The Role of Tuber Crops Production in Enhancing Food Security in Nigeria: A Variance Decomposition Analysis

***[1]Oraka, E. O. and [2]Abu, O.**
[1]Department of Agribusiness
Joseph Sarwuan Tarka University, Makurdi, P.M.B. 2373, Benue State, Nigeria.
*Corresponding Author's email: oraka.evelyn@uam.edu.ng
[2]Department of Agricultural Economics
Joseph Sarwuan Tarka University, Makurdi, P.M.B. 2373, Benue State, Nigeria.
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Abstract
This study analyzed the role of tuber crops production in enhancing food security in Nigeria. The study adopted a longitudinal documentary survey design that made use of time series data spanning from the year 1981-2021. Data on the variables for the study were collected from the Food and Agriculture Organization (FAO) and World Bank database. Data for this study were analyzed using Augmented Dickey-Fuller (ADF) test, Philips-Perron (PP) test, Johansen co-integration and variance decomposition. The result of the Augmented Dickey Fuller (ADF) test for unit root indicated that all the variables were found to be integrated of order one and became stationary on first differencing. The result of Johansen co-integration test indicated that there exist co-integration among the variables. The result of Variance decomposition indicated that contribution from cassava yield is strongly exogenous (0.106%) in the short run; potato yield has strong exogenous impact (0.016%) on food security in the short run; while yam yield is moderately exogenous (6.403%) in the short run. The study concluded that enhancing the productivity and resilience of cassava, yam, and potatoes can provide a robust foundation for improving food security in Nigeria. The study therefore recommended that policy makers should formulate and implement policies that support the growth and stability of the tuber crop sector, including subsidies, tax incentives, and price stabilization mechanisms.

Keywords: *Tuber, Production, Food, Security, Variance, Decomposition*

1.0 INTRODUCTION

Tuber crops are among the most important food crops for human consumption, revenue generation and raw materials for some industries. They are versatile staple crops that address food and nutritional security for millions of people. Tuber crops are cheap, but they are nutritionally rich staple foods that contributes carbohydrate, protein, vitamin-C, vitamin-A, zinc and iron towards the dietary demand of the populace (Singinga and Mbabu, 2015).

Sub-Saharan Africa generates 20% of the world's root and tuber crop production (FAO, 2013). Since they are significant sources of energy in developing countries with rapid population expansion, roots and tuber crops are essential for ensuring global food security. Nigeria holds an exceptional position in the production of certain of these root and tuber crops, including cassava and yam (Ochoche *et al*., 2022).

According to Essien (2013), food security intrinsically entails three fundamental aspects namely, availability, sufficiency and accessibility, which must occur simultaneously. Absence of any of these fundamental aspects at any time will result to food insecurity – a condition in which households experience a lack/inadequate food stock. In other words, when food security is threatened for some time without adequate rescue measures, it results in food insecurity, a phenomenon which seems to characterize the present world food situation.

Rural food production plays an important role in ensuring household food security and household food security could be achieved by increasing agricultural productivity. Cassava as a food-security crop has played important roles in many households as it provides about 45% of all calories consumed in Africa and about 70% of the daily calorie intake of over 50 million Nigerians. Also, potato is considered to be an important crop to achieve nutritional security of the nation. Potato has 75% more food energy per unit area than wheat and 58% more than rice. Also, potato has 54% more protein per unit area than wheat and 78% higher than rice. Yam is a food and cash crop; it plays an important role in food security and in the livelihoods of 60 million people in the region (Karya and Otsanjugu, 2019).

Ochoche *et al.* (2022) reported that root and tubers are multifarious mainstay crops that can help in addressing food security in Nigeria, thus there are many compelling reasons to encourage them for sustainable food production. They further posited that instability in the area, production and yield of root and tuber crops could be detrimental for food security given that roots and tubers is a source of income for poor farmers and of food for the rural and urban poor. Therefore, reducing instability and improving tuber crops yield will ensure sectorial growth and enhance food security which is an essential part in eradicating hunger and poverty in the country.

2.0 RESEARCH 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 tuber yields were collected from the records of Food and Agriculture Organization (FAO) while data on food security were collected from World Bank database. Data for this study were analyzed using Augmented Dickey-Fuller (ADF) test, Philips-Perron (PP) test, Johansen co-integration and variance decomposition.

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.

$$\Delta Y_t = \alpha_0 + \alpha_1 t + \beta Y_{t-1} + \sum_{i=1}^{p} \delta_i \, \Delta Y_{t-i} + \varepsilon_1 \qquad (1)$$

where Y is cassava yield or yam yield, or potatoes yield or food security as the case may be.

α_0 is the constant,
α_1 is the coefficient of the trend series,
p is the lag order of the autoregressive process,
Y_{t-i} is the lag value of order one of Y_t and
ε_1 is the error term.
Δ is the change operator
t represents the variable time and
u_t is the white noise error.

The null hypothesis that σ = 0 means existence of a unit root in Y_t or that the time series is non-stationary. The decision rule is that if the computed ADF statistics is greater than the critical at the specified level of significance, then the hull hypothesis of unit root is accepted otherwise it is rejected.

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). The Johansen (1991) co-integration method was employed in this study. Johansen procedure is based on the estimation of VAR model transformed into Vector Error Correction Model (VECM) form. If there is co-integration we transform the regression to its VECM form, but if there is no co integration we leave it in VAR form.

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

$$\nabla \mathrm{Y_t} = \Pi \mathrm{Y_{t-1}} + \sum_{\mathrm{i}}^{\mathrm{k}} \binom{k-1}{i=1} ţ i \nabla \mathrm{Y_{t-1}} + \mu + \varepsilon_t - - - - - - - - - (2)$$

Where:

$\nabla \mathrm{Y_t}$ First difference of a (n x n) vector of the n variables of interest (yields of cassava, yam, potatoes and food security);

Π = (n x n) coefficient matrix associated with lagged values of the endogenous dependent variables

$\mathrm{Y_{t-1}}$ = lagged values of $\mathrm{Y_t}$,

ţ = $(nXk - 1)$ Matrix of short-term coefficients,

μ = (n x 1) Vector of constant and

ε_t = (n x 1) vector of White Noise Residuals

If the Π-matrix has reduced rank but is 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 Y 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 in levels, Π would have full rank.

2.3.3 Vector Error Correction Model (VECM) and Variance Decomposition

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:

$$\mathrm{lnFS_t} = \varphi_1 + \sum_{i=1}^{p} \alpha_{1i} lnFS_{t-i} + \sum_{i=1}^{p} \alpha_{2i} lnCY_{t-i} + \sum_{i=1}^{p} \alpha_{3i} lnYY_{t-i} + \sum_{i=1}^{p} \alpha_{4i} lnPY_{t-i} + \sigma_1 ECT + \xi_{1t} \ldots\ldots \quad (3)$$

where: φ *and* σ are mx1 vector of parameters; α_1-α_7 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 (yields of cassava, yam, potatoes and food security); ξ_{jt} is an mx1 vector of random variables assumed to be normally distributed white noise process.

FS = Food security
CY = Cassava yield
PY = Potatoes yield
YY = Yam yield

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:

$$\mathrm{FS_t} = \gamma_1 + \lambda_j (FS_{t-1} - \alpha_1 CY_{t-1} - \alpha_2 YY_{t-1} - \alpha_3 PY_{t-1}) + \sum_{i=1}^{p-1} A_{1i} \Delta FS_{t-i+1} + \sum_{i=1}^{p-1} A_{2i} \Delta CY_{t-i+1} + \sum_{i=1}^{p-1} A_{3i} \Delta YY_{t-i+1} + \sum_{i=1}^{p-1} A_{4i} \Delta PY_{t-i+1} + \varepsilon_{1t} \ldots\ldots \quad (4)$$

The parameter λ_j in (4) measures the speed of adjustment of short run disequilibrium to long run equilibrium position; while the parameter A_1-A_7 measure the short run temporary influence of the past values of the endogenous variables. Furthermore, the optimal lag order for the model was determined by the lag order that minimizes Akaike information criterion (AIC). The Information criterion is 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.

A variance decomposition or forecast error variance decomposition (FEVD) is used to aid in the interpretation of VECM/VAR model once it has been fitted. The variance decomposition indicates the amount of information each variable contributes to the other variables in the autoregression. It determines how much of the forecast error variance of each of the variables can be explained by exogenous shocks to the other variables.

Variance decomposition in the context of a VECM/VAR model can be calculated as follows:

For the variance decomposition of the forecast error variance of the Food Security variable (FS) into its own-shock and cross-shock components:

a. Own-Shock Variance (FS): The own-shock variance represents the portion of the forecast error variance of Food Security that can be attributed to its own past values.

$$\mathrm{FS_t} = \sum_{i=1}^{n} \varphi_{1i}^2 \times \delta_i^{\,2} \ldots\ldots \quad 5$$

Where:
n is the lag order of your VAR/VEC model.
φ_{1i}^2 is the coefficient of the Food Security variable at lag *i* in the VAR/VEC model.

${\delta_i}^2$ is the variance of the residual (forecast error) of the Food Security equation at lag *i*.

b. Cross-Shock Variance (FS): The cross-shock variance represents the portion of the forecast error variance of Food Security that can be attributed to the past values of the other independent variables (Cassava Yield, Yam Yield, Potato Yield).

$$\mathrm{FS_t} = \sum_{i=1}^{n} \left(\sum_{j \neq 1}^{n} \varphi_{1j} \times \varphi_{ij} \times \delta_j \times \delta_i \right) \ldots\ldots\ldots\ldots\ldots\ldots 6$$

Where:
n is the lag order of your VAR/VEC model.
φ_{1j} is the coefficient of the Food Security equation at lag *j* in the VAR/VEC model.
φ_{ij} is the coefficient of the independent variable equation at lag *i* in the VAR/VEC model.
δ_j is the variance of the residual (forecast error) of the independent variable equation at lag *j*.
δ_i is the variance of the residual (forecast error) of the Food Security equation at lag *i*.
By calculating the above equations for each lag *i* in your VAR/VEC model, you can decompose the forecast error variance of the Food Security variable into the portions explained by its own past values and the past values of the independent variables (Cassava Yield, Yam Yield, Potato Yield) in the system. This decomposition helps to understand the relative contributions of these variables to the variance in Food Security.

3.0 RESULTS AND DISCUSSION

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 1). Decision was made based on the outcome of the Augmented Dickey Fuller (ADF) and Philips-Perron (PP) tests as the results obtained were the same using both tests. The result indicated that all the variables (cassava yield, yam yield, potatoes yield and food security) were found to be integrated of order one and became stationary on first differencing. This indicates that the variables exhibit random walk (unit roots) or the future values of these variables do not converge from their past values.

Table 1: 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**	
Cass yield	-7.7157***	0.0000	-3.6104	Δ I(1)	-8.0771	0.0000***	-3.6104	Δ I(1)	Stationary
Yam yield	-8.2184***	0.0000	-3.6104	Δ I(1)	-8.4441	0.0000***	-3.6104	Δ I(1)	Stationary
Potat yield	-6.7528***	0.0000	-3.6104	Δ I(1)	-6.7403	0.0000***	-3.6104	Δ I(1)	Stationary
Food sec.	-10.216***	0.0000	-3.6155	Δ I(1)	-19.2364	0.0000***	-3.6155	Δ I(1)	Stationary

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

Result of Co-integration rank test for the long run relationship among the variables

The results of the co-integration tests are shown on Table 2. Co-integration test investigation was carried out on the series properties of 1(1) variable through the Johansen Co-integration test to determine whether long run linear combination of non-stationary variables is stationary. Variables are said to be cointegrated if they have long run association. Since the variables are non-stationary, it becomes imperative to test whether or not the variables are cointegrated. Using trace statistics, the result revealed that combination of these variables has one (1) co-integrating equation and this means that linear combination of these variables has one long run linear combination of relationship or one co-integrating equation. Similalry, using the maximum Eigen statistics, the result revealed that combination of these variables has one co-integrating equation and this means that linear combination of these variables have one long run linear combinations of relationship or one co-integrating equation. This implies that a long run relationship exists among the variables (cassava yield, yam yield, potatoes yield and food security).

Table 2. Johansen Co-integration Test

Trace				
Hypothesized No. Of CE(S)	**Eigenvalue**	**Trace Statistics**	**0.05 Critical value**	**Prob****
None *	0.531308	54.11271	47.85613	0.0115
At most 1	0.353203	24.55816	29.79707	0.1778
At most 2	0.167862	7.564971	15.49471	0.513
At most 3	0.010165	0.398456	3.841466	0.5279
Maximum Eigenvalue				
Hypothesized No. Of CE(S)	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical value**	**Prob****
None *	0.531308	29.55455	27.58434	0.0276
At most 1	0.353203	16.99319	21.13162	0.1723
At most 2	0.167862	7.166515	14.2646	0.4696
At most 3	0.010165	0.398456	3.841466	0.5279

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
*denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values
Source: Data Analysis, 2023.

Contribution of tuber crops yield to food security in the short and long run

Variance decomposition of forecast errors was estimated to show the short run and long run contributions of tuber crops yield to food security in Nigeria. The result as shown in Table 3 indicated that tuber crops yield (cassava, yam and potatoes yield) positively contributed to food security both in the short run and long run. Therefore, the null hypothesis which stipulated that yield of tuber crops have no significant effect on food security in the long run is hereby rejected and the alternative accepted. This is consistent with the findings by Karya and Otsanjugu (2019) who observed that root and tuber crops have great potential for contributing to food security. They reported that tuber crops alone contribute 3.9% energy for an average consumption of 28.6 kg/capita/year (76 kcal/capita/day). It is estimated that this contribution will be doubled to 8% by 2030. Ochoche *et al.* (2022) reported that root and tubers are multifarious mainstay crops that can help in addressing food security in Nigeria.

Specifically, contribution from cassava yield is strongly exogenous in the short run. This implies that cassava yield have weak influence on predicting food security in the short run. In the initial three periods (short run), 0.106% of the forecast error variance is explained by cassava yield. This implies that cassava yield contributed 0.106% to food security in the short run. The influence increased gradually in the long run to about 6.577% in the 10th period. This implies that cassava yield contributed about 6.577% to food security in the long run. Cassava as a food-security crop has played an important role in many households. It derives its importance from the fact that it is starchy and a cheap source of carbohydrate; more so, its tuberous roots are a valuable source of cheap calories especially in developing countries where calorie deficiency and malnutrition are widespread (Karya and Otsanjugu, 2019).

Similarly, potato yield has strong exogenous impact on food security in the short run. This implies that potato yield has a weak influence on predicting food security in the short run. 0.016% of the forecast error variance is explained by potato yield. This implies that potato yield contributed 0.016% to food security in the short run. This impact suggests a relatively modest ability to predict food security during this period. Though exerting a weak influence, the influence continued to increase gradually in the long run to about 0.99% in the 10th period. This is similar to the results of Shrinivas (2011) who posited that potato is considered to be an important crop to achieve food and nutritional security of the nation because, being a short duration crop, it produces more quantity of dry matter, edible energy and edible protein in a lesser duration of time compared with cereals like rice and wheat. IITA (2015) reported that for the same cubic meter, potato yields 150 g of protein; double that of wheat and maize, and 540 mg of calcium, double that of wheat and four times that of rice. These qualities make potato an important food security and cash crop for smallholder farmers with limited options.

Furthermore, contribution from yam yield is moderately exogenous in the short run. This implies that yam yield has moderate influence on predicting food security in the short run. In the initial three periods (short run), a substantial 6.403% of the forecast error variance can be attributed to yam yield, underscoring its significant contribution to food security in the short run. This implies that yam yield contributed 6.403% to food security in the short run. The influence increased gradually in the long run to about 28.768% in the 10th period. This implies that yam yield contributed about 28.768% to food security in the long run. This result suggests that yam yield plays a more significant role in ensuring food security in the long run. An NBS survey in 2012 reported that yam plays an important role in food security and in the livelihoods of more than 60 million people in the Nigeria and that the crop is socially and economically important in terms of food, cash and medicine (NBS, 2012).

Table 3. Contribution of Tuber Crops Yield to Food Security

Period	S.E.	FOOD SECURITY	CASSAVA YIELD	POTATO YIELD	YAM YIELD
1	0.095255	100	0.000	0.000	0.000
2	0.156211	97.84616	0.026882	0.007409	2.119548
3	0.212298	93.47494	0.106228	0.015942	6.402894
4	0.266926	88.21515	0.386377	0.059821	11.33865
5	0.320451	83.11451	0.912654	0.140161	15.83268
6	0.372985	78.42702	1.65885	0.254014	19.66011
7	0.424446	74.19632	2.615032	0.398298	22.79035
8	0.474839	70.37008	3.764181	0.570677	25.29506
9	0.52422	66.88031	5.090678	0.768837	27.26017
10	0.572691	63.66392	6.577354	0.990514	28.76821

Source: Data Analysis, 2023.

4.0 CONCLUSION AND RECOMMENDATIONS

The study revealed that tuber crops yield significantly contribute to food security in Nigeria both in the short run and the long run, with varying degrees of impact depending on the type of tuber crop. These findings suggest that while all three tuber crops are important for food security, yam, in particular, stands out as a key crop with both immediate and sustained contributions. Enhancing the productivity and resilience of cassava, yam, and potatoes can provide a robust foundation for improving food security in Nigeria. This underscores the necessity for targeted agricultural policies and support mechanisms that enhance the production and yield of tuber crops, with a particular emphasis on yam, to ensure long-term food security in Nigeria.

The study therefore recommended that:

i. Government should make provision for modern agricultural techniques and operations in order to protect farmers in the face of climate-related risks so as to forestall food insecurity situation in the nation.
ii. Policy makers should formulate and implement policies that support the growth and stability of the tuber crop sector, including subsidies, tax incentives, and price stabilization mechanisms.
iii. Institutional strengthening of agricultural institutions to provide better support and services to tuber crop farmers, including research, extension, and market facilitation.

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