Analysis of relationships between production of yam *[Dioscorea spp.]* and its determinants in Nigeria: A cointegration approach

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Abstract
The associations between the production and some of the variously-debated factors that have the tendency to influence it, including cultivated land area, yield, and climatic conditions, were investigated for yams *(Discora Roundata),* a leading tuber crop in Nigeria. Secondary data collected from two reliable sources covering the 1961-2008 periods were used for the study. Data were analyzed using advanced econometric cointegration technique. Results of the unit roots tests revealed that production, land area, and yield of yams were each integrated of order one, I(1), compelling their use for cointegration analysis. However, the two included climatic factors, rainfall and temperature integrated only at levels, I(0), making them unsuitable for use in cointegration tests and were consequently dropped. Results showed further that cointegration existed between production and land area on the one hand and yield on the other. The resultant trace- and maximum eigenvalue statistics were 29.83 ($p<0.01$) and 29.22 ($p<0.01$) respectively for test involving production and land area, and 29.85 ($p<0.01$) and 29.23 ($p<0.1$) respectively for test of production with yield. The Bivariate Granger causality tests could not reveal any causality either from land area to production or vise versa. Also, although causality could not be revealed from yield to production, an inverse, but weak, causality ($F=2.83$; $p<0.05$) was observed from production to yield. The implication of the finding is that past values of cultivated land area and yield could not be used as reliable indicators for predicting the future values of yam production in Nigeria. A lot more other factors had contributed to past fluctuations in yam production and there was need to adopt an across-the-board approach in the development of the yams sector in Nigeria.

Keywords: Yams, production, cultivated land area, yield, weather conditions, cointegration, Nigeria.

Introduction
Roots and tubers (R&T) are valued among the world's poorest producers worldwide as source of food and nutrition (Scott et al. 2000). This is due mainly to the fact that the R&T produce large quantities of dietary energy and stable yields under conditions in which other crops may fail (Alexandrotos 1995). In 1995-97, about 50 million hectares of land were devoted to the major R&T, which includes cassava (*Manihot exculenta* Crantz), yam (Discorea spp), potato (*Solanum tuberosum*), and sweet potato [*Ipomoea batatas* L. (Lam)] (Scott et al. 2000). In Nigeria as in the rest of West Africa, yam is a very important food security crop, considering its contribution to the growth of the economy and its socio-cultural significance in the people's life (Ikwelle et al. 2003). As reported by Asiedu (1989), yams play an important role in social and religious festivals as it constitutes an integral part of the cultural heritage for many people in the yam growing areas of Nigeria. Also, Komolafe et al. (1983) described yams as a "famine fighter" because of its relative durable nature.

Globally, Nigeria is also credited to be the largest producer of yams. Its production accounted for over 70-76 percent of the world total output in 1992 (Hahn et al., 1993). By 2005, the FAO reported Nigeria's yam production as 34.0 million metric tonnes, an increase of 85.8% over the 1985 output. Akande and Ogundele (2007), succinctly argued that **y**am production serves as a source of income generation to the peasant farmers and labourers who work on yam farms, numerous others who engage in yam sale, the itinerant traders who assemble the crop from village to village, and the urban centre marketers who retail the commodity. They also observed that peelings and waste from yam were often used for feeding poultry and livestock.

Notwithstanding the associated numerous benefits, the production and marketing of yam have been faced with numerous challenges, which include unavailability and affordability of high quality seed yams, on-farm postharvest losses, low soil fertility, unexploited potential of (ware and seed) yam markets by smallholder farmers, unavailability of adapted varieties to stress environments of the savannah agro-ecologies, diseases and pests, and limited opportunities for farmers who are mainly smallholder rural women (YIIFSWA, 2011). Other challenges are the bulkiness of quantity, high cost of seed yams labour and staking materials requirements (Ikwelle et al., 2003). Among other factors, these have caused significant reduction in the crop's potential to support rural development and meet consumers' needs (YIIFSWA, 2011).

In view of the aforementioned challenges, this study seeks to investigate the factors that drive yam production and the nature of the relationship between production and the identified determinants in Nigeria. Among the factors studied alongside production are the cultivated land area, yield, and climatic variables of rainfall and temperature. The results of this investigation are expected to serve as guide to policy makers, agricultural ministries and agencies of government, non-governmental and other development organizations in their respective efforts in the development of the yams industry in Nigeria.

Methodology

The study area

The study was conducted based on time series data for Nigeria. The country is located between latitudes 4.67° N and 13.87° N and longitudes 2.82° E and 14.62° E in the western part of Africa. It is the largest country in Africa with a total geographical area of 923768 sqkm and an estimated population of 167million given by the United Nations Population Fund (UNFPA) for 2011 (NgEx 2011). Nigeria shares boundaries in the north with Niger Republic, in the West with Benin Republic, and in the East with the Republic of Cameroun. It also shares boundaries in the North-East with Republic of Chad and in the South with the Atlantic Ocean, via the Gulf of Guinea. Nigeria lies wholly within the tropics along the Gulf of Guinea on the western coast of Africa. The country has 6 geo-political zones, 36 states and a federal capital territory (FCT), 774 local government councils, and about 478 different ethnic groups, of which only ten (Hausa, Fulani, Yoruba, lgbo, Kanuri, Tiv, Edo, Nupe, Ibibio, and Ijaw) account for nearly 80% of the country's population (Global Corp, 2009). Around Nigeria, the lowest population densities are found in the northern regions, especially in the states of Adamawa, Borno, Kebbi, Kwara, Taraba, Yobe and Zamfara.

The country's annual rainfall ranges from about 450 mm in the northeast to about 3500 mm in the coastal south-east, with rains falling within 90-290 days respectively. The mean annual temperature ranges from 21°C in the south to 30°C in the north with extremes of 14°C and 45°C respectively and an altitude range of 0-1000m above sea level. By virtue of its wide geographical spread, Nigeria consists of different climatic and agro-ecological zones with agriculture being the principal occupation of the rural population. The agricultural sector of the Nigerian economy is so well linked to the production matrix employing about 70% of the virile component of the nation's demography (Global Corp, 2009). Nigeria has a highly diversified agro-ecological condition, which makes the production of a wide range of agricultural products possible. Yam production is part of the culture and way of life of Nigerians. Nigeria is adjudged the world's highest producer of yam, producing over 35.02 million metric tonnes in 2008 (FAO, 2012). Among the major yam producing states in Nigeria are Adamawa, Benue, Cross River, Delta, Edo, Ekiti, Imo, Kaduna, Kwara, Ogun, Ondo, Osun, Oyo, and Plateau (FOS 1997). Other states include Abia, Anambra, Kogi, Kwara, Nasarawa, and Niger.

Study data

Data used for the study were secondary data collected from two reliable sources. Data on yam production, land area devoted to yam, and yield of yam were collected from the Statistics Division of the Food and Agriculture organization (FAO, 2012) while the weather data (specifically data on annual rainfall and average temperature) were collected from the Central Weather Station of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. All data series covered the period 1961-2008. The national time series data, like those documented by the Central Bank of Nigeria (CBN), National Bureau of Statistics (NBS) or any other relevant government agency e could alternatively have been used. However, it is common to find differences in such data series from different sources (Manyong and Nokoe, 2003) while the existing data were not available over the 1961-2008 period covered by this study.

Methods of data analysis

Numerous data analytical tools were used in this study. They include descriptive statistics, correlation analysis, cointegration and its related Granger casuality analysis.

Descriptive Statistics and correlation analysis

Descriptive statistics used in the study include charts, measures of central tendency (including mean and median), measures of dispersion (standard deviation and variance), skewness and kurtosis in the data series used for the study. Moreover, correlation coefficients based on pearson's product moment method was used to determine the direction of the association between variables.

Cointegration and error correction representation

Fundamentally, co-integration analysis seeks to detect existence of any common stochastic trends in economic data series with a view to conducting a dynamic analysis of correlation returns. Cointegration was a statistical implication of long-run relationship between economic variables (Thomas, 1993). If a long-term relationship was found between two variables, it implies that they move together overtime so that short-term disturbances from the long-run trend can be corrected (Manning and Adriacanos, 1993). When there is no cointegration between two economic variables, it means that they can wander arbitrarily far away from each other (Dickey et al, 1991). A set of nonstationary variables is cointegrated if some linear combinations of the variables are stationary (Benerjee et al. 1993). The investigation of stationarity or nonstationarity in a time series is closely related to the tests of unit roots since existence of unit roots in a time series denotes non-stationarity (Demirbas, 1999), in which case the ordinary least squares (OLS) estimator is not normally distributed.

A series is said to be integrated of order 'd', denoted by *I(d)*, if it can be differenced *d* times to produce a stationary series. A "white noise" is an example of a *I(0)* series. A "random walk process" is an example of a *I(1)* series while accumulating a random walk would give rise to a *I(2)* series. Suppose two variables, X_{1t} and X_{2t} are *I(d)* then any linear combination of the variables will also be *I(d)* by definition. Most economic variables are *I(1)* and cointegration is defined for *I(1)* variables (Silvapulle and Jayasuriya, 1994). It follows that the necessary condition for testing for cointegration is that the individual time series should have similar statistical property, meaning that they should be integrated of the same order (Tambi, 1999).

Appropriate tests for stationarity were provided by Engle and Granger (1987) as the Dickey-Fuller (DF) and the augmented Dickey-Fuller (ADF) statistics. The test is based on the t-statistics obtained for parameter *b* after estimating the ordinary least square (OLS) regressions given by:

$$\Delta X_t = a + bX_{t-1} + u_t \quad (1)$$

$$\Delta X_t = a + bX_{t-1} + \sum_{i=1}^{k} c_i \Delta X_{t-i} + u_t \quad (2)$$

where X_t is the variable of interest; $\Delta X_t = (X_{t-1} - X_t)$; a, b and c are unknown parameters, u_t is an error term, and k is the lag length chosen for ADF to ensure that u_t is empirical white noise. The hypothesis of nonstationarity, or unit root ($b = 1$) will be accepted at 0.01 or 0.05 levels if the DF or ADF statistic is greater than the critical value of -3.50 or -2.89 for a model with only intercept and -4.06 or -3.46 for a model with intercept and trend.

The general form of the Johansen's model used in this study is presented below.

If X_t denotes an *n x* 1 unrestricted vector auto-regression (VAR) in the levels of the non-stationary I(1) time series being considered, then:

$$X_t = \mu + a_1 X_{t-1} + a_2 X_{t-2} + \cdots + a_p X_{t-p} + e_t$$

$$= \mu + \sum_{i=1}^{p} a_i X_{t-i} + e_t \quad (3)$$

where X_1 is px1 vector of variable X; X_{t-i} is a px1 vector of the ith lagged values of x_i; μ is a px1 vector of constants; a_i is a pxp matrix of unknown coefficients to be estimated; *p* is the lag length; and e_t is a px1 vector of identically and independently distributed error terms with zero mean and contemporaneous covariance matrix, $E(e_t e_t) = \Omega$. Necessary transformation of equation (3) results to:.

$$\Delta X_t = \mu + \zeta_1 \Delta X_{t-1} + \cdots + \zeta_{p-1} \Delta X_{t-(p-1)} +$$

$$\Pi X_{t-p} + E_t = \mu + \sum_{i=1}^{p-1} \zeta_i \Delta X_{t-i} + \Pi X_{t-p} + e_t \quad (4)$$

where $\zeta_1 = -(1 - \sum_{j=1}^{i} a_j)$, for j=1,2, …, p -1; $\Pi = -(1 - \sum_{i=1}^{p} a_i)$; and $\Delta X_{t-1} = (p\,x\,p)$ vector of X_{t-1} in first differences, for i = 1,2, …, p-1; all other variables are as previously defined.

It follows that the VAR (p) has been transformed into an ECM (p) with an error correction component, ΠX_{t-p} The matrix Π is of primary interest in equation (4) for two main reasons. First is that the rank of Π, *rank* (Π) is used to determine existence or otherwise of cointegration or long-run relationships between the variables of interest– if the *rank* (Π) = 0 the variables are not cointegrated and the model is equivalent to a VAR in first difference; if $0 < rank(\Pi) < n$, the variables are cointegrated; and if $rank(\Pi) = n$, the variables are stationary and the model is equivalent to a VAR in levels (Chang 2000); Secondly, the Π represents a product of two matrices α and β or ($\Pi = \alpha\beta'$), where β is the matrix of the cointegrating relationship. If $\beta' X_t = 0$, the system is in equilibrium; if not, $\beta' X_t$ is the deviation from the long-run equilibrium, or the equilibrium error, which is stationary in a cointegrated system (Johansen and Juselius, 1990). α represents the matrix of speed of adjustment coefficients that characterizes the long run dynamics of the system. If α has a large value, the system will respond to a deviation from the long-run equilibrium with rapid adjustment. Contrarily, if it has a small value the system will respond with slow adjustment to a deviation from the long-run equilibrium. At times the value of $\alpha = 0$ for some system equations implies that the corresponding variable is weakly exogenous and does not respond to equilibrium error. At least one α must have a non-zero value in a cointegrated system (Chang 2000).

Causality tests

The Granger causality tests are useful when the interest is to measure the predictive ability of the time series models (Luis,2005). A series, Y_t, Granger causes another series, X_t, if the present values of X_t, can be better predicted by including, among other variables, the past values of Y_t rather than not including it (Luis, 2005). We can formally state that area cultivated to yam ($YMAR_t$) Granger causes the production output of yam ($YMPR_t$) if the value of α_I in the following equation is different from zero.

$$YMPR_t = \alpha_0 + \sum_{i=1}^{m} \alpha_i YMAR_{t-i} + \sum_{j=1}^{m} \beta_j YMPR_{t-j} + e_t \quad (5)$$

The variables are as previously defined. To prove the existence of causality, an F-test, which is equivalent to the Wald Test, is used. It is expressed as

$$F_{YMAR_t \rightarrow YMPR_t} = \frac{(SSE_r - SSE_u)/m}{SSE_u/(n-2m-1)} \sim F_{[m,(n-2m+1)]}(\alpha) \quad (6)$$

where SSE_r is the sum of squared errors of equation (5) with restricted coefficients of lagged $YMAR_t$ (that is to say that coefficients are set to zero); SSE_u is the sum of squared errors of the unrestricted form of the equation, α is the critical value; *n* is the number of observations; and *m* is the number of lags. If $_{YMARP \rightarrow RPt}$ is less than $F_{[(m,n-2wm+1)]}(\alpha)$, $YMAR_t$ does not Granger cause $YMPR_t$; otherwise it does. If it holds true from the tests that the $YMAR_t$ Granger causes the $YMPR_t$ and also $YMPR_t$ Granger causes the $YMAR_t$, it reflects a feedback relationship between the two series.

Results and discussion

The descriptive statistics of variables are presented in Table 1. The averages were calculated as: production (14.25 million metric tonnes), area (1.44 million ha), yield (9.37 tonnes/ha), rainfall (1290.05 mm) and temperature (26.56°C). The production data ranged from 3.50 million tonnes (minimum) in 1961 to 36.72 million tonnes (maximum) recorded for 2006.

Table 1: Descriptive statistics of variables

Statistic	Production (tonnes)	Area (ha)	Yield (t/ha)	Rainfall (mm)	Average Temp (°C)
Mean	14. 254	1.439E+06	9.370	1290.051	26.562
Median	8.876	9.520E+05	9.899	1314.200	26.523
Maximum	36.720	3.123E+06	12.272	1886.800	27.692
Minimum	3.500	4.500E+05	5.628	794.300	25.843
Std. dev.	10.459	8.959E+05	1.949	238.681	0.339
Skewness	0.717	0.660	-0.705	0. 009	0.914
Kurtosis	2.004	1.873	2.366	2.654	4.727
Jarque - Bera	6.096	6.026	4.786	0.239	12.655
Probability	0.047	0.049	0.091	0.887	0.001
Sum	684.179	6.907E+07	449.769	61922.47	1274.99
Sum Sq. Dev.	5142.224	3.77E+13	178.717	2.678E+06	5.407
No. of observations	48	48	48	48	48

Table 1 also shows the Jarque-Berra statistics (a goodness-of-fit measure of departure of value of variables from normality), popularly called the J-B statistics. It reveals that the null (joint) hypothesis that the skewness and the excess kurtosis was zero was rejected at $p<0.01$ for temperature, $p<0.05$ for production and area. It suggests that the distribution of the two variables were significantly skewed. The JB-statistic for yield was only significant at 10% while that of rainfall and temperature were not significant. The correlation coefficients for the pair of variables under consideration are presented in Figure 1.

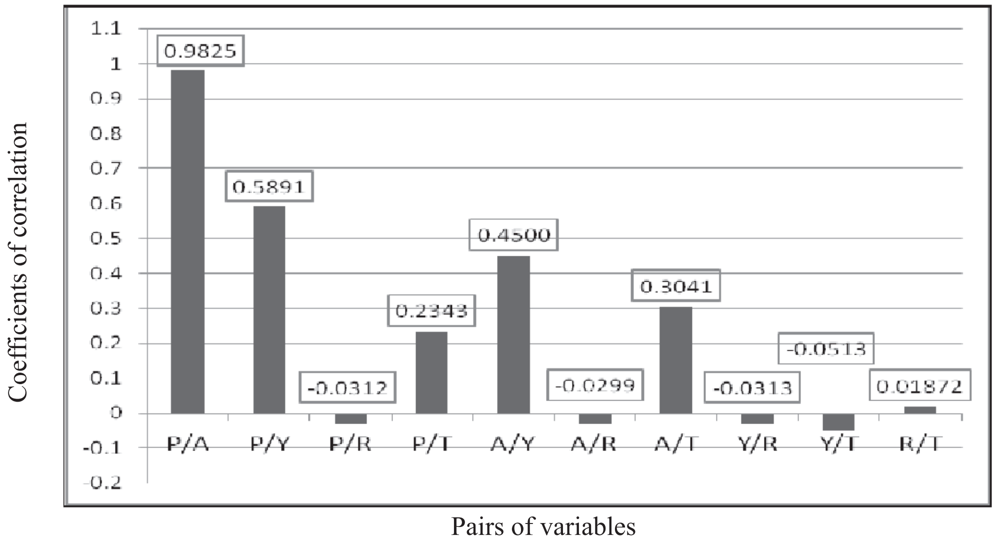

Figure 1: Pair-wise correlation coefficients of variables

Note: P/A=Production on area; P/Y=Production on yield; P/R=Production on rainfall; P/T=Production on temperature; A/Y=Area on yield; A/R=Area on rainfall; A/T=Area on temperature; Y/R=Yield on rainfall; Y/T=Yield on temperature; R/T=Rainfall on temperature.

The pair-wise correlation between yam production and area was positive, very high ($r=0.98$) and statistically significant ($p<0.01$). Also, positive and significant but not as high were associations between production and yield ($r=0.59$; $p<0.01$), yield and area ($r=0.45$; $p<0.01$), and area and temp ($r=0.30$; $p<0.05$). The pairs of production and rainfall, area and rainfall, yield and rainfall, and yield and temperature had negative not-significant coefficients while production and temperature, area and temperature, and rainfall and temperature had positive and equally not-significant correlations. The results corroborated the view that increases in yam production overtime was related to increases in cultivated land (Ojiako and Ojiako, 2011).

Table 2: The Stationarity – Augmented Dickey-Fuller unit roots – tests

Variable	ADF test statistic				Conclusion
	At levels		At first differences		
	Intercept only	Intercept and trend	Intercept only	Intercept and trend	
YMPR	-0.648 ^{NS} (p=0.849)	-1.261 ^{NS} (p =0.885)	-5.716 *** (p=000)	-5.651 *** (p=0.000)	U ~ I (1)
YMAR	-0.915 ^{NS} (p=0.775)	-1.715 ^{NS} (p=0.729)	-6.521 *** (p=0.000)	-6.446 *** (p=0.000)	U ~ I (1)
YMYD	-2.258 ^{NS} (P=0.189)	-2.449 ^{NS} (p=0.351)	-6.555 *** (p=0.000)	-6.479 *** (0.000)	U ~ I (1)
RAIN	-7.7 53 *** (p=0.000)	-7.665 *** (p=0.000)	-	-	U ~ I (0)
TEMP	-5.223 *** (p=0.000)	-5.521 *** (p=0.000)	-	-	U ~ I (0)
ADF CV (5%)	-2.925	-3.508	-2.926	-3.510	-
ADF CV (1%)	-3.577	-4.165	-3.581	-4.170	-

***=Significant at 1%; **=Significant at 5%; ^{NS}=Significant

Stationarity analysis–test of unit roots

The output of the unit roots' test is reported in Table 2. It revealed that the ADF-statistics for yam production, area, and yield were not significant at levels, but highly significant ($p<0.01$) at first differences. The result was consistent for the model with intercept only and trend. It follows that the three variables were integrated of order one, that is YMPR ~ I (1), YMAR ~ I (1), and YMYD ~ I (1), or each was stationary in levels but non-stationary in first differences as indicated in the last column under conclusion. The calculated ADF-statistics for the models with intercepts and trends were given as -5.65, -6.45 and -6.48 for production, area and yield respectively. Each was significant ($p<0.01$) and higher (in absolute terms) than the critical values of -3.51 at 5% and -4.17 at 1% levels, meaning that each pair could be used for further investigation of existence or otherwise of cointegration (Silvapulle and Jayasuriya, 1994).

Similar conclusions could not be drawn for the climatic variables, rainfall and temperature. Each of these variables was integrated of order zero (or non-stationery in levels) with calculated ADF-statistics of -7.66 and -5.52, which in levels exceed the critical values at both 5% and 1%. Therefore the two variables were mere "white noise" and, consequently, were dropped at this level because they could not conform for use in further investigation of cointegration.

Cointegration analysis

Cointegration was investigated pair-wise for the conforming variables and the results are reported in Table 3. The trace-statistic (29.83) and the maximum eigenvalue-statistic (29.21) revealed cointegration for production and area and for production and yield of yams. Each was significant at $p<0.01$ levels, indicating the existence of one cointegrating relation at that significant level for pair of variables.

Table 3: Cointegration tests for yam production and area and yield

	Production and area		Production and yield	
Hypothesis	$r = 0$	$r = \leq 0$	$r = 0$	$r = \leq 0$
Trace statistic	29.83***	0.61	29.83***	0.61
1% CV	20.04	6.65	20.04	6.65
5% CV	15.41	3.76	15.41	3.76
Max. eigenvalue statistic	29.21***	0.61	29.22	0.61
1% CV	18.63	6.65	18.63	6.65
5% CV	14.07	3.76	14.07	3.76
Lag interval	1 to 5	1 to 5	1 to 5	1 to 5

***=Significant at 1%; **=Significant at 5%.

Existence of cointegrating relationship implied that the system was expected to respond to exogenous shocks and return to equilibrium in the long-run. Estimation of the vector error correction model (VECM) would have assisted in the determination of the speed of adjustment, but, that was outside the conceptualized scope of this investigation.

Granger causality test

The results of Granger causality tests that measured the predictive ability of the time series models (Luis, 2005) were reported in Table 4. Only the null hypothesis that yam production did not Granger cause yield changes was rejected at 5% suggesting that causality ran from production to yield with no feedback loop. Other pairs failed to reveal causality links.

Table 4: Granger causality test output

Null hypothesis	Obs.(lag=6)	F-stat.	P(F-value)
Production did not "Granger cause" area	42	1.482	0.219
Area did not "Granger cause production	42	1.589	0.186
Production did not "Granger cause yield"	42	2.832	0.027
Yield did not "Granger cause" production	42	1.571	0.191

Conclusion

The investigation has revealed existence of long term significant positive link between yam production and area cultivated on one hand and production and yield on the other. No such long term relationship could be concluded with climatic factors, including rainfall and temperature. Although direction of causality could not be determined for production and area it was observed that causality ran from production to yield without any feedback loop. In fact, the finding is highly worrisome because yield was supposed to drive production in the context of the development and dissemination of improved technological innovations/packages, like use of improved high-yielding and disease-resisting seed yams as well as best farm management practices that had been propagated nationwide during the last three decades. There seems to be a serious disconnect that could have resulted from interplay of combination of several forces. There was the need to adopt an across-the-board approach in the development of the yams sector in Nigeria.

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