ASSESSMENT OF THE IMPACT OF CLIMATIC VARIATION ON THE PRODUCTION OF SOME MAJOR ROOT CROPS IN NIGERIA: A CO-INTEGRATION APPROACH

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ABSTRACT

This study assessed the impact of variations in climate on the production of root and tuber crops in Nigeria from 1975 to 2013. Secondary time series data obtained from Food and Agriculture Organization statistics (FAOSTAT) and Nigerian Meteorological Agency (NIMET) were used for the study. The data were analyzed using some econometric tools such as Augmented Dickey Fuller (ADF) test, Johansen Test and Vector Error Correction (VEC) Estimates. The ADF test revealed that relative humidity, rainfall and temperature and agricultural output were stationary after differencing at level 1 thus showing that the variables had relationship. The results of the Johansen co-integrated test revealed that there is one co-integrating equation at 5% level of probability showing a co-integrating relationship between root and tuber crops production output and the climatic variables. The Vector Error Correction Estimates indicated that none of the climatic variables was significant to root and tuber crops production on the short run. However, rainfall and temperature were positively significant at 5% level of probability on the long run indicating that variation in climate especially rainfall affected root and tuber crops production and output in Nigeria. It was therefore recommended that some measures which could help to ensure adequate water supply such as e.g. irrigation, drought resistant/tolerant crops varieties among others should be put in place by the government.

Keywords: Adaptation, co-integration, climatic variations, root and tuber crops

INTRODUCTION

Climate change is a major challenge facing the world today as it has become more threatening to the natural and human systems both globally and locally. Climate change which is the gradual changes in mean temperatures and rainfall over time has resulted in the loss of biodiversity and ecosystem functioning of natural habitats, loss of arable land, ground water depletion and sea level rise as well as changes in health and productivity of forests, the distribution, productivity and community composition of marine resources (FAO, 2008). Ayinde et al. (2011) opined that climatic fluctuation is putting Nigeria's agricultural system under serious threat and stress. This implies that rural sustenance and food security in Nigeria is under serious threat as food crop production takes significant aspect of agricultural activities in Nigeria. The threats of climate change are already being felt across the country with several incidences of flooding, prolonged changes in rainfall pattern and marked changes in water resources and agricultural produce. Against this background there is a need to examine the impact of climatic trends as it affects the output and yield of major root and tuber crops in Nigeria.

Root and tuber crops (RTCs) are important food crops in sub-Saharan Africa (SSA) especially in Nigeria as they form a major part of the staple food consumed by the populace. The crops are the most important food crops for direct human consumption in Africa. The major root and tuber crops grown in Nigeria are cassava *(Manihot esculenta*), yams (*Dioscorea* spp.), sweet potato (*Ipomoea batatas*), cocoyams (*Xanthosoma* spp and *Colocasia* spp), while others which are gaining prominence are carrot (*Daucus carota*), ginger (*Zingiber officinale*) and irish potato (*Solanum tuberosum*). They are historically and currently more than 90% of them that are mainly used as food (Quin, 2001). They are mainly carbohydrate energy food staples, used by both rural and urban communities in fresh and processed food preparations. Some are used as substitute for wheat flour in bread, cake and making pie (cassava) and confectioneries (e.g. cassava). Some are used as animal feed; residues - cassava, sweet potato, yams; direct use - cassava; agro-industrial uses (e.g. starch, alcohol), the peels are used in organo-mineral fertilizers formulation and raw materials in the textile and pharmaceutical industries and battery casing (Ojeniyi, 2001; Akanbi, et al., 2006). Cassava recently has become the magic crop as a result of the government initiative on cassava production with good export potential. The different tiers of government in the country are supporting the small-scale farmers who are the major food producers in the recently introduced cassava cultivation programme.

Yam, cassava, potato and sweet potato as well as cocoyam are cheap but nutritionally rich staple foods that contribute protein, Vitamin A and C, zinc and iron towards the dietary demand of the rural poor in the developing world. In some areas they are more important than grains. Total production of roots and tuber crops in SSA was estimated as 254 million tons per annum in 2012 (FAOSTAT, 2013), of which cassava production had the largest share of 132 million tons/annum followed by yam, 56 million tons/annum and sweet potato 17 million tons/annum. In all, sub-Saharan African produces about 20% of the world's total production of root and tuber crops, for about 10% of the world's total human population (FAOSTAT, 2013). The tropical root and tuber crops are the second group of cultivated species after cereals in tropical countries and are of utmost importance for the world food security as they are major sources of energy in developing countries characterized by fast population growth.

Nigeria's position in the production of some of these RTCs is quite outstanding especially with regards to cassava and yam. Out of the annual global production level of cassava estimated at 276 million metric tons (MT) in 2013, Nigeria produced 19% of the total topping the list of the producing countries in the world followed by Thailand (11%), Indonesia (9%), Brazil (8%) and Democratic Republic of Congo (6%)(Sanginga and Mbabu, 2015**)**. Yam production in Nigeria has more than tripled over the past 53 years from 6.7 million tons 1961 to 45 million in 2014 (FAO, 2014). This increase in output is however, attributed more to the large area planted with yam than increase in productivity (Nwosu and Okoli, 2010).

Roots and tuber crops are grown in varied agro-ecological zones of Nigeria and under different production systems ranging from highland densely populated regions to lowland drier areas prone to drought or floods. They are produced with low input, consumed by the poorest and contribute significantly to food security and are also used for animal feed or as raw materials for processing industries (Lebot, 2010). It is worthy to note that the root crops occupy a strategic position among cultivated crops and the positions they occupy vary in the different agro-ecological zones in the country. While in the Southern part of the country, cassava occupies the first position, it is yams in the middle belt and in the semi-arid region sorghum with cassava occupying the 8th position (Amans et al., 2001; Olaniyan et al., 2001). Production of RTCs depends largely on favourable soil and climatic conditions.

Several studies have reported the impact of climate variability and climate change on crop yield and agricultural productivity in Nigeria (Adejuwon, 2004; Akintunde *et. al*, 2013, Apata et al, 2010). However, very few studies such as Akinbola and Imoudu, (2014); Chikezie *et. al* (2015); Adewuyi et al, (2014) have so far been carried out to determine the effects of climate change on the production of some root and tubers crops in Nigeria. All of the studies have been at the state and regional level. This study is, however, different from the previous studies in that it tries to determine the effects of climate change on root and tuber crops using aggregate national data of some major root and tuber crops namely yam, cassava and cocoyam. This is the objective and focus of this study.

MATERIALS AND METHODS

Study Area

This study was conducted in Nigeria. Nigeria is located in West Africa between latitude 40-14^{0}N and longitude 30-15^{0}E. It is bordered by the Gulf of Guinea to the south, Benin to the West, Niger to the North and Cameroon and Chad to the East (see map below). Nigeria has a total land area of 923,768sqkm including 13,000sqkm of water, a border length of 4,047km and a coastline of 853km. The climate and vegetation of Nigeria is equatorial in the south, tropical in the center, and arid in the north. There are two distinct seasons in the country: the rainy season and the dry season.

Fig.1: Map of Nigeria

The data used for this study were secondary data (time series) obtained from Food and Agriculture Organization statistics (FAOSTAT) and climatic data from 1975 to 2010 obtained from the Nigerian Meteorological Agency(NIMET). The data collected include annual output of some major root and tuber crops, annual mean temperature, annual mean rainfall and average mean relative humidity. Table 1 shows the summary statistics of the production, yield and output some major root and tubers crops in Nigeria.

Table 1: Summary statistics of major root and tubers crops in Nigeria (1975-2013)

Variable	Mean	Std. Dev	Min.	Max
Production(000tonnes)				
Yam	19549.79	12032.22	4600	38000
Cassava	27375.87	14001.22	9950	54000
Cocoyam	2048.38	1851.48	132	5473
Potato	361.43	416.15	28	1200
Sweet Potato	1367.43	1382.99	80	3462
Yield(ha)				
Yam	100.23	22.13	56.28	131.03
Cassava	108.54	12.38	90.45	140.26
Cocoyam	53.63	15.16	30.44	76.86
Potato	53.15	16.97	24.61	73.68
Sweet Potato	51.97	21.55	21.50	90.91
Area Harvested(Ha)				
Yam	1846.38	960.58	471	3123
Cassava	2463.61	1102.22	1050	3875
Cocoyam	320.25	244.35	40	739
Potato	100.19	117.53	3.8	269
Sweet Potato	426.38	471.28	11	1131

Source: FAOSTAT, 2013

Data Analysis

Augmented Dickey Fuller (ADF)

Augmented Dickey Fuller (ADF) test was used to examine the stationarity of the dataset as suggested by Johansen (1988, 1991) in order to overcome the problem of spurious regression that is common in time series analysis of non-stationary variables. The model of the ADF test with the constant term and trend is as follows:

$$\Delta Y_t = a_1 + a_{2t} + \beta Y_{t-i} \sum_{i=1}^{n} \gamma_i \Delta Y_{t-i} + \varepsilon_i$$

Where

ΔY_t = first difference of Y_t.

Y_{t-1}= lagged difference of Y_t

β= test coefficient

α_1 = constant

α_{2t} = coefficient of variable

εi = Gaussian white noise error term

Y_t= output in year t

Co-integration test

Following Johansen (1988) co-integration test was adopted to determine the presence of co-integrating vectors and the estimation of long-run relationship if the data set contains two or more time series as well as gives the maximum rank of co-integration.

According to Hjalmersson and Osterholm (2007), Johansen's methodology takes its starting point in the vector regression (VAR) of **n** order given by

$$\Delta yt = \prod yt - 1 + \sum_{i=1}^{k-1} \Gamma i \, \Delta yt - 1 + \mu + \varepsilon i$$

Where

$\Delta yt-1$ = first difference of an (n x1) vector of the n variables

$\prod$= (n x n) coefficient matrix

y_{t-1} = lagged values of Y_t

Γ = (n x (k-1) matrix of short run coefficients

μ = (n x 1) vector of constant

εi = (n x1) vector of white noise residuals

Y_t =output in year t

Model Specification

The explicit model for long run relationship among variables was given as:

ln $ROOT\ CROPS\ OUTPUT = \beta o + \beta 1 \ lnTEMP_t + \beta 2 lnRAINFALL_t + \beta 3 lnRELHUM_t$ ----- μt

In order to examine the short-run relationship among the variables, the corresponding error correction equation was estimated as

$$\Delta lnROOT\ CROPS\ OUTPUTt = \beta o + \sum_{i=1}^{p} \beta 1 \, \Delta lnTEMPt + \sum_{i=1}^{p} \beta 1 \, \Delta lnRAINFALLt + \sum_{i=1}^{p} \beta 1 \, \Delta lnRELHUMt + \omega ECMt - 1 + \mu t$$

where

$ROOT\ CROPS\ OUTPUT$ = Sub-Total Root and Tuber Crops Output (million tons)*

TEMP= Temperature (^{0}C)

RAINFALL = Rainfall (mm)

RELHUM = Relative humidity

ECM= Error Correction term

ln = Natural logarithm

Δ = Difference operator

The a priori expectations are β_1, β_2, β_3, <0

*output of yam, cassava and cocoyam only.

RESULTS AND DISCUSSION

Figure 1 shows the trend of annual mean temperature in Nigeria between 1975 and 2010. The result showed a gradual rise in temperature between 1975 to mid 1990s with a slight drop in 1994 and subsequent increase till late 2000. The mean temperature between 1975 and 1992 was 25.2^{0}C while the mean between 1993 and 2010 was 27.1^{0}C. This reveals an overall mean increase of 1.9^{0}C.

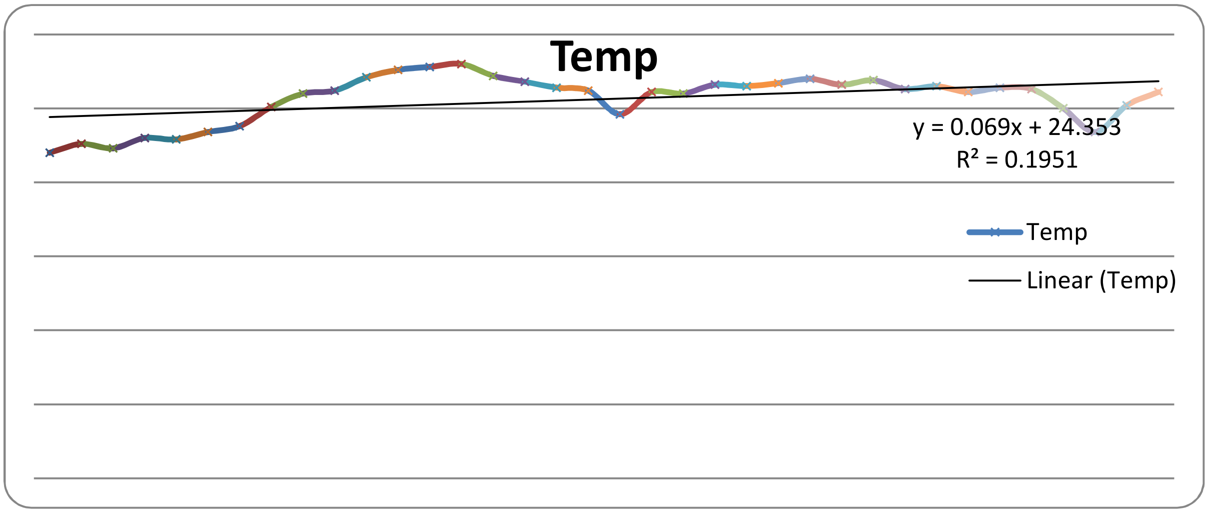

Figure 1: Annual mean temperature in Nigeria (between 1975 and 2010)

The study reveals an irregular rainfall pattern as shown in Figure 2. The highest rainfall was experienced in 1991 and 2008 while lowest rainfall was observed in 1994, which was followed by a gradual increase; it also corresponds with the period of low output. This marked the beginning of changes in climatic factor in Nigeria. Although the increase and decrease in rainfall pattern does not show a corresponding fluctuation in agricultural output that does not suggest that it did not affect agricultural output as food production in Nigeria is largely dependent on natural rainfall. However, 4.2mm increase change in rainfall will likely result into a change in agricultural output and vice-versa.

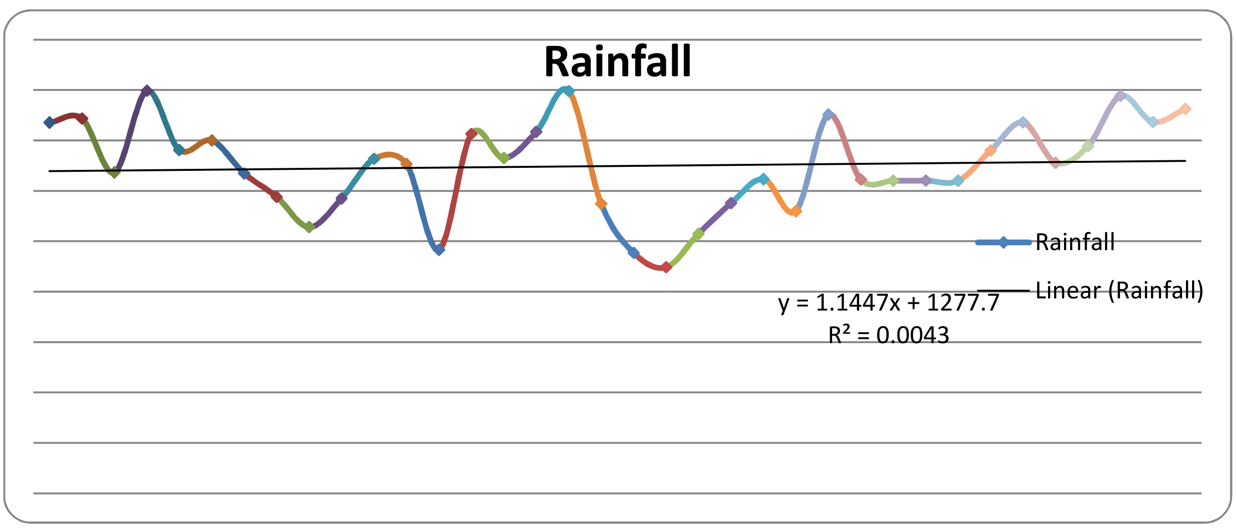

Figure 2: Annual mean rainfall in Nigeria (between 1975 and 2010)

Figure 3 shows the trend of relative humidity in Nigeria. It reveals an increasing trend with some deviations. However, there was a direct effect of the relative humidity of the atmosphere on agricultural product. For instance, the mean relative humidity between 1975 and 1992 was 50.7% at 25.20^{0}C temperature which means that every kilogram of the air contains 50.7% of the maximum amount of water that it can hold at that temperature while the relative humidity between 1993 and 2010 is 51.4% at 27.10^{0}C. It is noticed that the study period experienced dry air in the early period and moist air towards the later period. This observation coincides with the period of increased rainfall within the study period.

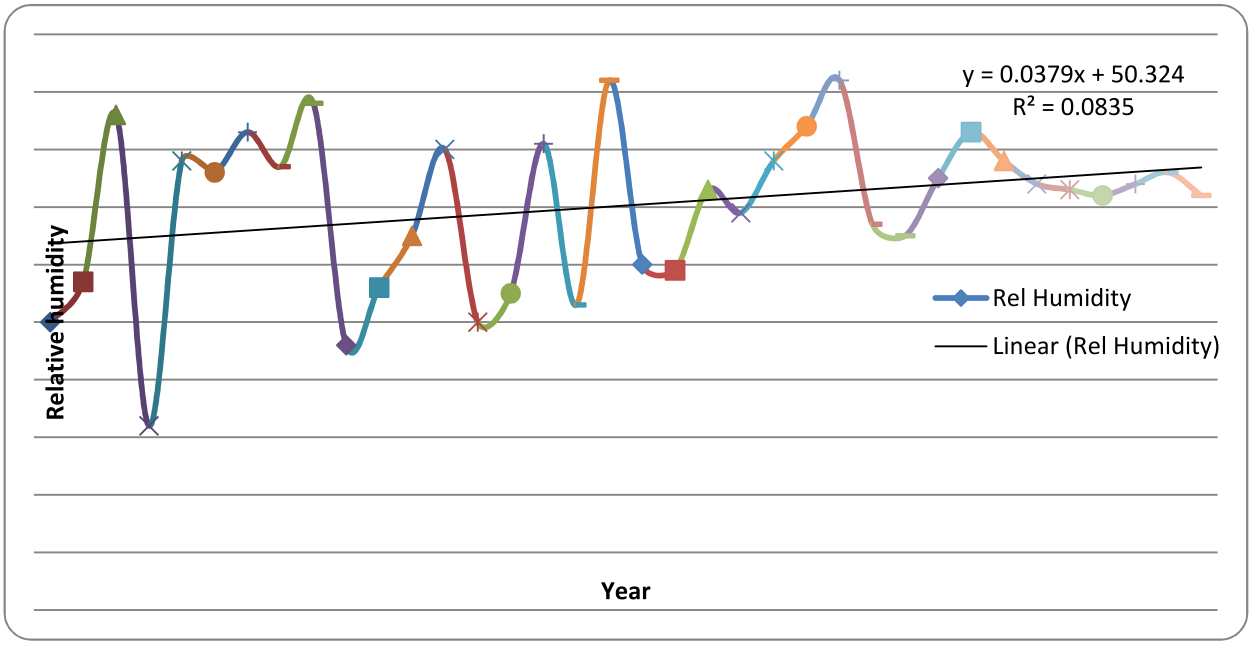

Figure 3: Annual mean relative humidity in Nigeria (between 1975 and 2010)

Crop Production

Figure 4 shows the trend in production of some of the root crops in Nigeria from 1975 to 2013. This trend reveals a continuous increase in production during the period especially cassava and yam production which shows a remarkable level of growth.

Augmented Dickey Fuller (ADF) test

The result of the ADF test in Table 2 shows that only relative humidity integrated at order zero level while rainfall, temperature and subtotal of the roots and tubers crops output were non stationary at zero level; however, after differencing at level 1 all the variables became stationary. Therefore, the null hypothesis of having a unit root is rejected and the alternative is accepted.

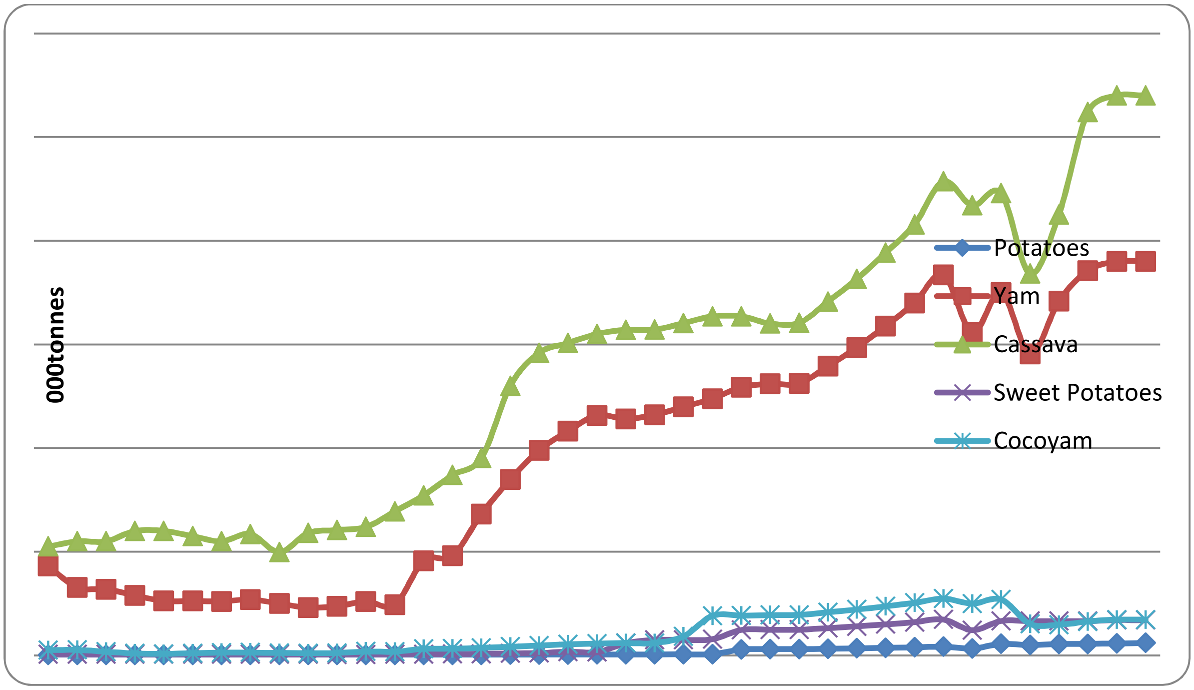

Fig 4: Output of some major root crops in Nigeria from 1975 to 2013.

Table 2: Augmented Dickey Fuller (ADF) Test Result

Variable	Level	t-statistics	Test Critical values			Prob.	Remarks
			1%	5%	10%		
Cassava	D(0)	-0.311823	-3.632900	-2.948404	-2.612874		NS
	D(1)	-3.015499	-3.653730	-2.957110	-2.617434	0.0004	S at 5%
Yam	D(0)	-1.211407	-3.646342	-2.954021	-2.615817		NS
	D(1)	-2.295340	-3.646342	-2.954021	-2.615817		NS
	D(2)	-4.143074	-3.646342	-2.954021	-2.615817	0.0003	S
Cocoyam	D(0)	-0.946600	-3.632900	-2.948404	-2.612874		NS
	D(1)	-5.409780	-3.639407	-2.951125	-2.614300	0.0000	S
Temp	D(0)	-2.382431	-3.632900			0.1538	**NS**
	D(1)	-5.523519	-3. 639407			0.0001	**S**
Rainfall	D(0)	-3.530388	-3.632900			0.0003	**NS**
	D(1)	-8.274938	-3.639407			0.0000	**S**
Relhum	D(0)	-6.667657	-3.632900			0.0000	**S**
	D(1)	-4.325393	-3.661661			0.0019	**S**

Source: Computed from Data Analysis

*NS=Non stationary, S= Stationary; D (0) = zero level, D (1) =Differencing at level 1, D (2) =Differencing at level 2

Table 3: Unrestricted Co-integration Rank Test (Trace)

Hypothesized No. of co-integrating equation(s)	Eigen value	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.571447	55.87493	47.85613	0.0074
At most 1	0.348764	27.06537	29.79707	0.1000
At most 2	0.230743	12.48331	15.49471	0.1352
At most 3	0.099519	3.564073	3.841466	0.0590

Trace test indicates 1 co-integrating equation(s) at the 0.05 level of probability
* denotes rejection of the hypothesis at the 0.05 level of probability
**MacKinnon-Haug-Michelis (1999) p-values

Table 4: Unrestricted Co-integration Rank Test (Maximum Eigen value)

Hypothesized No. of CE(s)	Eigen value	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.571447	28.80957	27.58434	0.0347
At most 1	0.348764	14.58205	21.13162	0.3193
At most 2	0.230743	8.919242	14.26460	0.2929
At most 3	0.099519	3.564073	3.841466	0.0590

Max-eigen value test indicates 1 co-integrating equation(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level

Johansen Test

The results of the Johansen co-integration test (Trace and Max-Eigen) as shown in Tables 3 and 4 indicate that there is one co-integrating equation at 5% level of probability and this implies that the null hypothesis of not having a co-integrating equation (r =0) is rejected and the alternative hypothesis of having one co-integrating equation (r =1) is accepted.

Table 5. Vector error correction estimates of some root and tubers crops output in Nigeria

Variable	Coefficient	Standard Error	t-statistics
Long run			
Constant	104.7345		
ln sub rtcs output (-1)	1.0000		
ln Temp (-1)	86.55922	22.5584	3.83712***
ln Rainfall (-1)	36.60457	10.0478	3.64305***
ln Relhum (-1)	-201.9726	65.9352	-3.06320***
Short run			
Constant			
Δln Sub Rtcs output (-1)	0.029006	0.00141	0.37436
Δln Sub Rtcs output (-2)	0.001638	0.08237	0.01988
Δln Rainfall (-1)	0.033900	0.06083	0.55726
Δln Rainfall (-2)	0.068308	0.05100	1.33935
Δln Temp (-1)	0.076851	0.19550	0.39311
Δln Temp (-2)	-0.162777	0.20459	-0.79562
Δln RelHum (-1)	-0.662784	0.24784	-2.67428**
Δln RelHum (-2)	0.209749	0.18196	-1.15269
ECM (-1)	-0.000475	0.00311	-0.15287

Note. ** 5%, *** 1% level of significance. R-squared 0.577044, F-statistic 3.486571; rtcs= root and tuber crops
Source: Computed from Data Analysis

Vector Error Correction Estimates

The existence of co-integrating relationship between the dependent and independent variables as indicated by Johansen co-integration test necessitated examining the short run dynamics between the variables in the co-integrating equation by estimating the error correction model. The result of the vector error correction as shown in Table 5 contains the long- run estimates, short- run estimates and diagnostics statistics. The long run estimates show that RAINFAL, TEMP were positively related to RTCs output while RELHUM was negatively related to ROOT and Tubers crops OUTPUT in the long run and this is consistent with a priori expectation. RAINFALL and TEMP were positive but not significant in the short run but positive and significant in the long run and this gives support to the fact that the vagaries of these climatic variables will have effects on the production of root and tuber crops and by extension availability, affordability, accessibility and quality in Nigeria both in the near and far future. This is in agreement with Ayinde et al. (2011) and Adewuyi et al. (2014). The error correction coefficient of -0.000475 of the model had negative sign and not significant showing that there is no long run relationship between the dependent and independent variables (temperature, rainfall), all things being equal. This implies that other technical and agronomic factors like farm inputs use may come to play in the production process of these crops. A feedback of about 0.03% of the previous year disequilibrium from the long run value of the independent variables shows that root and tuber crops production in Nigeria does not have a strong positive response to rainfall, temperature and relative humidity like in all other tropical countries.

CONCLUSION

The study has been able to establish that climatic data are related to root and tuber crops production in the long run. Results indicated that only rainfall was positively related to root and tuber crops production on the short run indicating that vagaries in climate affected food production and output in Nigeria. The results also established the strong influence of rainfall as a key determinant of the level of production of root and tuber crops and by extension on food security attainment in Nigeria. The long run estimates show that rainfall and temperature were positively related to RTCs output while relative humidity was negatively related to root and tubers crops output and this is consistent with a priori expectation. This implies that vagaries in climate will negatively impact on root and tuber crops production and output in Nigeria in both short and long run, hence the need for timely policy intervention by the government to mitigate the adverse effects of inadequate rainfall or too much rainfall that are likely to result in drought and flooding/ erosion respectively. Therefore, to firmly address the problems and challenges of climate change, farmers should equally be sensitized and trained in the area of climate change adaptation and mitigation as well as modern agronomic practices that will help to ameliorate large scale failure in root and tuber crops production in the country.

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