RESEARCH ARTICLE

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Autoregressive Integration Moving Average (ARIMA) Model for Prices of Selected Grains in the South West Nigeria

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ABSTRACT

Background: Price serves as signals of relative scarcity as well as abundance of a given agricultural product. Prices of agricultural products vary from month to month and even from day to day and this constitutes a source of risk to farmers whose livelihood depends on good pricing of their products.

Method: This study was conducted to identify pattern of price dynamics and to develop model for price dynamics of beans, yellow maize and local rice using monthly price data of grains from the National Bureau of Statistics (2006-2015).

Result: The rk of the beans followed a regular decline ranging from 0.4035 to 1 while those (rk) of yellow maize and local rice follow non regular decline with the range 0.1448-1(yellow maize) and 0.2945-1 (local rice) thus indicating that the data are non-stationary. The corrected Akaike information criteria (AICC) and other information obtained for the ARIMA1,2,2 were higher than those of ARIMA2,2,2. The AICC obtained for the ARIMA1,2,2 are 958.422 (beans), 1178.169 (yellow Maize) and 1211.778 (local rice). The ARIMA2,2,2 was thence favored above ARIMA1,2,2.

Key words: Correlogram, Droop, Heteroscedastic, Hop, Signal.

INTRODUCTION

Price according to business dictionary is a value that will purchase a finite quantity, weight or other measure of goods or services or a value that is put to a product or service. Price is a result of activities including calculations, research and understanding as well as risk taking ability (Economic Times, 2019). Prices of agricultural products vary from month to month and even from day to day and this constitutes a source of risk to farmers whose livelihood depends on good pricing of their products. Prices also differ between various grades of products and also differ between alternative markets and it (price) serves as signal of the relative scarcity as well as abundance of a given agricultural product (Akintunde *et al*., 2012). Beans, maize and rice are among the staple grains that are highly valued in Nigeria (Akpan *et al.,* 2014). The prices of these grains are also said to be highly heteroscedastic seasonally and market-wise (Gieri *et al.,* 2015). Beans and these other grains are sensitive to weather condition variability and this thus makes their cultivation very difficult (Akintunde, 2012). This (sensitivity to weather condition) coupled with unfavorable price fluctuation of the commodities can frustrate farmers' efforts and thus constitute a risk to farmers.

Previous study on time series analysis (Abu *et al*., 2015) has examined acreage response of soybean to price in Nigeria. Also, monthly price analysis of cowpea (Beans) and Maize in Akwa Ibom State, Nigeria (Akpan, *et al.,* 2014), Forecasting of meteorological drought using ARIMA model (Karthika *et al.,* 2017) and Hectrage Response of some selected cereal crops to price and non-price factors in Nigeria (Tahir, 2014) have being conducted. These works nevertheless, there exist little or no known work on the price dynamics of the selected grains in the Southwest, Nigeria and for the period under study. The goal of time series analysis has been identification of systematic pattern and random noise as well as trend analysis (Montgomery, 1990). These two goals are important to strategic planning of food supply for ensuring food security of a nation. The practical application of the present study is therefore in the forecasting and modeling of prices of these grains for profit maximization and risk management by farmers as well as for strategic grain reserves planning. The objective of this study was therefore to identify pattern of price dynamics and to develop model for future price dynamics of beans, yellow maize and local rice.

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MATERIALS AND METHODS

Data for this study were obtained from the National Bureau of Statistics (NBS) formerly, Federal office of Statistics, Oyo State, Ibadan. The study area was the urban market of the South West Nigeria (Oyo, Ondo, Ogun, Osun, Lagos and Ekiti States) between the year 2006 and 2015.The South West Nigeria is one of the six geographical regions of the country and it falls between longitude 2°311 and 6°001 East and Latitude 6°211 and 8° 371N and cover a land area of 77,818 km^2. The region is having boundary with Edo and Delta States in the East and in the North by Kwara and Kogi States while in the West it is bounded by the Republic of Benin and in the South by the Gulf of Guinea. The States were predominantly Yoruba States with other tribes found in large chunks and are largely agrarian in nature. The region has a tropical climate and bless with 2 usually distinct (wet and dry) seasons. The wet seasons last from April to October while the dry season last from November to March. Mean annual rainfall of the region falls between 1,000 to 3,000mm and mean temperature ranges from 21°C to 31°C.

The data obtained were subjected to descriptive statistics (mean, variance and standard error) and autocorrelation. Let X_t be a discrete time series or a process then the autocorrelation or lagged correlation is defined as the correlation of the process against a time shifted version of itself(Box and Jenikins, 1976).It is given as;

$$r_k = \frac{\sum_{t=1}^{N-1}(x_t-\bar{x}_{(1)})(x_{t+1}-\bar{x}_{(2)})}{\left[\sum_{t=1}^{N-1}(x_t-\bar{x}_{(1)})^2\right]^{1/2}\left[\sum_{t=1}^{N}(x_{t+1}-\bar{x}_{(2)})^2\right]^{1/2}}$$

Where, $\bar{x}_1$ is the mean of the first N-1 observation and $\bar{x}_2$ is the mean of the last n-1 observation. x_1 is the first N-1 which is x_t $t = 1,2,3,4,\ldots..N\text{-}1$ and x_2 is the last N-1 which x_{t+1}, $t, 2,3,4,\ldots.N\text{-}1$.

The ARIMA model otherwise depicted as ARIMA (p, g, q) is of general form;

$$X_t = a_1X_{t-1} + a_2X_{t-2} + \ldots + a_zX_{t-z} + b_1\ell_{t-1} + b_2\ell_{t-2}\ldots b_z\ell_{t-z}$$

Where

X_t = the price of the grain at time t

$$a_1X_{t-1} + a_2X_{t-2} + \ldots\ a_zX_{t-z}$$

are the response variable at lag time $t\text{-}1, t\text{-}2,\ldots\ t\text{-}z$; $a_1, a_2\ldots a_z$ $\ell_1,\ell_2\ldots\ell_z$ are coefficient of past variable at the lag time; are past errors and $b_1, b_2\ldots.b_z$ are coefficient of past errors. This model is in line with general ARIMA model proposed by Box and Jenkins (1970).

Two (2) ARIMA models, $ARIMA_{1,2,2}$ and $ARIMA_{2,2,2}$ were investigated and their model statistics including the adjusted coefficient of determination which indicates the proportion of the variance in the dependent variable (Y) that is predicted or explained by the ARIMA model. Four processes are involved in the use of ARIMA model for Time series data and include identification (of data trends), estimation (of the model coefficient), model checking for efficiency and forecasting (Assis *et al.*, 2010). These 4 processes were employed in the current study.

RESULTS AND DISCUSSION

Descriptive statistics of the price of the grains

The annual average price of the beans increases but not steadily over the years and ranged between ₦60.960 for 2007 and ₦251.110 for 2013. The variance ranged between 34.697 for 2010 and 689.687 for 2012 (Table 1). The average prices of yellow maize are non-regular and ranged from ₦40.399 (for 2008) to ₦135.768 for 2013. The variance however has a very wide range of 12.081 (for 2016) and 6948.16 for 2007. Mean price of the local rice was found to fall between ₦53.129 for 2006 and ₦207.384 for 2013 while the variances were from 1.077 for 2006 and 8527.77 for 2013 (Table 1). The implications of these results are:

1. The variability of the prices have high/wide margin with the rice having the highest of the margin.
2. Average annual prices of the beans were the highest while the average annual price of yellow maize were the least.

The average monthly prices of the beans returned an increasing trend for the first 9 months (January – September) of the year. It ranged between ₦138.094 and ₦158.329 for September (Table 2).The average monthly price of the beans for the remaining months dropped to ₦149.143 for December. The variance is generally very high and ranged between 6106.80 for May and 8745.75 for September. The average monthly price of yellow maize was generally low and ranged between ₦68.672 for February and ₦96.413 for November (Table 2). The variance is also generally high but lesser than that of beans and it ranged between 674.564 for October and 4968.15 for May. The average monthly price of rice ranged between ₦104.785 for January and ₦131.547 for June while the variance fall between 1793.39 for November and 11688.95 for May. The implications of the results are;

Table 1: Summary of Annual Price of the Grains.

Variables	Beans		Maize		Rice	
	Mean ± SE	Variance	Mean ± SE	Variance	Mean ± SE	Variance
2006	67.407 ± 1.859	41.484	41.621 ± 1.003	12.081	53.129 ± 0.300	1.077
2007	60.960 ± 3.764	169.997	72.175 ± 24.063	6948.16	78.653 ± 12.376	1837.84
2008	77.312 ± 2.521	76.246	40.399 ± 1.149	15.831	75.488 ± 2.628	82.873
2009	102.383 ± 3.077	113.601	55.232 ± 2.107	53.25	69.048 ± 7.896	748.166
2010	87.908 ± 1.700	34.697	-	-	91.534 ± 2.499	74.942
2011	-	-	74.641 ± 2.495	74.682	118.674 ± 4.46	239.751
2012	224.088 ± 7.581	689.687	95.520 ± 0.902	9.756	144.274 ± 0.687	5.664
2013	251.110 ± 4.453	237.964	135.768 ±17.848	3822.69	207.384 ± 26.658	8527.77
2014	234.944 ± 2.269	61.779	107.293 ± 4.845	281.671	176.387 ± 9.856	1165.68
2015	228.788 ± 4.138	205.440	94.623 ± 3.069	113.007	165.036 ± 2.895	100.553

Table 2: Summary of monthly price of the grains.

Variables	Beans		Maize		Rice	
	Mean ± SE	Variance	Mean ± SE	Variance	Mean ± SE	Variance
January	138.094 ± 26.164	6161.03	71.313 ± 10.981	1085.34	104.785 ± 14.596	2130.69
February	140.077 ± 26.390	6268.01	68.672 ± 10.653	1021.44	104.806 ± 14.932	2229.76
March	147.84 ± 28.703	7414.73	73.182 ± 10.458	984.296	113.164 ± 15.351	2356.49
April	144.384 ± 27.975	7043.40	73.597 ± 10.161	929.141	108.194 ± 17.938	3217.85
May	144.739 ± 26.049	6106.80	88.864 ± 23.495	4968.15	128.29 ± 34.189	11688.95
June	147.918 ± 26.256	6204.33	88.721 ± 23.438	4944.06	131.547 ± 33.740	11383.76
July	154.553 ± 28.045	7078.60	77.310 ± 12.905	1498.80	112.175 ± 13.961	1949.08
August	155.567 ± 28.001	7056.67	82.892 ± 12.243	1348.96	125.037 ± 18.310	3352.72
September	158.329 ± 31.173	8745.75	73.042 ± 9.813	866.611	118.076 ± 14.353	2060.17
October	153.890 ± 28.334	7225.28	69.831 ± 8.657	674.564	121.623 ± 18.967	3597.40
November	145.324 ± 28.452	7285.74	96.413 ± 20.739	3870.80	124.341 ± 13.392	1793.39
December	149.143 ± 29.933	8063.97	92.523 ± 21.858	4300.06	123.489 ± 14.562	2120.55

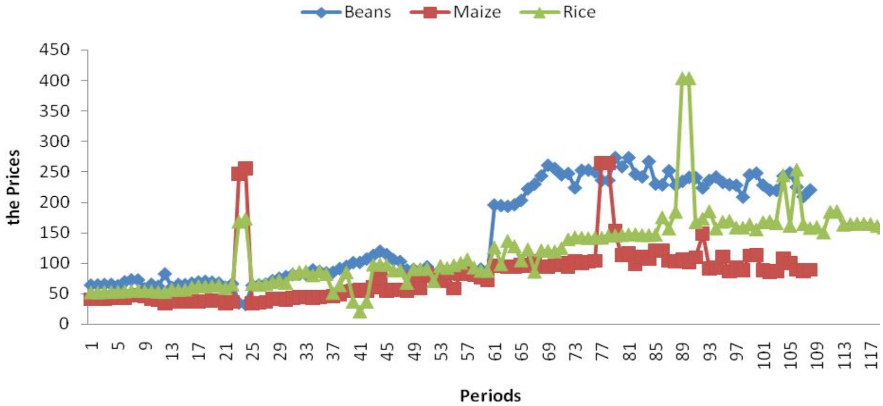

Fig 1: Time series graphs of the grains (Beans, Yellow Maize and Local rice).

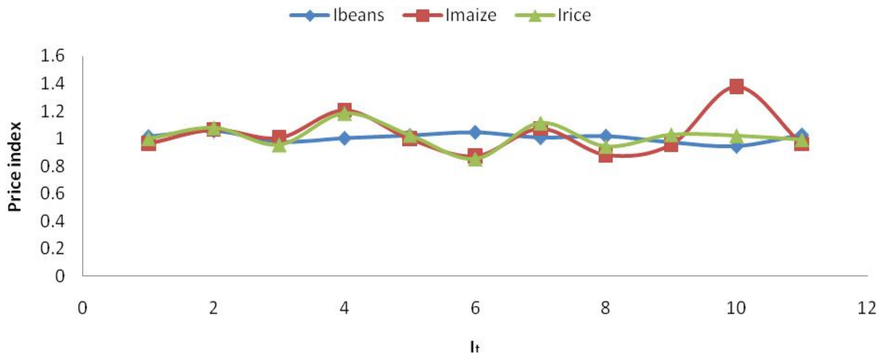

Fig 2: Price index for the commodities (Beans, Maize and Rice).

I_t is the series for the changes.

1. Bean had the highest average monthly price while yellow maize had the least average monthly price.
2. The monthly price (N) of the rice returned the highest variability.

The trend of the series plot established in the present work conflict with the time series plot of rice production in the entire Nigeria (Aina *et al.*, 2015) which can be described a random series. This dissimilarity might have been caused by the difference in the study areas (South west and Nigeria) and parameters (price and production) of the two studies. The results of the visual analysis in the present study clearly depict non stationary of the price data and it is in line with Dickey and Pantula (2002). Also, the non-stationary nature of the price of the grains in the present study is similar to Abu *et al.* (2015) for soybean acreage response to price fluctuation. It was maintained that if a series does not seem to have a constant mean and the plot of the estimated autocorrelations dies down very slowly with increasing *j,* then the series is non-stationary. Similarly, the hops of the time series might have been caused by naturally occurring

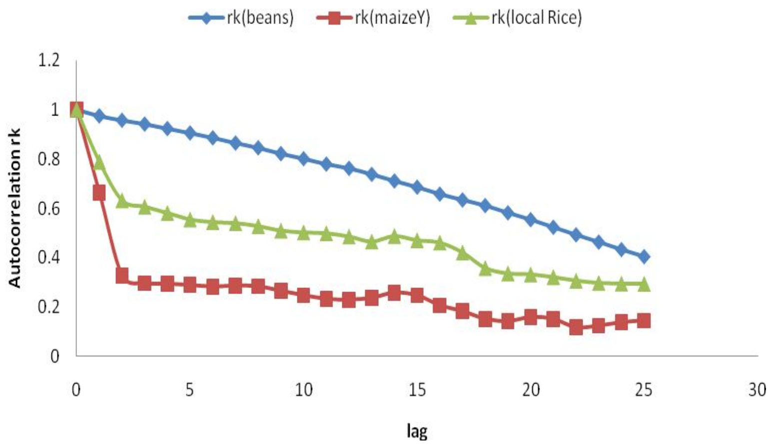

Fig 3: Correlogram of the average price of beans, yellow maize and local rice (for lag 25).

phenomena like the Boko haram saga and other security challenge in the Country. Two phenomena have been identified for sudden hop in series plot and are naturally occurring phenomena and quasi-experiment (Chatfield, 2003). Similarly, price instability was established by the area of acreage allocation for soybean cultivation (Abu *et al.*, 2015), political instability, oil price fluctuation, population growth and climate change (Mustapha and Culas, 2019). Nature of product, fluctuation of currency exchange rate and poor infrastructure were identified as causes of price fluctuation in Kilmanjaro, Tanzania (Huka *et al.*, 2014).There existed an indication of food crisis in the series plots obtained and it is in conformity with Ikeokwu (2019) who maintained that Africa Countries are facing a worsening food crisis unseen in the last 30 years. In addition, the high/wide variability margin for the commodities' price with the rice having the highest of the margin can be hinged on persistency of the price instability factors established by early authors. Also, Kassim (2012) established that consumer price instability can be linked with persistent factors such as season, input price changes, production and marketing technologies and consumer taste.

Visual analysis of price dynamics and correlelogram of the selected grains

Generally, the visual analysis of the series indicated that beans returned higher prices over the period while the yellow maize was the least (Fig 1). The visual analysis of the time plots of the grains (bean, yellow maize and local rice) returned an increasing cyclical trend for the period. It was however noticed that the series showed low trends for the first half of the period and later hop for the latter part of the period (Fig 1). The implication of the results is that the prices of the commodities rose up tangentially after some period of the study. The results of the visual analysis of the price index of the beans indicated that beans' price index was regular while those of yellow maize and local rice were random (Fig 2). The implication of the result is that price dynamics for both yellow maize and local rice are almost the same and thus followed a regular random pattern. The implication of this

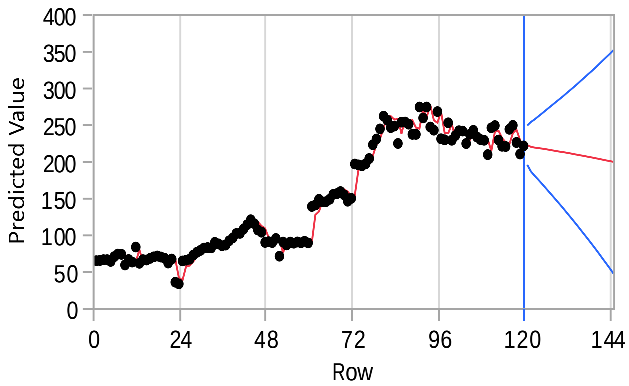

Fig 4: Model forecasting for average price of beans.

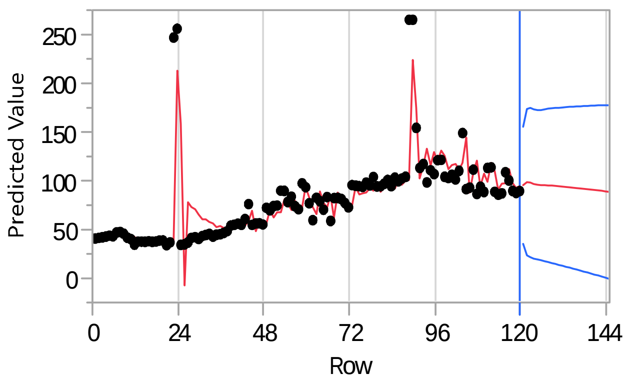

Fig 5: Model forecasting for average price of yellow maize.

result is that the rate of change of the three commodities (beans, yellow maize and local rice).

The visual analysis of the correlogram for all the grains (Fig 3) showed that the autocorrelation, r_k die down as the lag increases. It was also obtained that the r_k for both local rice and yellow maize followed the same pattern while the r_k for beans followed different pattern and was the highest at any of the lag. The r_k of the beans followed a regular decline ranging from 0.4035 to 1 while those (r_k) of yellow maize and local rice follow non regular decline with the range 0.1448- 1(yellow maize) and 0.2945 -1 (local rice). This

Table 3: ARMA Model components' Summary.

Types	Term	Lag	Beans			Yellow maize			Local rice		
			Estimate	Std Error	t Ratio	Estimate	Std Error	t Ratio	Estimate	Std Error	t Ratio
$ARIMA_{2,2,2}$	AR1	1	0.086968	0.2948902	0.29	0.6333664	0.1017427	6.23**	0.518981	0.1056629	4.91**
	AR2	2	-0.129719	0.1222212	-1.06	-0.340892	0.0921304	-3.7**	-0.188143	0.0864116	-2.18**
	MA1	1	1.320494	0.2867755	4.6**	1.881972	0.094548	19.9**	1.871213	0.0806924	23.19**
	MA2	2	-0.361315	0.2831251	-1.28	-0.881973	0.0932698	-9.46**	-0.871213	0.0787653	-11.06**
	Intercept	0	-0.011413	0.0558713	-0.2	-0.011829	0.0164481	-0.72	-0.007772	0.0205854	-0.38
$ARIMA_{1,2,2}$	AR1	1	0.266663	0.2150633	1.24	-0.564733	0.1316604	-4.29**	-0.721684	0.2708999	-2.66**
	MA1	1	1.515071	0.1813999	8.35**	0.1723493	0.0873042	1.97**	0.230885	0.2453609	0.94
	MA2	2	-0.54488	0.1822066	-2.99**	0.8276313	0.0865114	9.57*	0.7690782	0.2449898	3.14**
	Intercept	0	-0.01157	0.0568741	-0.2	-0.012158	0.0976511	-0.12	-0.009555	0.103481	-0.09

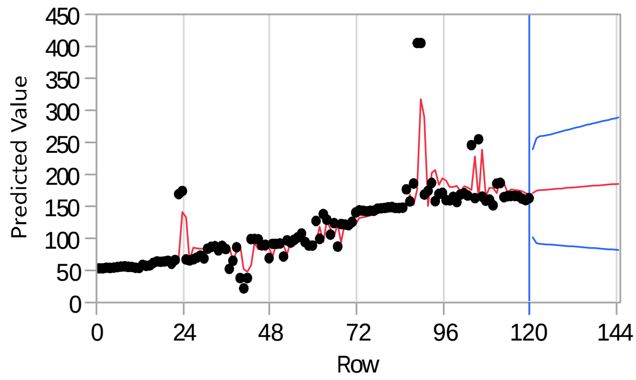

Fig 6: Model forecasting for average price of local rice.

indicates that as the period of the study increases, the relationships between the price of any of the commodities and the previous price decreases. Also, from the visual analysis, it is glaring that the data are non-stationary and thus would require differentiation for further analysis.

From the visual analysis, series plots obtained in the present study can be partitioned into two distinct parts, early and reduced price of the commodities and latter and increased commodities price period. The hop nature of the prices of the commodity in the latter period under study is not in conformity with the steady rise in the price of both commodities in the Northern Nigeria (Akanni, 2014). The hop of this time series data is however similar to average crop prices and percentage change in Africa obtained from FAOSTAT by Mustapha and Culas (2019).The ARIMA model components (particularly the intercept) revealed that the non-stationary nature of the initial data have been removed after the first differentiation based on the negative intercept obtained for all the models.

The ARIMA model components and statistics

The analysis of the autoregressive moving average model of the beans returned the model components that are not significantly different from zero except the first moving average (MA1 - Table 3). The $t_{(113;\ 0.05)}$ = 4.6 obtained for the MA1 is significant ($P < 0.05$) while that of other model components (0.29 = AR1; -1.06 = AR2; -1.28= MA2 and -0.2= intercept) were not significant. The standard errors of the estimates were generally low(less than unity) and ranged between 0.06 for the intercept and 0.295 for the AR1). For the yellow maize, the ARMA model components were al significant except the intercept. The $t_{(113;\ 0.05)}$ = 6.23, -3.7, 19.9 and 9.46 obtained respectively for AR1, AR2, MA1 and MA2 were significant ($P < 0.05$ - Table 3). The standard error of the ARMA model estimates fall between 0.016 for the intercept 0.102 for AR1. Similarly, all the model components of the ARMA model for the local rice except were significant. The $t_{(113;\ 0.05)}$ = 4.91, -2.18, 23.19 and 11.06 obtained for AR1, AR2, MA1 and MA2 were significant ($P < 0.05$ - Table 3). The standard error of the ARIMA models components ranged between 0.021 for the intercept and 0.106 for AR1.

The model statistics for the $ARMA_{2,2,2}$ model indicated that high standard error ranging from 20998.333 (beans) to 138609.41 (local rice) and high variance (959.471-1187.905)

Table 4: Comparison of Model Statistics for $ARIMA_{(1,2,2)}$ and $ARIMA_{(2,2,2)}$ Models.

Model	Beans		Yellow Maize		Local rice	
	ARIMA (1, 2, 2)	ARIMA (2, 2, 2)	ARIMA (1, 2, 2)	ARIMA (2, 2, 2)	ARIMA (1, 2, 2)	ARIMA (2, 2, 2)
DF	114	113	114	113	114	113
Variance	185.764	185.826	1179.751	936.887	1568.693	1226.632
AIC	958.422	959.471	1178.169	1156.716	1211.778	1187.905
SBC	969.505	973.324	1189.252	1170.569	1222.861	1201.758
R^2 Adj.	0.968	0.968	0.367	0.487	0.579	0.671
-2LogLH	950.422	949.471	1170.169	1146.716	1203.778	1177.905
Weights	0.628	0.372	0.000	1.000	0.000	1.000
MAPE	7.489	7.592	19.253	18.776	14.644	15.303
MAE	9.405	9.449	15.618	14.235	17.151	18.311

MAPE - Mean Absolute Percentage Error; MAE - Mean Absolute Error.

were obtained. The adjusted R^2 of the model are 0.967, 0.46 and 0.660 for beans, yellow maize and local rice. Also, the corrected Akaike information criteria (AICC) obtained were 959.471, 1156.716 and 1187.905 for bean, yellow maize and local rice. The model prediction for the beans followed a similar trend (of increasing cyclical but non regular trend) with the original prices (Fig 4). This indicated a parsimonious prediction and it is in line with the adjusted coefficient of determination (R^2 = 0.967) obtained for the model. The $ARMA_{2,2,2}$ model prediction for yellow maize also has similar random but increasing trend with the original price data (Fig 5). The adjusted coefficient of determination (R^2 = 0.469) obtained for the model is also an indication of good prediction though lesser than that of the model for the beans. The visual analysis of the model prediction for the local rice returned a similar cyclical but non regular increasing trend for the price of rice (Fig 6). The model statistics for the $ARMA_{1,2,2}$ model on the other hand gave a higher variance of the estimates including 185.764, 1179.751 and 1568.693 for bean prices, yellow maize prices and local rice prices respectively. Similarly, the corrected Akaike information criteria (AICC) and other information obtained for the $ARIMA_{1,2,2}$ were higher than those of $ARIMA_{2,2,2}$. The AICC obtained for the $ARIMA_{1,2,2}$ are 958.422 (beans), 1178.169 (yellow maize) and 1211.778 (local rice - Table 5).

The implication of these results is that each of the $ARMA_{2,2,2}$ model can sufficiently predict the price of the commodities at any period of time than the $ARMA_{1,2,2}$ model and that this prediction are done at different level of reliability. The parsimony of the $ARIMA_{2,2,2}$ model arrived at in this study is similar to Assis *et al.,* (2010) which established that Mixed ARIMA model outperformed other investigated models for cocoa bean price forecasting. It was also found suitable for forecasting food grains production in Bangladesh (Lasker *et al.,* 2013). $ARIMA_{2,2,2}$ was found to outperformed $ARIMA_{1,2,2}$ or of any other order though with the AICC far more than those of Kirimi (2016). This may be hinged on the nature of the data in both studies (Present study and Kirimi, 2016). GARCH model was however preferred to ARIMA model in the forecasting of weekly price of green gram (Pani *et al.,* 2019). This difference might have been due to the fact that pricing in each study case might be affected by disparate factors.

CONCLUSION

The grain deficit of the nation (Nigeria) in conclusion has been established using behavioural model in previous study (Akanni, 2014). Efficient utilization of the instrument of the time series analysis results in the current study and similar studies can be an asset in optimum grain production for self-sufficiency in food production especially in this era of rice importation ban. It is therefore recommended that farmers should be guided based on the grain price dynamics on grain production for profit maximization and the grain reserve body should utilize the price regime dynamics for adequate grain reserve activities.

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