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Forecasting Cultivated Areas and Production of Maize in Nigerian using ARIMA Model

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Abstract: This study focuses on forecasting the cultivated area and production of maize in Nigeria using Autoregressive Integrated Moving Average (ARIMA) model. Time Series data covering the period of 1970-2005 was used for the Study. The data were obtained from the Central Bank of Nigeria (CBN), International Financial Statistical (IFS) reports and National Bureau of Statistics (NBS). The result also shows maize production forecast for the year 2020 to be about 9952.72 tons with upper and lower limits 6479.8 and 13425.64 thousand tons respectively. The model also shows that the maize area would be 9229.74 thousand hectares with lower and upper limit of 7087.67 and 11371.81 thousand hectares respectively by 2020. This projection is important as it helps inform good policies with respect to relative production, price structure as well as consumption of maize in the country. The conclusion from the study is that, total cropped area can be increased in future, if land reclamation and conservation measures are adopted.

Key words: ARIMA, maize, Nigerian, production, trends

INTRODUCTION

Maize (*Zea mays* L.) is the most important cereal crop in sub-Saharan Africa (SSA). Along with rice and wheat, maize is one of the three most important cereal crops in the world. According to FAO data, the land areas planted to maize in West and Central Africa alone increased from 3.2 million in 1961 to 8.9 million in 2005. This phenomenal expansion of the land area devoted to maize cultivation resulted in increased production from 2.4 million metric tonnes in 1961 to 10.6 million metric tonnes in 2005. While the average yield of maize in developed countries can reach up to 8.6 ton/ha, production per hectare in many SSA countries is still very low (1.3 ton/ha) (IITA, 2007).

In Nigeria, maize is a staple food of great socio-economic importance. The demand for maize sometimes outstrips supply as a result of the various domestic uses (Akande, 1994). Additionally, other factors like price fluctuation, diseases and pests, poor storage facilities have been associated with low maize production in the country (Ojo, 2003). In view of this, national and international bodies have developed interest in promoting maize production for households' food security and poverty alleviation. Some of these efforts have been channeled through biological and agronomic research into the development of high-yielding varieties along with best cultural practices. Studies in maize production in different parts of the country (Nigeria) have shown an increasing

importance of the crop amidst growing utilization by food processing industries and livestock feed mills. The crop has thus grown to be a local "cash crop" most especially in the Southwest part of Nigeria where at least 30% of the cropland has been put to maize production under various cropping system. Growing maize in farms of 1-2 ha can overcome hunger in the household and the aggregate effect could double food production in Africa. Maize has been in the diet of Nigerian's for centuries. It started as a subsistence crop and has gradually become more important crop.

Maize production plays an importance role in the Nigerian's economy. Using the Past trends, it is imperative to assess scientifically accurate prediction of future production potentials of this crop. One of the most important and highly popularized time series models is the Box-Jenkins approach, common known as ARIMA (autoregressive integrated moving average). Qureshi *et al.* (1992) analyzed the relative contribution of area and yield to total production of wheat and maize in Pakistan and concluded that there was more than 100% increase in total wheat production that can be attributed to yield enhancement. Fatoki *et al.* (2010) applied ARIMA model to the Nigeria Gross Domestic Production (GDP). The results showed that ARIMA (1, 2, 1) was sufficient for the data from the second differentials which shows stability and Invariability Gibert (2005) used ARIMA time-series models to present multistage supply chain model. Given an ARIMA model of consumer demand

and lead time at each stage, it was showed that the orders and inventories at each stage are also ARIMA. Ahmad *et al.* (2001) analyzed water quality data using an ARIMA model. ARIMA model has been frequently employed to forecast the future requirements in terms of internal consumption and export to adopt appropriate measures (Muhammed *et al.*, 1992; Shahur and Haque, 1993; Kahforoushan *et al.*, 2010; Sohail *et al.*, 1994).

Virtually all crops in general and maize in particular been a stapled food in Nigeria provide linkage through which it can stimulate economic growth in other sectors. Maize cultivation in Nigeria had suffered various problems, rural-urban migration, low yield, pest and diseases, poor shortage facilities, shortage of key inputs and shortage of irrigation water. Nigeria has experience shortages in maize production in the past. Prices of maize and other product derived from maize boosts up during low production seasons and falls drastically when there is a surplus production, however, due to inadequate marketing facilities in the control, farmers loses some of the product. Since farmers do not know future of maize production and prices while deciding to cultivate this and other crops. There is need to forecast cultivation area, yield and production of maize in Nigeria. The objective of this paper is therefore, to determine future prospects of maize in the Nigeria using past trends.

MATERIALS AND METHODS

Time Series data was used for the Study. The data were obtained from the Central Bank of Nigeria, International Financial Statistical (IFS) report and Federal Office of Statistics (FOS), now known as National Bureau of Statistics (NBS). The data Covered the Period of 1970-2005. Box and Jenkin (1976) linear time series model was applied on the data. This model is commonly known as Autoregressive Integrated Moving Average Model (ARIMA Model).

One of time series models which is popular and mostly used in ARIMA model. ARIMA (p, d, q) model is a mixture of Autoregressive (AR) model which shows that there is a relation of a value in the present (Z_t) and value in the past (Z_{t-k}), added by random value and Moving average (MA) model which shows that there is a relation between a value in the present (Z_t) and residuals in the past

$$(Z_{t-k} \text{ } k = 1, 2, \dots)$$

with a non-stationary data pattern and d differencing order. The form of ARIMA (p,d,q) is:

$$\Phi_p(B)(1-B)^d Z_t = \theta_q(B)a_t$$

where, p is AR model order, q is MA model order, d is differencing order and:

$$\Phi_p(B) = (1 - \Phi_1 B - \Phi_2 B^2 - \dots - \Phi_p B^p)$$

$$\Phi_p(B) = (1 - \Phi_1 B - \Phi_2 B^2 - \dots - \Phi_q B^q)$$

Generalization of ARIMA model for a seasonal pattern data, which is written as:

$$ARIM(p, d, q)(P, D, Q)^2 =$$

$$\Phi_p(B)\Phi_p(B^s)(1-B)^d(1-B^s)(1-B^s)^D Z_t \\ = \theta_q(B)^Q Q(B^s)a_t$$

where, s is seasonal period.

$$\Phi_p(B^s) = (1 - \Phi_1 B - \Phi_2 B^2 - \dots - \Phi_p B^p)$$

$$\theta_q(B) = (1 - \theta_1 B - \theta_2 B^2 - \dots - \theta_q B^q)$$

Model Identification: To determine whether the series is stationary or not we considered the graph of ACF. If a graph of ACF cuts off fairly quickly or dies down fairly quickly, then the time series value should be considered stationary. Model for non-seasonal series are called Autoregressive Integrated Moving average model, denoted by ARIMA (p,d,q). Here p indicates the order of the autoregressive part, d indicates the amount average of difference and q indicates the order of the moving average part. If the original series is stationary, d = 0 and the ARIMA models reduce to the ARMA models.

The difference linear operator (Δ), denoted by:

$$\Delta Y_t = Y_t - Y_{t-1} = Y_t - BY_t = (1-B)Y_t$$

The stationary series:

$$W_t = \Delta^d Y_t = (1-B)^d Y_t = \mu + \theta_q(B)\varepsilon_t$$

$$\text{or } \Phi_p(B)W_t = \mu + \theta_q(B)\varepsilon_t$$

Model estimation and checking: Estimate the parameters for a tentative model has been selected. The derived model must be checked for adequacy by considering the properties of the residuals whether the residuals from an ARIMA model is normal and randomly distribution. An overall check of the model adequacy is provided by Ljung-Box Q statistics. The test statistics Q is given in equation below:

$$Q_m = n(n+2) \sum_{k=1}^n \frac{r_k^2(e)}{n-k} \quad \chi_{m-r}^2$$

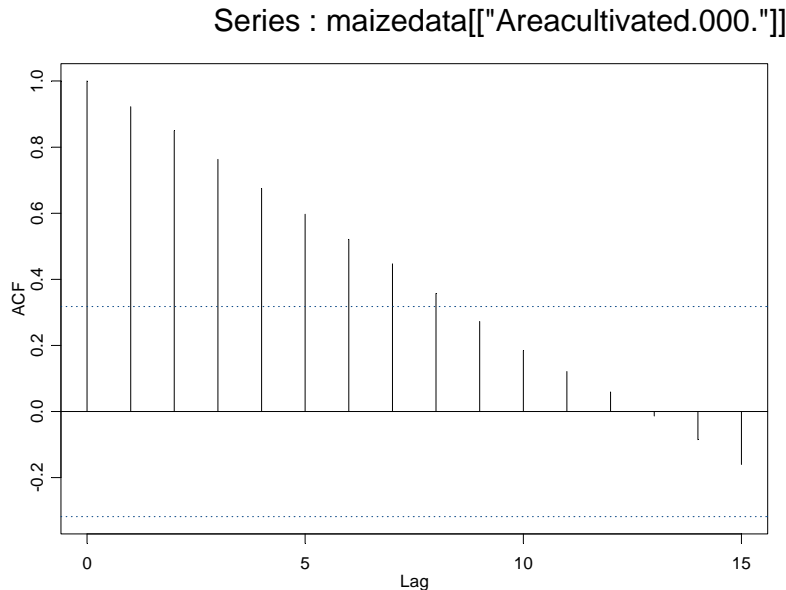


Fig. 1: Auto correlation function plot of Maize cultivation area

where, $r_k(e)$ = the residual autocorrelation at lag K.
 n = the number of residuals
 m = the number of time lags includes in the test.

If the p-value associated with the Q Statistics is small ($p\text{-value} < \alpha$), the model is considered inadequate. The analysts should consider a new or modified model and continue the analysis until a satisfactory model has been determined.

RESULTS AND DISCUSSION

The maximum cultivation Area of maize was 9244000 hectares in 2007 and was minimum 425000 hectares in 1979. For production, the maximum production of maize in Nigeria was obtained in 2007-2008 year (9876000 tons) and minimum in 1979-1980 year (488000 tons).

Last 36 years data of cultivation area and production of maize in Nigeria was used for modeling purpose. In model specification, we looked at the plots of auto-correlation function (ACF) for maize cultivation areas (Fig. 1) and production figures

(Fig. 2). Also, partial auto correlation function (PACF) for maize cultivation area (Fig. 3) and production (Fig. 4). Auto correlation function indicated the order of the auto regression compounds “q” of the model while the partial correlation function gave an indication for the parameter p.

The time series plot (Fig. 5 and 6) of cultivation areas and production showed an increasing trend. ACF of both series showed non-stationary as ACF did not fall as

quickly as the log K increased. To check the further stationary, second difference of the original series for cultivation area and production was taken. The auto correlation formulation of second series and correlogram shows some more stationary than that of the first different. The corellogram of the auto correlation function of first difference series showed that the auto correlation function falls finally after lag 1 for area and lag 2 for production, hence the respective values of the parameter “q” decided to be 1 and 2.

PAC function of the first differenced series of the cultivation area and production was used to determine parameter “p”. Thus, we chose “p” to be 1 and 2 for cultivation area and production respectively which gave good results consequently, the respective value of p,d,q were determined for ARIMA, that is ARIMA (1,1,1) and ARIMA (2,1,2).

Model esimation: ARIMA (1,1,1) and (2,1,2) model were estimated using S-plus statistical difference and estimation of the models for the maize area and production are given in Table 1 and 2.

Goodness of fit of the model given in as the diagnostic check of the estimated model.

Residual analysis: The time series plot of the residual cultivated area and production data showed scattered trend, therefore, models were fitted properly by residual analysis.

For normality test, Shapiro-wilk test was used. The test was significant and assumption of normality was

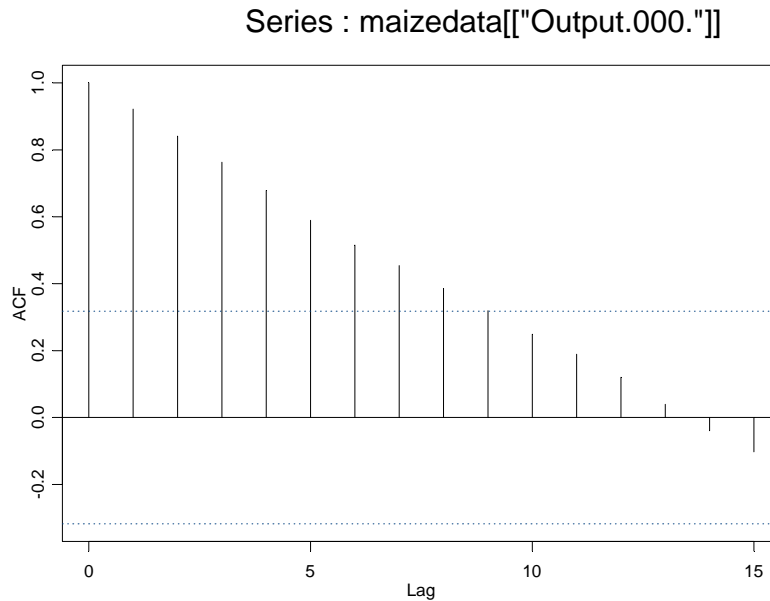


Fig. 2: Auto correlation function of Maize production

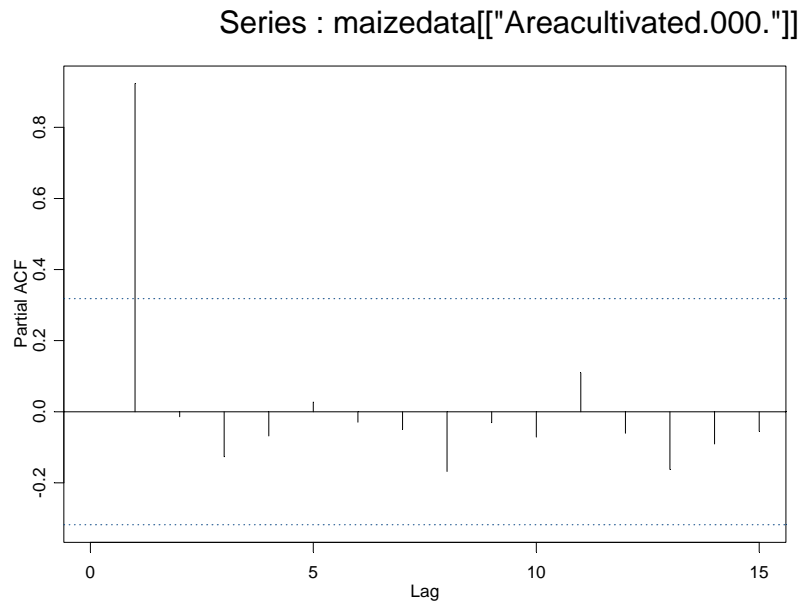


Fig. 3: Partial auto correlation function for Maize cultivation area

accepted. Since the series fitted shows normality, the model is a good fit.

Forecast of area and production. ARIMA (1,1,1) and ARIMA(2,1,2) were taken for 38 years ahead and forecasts for maize area and production are given in Table 3 at 95% confidence interval values.

For 2006-07, a forecast of maize area was 9225.41 thousand ha with lower and upper limit of 8623.12 and

9827.7 thousand ha, respectively. A maize area forecast for the year 2020 was 9229.74 thousand ha with lower and upper limit of 7087.67 and 11371.81 thousand ha, respectively. Forecast of maize production showed an increasing trend. For 2006-07, a maize production was about 9848.95 thousand tons with lower and upper limit 9115.28 and 10582.64 thousand tons. The maize production forecast for the year 2020 is about 9952.72

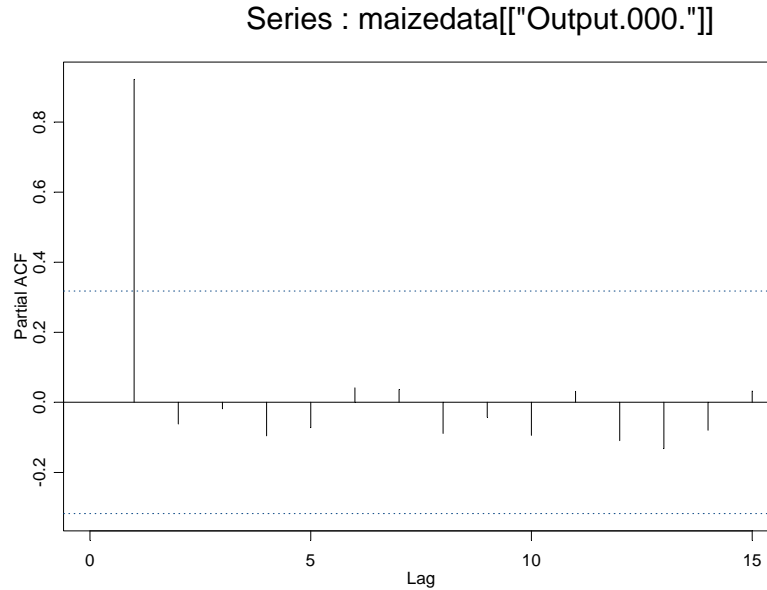


Fig. 4: Partial auto correlation function for Maize production

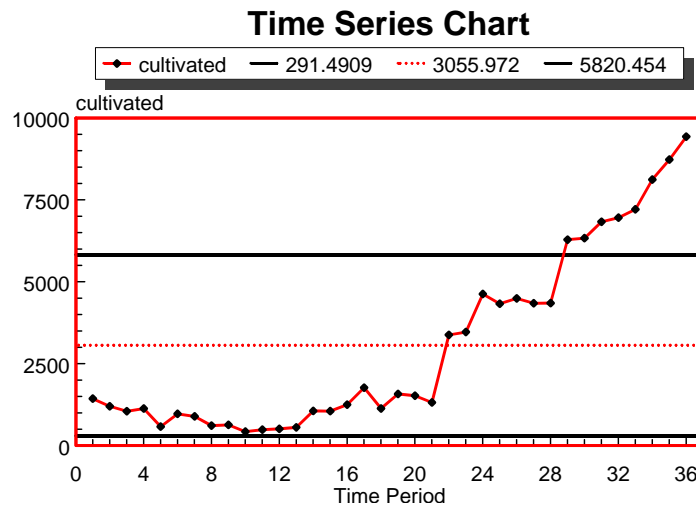


Fig. 5: Time series plot for cultivation area

Table1: Estimates of area parameters

Type	Coefficients	S.D	t-ratio
AR ₁	- 0.30096	0.3471	- 7.12
AR ₂	- 0.17331	0.2972	- 5.01
AR ₃	- 0.16521	0.3123	- 2.33
MA ₁	- 0.12807	0.4569	- 0.192

Table 2: Estimates of production parameters

Type	Coefficients	S.D	t-ratio
AR ₁	- 0.17331	0.1471	- 5.12
AR ₂	- 0.16521	0.2187	- 3.01
MA ₁	1.12807	0.1974	- 6.192

tons with upper and lower limits 6479.8 and 13425.64 thousand tons, respectively.

Table 3: Forecast of Maize area and production up to year 2020

Year	Area (000 ha)	Production (000 tons)
2006-07	9225.41±602.29	9848.96±733.68
2007-08	9231.05±823.41	9863.96±1163.60
2008-09	9229.34±1003.66	9855.64±1417.27
2009-10	9229.70±1154.27	9860.25±1658.46
2010-11	9229.70±1287.89	9857.69±1855.61
2011-12	9229.75±1408.70	9859.11±2040.37
2012-13	9229.73±1520.08	9858.33±2206.32
2013-14	9229.74±1623.77	9858.76±2362.40
2014-15	9229.73±1721.24	9558.65±2507.83
2015-16	9229.74±1813.47	9858.58±2776.70
2016-17	9229.74±1901.24	9858.62±2901.80
2017-18	9229.74±1985.12	9858.60±3021.65
2018-19	9229.74±2065.61	9858.61±3136.97
2019-20	9229.74±2142.07	9952.72±3472.92

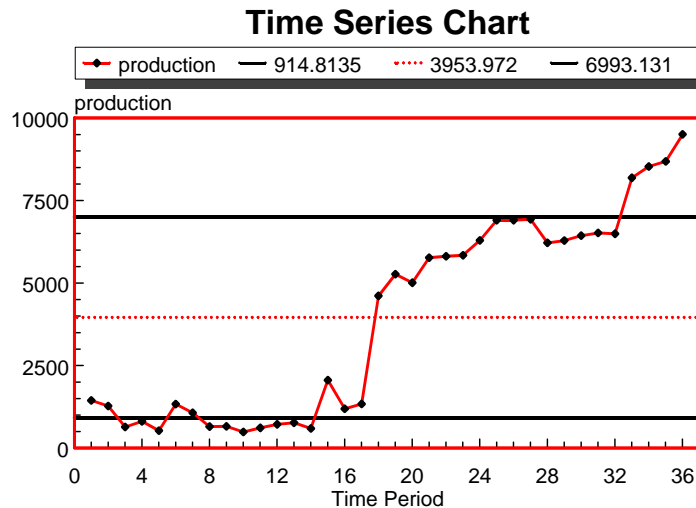


Fig. 6: Time series plot of production area

CONCLUSION

Increase in government funding to agriculture, selection of high yielding varieties, increasing agricultural linkage between farmers and research institutes are important factors needed to increase the yield and production of maize in future. Also, total cropped area can be increased in future, if land reclamation and conservation measures are adopted. The supply projection of an agricultural commodity especially maize plays a vital role in the adjustment of supply to demand. These projections help the government to make policies with regards to relative price structure, production and consumption patterns and also, to establish relationship with other countries of the world.

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AUTHOR'S CONTRIBUTION

Problem statement and the Material were framed by Badmus, M.A. (An Agricultural Economists) while the analysis and method was carried out by Ariyo, O.S. (a Statistician). Results and discussion as well as conclusion were jointly done by both Authors.