International Journal of Applied Economics, Agriculture and Management Sciences (IJAAMS)
Vol. 2, Issue 1, pp. 164-179, 2023

Analysis of Long and Short Run Effects of Cereal Crops Yield on Food Security in Nigeria: 1981-2020

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Abstract

The study assessed the effects of cereal yield on food security in Nigeria in the long run and short run. The study adopted a longitudinal survey design using time series data spanning from 1981 to 2020. Data on rainfall were collected from the archives of National Bureau of Statistics (NBS) while data on yields and prices were collected from the records of Food Agriculture Organization (FAO). Data for this study were analyzed using descriptive statistics, Augmented Dickey Fuller Test and Vector Error Correction Model (VECM). The result of the Augmented Dickey Fuller (ADF) test (table 2) indicated that all the variables were found to be stationary on first differencing and Johansen co-integration mechanism indicated that there was co-integration among the variables. The result of VECM (table 5) showed that in the long run, a unit increase in maize yield will increase food insecurity by 4.790 units; a unit increase in rice yield will decrease food insecurity by 3.581 units; while a unit increase in sorghum yield decreased food insecurity by 0.469 units *ceteris paribus*. The study concludes that though the yields of selected cereal crops (maize, rice and sorghum) are low compared to world average, the crops possess enormous potentials and strong implications for both food security and food independence. The study therefore recommended that appropriate strategy aimed at improving cereal crop yield should be put in place to promote the desired growth in the cereal sector and enhance the availability and access to the selected cereals which in turn will lead to attainment of food security.

Keywords: Cereal, Yield, Effect, Food, Security, VECM

1.0 INTRODUCTION

Cereals are a major contributor to agriculture and food security in Nigeria consisting between 55 and 60% of subsistent farmers output, and provides income as well as forms the basis for` many households' diets both in the rural and urban areas (Balami *et al.*, 2011). Interestingly, cereals form the major source of food for human consumption globally. Bezadih, Falco and Yesuf

(2011), identified that cereal production is the key to feeding the growing human population. They further asserted that 80-100 million additional people must be supplied with cereal each year which will require a 70% increase in production over the next 30 years.

The heavy dependence of the economy and food security on rain-fed agriculture makes Nigeria highly susceptible to fluctuations in rainfall. Consequently, unreliable amount and spread of rainfall, has been implicated as a major factor leading to Nigeria's declining crop production, productivity and consequently, food security. The effects of this will lead to low/poor agricultural production which crucial role in food security in Nigeria.

In recent times, Nigeria has faced a rise in food prices, especially cereals. Audu (2012) noted that cereals are becoming scarce and more expensive therefore; the need to increase cereal production becomes more glaring. Because of the increased demand for cereal crops resulting from an increase in population density and income growth~~,~~ relative to the low productivity of some cereal crops by farms, Nigeria has become a net importer of some cereal crops from other countries. Thus, Nigeria first goal is to meet the domestic demand and then if possible seek to become net exporter to other countries.

Cereal production has not been able to keep pace with population increase in Nigeria. Tackling food insecurity and hunger is a more difficult task in the face of erratic rainfall pattern, global population, and high and volatile food prices. The other factor contributing to problems of food insecurity and hunger is an increase in the level and volatility of food prices. In fact, rising population and rainfall variability are the major causes of high and volatile food prices (von Braun and Tadesse, 2012).

Food crops such as rice, maize, cowpea, melon, groundnut, cassava, sweet potatoes, millet, sorghum, etc. are crops that contribute to food security to meet the consumption needs of the households, and as a source for livestock feeds. Its production is therefore important in meeting the food need of the poor rural households in particular and Nigeria in general. FAO (2009) posits that food production by the farmers forms the basic pre-requisite for improved household food security. According to Gillespie and Haddad (2001), food insecurity boils down to inability of households to have reliable access to food in sufficient quantity and quality to enjoy active and healthy life. Similarly, Ijarotimi and Oyeneyin (2005) asserted that food insecurity exists when people lack access to capital to produce food and this leads to insufficient amount of safe and nutritious food required for normal growth and development of healthy life.

However, to Oriola (2009), food security entails producing food that will go round every citizen both in quality and quantity. To achieve this, agricultural production needs to be enhanced with adequate knowledge of the environment, climatic condition, the market and its operation, and be aware of price and price mechanism, good transportation system, storage, fashion modality to check glut and be well prepared in case of disasters. Food insecurity is the opposite of this, it is the lack of access to sufficient quality and quantity of save nutrition food for an active and healthy life; the inability of households or individuals to meet the required consumption level in the face of fluctuating production, price, and income (Maharjan and Chhetri, 2006).

Abu and Adakole (2017) posited that the instability in the area, output and yield of cereals could create problems for food security given that majority of the population relies on cereals for food, in view of the fact that it is relatively cheaper than other food items. They further opined that given that cereal contributes for the most part to attainment of food security of developing country, factors that affects output of cereals would have direct effect on food security. Therefore, improving cereal productivity growth and reducing instability cannot be overemphasized because of the role of cereals in ensuring food security which is an essential part in eradicating hunger and poverty. Consequent upon this, this study will assess the effect of cereal yield on food security in Nigeria in the long run and short run.

2.0 METHODOLOGY

2.1 Study Area

The study area is Nigeria. Nigeria with a projected population of 210.87 million in 2021 (NBS, 2021) and a total geographical area of 923,768 square kilometers is located between latitudes 4º N and 14º N and longitudes 2º2' and 14º 30' East. The nation is bordered in the north by the Republic of Niger and Chad, in the south by Atlantic Ocean, in the east and west by Republic of Cameroon and Benin respectively.

Nigeria has five main vegetation belts; these are the Mangrove forest, Savannah grassland, Equatorial forest, Semi desert, Guinean savannah. The country has a wide range of climatic conditions but as a tropical country, it is generally hot and humid. The specific location is of advantage in terms of environmental diversity, culture, cultivation and human practices; thus the country is blessed with favourable climatic conditions which is good for almost all the food crops. The agricultural sector is particularly important in terms of its employment generation and its contribution to Gross Domestic Product (GDP) and export earnings. Administratively, Nigeria has 36 states with six geopolitical zones and FCT Abuja. These are; South-East, South-South, South-West, North-East, North-West and North-Central.

2.2 Methods of Data Collection and Analytic Technique

The study used time series data spanning from 1981 to 2020. Data on rainfall were collected from the archives of National Bureau of Statistics (NBS) while data on yields, prices and food security were collected from the records of Food and Agriculture Organization (FAO). Data for this study were analyzed using descriptive statistics, Augmented Dickey-Fuller (ADF), Johansen Co-integration and Vector Error Correction Model (VECM).

2.3 Model Specification

2.3.1 Unit Root Test

The Augmented Dickey Fuller (ADF) test for the presence of unit root (evidence of non stationarity) was employed. The advantage of the method lies on its robustness to handle both first order and higher order auto regressive processes (Nkang, Ndifo and Edet, 2007):

$$\Delta Y_t = \alpha + \sigma Y_{t-1} + \psi T + \sum_{k=0}^{N} \beta_k \Delta Y_{t-k} + u_t \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots..(1)$$

Where Y_t represents current values of sorghum, rice and maize yields

Y_{t-i} is the immediate past values of sorghum, rice and maize yields

Δ is the change operator

T represent the variable time

$$\Delta Fs_t = \alpha + \sigma Fs_{t-1} + \psi T + \sum_{k=0}^{N} \beta_k \Delta Fs_{t-k} + u_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (2)$$

Where Fs_t represents current values of Food security

Fs_{t-i} is the immediate past values of Food security

Δ is the change operator

T represents the variable time

Where α, β, ψ are parameters, Y has unit root if in the regression σ = 0; otherwise the unit root does not exist $Ho: \sigma = 0\ (Y\ has\ unitroot)$

2.3.2 Co-integration Test

Co-integration test looks for linear combinations of I(1) time series that are stationary (or, more generally, linear combinations of I(d) time series that are integrated of an order lower than (d).

This procedure focuses on the rank of the Π-matrix (row matrix)

$$\Delta Z_t = \varphi + \sum_{i}^{p} \Gamma_I \Delta Z_{t-i} + Y_{t-i} + Fs_{t-i} + \Pi Z_{t-p} + Y_{t-p} + Fs_{t-p} \ldots\ldots + \xi_t \ldots\ldots\ldots (3)$$

Where

ΔZ_t is a vector of change in the current value of the endogenous variables under investigation (yields of rice, maize, sorghum and food security); Z_{t-I} are the past values of these variables; Δ is a change operator.

If the Π-matrix has reduced rank but not equal to zero, is a case of co integration implying that Π can be decomposed as α and β. The endogenous variables depicted by Z are co integrated, where α is the matrix of speed of adjustment coefficients which explain the short run effects of changes in the explanatory variable on the dependent variable ,whereas β's represent the long run equilibrium effect. However, if the variables are stationary at levels, Π would have full rank.

The Π is a (n x 1) is a long-run impact matrix which is product of two (n x 1) matrices. If the coefficient matrix Π has reduced rank r<n, subsequently there exist (n x r) matrices α and β each one with rank r such that $\Pi = \alpha\beta'$ and ΔZ_t is stationary. The r is the number of co integrating relationships, the elements of α is known as the adjustment parameters in the vector error correction model and each column of β is a cointegrating vector. It can be shown that for a known r, the maximum likelihood estimator of β defines the combination of Z_{t-1} that yields the r largest canonical correlations of ΔZ_t with Z_{t-1} after correcting for lagged differences and deterministic variables once present. Johansen (1995) suggested two different likelihood ratio tests, the trace test which tests the null hypothesis of r co integrating vectors against the alternative hypothesis of k co integrating vectors and maximum eigen value test, which tests the null hypothesis of r co integrating vectors against the alternative hypothesis of r + 1 co integrating vectors.

2.3.3. Vector Error Correction Model (VECM)

The vector error correction model is useful for the evaluation of a short term adjustment which adjusts towards the long run equilibrium in each time period. The relationship between these variables can be described such that:

$$lnY_t = \varphi_1 + \sum_{i=1}^{p} \alpha_{1i} lnY_{t-i} + \sum_{i=1}^{p} \emptyset_{1i} lnFs_{t-i} + \sigma_1 ECT + \xi_{1t} \ldots\ldots (4)$$

$$lnFs_t = \varphi_2 + \sum_{i=1}^{p} \alpha_{2i} lnY_{t-i} + \sum_{i=1}^{p} \emptyset_{2i} lnFs_{t-i} + \sigma_2 + \xi_{2t} \ldots\ldots (5)$$

where: φ *and* σ are mx1 vector of parameters; $\alpha, \beta, \emptyset$ 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 food security and yield of the variable under investigation (rice or maize or sorghum); ξ_{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:

$$Y_t = \gamma_1 + \lambda_j(Y_{t-1} - \alpha_1 Fs_{t-1}) + \sum_{i=1}^{p-1} A_{1i}\Delta Y_{t-i+1} + \sum_{i=1}^{p-1} \beta_{1i}\Delta Fs_{t-i+1} + \varepsilon_{1t} \dots (6)$$

$$Fs_t = \gamma_2 + \lambda_j(Y_{t-1} - \alpha_1 Fs_{t-1}) + \sum_{i=1}^{p-1} A_{2i}\Delta Y_{t-i+1} + \sum_{i=1}^{p-1} \beta_{2i}\Delta Fs_{t-i+1} + \varepsilon_{2t} \dots (7)$$

produce consistent estimates of the system parameters. The parameterλ_j in (6) and (7) measures the speed of adjustment of short run disequilibrium to long run equilibrium position; while the parameter$A, \beta\ and \Phi$ measure the short run temporary influence of the past values of yield on food security and past values of food security on yield respectively, such that if the coefficient in equation (6) and (7) are respectively such that,

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

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

the past values of the variables yields, prices and rainfall were said not to Granger cause the current value of yield (Y). Furthermore, the optimal lag order for the model was determined by the lag order that minimizes Akaike information criterion (AIC). The Information criterion was based on the model log likelihood and lag length such that:

AIC = − 2(*l*/*T*) + 2(*k*/*T*) where l is the value of the log likelihood function; T is the sample size; and K is the number parameters.

3.0 RESULTS AND DISCUSSION

3.1 Summary statistics of the variables

The summary statistics of the variables used in the study is presented in Table 1. The result showed that the variables maize yield, rice yield, sorghum yield and food security were positively skewed to the right tail implying the presence of more values that are higher than the sample mean.

The result further showed that the variable rice yield was platykurtic (negative kurtosis) with a kurtosis value less than 3 implying that the distribution had a flatten curve relative to the normal. This shows that there were more values that are lower than the sample mean. The variable maize yield was mesokurtic showing a normal distribution of the variable. However, the variables sorghum yield and food security were leptokurtic (positive kurtosis) a kurtosis value greater than 3 showing that the distribution had a peaked curve relative to the normal.

More so, the result of the Jarque-Bera probability test of normality showed that the variables rice yield and maize yield were not statistically significant at 5% significant level having probability values greater than 0.05 (5%) which indicated the normal distribution of the variables used in the study. However, the variables sorghum yield and food security were not normally distributed.

Table 1. Descriptive Statistics of the Variables

	Maize Yield	Rice Yield	Sorghum Yield	Food Security
Mean	1.46894	1.74620	1.17929	72.93625
Median	1.49490	1.75210	1.14435	35.28500
Maximum	2.19610	2.38930	1.63320	329.9900
Minimum	0.970700	1.29990	0.969100	0.500000
Std. Dev.	0.253188	0.287681	0.164853	88.01594
Skewness	0.436271	0.070658	1.434259	1.363045
Kurtosis	3.325710	1.810607	4.763232	4.010547
Jarque-Bera	1.445696	2.391044	18.89563	14.08795
Probability	0.485368	0.302546	0.000179	0.000873
Sum	58.77180	69.90600	47.19940	2917.450
Sum Sq. Dev.	2.503541	3.203408	1.061832	302125.5
Observations	40	40	40	40

Source: Data Analysis, 2023.

3.2 Unit Root Test

The Augmented Dickey Fuller (ADF) test and Philips-Perron (PP) test for unit root were employed to test whether or not a variable is stationary and also determine the order of integration of the variable (Table 2). The result indicated that all the variables (rice yield, maize yield, sorghum yield and food security) were found to be integrated of order one and became stationary on first differencing. This indicates that the variables exhibited random walk (unit roots) or the future values of these variables do not converge from their past values.

Table 2: Result of ADF and PP Tests

Variables	Augmented Dickey-Fuller Test				Phillips – Perron Test				Decision
	ADF stat	Prob.	Critical value @ 1%	Order	PP Stat	Prob.	Critical value @ 1%	Order	
Maize yield	-6.092701***	0.0000	-3.616	Δ I(1)	-8.405501	0.0000***	-3.615588	Δ I(1)	Stationary
Rice yield	-6.327061***	0.0000	-3.611	Δ I(1)	-11.17025	0.0000***	-3.615588	Δ I(1)	Stationary
Sorghum yield	-6.867353***	0.0000	-3.611	Δ I(1)	-6.296921	0.0000***	-3.615588	Δ I(1)	Stationary
Food security	-4.691889***	0.0003	-3.616	Δ I(1)	-8.105528	0.0000***	-3.615588	Δ I(1)	Stationary

Source: Data Analysis, 2023. Δ = difference operator ***significant at 1% ($P < 0.01$) level of significance

3.3 Result of 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 Johansen co-integration mechanism indicates that there is co-integration among the variables (Table 3). Variables were said to be cointegrated if they have long run association. Using trace statistics, the result showed that combination of these variables has four (4) co-integrating equations and this means that linear combination of these variables has four long run linear combination of relationship or four co-integrating equations. Using the maximum Eigen statistics, the result showed that combination of these variables had one co-integrating equation and this means that linear combination of these variables had a single long run linear combination of relationship or one co-integrating equation. However, the trace statistics was adopted in this research for the purpose of simplicity in analysis. This implies that a long run relationship exists among the variables (rice yield, maize yield, sorghum yield and food security).

Table 3. 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*	0.855275	232.7544	159.5297	0.0000
At most 1*	0.703845	159.3033	125.6154	0.0001
At most 2*	0.583160	113.0621	95.75366	0.0019

At most 3*	0.549878	79.81012	69.81889	0.0064
At most 4*	0.395427	49.47711	47.85613	0.0349
Maximum Eigenvalue				
Hypothesized No. Of CE(S)	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical value**	**Prob****
None *	0.856859	73.86919	52.36261	0.0001
At most 1	0.700683	45.83762	46.23142	0.0551
At most 2	0.585610	33.47602	40.07757	0.2290
At most 3	0.552268	30.53534	33.87687	0.1190
At most 4	0.396594	19.19628	27.58434	0.3995

Source: Data Analysis, 2023.

3.4 Lag Length Selection Criteria

The result of the lag length selection criteria is presented in Table 4. The lag length was selected from six different selection criteria. Akaike information criterion (AIC) was chosen because of its lowest value 21.33103 at lag 1. Therefore, lag 1 is the appropriate lag to be used for the model. The determination of appropriate lag length is important because estimates of VAR whose lag length differs from the true lag length are inconsistent. In general, too many lags inflate the standard errors of the coefficient estimates and thus imply an increase in the forecast error. On the other hand, omitting lags that should be included in the model may result in an estimation bias.

Table 4. Lag Length Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-451.0631	NA	9160048.	24.54395	24.67457	24.59000
1	-382.6241	122.0804*	369515.5*	21.33103*	21.85349*	21.51523*
2	-378.1608	7.237902	477570.9	21.57626	22.49056	21.89859
3	-368.4239	14.21058	471703.4	21.53643	22.84258	21.99691

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

3.5 Long and Short Run Effects of Cereal Yield on Food Insecurity in Nigeria

Vector Error Correction Model (VECM) was estimated as result of the existence of co-integrating equations among the variables, implying long run relationship exist among the variables. The Vector Error Correction model shows the short run and long run effects of cereal yield on food security in Nigeria.

The result of VECM as shown in Table 5 indicated that in a long run, maize yield positively influenced food insecurity while rice yield and sorghum yield negatively influenced food insecurity. Specifically, the coefficient of maize yield (4.790) was positive and statistically significant at 5% probability level. This implies that a unit increase in maize yield will increase food insecurity by 4.790 units *ceteris paribus*. However, this finding is not in line with *apriori* expectation as an increase in maize yield is expected to decrease food insecurity in Nigeria. This may be attributed to the fact that maize prices has experienced increasing trends over the years thereby making it unavailable for vulnerable households that are food insecure.

Furthermore, the coefficient of rice yield (3.581) was negative and statistically significant at 5% probability level. This implies that a unit increase in rice yield will decrease food insecurity by 3.581 units *ceteris paribus*. Similarly, the coefficient of sorghum yield (0.469) was negative and statistically significant at 1% probability level. This implies that a unit increase in sorghum yield will decrease food insecurity by 0.469 units *ceteris paribus*.

The result of the short run indicated that Error Correction Term [ECT (-1)] is statistically significant and negative (-0.166) indicating a slow speed of adjustment (that is, the speed at which the deviation from long run equilibrium is adjusted quickly where 0.166 of the disequilibrium is removed immediately in each period). The result implies that 16.6% deviation from equilibrium position is corrected within the year. This is the error corrected each year due to the disequilibrium between the short-run and long-run model.

The result further shows that in the short run, change in the coefficient of rice yield (0.496) was negative and statistically significant at 5% probability level. This implies that a unit increase in rice yield will decrease food insecurity by 0.496 units in the short run *ceteris paribus*. This is consistent with the findings by Abu and Adakole (2017) who opined that given that cereal contributes for the most part to attainment of food security of developing country, factors that affects output of cereals would have direct effect on food security.

Table 5. Long and Short-run Effects of Selected Cereal Yield on Food Security

Long run	**Estimates**			
Regressors	**CointEq1**			
Food insecurity (-1)	1.000000			
Maize Yield (-1)	4.790 (2.190**)			
Rice Yield (-1)	-3.581 (-1.990**)			
Sorghum Yield (-1)	-0.469 (-3.520***)			
Constant	70.26373			
Short-run	**Estimates**			
ECM	**Food insecurity**	**Maize Yield**	**Rice Yield**	**Sorghum Yield**
CointEq1	-0.166 (-6.95***)	0.010 (1.776*)	-0.023 (-1.226)	0.036 (0.545)
ΔFood insecurity(-1)	0.031 (1.920**)	-0.079 (-1.169)	0.028 (0.341)	-0.019 (-0.357)
ΔMaize Yield (-1)	0.198 (0.425)	0.045 (0.283)	0.040 (0.197)	0.029 (2.249**)
ΔRice Yield(-1)	-0.496 (-1.986**)	0.125 (0.892)	-0.262(-1.535)	0.051 (0.458)
ΔSorghum Yield(-1)	-0.543 (-0.939)	-0.012 (0.059)	-0.131 (-0.561)	-0.219 (-1.334)
Constant	11.213 (6.725***)	0.676 (1.135)	-0.412 (0.566)	0.021 (0.046)
R^2	0.831	0.462	0.380	0.198
Adj. R^2	0.804	0.382	0.363	0.073
F statistics	31.422***	3.435***	2.181**	0.780
Sum sq. resids	742.079	94.553	141.918	60.238
S.E. equation	4.815	1.718	2.105	1.372
Mean dependent	8.670	0.054	0.151	0.113

Likelihood -321.159 Akaike Information Criteria 18.376 Schwarz Criteria 19.583

Figures in parentheses are t-values, ** significant at 5%, *** significant at 1%

Source: Data Analysis, 2023.

3.6 Stability Diagnostic

Figure 1 presents the result for the structural break of the model using the CUSUM of square test. The CUSUM of square test lies between the gridlines, this implies that it lies between two standard deviation or 95% confidence interval. The graph shows that the fitted model was stable and therefore relevant for policy direction.

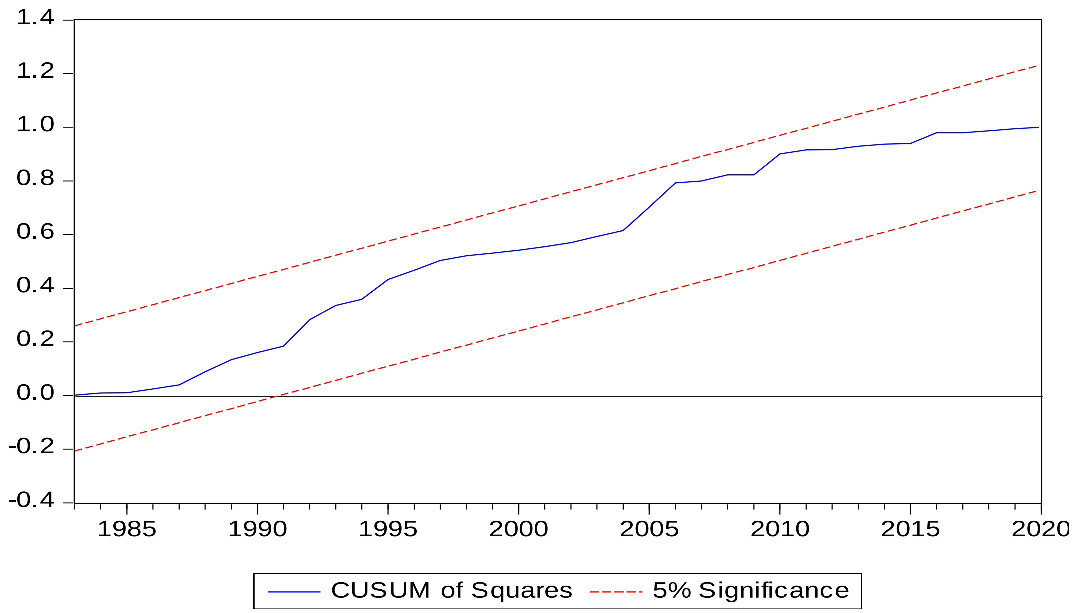

Figure 1. CUSUM of Square Test for Structural Break

Source: Data analysis, 2023.

4.0 CONCLUSION AND RECOMMENDATIONS

The study concludes that though the yields of selected cereal crops (maize, rice and sorghum) were low compared to world average, the crops possess enormous potentials and strong implications for both food security and food independence.

The study therefore recommended that appropriate strategy aimed at improving cereal crop yield such investing in agricultural research, timely supply of agricultural inputs such as improved seeds and fertilizer, education of farmers on the use of high yielding technologies should be put in place to promote the desired growth in the cereal sector and enhance the availability and access to the selected cereals which in turn will lead to attainment of food security.

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