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Cassava production and agricultural growth in Nigeria: Analysis of effects and forecast

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Abstract

This study analyzed the trend in agricultural growth and cassava productivity in Nigeria (1961 – 2020). Time series on variables of interest were sourced from the Central Bank of Nigeria (CBN) statistical bulletin, the National Bureau of Statistics (NBS), and FAOSTAT. The secondary data obtained were analysed Vector Error Correction Model (VECM) and the autoregressive integrated moving average (ARIMA) model. The result of the short-run model indicated that the Vector Error Correction Term [VECT (-1)] was rightly signed (-1.74) indicating a high speed of adjustment. The results of the ARIMA forecast showed that in the next decade, the area cultivated for cassava will be 11295.04 ('000 hectares), the output of cassava will be 73300.33 ('000 tonnes), the yield of cassava will be 10.98 tonnes/ha while agricultural growth will be 80612.60 ('000). The findings are compelling reasons for encouraging cassava production for sustainable food production in Nigeria as it is a versatile staple to address food security in Nigeria.

Keywords: ARIMA; Agricultural growth; Cassava production; Forecast; Long-Run; Short-run; VECM

1. Introduction

Agricultural growth is a cornerstone of economic development, particularly in countries with agrarian economies like Nigeria. The sector has long been central to Nigeria's economy, significantly contributing to domestic production, employment, and foreign exchange earnings (National Bureau of Statistics, NBS, 2018). Cassava, a staple crop, is integral to the agricultural sector due to its adaptability, high yield potential, and role in food security (Olutumise et al., 2024; Donkor et al., 2017). Despite its importance, the dynamics of cassava production and its impact on agricultural growth have not been fully explored, necessitating a comprehensive analysis. Cassava (*Manihot esculenta*), a crucial crop in Nigeria, is essential in ensuring food security and providing income for rural households. As global population growth is expected to surpass 9 billion by 2050, food security concerns are mounting, especially in developing countries like Nigeria (Food and Agriculture Organization, FAO, 2020). Cassava's resilience under challenging conditions and its ability to yield despite poor soils make it a valuable crop, especially in sub-Saharan Africa (Philip, 2004). Moreover, its wide-ranging applications, from food to industrial uses such as animal feed, starch, and bio-degradable products, underscore its economic significance (Agricultural Research Council, ARC, 2019).

Despite Nigeria's position as the largest global producer of cassava, significant challenges remain in improving cassava yield per hectare. Smallholder farmers largely manage current cassava production with minimal mechanization and low access to modern inputs. Although cassava has the potential to contribute significantly to food security, inefficiencies in farming systems, combined with limited access to agricultural technologies, have resulted in stagnant productivity. Furthermore, while cassava production has increased over time, the broader relationship between cassava output and agricultural growth remains critical. Understanding this relationship is crucial for developing effective policies and interventions. This study aims to examine the short-run and long-run effects of cassava area and production on agricultural growth using the Vector Error Correction Model (VECM).

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This study is significant for several reasons. First, it provides empirical evidence on the impact of cassava cultivation on agricultural growth, offering valuable insights for policymakers and stakeholders. Second, the study's findings can inform the design of targeted interventions to enhance cassava production, thereby boosting agricultural growth and economic development. Finally, by validating the VECM model through stability checks, this study ensures the reliability of its findings, contributing to the broader body of knowledge.

2. Methodology

The study area is Nigeria. The longitudinal survey design was adopted for this study. Annual time series data on cassava production, area harvested, productivity (yield), and agricultural growth from 1961 to 2020 was used. The data was sourced from the Central Bank of Nigeria (CBN) statistical bulletin, the National Bureau of Statistics (NBS), and FAO Statistics (FAOSTAT). Time series (secondary) data on cassava production, yield, and land area were collected for a period of sixty years (1961 – 2020).

The secondary data was analysed using descriptive and econometric statistical tools. The effects of area and production of cassava on agricultural growth in the long run and short run were achieved using the Vector Error Correction Model (VECM), while the estimate of the trend of area, production and yield of cassava and agricultural growth in Nigeria in the next decade was achieved using the autoregressive integrated moving average (ARIMA) model.

The error correction model was used to model the causal influence between non-stationary I(1) variables with evidence of a long-run relationship. The vector error correction model is useful for the evaluation of a short-term adjustment which adjusts towards the long-run equilibrium in each period. If the variables are found to be cointegrated, a vector error correction model (VECM) is estimated because a co-integrating relationship deals only with a long-run relationship without considering the short-run dynamics. The advantage of this procedure lies in the fact that both long-run and short-run influences of the endogenous variables in the model can be determined with the mechanism that keeps the variable in equilibrium. For instance, if we hypothesized that variables area, production, and productivity are jointly determined (i.e. endogenous to a system).

The relationship between these variables can be described by VAR such that:

$$Y_t = \phi_1 + \sum_{i=1}^{p} \alpha_{1i} Y_{t-i} + \sum_{i=1}^{p} \beta_{1i} P_{t-i} + \sum_{i=1}^{p} \emptyset_{1i} R_{t-i} + \sigma_1 + \varepsilon_{1t}$$

$$P_t = \phi_2 + \sum_{i=1}^{p} \alpha_{2i} Y_{t-i} + \sum_{i=1}^{p} \beta_{2i} P_{t-i} + \sum_{i=1}^{p} \emptyset_{2i} R_{t-i} + \sigma_1 + \varepsilon_{2t}$$

$$R_t = \phi_3 + \sum_{i=1}^{p} \alpha_{3i} Y_{t-i} + \sum_{i=1}^{p} \beta_{3i} P_{t-i} + \sum_{i=1}^{p} \emptyset_{3i} R_{t-i} + \sigma_3 + \varepsilon_{3t}$$

where: ϕ and σ are mx1 vector parameters; α, β, and Ø are mx1 and m x p vectors of parameters respectively; p is the optimal lag order that minimizes information criteria; m is the number of endogenous variables under investigation (area, production, and productivity); ε_{jt} is an mx1 vector of random variables assumed to be normally distributed white noise process.

Suppose we hypothesized further that the series under investigation have unit roots and possibly co-integrated, the Granger representation theorem asserts that error correction model (ECM) or restricted VAR of the form:

$$Y_t = \mathrm{Y}_1 + \lambda_j (Y_{t-1} - \alpha_1 P_{t-1} - \alpha_2 R_{t-1}) + \sum_{i=1}^{p-1} A_{1i} \Delta Y_{t-i+1} + \sum_{i=1}^{p-1} \beta_{1i} \Delta P_{t-i+1} + \sum_{i=1}^{p-1} \emptyset_{1i} \Delta R_{t-i+1} + \varepsilon_{1t}$$

$$P_t = \mathrm{Y}_2 + \lambda_j (Y_{t-1} - \alpha_1 P_{t-1} - \alpha_2 R_{t-1}) + \sum_{i=1}^{p-1} A_{2i} \Delta Y_{t-i+1} + \sum_{i=1}^{p-1} \beta_{2i} \Delta P_{t-i+1} + \sum_{i=1}^{p-1} \emptyset_{2i} \Delta R_{t-i+1} + \varepsilon_{2t}$$

$$R_t = \mathrm{Y}_3 + \lambda_j (Y_{t-1} - \alpha_1 P_{t-1} - \alpha_2 R_{t-1}) + \sum_{i=1}^{p-1} A_{3i} \Delta Y_{t-i+1} + \sum_{i=1}^{p-1} \beta_{3i} \Delta P_{t-i+1} + \sum_{i=1}^{p-1} \emptyset_{3i} \Delta R_{t-i+1} + \varepsilon$$

Produce consistent estimates of the system parameters. The parameters λ_j in the above equations measure the speed of adjustment of short-run disequilibrium to long-run equilibrium position; while the parameter A, β, and Ø measures the short-run temporary influence of the pat values of the area on production, past values of production on productivity, and past values of productivity on agricultural growth, respectively; such that the coefficient in equations are respectively;

$A_{11} = A_{12} = A_{13} \ldots\ldots\ldots A_{1p-1} = 0$

$\beta_{11} = \beta_{12} = A_{13} \ldots\ldots\ldots \beta_{1p-1} = 0$

$\phi_{11} = \phi_{12} = A_{13} \ldots\ldots\ldots \phi_{1p-1} = 0$

3. Results

3.1. Unit Root Test

Before the estimation of the effect of cassava production and area under cultivation on agricultural growth in Nigeria during the period under study, the included variables in the model were subjected to stationarity tests. Decision was made based on the outcome of the ADF unit root test and the results are presented in Table 1.

Table 1 Result of ADF and PP Test

Variables	**Augmented Dickey-Fuller Test**				**Decision**
	ADF stat	Prob.	Critical value @ %	Order	
PRDN	-8.4619	0.0000*	-2.9126	Δ I(1)	Stationary
AREA	-5.6870	0.0000***	-2.9126	Δ I(1)	Stationary
AGROWTH	-3.3808	0.0158**	-2.9135	Δ I(1)	Stationary

Source: Author's Computation using EViews 11; Δ = difference operator *** and ** ➔ figures are significant at 1% (P < 0.01) and 5% (P < 0.01) level of significance, respectively.

3.2. Result of the Co-integration Rank Test for the Long Run Relationship among the Variables

Further investigation into the series properties of the variables through the use of the Johansen cointegration mechanism indicates that there is co-integration among the variables (Table 2).

Table 2 Johansen Co-integration Test for unrestricted co-integration Rank Test (Trace)

Hypothesized No. Of CE(S)	**Eigenvalue**	**Trace Statistics**	**0.05 Critical value**	**Prob****
None	0.2696	37.9972	29.7971	0.0047
At most 1	0.2039	19.6636	15.4947	0.0111
At most 2	0.1050	6.4344	3.8415	0.0112

Source: Author's Computation Using E-Views 11

3.3. Long Run and Short Run Effects of Cassava Production and Area Harvested on Agricultural Growth

Consequent upon the existence of one co-integrating equation among the variables, implying the existence of a long-run relationship among the variables, the Vector Error Correction Model (VECM) was estimated. The Vector Error Correction model shows the short-run and long-run effects of area and production of cassava on agricultural growth in Nigeria.

Table 3 Vector Error Correction Model of the long and short-run effect of cassava production and area on agricultural growth in Nigeria

Long run	**Estimates**
Regressors	CointEq1
Agric. growth (-1)	1.000000

Area (-1)	3.3022 (2.7987***)		
Production (-1)	1.3436 (10.3433***)		
Short-run	Estimates		
Variable	Coefficient	Std. Error	Prob.
CointEq1	-1.7440	1.9474 (-0.8956)	0.3745
LNAGROTH (-1)	2.5632	1.9463 (1.3169)	0.1934
LNPRDN	0.4095	0.0778 (5.2582)	0.0000***
LNPRDN(-1)	-1.6773	1.5859 (-1.0577))	0.2949
Constant	-3.1672	3.9234 (-0.8073)	0.4231
R2	0.99		
F statistics	2397.0720		0.0000
Durbi-Watson Stat	2.0177		

Figures in parentheses are t-values; *** significant at 1% ; Source: Author's Computation Using E-Views 11

3.4. Diagnostic and Stability Tests

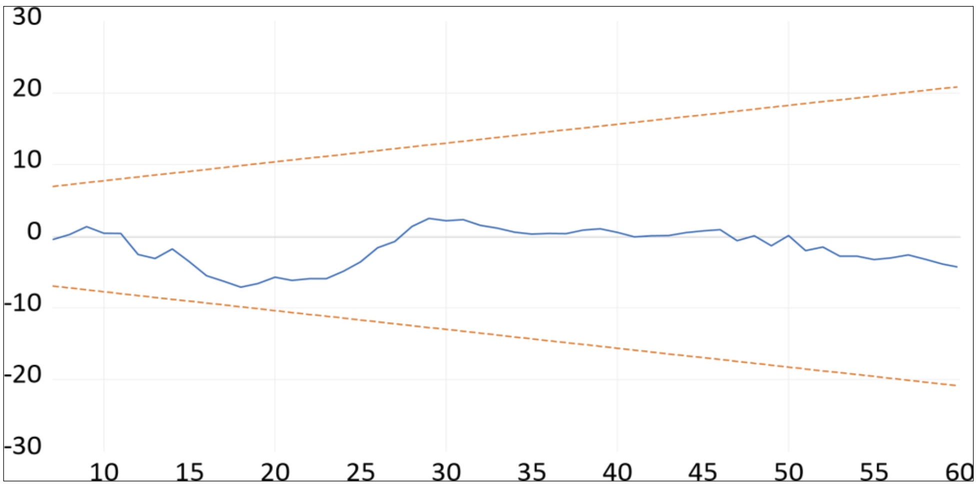
The ECM model was validated and verified using a series of diagnostic and stability checks to confirm the independence of the residuals from the fitted model. Following Pesaran *et al*., (2001), for a robust model, the residuals must exhibit the required independence during the diagnostic and stability checks, if not, the model is unacceptable statistically and requires further model modification before additional diagnostic and stability checks. In this way, such a model becomes unbiased and robust to make the correct statistical inferences.

Table 4 Diagnostic tests of the model

Statistics	**Breusch-Pagan-Godfrey**	**Jarque-Bera**
F – stat.	0.008573	3.6671
Prob. F(2,52)	0.9915	0.1598
Obs*R-sq.	0.0194	
Prob. Chi-square	0.9903	

Source: Author's Computation using E-Views 11

To estimate the structural stability of the equation in the model, the study employed the CUSUM (Cumulative Sum test) and CUSUM of squares (Cumulative Sum of Squares residual) presented in Figures 1 and 2, respectively.



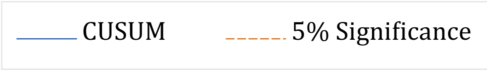


Figure 1 Stability Test – CUSUM Test

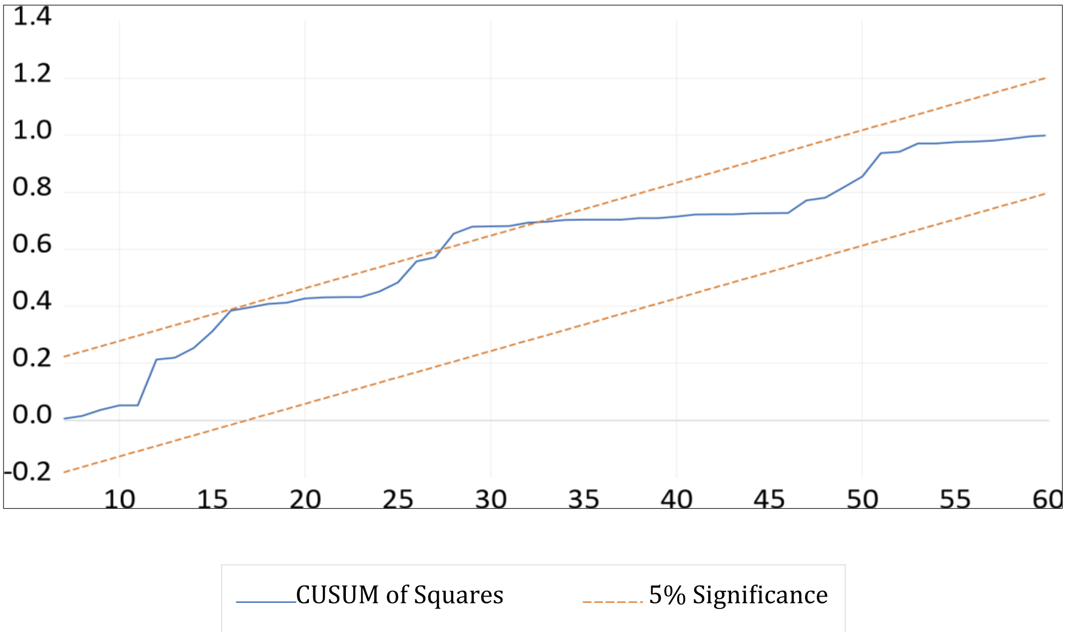


Figure 2 Stability Test – CUSUM Test

3.5. Estimate of the trend of area, production and yield of cassava and agricultural growth

The results of the ARIMA estimate of the trend of area, production and yield of cassava and agricultural growth in the next decade are presented in Table 5.

Table 5 ten years forecast of area, production, yield and agricultural growth

Year	Agric. Growth ('000)	Area ('000ha)	Production ('000tonnes)	Yield
2021	62320.89	7795.77	64280.51	10.75
2022	63788.14	8572.29	67155.88	10.83
2023	65912.89	8486.91	65607.86	10.88
2024	67736.59	9103.23	68857.11	10.92
2025	69721.66	9286.49	68094.10	10.94
2026	71845.07	9728.44	70041.85	10.95
2027	73857.20	10082.52	70611.23	10.97
2028	76111.58	10466.90	71487.49	10.98
2029	78294.05	10893.94	72750.67	10.98
2030	80612.60	11295.04	73300.33	10.98

Source: Author's Computation, 2021.

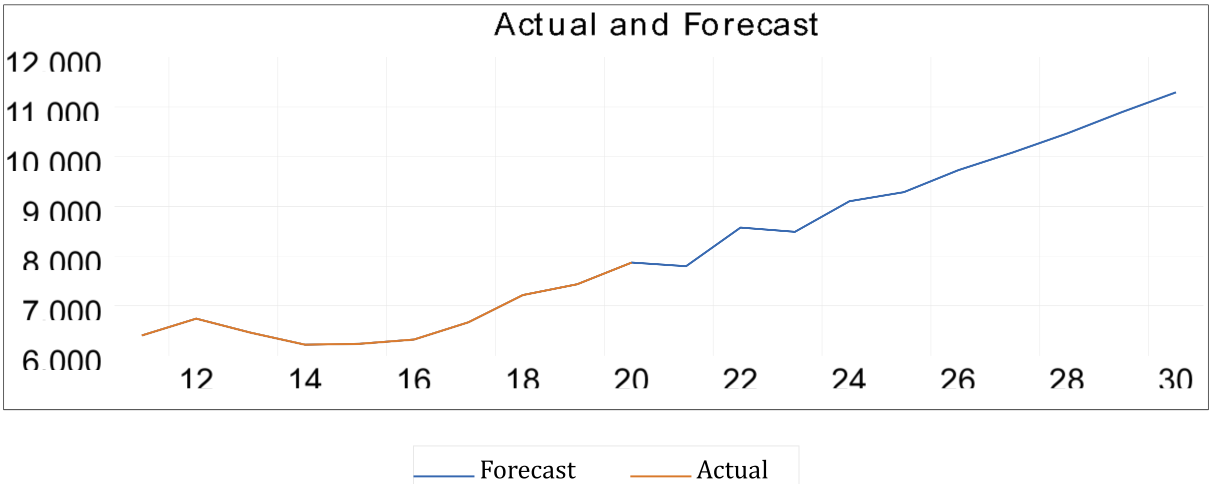


Figure 3 Forecast plot of area of cassava cultivated in Nigeria from 2021-2030

Source: Author's Computation, 2021

Actual and Forecast

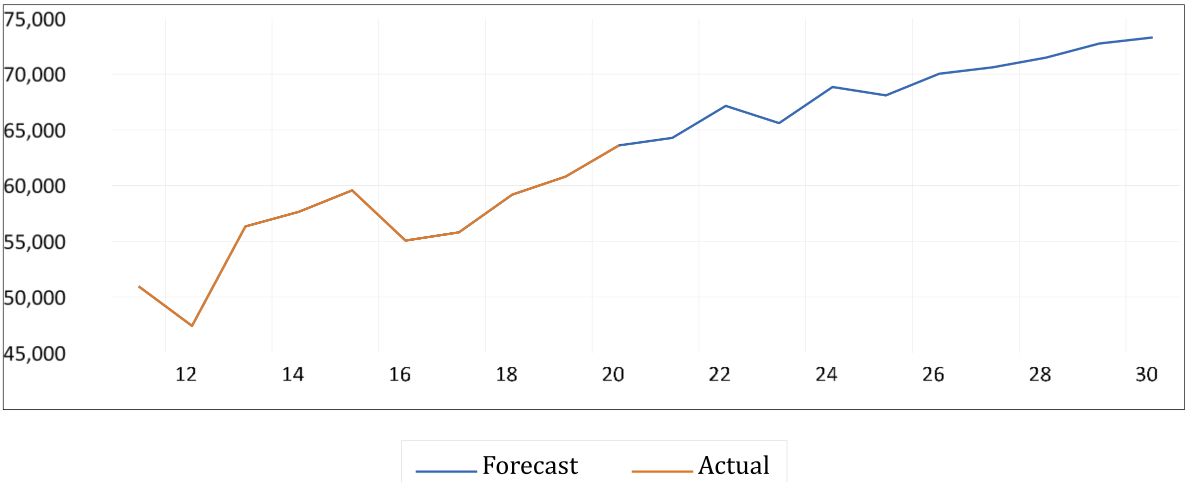


Figure 4 Forecast plot of production of cassava from 2021-2030

Source: Author's Computation, 2021

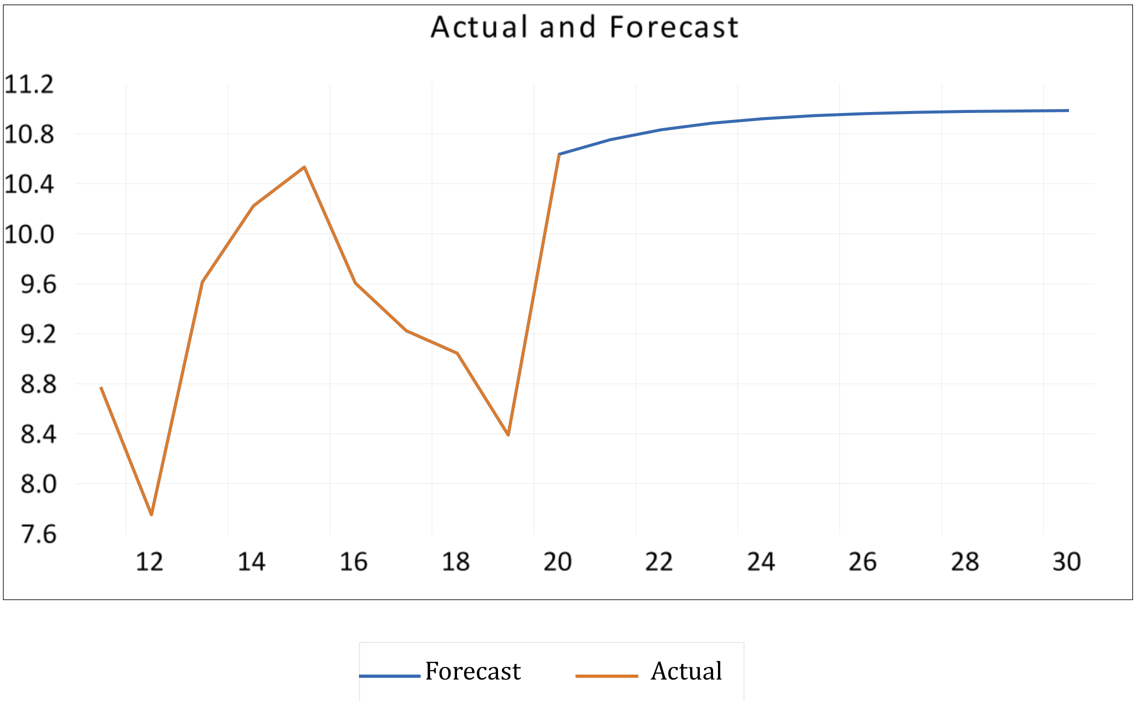


Figure 5 Forecast plot of yield of cassava from 2021-2030

Source: Author's Computation, 2021

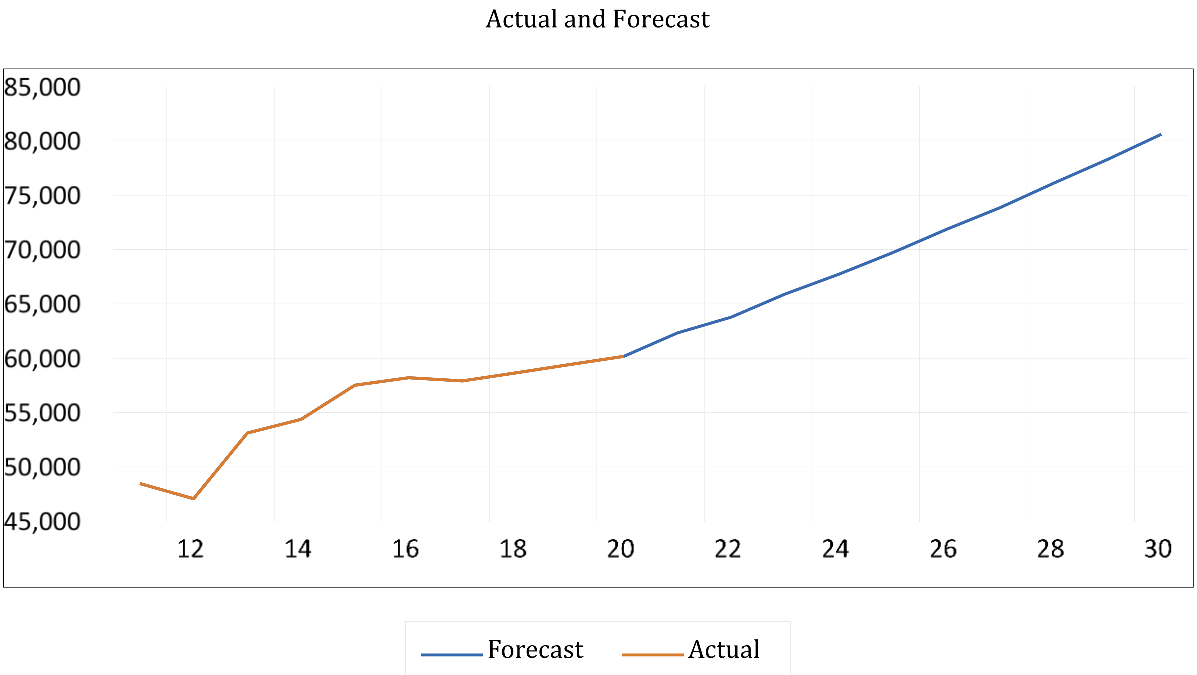


Figure 6 Forecast plot of agricultural growth from 2021-2030

Source: Author's Computation, 2021

4. Discussion

On application of the ADF test, all the variables attained stationarity after differencing once and thus, it can be concluded that the variables are integrated of the order one, I(1). This indicates that the variables exhibit random walk (unit roots) or the future values of these variables do not converge from their past values. Stationarity is confirmed when the test statistic is greater than the critical value in absolute terms. Consequently, the ECM was used to analyze the effect of cassava production and area on agricultural growth. According to Philips and Hansen (1990), the ECM is used for estimating a single cointegrating relationship that has a combination of I(1). Further investigation into the series properties of the variables through the use of the Johansen co-integration mechanism indicates that there is co-integration among the variables (Table 1). According to Engle and Granger (1987), regressing a non-stationary series on another non-stationary series yields spurious regression, but if the linear combination of the series is stationary, it could be concluded that the variables are cointegrated and the regression is no longer spurious. Variables are said to be cointegrated if they have long-run association. The result of the Johansen cointegration test shows that the computed trace statistic (37.9972) is greater than the critical value (29.7971) at 0.05 level; therefore, co-integration exists among the variables. This implies that a long-run relationship exists among cassava production, area harvested, and agricultural growth.

The Vector Error Correction model shows the short-run and long-run effects of area and production of cassava on agricultural growth in Nigeria. The result of VECM indicated that in the long run, the coefficient of area was rightly signed as expected and statistically significant at a 1% probability level. This implies that a unit increase in area will increase agricultural growth by 3.30 units *ceteris paribus*. Furthermore, the result indicated that in the long run, the coefficient of cassava production was rightly signed as expected and statistically significant at a 1% probability level. This implies that a unit increase in cassava production will increase agricultural growth by 1.34 units *ceteris paribus*. These findings are consistent with the studies of Nanbol and Namo (2019) who reported that root and tuber crops play vital roles in agricultural growth in the world. The result also agrees with Scott *et al.* (2000) who posited that an increase in the production of roots and tuber could increase agricultural growth substantially. This finding is noteworthy in that, cassava production in the country contributes more significantly to agricultural growth in the long run. The result of the short run indicated that the Vector Error Correction Term [VECT (-1)] is rightly signed (-1.74) indicating a high speed of adjustment (that is, the speed at which the deviation from long-run equilibrium is adjusted quickly where 1.74 of the disequilibrium is removed immediately in each period). The result implies that a 174% deviation from the equilibrium position is corrected within the year. The result further shows that in the short run, the change in the coefficient of cassava production was positive (0.4095) and significant at a 1% level of probability. This implies that an increase in cassava production will also lead to a 0.4095 increase in agricultural growth in the short run, *ceteris paribus*.

The ECM model was validated and verified using a series of diagnostic and stability checks to confirm the independence of the residuals from the fitted model. Following Pesaran *et al*., (2001), for a robust model, the residuals must exhibit the required independence during the diagnostic and stability checks, if not, the model is unacceptable statistically and requires further model modification before additional diagnostic and stability checks. In this way, such a model becomes unbiased and robust to make the correct statistical inferences. Diagnostic tests employed to validate the VECM model in this study include the Jarque-Bera and Heteroskedasticity Test. VECM residual heteroskedasticity was tested with the Breusch-Pagan-Godfrey Test statistic as advanced by Breusch and Pagan (1979). The result showed that the Probability value of the observed R-squared is greater than 5 percent; this means the null hypothesis of no heteroskedasticity is accepted. Also, the model's residual normal distribution was tested with the Jarque-Bera test statistic. Evidence from The null hypothesis of multivariate normal distribution was accepted at the 5 percent significance level since the probability of the Jarque-Bera statistic is not significant ($p>0.05$); this means that; the model residuals are normally distributed.

To estimate the structural stability of the equation in the model, the study employed the CUSUM (Cumulative Sum test) and CUSUM of squares (Cumulative Sum of Squares residual) tests presented in Figures 1 and 2, respectively. As a rule of thumb, if the plot of the cumulative sum goes outside the area of 5 per cent critical lines, the parameter estimates are found not to be stable (Brown *et al.*, 1975). Evidence from Figures 1 and 2 shows that all the plots in CUSUM and CUSUM of Squares residual test lie within the 5% significance level. This implies that the estimated parameters of the equation in the model are constant and stable to verify and validate the evidence of the cointegration test, the long-run and short-run relationship. In other words, the estimated model in this study is robust and meets stability conditions to make unbiased statistical inferences, as advanced by Ploberger and Kramer (1992).

The results of the ARIMA forecast of the trend of area, production and yield of cassava and agricultural growth are presented in Table 5. Figure 3 shows that though there has been some sluggish increase in the area cultivated for cassava in the past few years, the forecasted series will continue to increase for this forecasted period *ceteris paribus*. Specifically, in the next decade, the area cultivated for cassava will be 11295.04 ('000 hectares). Similarly, Figure 4 shows that cassava production in Nigeria will continue to increase with very little fluctuations for this forecasted period *ceteris paribus*. Specifically, in the next decade, the production of cassava will be 73300.33 ('000 tonnes). Furthermore, Figure 5 shows that amidst the declining yield of cassava observed in 2015-2019, the yield will continue to increase for these forecasted periods *ceteris paribus*. Specifically, in the next decade, the yield of cassava will be 10.98 tonnes/hectare. Finally, the forecasted series showed that agricultural growth will continue to have an upward trend during this forecasted period *ceteris paribus*. Specifically, in the next decade, the agricultural growth will be 80612.60 ('000). These findings show that there are great prospects for agricultural growth and the cassava sub-sector in Nigeria.

5. Conclusion

The study reveals that cassava production and the area harvested have significant long-run and short-run positive effects on agricultural growth in Nigeria. Both variables exhibit strong co-integration with agricultural growth, emphasizing their importance in the country's agricultural sector. The forecasted trends indicate that cassava production and agricultural growth will continue to rise in the coming years, signaling a promising outlook for food security and economic development.

Based on findings from this study, the following policy recommendations are made:

1. The government of Nigeria should encourage policies that support expanding cassava cultivation areas and improving mechanization to boost productivity and reduce reliance on manual labour. Further, there should be increased access to improved, high-yield, and pest-resistant cassava varieties to sustain long-term growth and ensure stable production.
2. The government should provide smallholder farmers with access to credit, training, and modern farming technologies to optimize cassava yields and enhance their contribution to agricultural growth
3. Relevant agencies should strengthen cassava value chains by improving market access, storage facilities, and processing infrastructure to maximize profits and reduce post-harvest losses.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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