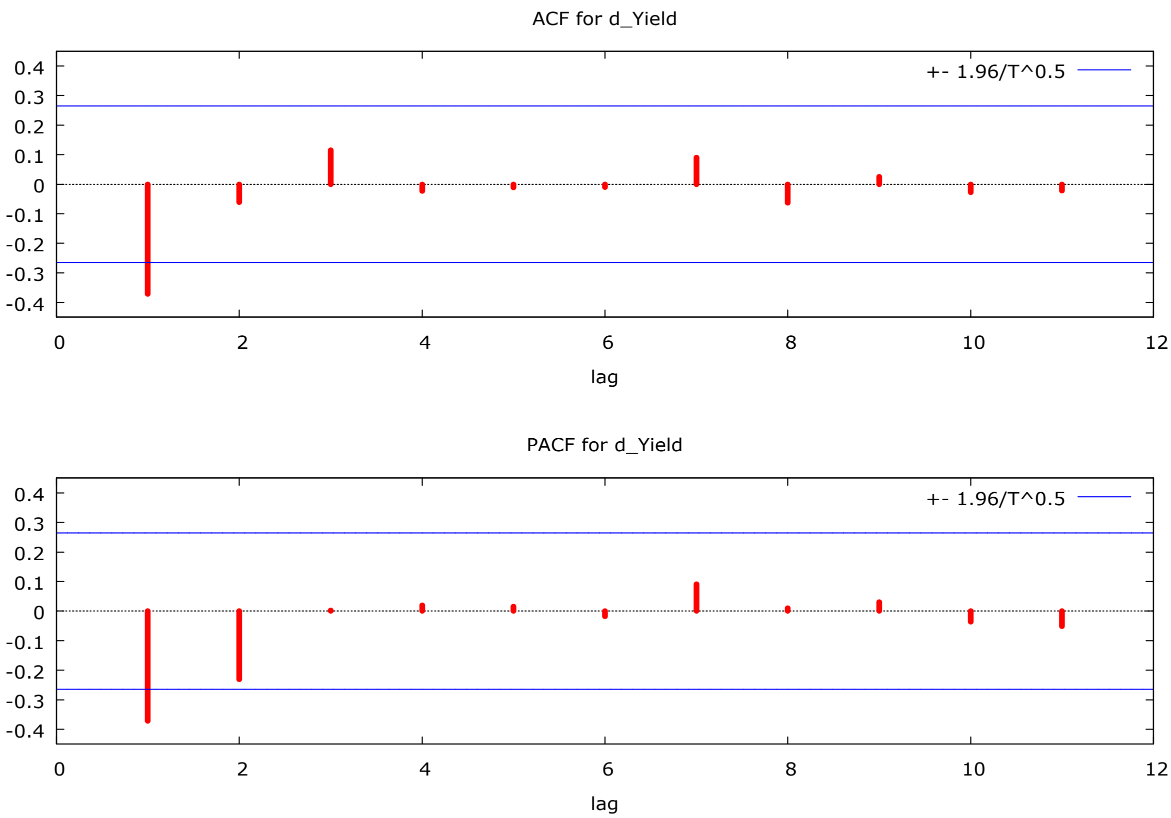

Figure 4: ACF and PACF of the differenced yield data

Model Parameter Estimation

ACF and PACF suggests the Model to be ARIMA (1,1,1) although after several iterations and consideration of other models ARIMA (0,1,1) with drift was suggested to be the best model because it has the smallest Akaike Criterion and Schwarz criterion

From Table 4, ARIMA (0, 1, 1) with drift (constant term) was the best model based on the selection criterion used. This is because it satisfies all the selection criterion. The ARIMA model (0, 1, 1) produced the least AIC, SIC, BIC and HQIC values of 673.8686, 679.8906, 679.891 and 676.1973 respectively and hence the best model that fits the data set and can be used for forecasting the coffee yield.

Table 4: Models suggested for Forecasting Coffee yield

NO	MODEL TYPE	AIC	SIC	BIC	HQIC
1	ARIMA (0,1,1)	673.8686*	679.8906*	679.891*	676.1973*
2	ARIMA (0,1,2)	675.8282	683.8576	683.858	678.9332
3	ARIMA (1,1,1)	675.8418	683.8712	683.871	678.9468
4	ARIMA (1,1,2)	677.0581	687.0948	687.095	680.9394

Source; *Data Analysis, 2018*

ARIMA Model Estimation

ARIMA (0, 1, 1) with drift is therefore given as $Y_t = \mu_t + \varepsilon_t + -\sigma\varepsilon_{t-1}$, where μ_t is the constant term, σ_1 is a vector of parameters and ε_t is a vector of residual terms, ε_{t-1} is the moving average term.
ARIMA models are usually estimated under forecasting into a stationary series. A stationary series is one whose values vary over time only around a constant mean and variance. Table 5, shows the parameter estimates of the adequate model for the coffee yield.

Table 5, displayed the estimated parameter that should be used in the model. Thus replacing the symbol with the estimated parameters gives

$Y_t = 19.4143 + 0.4598\,\varepsilon_{t-1} + \varepsilon_t$ as an appropriate model that explains the data generating process (DGP) of the coffee yield.

Table 5: Parameter Estimates for ARIMA (0, 1,1)

	Estimate
Drift term (Constant)	19.4134
MA(1)	-0.4598
Standard Error	0.0808
Sample size (n)	55
Mean Percentage Error (MPE)	-1.5704

Source; *Data Analysis, 2018*

Model Diagnostics

The model diagnostic checks are performed to determine the adequacy of the chosen model. These checks are done through the analyzing of the residuals from the fitted model. If the model fit the data well, the residuals are expected to be random, independent and identically distributed following the normal distribution. Plots of the residuals such as the histogram, the normal probability plot and the time series plot of residuals were used. The histogram of the residuals as well as the normal probability plot. The ACF and PACF of the standardized residuals and modified Box-Pierce (Ljung-Box) test were used to check adequacy of the model.

From the normality probability plot of residual in Figure 6, indicated that the residuals are normally distributed and this was also confirmed by the histogram in the same Figure 6. The plot of the residuals Figure 6, exhibited random variation about their mean and variable and hence it can be concluded that the residuals against fitted value and observation appear to be random.

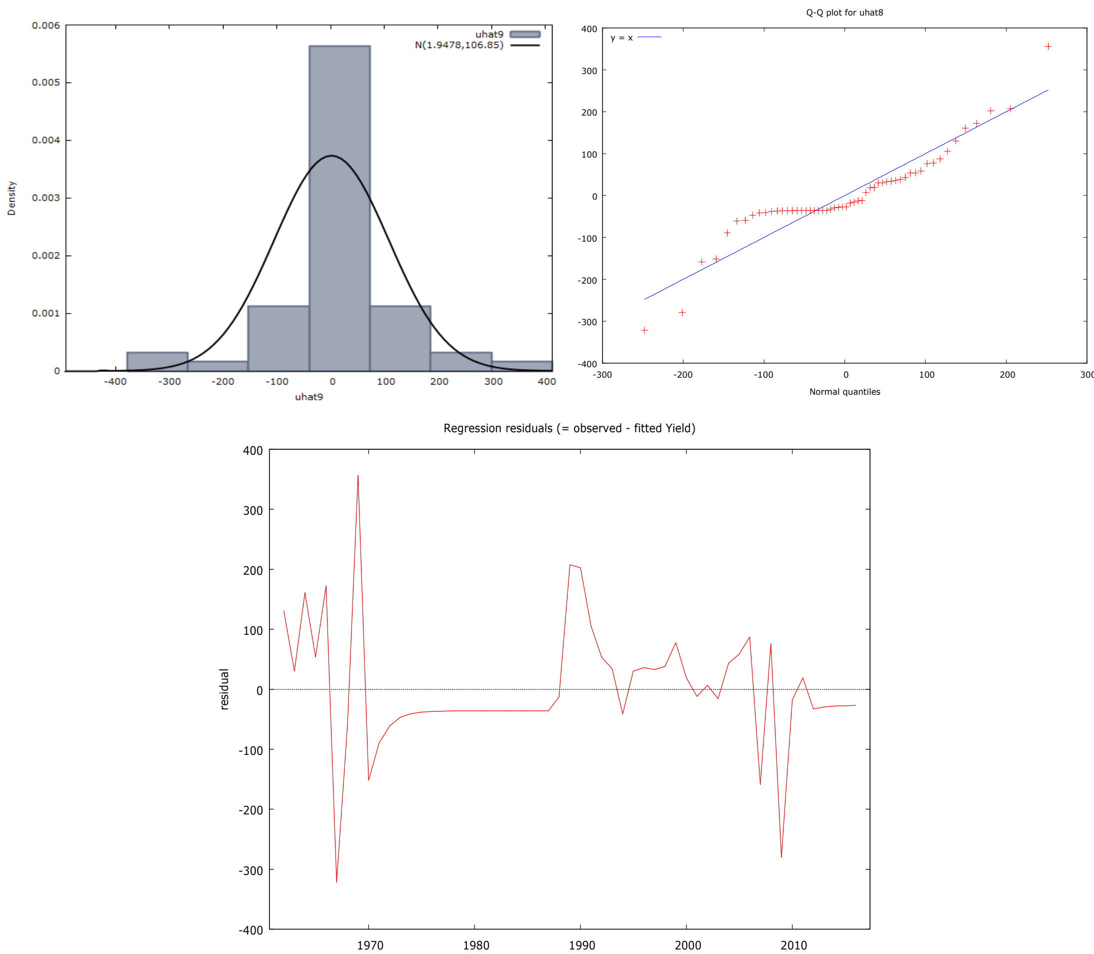

Figure 5: Histogram, QQ plot, Regression of residual plot

The Autocorrelation and Partial Autocorrelation functions of the residuals in Figure 7, confirmed that there is no form of correlation amongst the residuals. This therefore shows that the selected model is good for forecast purposes.

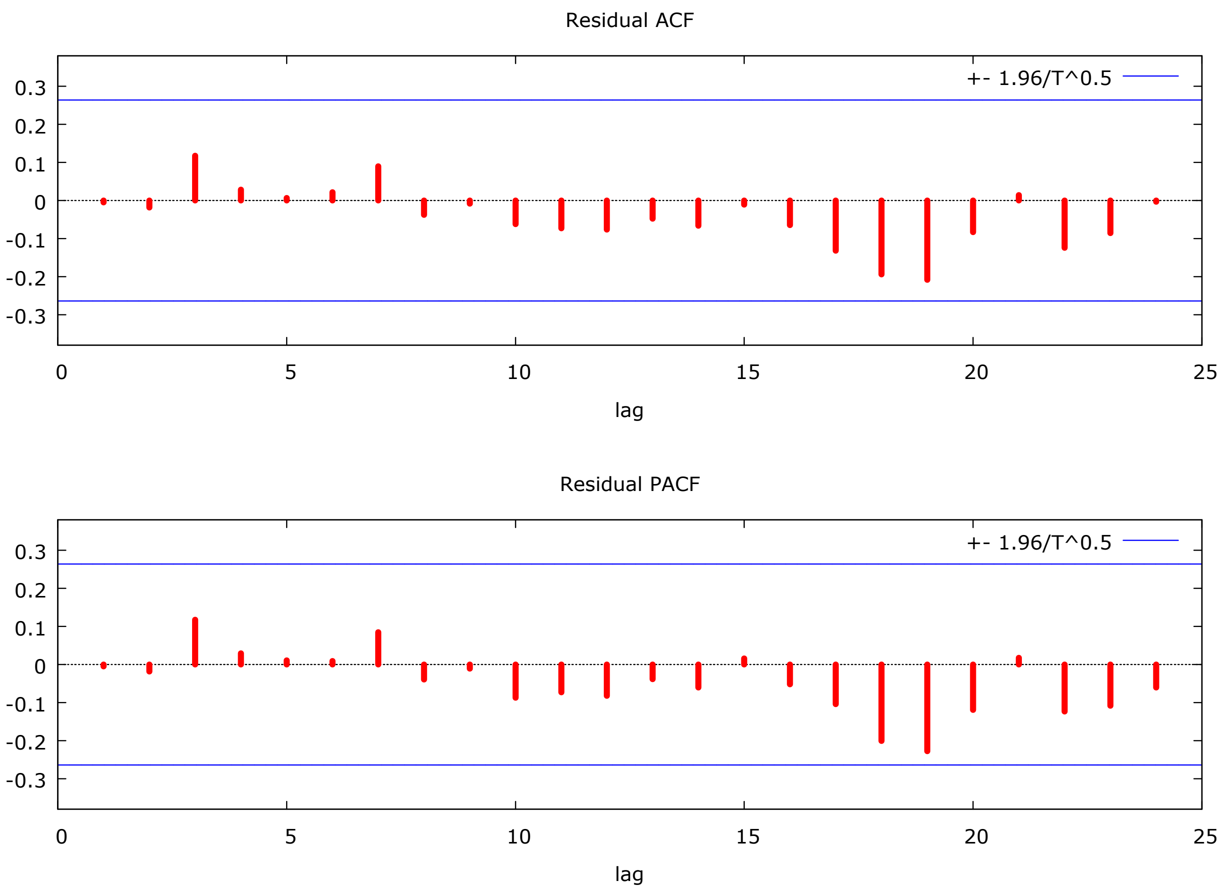

Figure 6: ACF and PACF plot of the Residual

Forecasting Evaluation and Accuracy Criteria

The model was also evaluated in terms of their forecasting ability of future coffee yield with Mean Error (ME), Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Mean Percentage Error (MPE), Mean Absolute Percentage Error (MAPE). Therefore, the model exhibit minimum values of the forecast error which depicts that the model is good and fit for the forecast.

Table 6: Model Evaluation Measure

Measure	ME	RMSE	MAE	MPE	MAPE
Parameter Estimation	1.9478	104.91	71.936	-1.5301	11.526

Source; *Data Analysis, 2018*

Forecasting

After testing for the adequacy of the model, it was used to make a 34 years forecast from 2017 - 2050. From Table 7, it was observed that that errors (difference) were increasing continuously. The forecasted values of coffee yield reveal that the yield will rise to 1339.90Kg/ha in 2017 and will continue to rise till it reaches 1980.50Kg/ha by 2050.

Table 7: Coffee Yield Forecast

Year	Yield Forecast	SE	95% Confidence Interval
2017	1339.90	104.63	1134.80 - 1545.00
2018	1359.30	118.92	1126.20 - 1592.40
2019	1378.70	131.67	1120.70 - 1636.80
2020	1398.10	143.29	1117.30 - 1679.00
2021	1417.60	154.04	1115.60 - 1719.50
2022	1437.00	164.08	1115.40 - 1758.60
2023	1456.40	173.55	1116.20 - 1796.50
2024	1475.80	182.52	1118.10 - 1833.50
2025	1495.20	191.07	1120.70 - 1869.70
2026	1514.60	199.26	1124.10 - 1905.20
2027	1534.00	207.12	1128.10 - 1940.00
2028	1553.40	214.69	1132.70 - 1974.20
2029	1572.90	222.01	1137.70 - 2008.00
2030	1592.30	229.09	1143.30 - 2041.30
2031	1611.70	235.96	1149.20 - 2074.20
2032	1631.10	242.64	1155.50 - 2106.70
2033	1650.50	249.14	1162.20 - 2138.80
2034	1669.90	255.47	1169.20 - 2170.60
2035	1689.30	261.65	1176.50 - 2202.20
2036	1708.80	267.68	1184.10 - 2233.40
2037	1728.20	273.59	1191.90 - 2264.40
2038	1747.60	279.37	1200.00 - 2295.10
2039	1767.00	285.03	1208.40 - 2325.60
2040	1786.40	290.58	1216.90 - 2355.90
2041	1805.80	296.02	1225.60 - 2386.00
2042	1825.20	301.37	1234.60 - 2415.90
2043	1844.70	306.63	1243.70 - 2445.60
2044	1864.10	311.79	1253.00 - 2475.20
2045	1883.50	316.88	1262.40 - 2504.50
2046	1902.90	321.88	1272.00 - 2533.80
2047	1922.30	326.80	1281.80 - 2562.80
2048	1941.70	331.66	1291.70 - 2591.80
2049	1961.10	336.44	1301.70 - 2620.50
2050	1980.50	341.15	1311.90 - 2649.20

Source; *Data Analysis, 2018*

Figure 8, shows the predicted coffee yield and the observed coffee which further confirms the accuracy of the model selected. It further reveals an upward trend in the forecasted Nigeria coffee yield from 2017 to 2050.

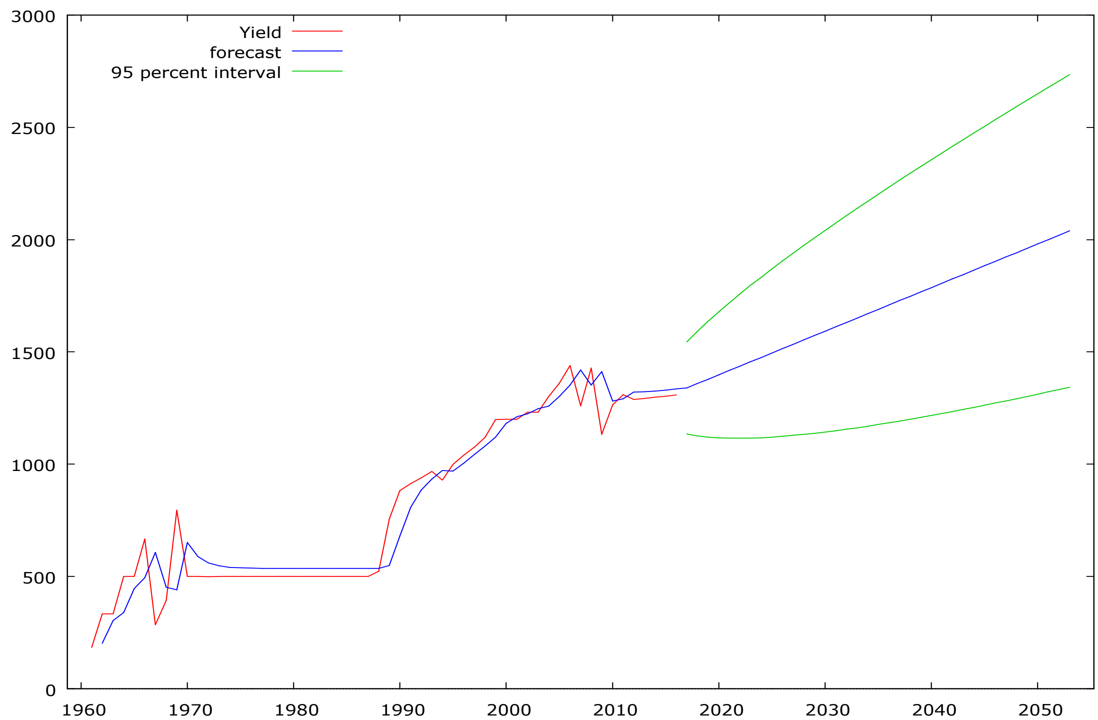

Figure 7: Plot of Forecasted Coffee Yield

Economic Implication of the Yield forecast

Groote and Traoré 2005 posited that agricultural statistics are essential for policymakers, administrators, and scientists concerned with planning and evaluation of agricultural investments. Therefore, forecast of coffee yield revealed that yield will continue to rise. This implies that Nigeria can take advantage of increase in coffee yield to increase the means of improving foreign exchange revenue.

The problem of falling coffee price has been a challenge to coffee grower in Nigeria, this has led to reducing acreage of coffee. Therefore, as the international market price is beyond the control of coffee growers, an increase in yield is expected to mitigate their cost of production, thus contributing to improving their income. High yields are therefore an important factor in achieving a sustainable coffee production.

CONCLUSION AND RECOMMENDATION

The best ARIMA model for the Nigeria Coffee yield is $Y_t = 19.4143 + 0.4598\varepsilon_{t-1} + \varepsilon_t$ for the forecasting of future values. The highest coffee yield (1439.4Kg/ha) was recorded in year 2006. Thereafter, coffee yield was unstable until 2010 from whence the coffee yield started rising at a minimal level but gradually. However, the future can be known with the model, as to whether the Nigerian coffee yield will continue to rise or otherwise. Findings from the study revealed that the Nigerian coffee will continue to rise on an increasing trend.

Based on the findings and conclusions made from the study, the following recommendation are made both in the area of policy formulation and further research.

- Efforts should be made by government make sure that coffee growers are supported through the provision of financial assistance and technical assistance.
- Price stabilization programmes should be made available for the farmers to reduce that shock of price fluctuation. This will make coffee production sustainable in Nigeria.

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