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EFFECTS OF CLIMATIC VARIABILITY ON CASSAVA PRODUCTION IN NIGERIA

Fatai Abiola Sowunmi[1✉], Oluwaseun Temitope Adeyemi[1], Abeeb Adetunji Bello[1]

[1]University of Ibadan, Nigeria

Abstract. Climate change has brought about an irregularity in pattern and intensity of climatic variables, such as rainfall and temperature, which are important in crop production, making planning in agriculture difficult. The importance of cassava in the diet of Nigerians and its industrial use created a need to examine the effects of climatic variability on cassava production. Secondary data obtained from the Nigerian Meteorological Agency (NIMET) were used for the study. An analysis of variance and error correction model was utilised. The study showed that the rainforest zone had the highest averages of annual rainfall (1,709 mm) and relative humidity (82.1%), while the Sahel savannah had the highest mean annual temperature (35.3°C). The variability in annual rainfall and relative humidity was low in the rainforest zone. The study showed that the rainforest zone had the least dispersion of average annual relative humidity (2.06%) while the Guinea savannah had the highest dispersion (4.68%). The average cassava output from the agro-ecological zones was 49,118,871 MT per year. Rainforest and Guinea savannah accounted for 56.3% and 41.9% of total cassava output respectively. There were significant variations in the climatic variables (rainfall and temperature) among the agro-ecological zones but not significant among the years ($p>0.05$). The annual rainfall and solar radiation were the factors that influenced cassava output in all the agro-ecological zones. Affordable irrigation systems available to cassava farmers and the adoption of climate-smart agriculture are recommended to boost cassava production in Sudan savannah and Sahel savannah.

Keywords: cassava production, co-integration, agro-ecological zones, climatic variables

INTRODUCTION

The Nigerian agriculture (crop subsector) is majorly rain-fed and practically dependent on the vagaries of the weather, especially rainfall, which has become more pronounced in the recent years due to climate change. The pattern of rainfall varies from one agro-ecological zone to another, due to this variability in rainfall pattern; tuber crops, including yam and especially cassava, are predominantly cultivated in the southern part of the country, though some states in the northern and central part of the country (Kwara, Benue, Kogi, Plateau, Taraba and the southern part of Adamawa) cultivate cassava in commercial quantities (Ogungbenero and Morakinyo, 2013). Moreover, the Food and Agricultural Organisation report (FAO, 2015) affirmed that over 60%of the total cassava production in Nigeria is carried out in the rainforest agro-ecological zone, while the rest (40%) is produced in the moist savannah zones.

Cassava is the third-largest source of food carbohydrates in the tropics, after rice and maize. It is a major staple food in the developing world, providing a basic diet for over half a billion people (Fauquet and Fargette, 1990; FAO, 1995). Philip et al. (2005) revealed that the average per capita cassava consumption per person per day in rural and urban areas in Nigeria are 239.74 gm and 213.76 gm respectively. The influence of weather and climate on the different components of crop production varies (Toshichika and Navin, 2015). Different types of climatic extremes can affect crop production

✉Fatai Abiola Sowunmi, Department of Agricultural Economics, University of Ibadan, Ibadan, Nigeria, e-mail: fasowunmi@live.co.uk, https://orcid.org/0000-0003-4108-8830

differently. Irregularity of rainfall, emergence of different rainfall patterns from the ones that farmers are used to and unexpected dry spells have contributed to risks involved in crop production in general, and cassava production in particular. The Intergovernmental Panel on Climate Change (IPCC, 2001) estimated that climate change is likely to reduce yields and/or damage crops in the 21st century. The effect of climate variability and climate change on crop yield has been a subject of long-standing interest as climate is a primary determinant of agricultural productivity. There is scant literature on the trends of climatic variables and effects of climate variability on the production of cassava, considering its importance in terms of food security and its potential as a huge foreign-exchange earner. This study is an attempt to determine the climatic and agronomic factors' influence on cassava production in different agro-ecological zones where its cultivation takes place.

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

There are two theories underlining this study. These are theories of production and adaptation to climate change. Production is a process by which inputs and resources are transformed into outputs. A production function describes the technical relationship that transforms input (resources) into outputs (commodities). Beside the conventional inputs of land, labour, capital and management, climatic factors (rainfall, humidity, sunshine and temperature) and agronomic factors (topography, soil type) are also significant (Ben, 2019).

The production function where there are several inputs is represented as:

$$y = f(x_i, m_i) \qquad (1)$$

where:
- y – represents the output
- x_i – represents the conventional inputs (land, labour, capital)
- m_i – represents the climatic factors (rainfall, temperature and humidity among others).

Adaptations are changes in behaviour and capital motivated by climate change. Economic theory suggests that adaptations are efficient (desirable) only if their benefit exceeds their cost. An understanding of how climate directly affects households is needed in order to understand how households will respond to its variability. A utility function is presented below:

$$MaxU\ (X,C)\text{s.t} \qquad Y = PX \qquad (2)$$

where:
- U – represents a utility function that entails goods (X) but contains climate (C)
- Y – represents income, which determines the budget constraints
- P – represents the vector of prices.

Using Roy's identity, a demand function can be identified for individuals as:

$$X_1 = D_1(P,Y) \qquad (3)$$
$$X_2 = D_2(P,Y,C) \qquad (4)$$

For the vector of goods X_1, C will not play a role. The desire for many goods such as transport or staples will not be climate sensitive. Households want to purchase the same quantity of these goods no matter the change in climatic factors. However, for another vector of goods, X_2, C will shift the demand function, for example, households may want the same quantity of cassava end product (examples are garri and starch) at the same price in a long period of dry spell which makes harvesting difficult (Mendelsohn, 2012). Given the price garri/starch, the household will have to reduce their demand or pay more to have the same quantity of the product because of reduction in supply brought about by climate change.

Various analytical tools have been used in studies on the effect of climatic variability on agricultural production. These tools include a coefficient of variation (Ayanlade et al., 2010; Girma et al., 2016; Kimengsi and Ngong, 2013), two-way analysis of variance (ANOVA) (Sowunmi and Akintola, 2010; Oluyole, 2010; Kansiime et al., 2013; Nyatuame et al., 2014; Gebrehiwot and van der Veen, 2013) and a co-integration analysis (Amos and Thompson, 2015; Amikuzono and Donkoh, 2012; Chikezie et al., 2015; Ayinde et al., 2013). The coefficient of variation in particular has been widely used to determine the extent of climatic variability. However, a known limitation of the coefficient of variation is that when the average value is zero, the value of coefficient of variation approaches infinity, and thus, it is quite sensitive to small changes in mean values. Furthermore, an analysis of variance is designed to test against any

and all alternatives to the null hypothesis and thus may be suboptimal for testing against specific hypothesis. The coefficient of variation and ANOVA do not address the causal relationship between variables (e.g. agricultural output and climatic variables). The use of co-integration regression analysis in this study makes it possible to establish linear combinations in series that may not be stationary (Ayinde et al., 2011). The need to test for stationarity of time series data in order to prevent spurious regression is addressed by the co-integration regression analysis.

MATERIALS AND METHODS

The study covered five of the agro-ecological zones (rainforest, Guinea savannah, montane, Sudan savannah and Sahel savannah) in Nigeria where cassava is cultivated. Generally, cassava is grown in all the five agro-ecological zones under consideration. The data used for the study were secondary data obtained from the National Bureau of Statistics (NBS) and the Nigerian Meteorological Agency (NIMET). Data obtained from NIMET were climatic characteristics (annual average temperature, annual maximum temperature, annual rainfall, annual relative humidity and annual radiation) for the agro-ecological zones from 1995 to 2015. Agronomic characteristics (Cassava production intonnes and size of land used for cassava production within the same period) were obtained from NBS.

Data were analysed using descriptive statistics to profile climatic and agronomic characteristics of each of the five agro-ecological zones. Variations in climatic and agronomic variables among the agro-ecological zones were tested using ANOVA ,while the variability in climatic variables within each zone was estimated using the coefficient of variation. The short- and long-run dynamic relationships between cassava output and the independent variables (climate variables and agronomic factors) in each agro-ecological zone were determined using a co-integration regression analysis. The co-integration analysis which gave a long-run dynamic relationship was determined as follows:

$$LnCOT = \beta_0 + \beta_1 LnLS_t + \beta_2 LnAAT_t + \beta_3 LnAAR_t + \beta_4 LnARH_t + \beta_5 LnARD_t + \beta_6 LnAMT_t - \mu t \quad (5)$$

The error correction equation (short-run dynamic relationship) is given as:

$$\Delta LnCOT = \beta_0 + \sum_{i=1}^{p} \beta_1 \Delta LnLS_t + \sum_{i=1}^{p} \beta_2 \Delta LnAAT_t + \sum_{i=1}^{p} \beta_3 \Delta LnAAR_t + \sum_{i=1}^{p} \beta_4 \Delta LnARH_t + \sum_{i=1}^{p} \beta_5 \Delta LnARD_t + \sum_{i=1}^{p} \beta_6 \Delta LnAMT_t + \omega ECM_t - 1 + \mu t \quad (6)$$

where:

COT – represents the cassava output (t)

LS – represents the annual hectares of land used for cassava cultivation (ha)

AAT – represents the average annual temperature (°C)

AAR – represents the average annual rainfall (mm)

ARH – represents the average annual relative humidity (mm)

ARD – represents the average annual radiation (W/m²)
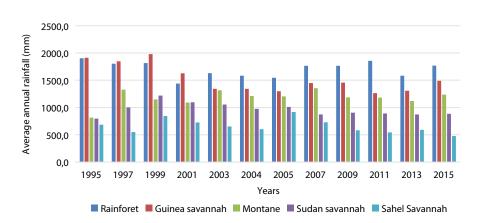
AMT – represents the average annual maximum temperature (°C).

RESULTS AND DISCUSSION

The mean annual rainfall in the cassava cultivating agro-ecological zones of Nigeria from 1995-2015 was 1,220.4 mm. The rainforest zone had the highest annual rainfall (1,709.6 mm), while the Sahel savannah had the lowest annual rainfall (633.9 mm) (see Fig. 1).

The rainforest zone had the lowest variability in the annual rainfall (8%), while the Sahel Savannah had the highest variation (21.14%) in the periods under consideration (see Table 1).

The mean annual temperature in the cassava cultivating agro-ecological zones of Nigeria from 1995–2015 was 26°C. The Sahel Savannah zone recorded the highest annual temperature (28.78°C), while the montane zone had the lowest annual temperature (20.08°C) (see Fig. 2). The coefficient of variation revealed that the Sudan Savannah zone had the lowest variation of average annual temperature (2.58%) while the Sahel Savannah zone recorded the highest variability (5.3%) (see Table 2).

The mean annual relative humidity in the cassava cultivating agro-ecological zones of Nigeria from 1995–2015 was 57%. The rainforest zone had the highest average annual relative humidity (82.1%), while the Sahel savannah had the lowest (37.7%) in the period of this study. The result showed that the rainforest zone had the least dispersion of average annual relative humidity (2.06%) while the Guinea savannah had the highest dispersion (4.68%) (see Table 3).

Fig. 1. Distribution of the average annual rainfall by agro-ecological zones (1995–2015)
Source: result of data analysis, 2017.

Table 1. Ranking of average annual rainfall and coefficient of variation

Agro-ecological zones	Ranking of average annual rainfall (mm)		Ranking of coefficient of variation (%)	
Guinea Savannah	1 544.6	2nd	14.9	4th
Rainforest	1 709.6	1st	8.0	1st
Montane	1 248.2	3rd	12.4	2nd
Sahel Savannah	633.9	4th	21.1	5th
Sudan Savannah	1 248.2	3rd	13.1	3rd

Source: own elaboration.

Table 2. Ranking of average annual temperature and coefficient of variation

Agro-ecological zones	Ranking of average annual temperature (°C)		Ranking of coefficient of variation (%)	
Guinea Savannah	27.76	2nd	3.09	3rd
Rainforest	27.1	3rd	2.59	2nd
Montane	22.08	5th	3.39	4th
Sahel Savannah	28.78	1st	5.30	5th
Sudan Savannah	26.74	4th	2.58	1st

Source: own elaboration.

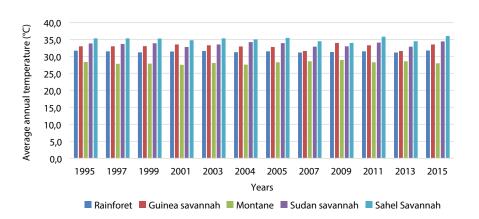**Fig. 2.** Distribution of the average annual temperature by agro-ecological zones (1995–2015)
Source: result of data analysis, 2017.

Table 3. Ranking of average annual relative humidity and coefficient of variation

Agro-ecological zones	Ranking of average annual relative humidity (%)		Ranking of coefficient of variation (%)	
Guinea Savannah	64.7	2nd	4.68	5th
Rainforest	82.13	1st	2.06	1st
Montane	52.2	3rd	4.64	4th
Sahel Savannah	37.7	5th	2.97	2nd
Sudan Savannah	47.3	4th	3.14	3rd

Source: own elaboration.

Table 4. Ranking of average annual solar radiation and coefficient of variation

Agro-ecological zones	Ranking of average annual radiation (mm)		Ranking of coefficient of variation (%)	
Guinea Savannah	20.01	4th	0.49	2nd
Rainforest	18.1	5th	0.46	1st
Montane	21.8	3rd	0.55	3rd
Sahel Savannah	23.16	1st	0.77	4th
Sudan Savannah	22.4	2nd	1.11	5th

Source: own elaboration.

The total cassava output in the five agro-ecological zones from 1995 to 2015 was 736,783,068.9 MT. Rainforest and Guinea savannah accounted for 56.3% and 41.9% of the total cassava output respectively. The average annual cassava yield of the agro-ecological zones from 1995 to 2015 was 7.9 MT/ha. This is below the national average output of cassava per hectare of 13.04 MT/ha reported by the National Agricultural Extension and Research Liaison Services (NAERLS, 2010). The disparity between the value from the study and the national average yield (2007–2011) may be attributed to the difference in the period. The rainforest zone had the highest yield of cassava (12.1 MT/ha), while the Sahel savannah had the lowest (3.5 MT/ha) in the period of this study. Among the zones, only rainforest zones recorded the yield close to the national average yield of cassava. The sharp drop in the yield of cassava in major producing zones (see Fig. 3) may be attributed to the migration of herdsmen down south (the panacea to the effect of climate change) in search of feed for cattle and along the way, crops like cassava, maize and rice are consumed by cattle during the day and at night.

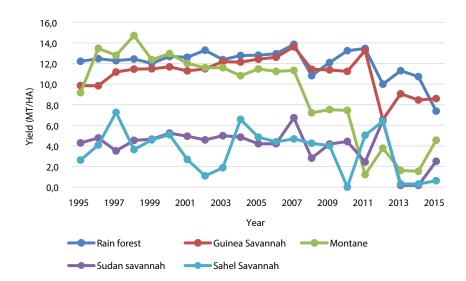This has often resulted in heavy losses suffered by crop farmers and conflicts between crop farmers and the

Fig. 3. Distribution of the cassava yield among the agro-ecological zones (1995–2015)
Source: result of data analysis, 2017.

Table 5. Ranking of average annual cassava output and coefficient of variation

Agro-ecological zones	Ranking of average annual cassava output (MT/Ha)		Ranking of coefficient of variation (%)	
Guinea Savannah	11	2nd	15.67	2nd
Rainforest	12.1	1st	11.89	1st
Montane	9.1	3rd	46.93	4th
Sahel Savannah	3.54	5th	61.17	5th
Sudan Savannah	4.03	4th	41.52	3rd

Source: own elaboration.

herdsmen. The result shows that the rainforest zone had the least variability in average annual yield (11.89%), while the Sahel savannah (61.17%) had the highest/largest dispersion of yield in the period of this study (see Table 5). This may be connected with the importance of water in cassava production. The results show that there were significant differences in climatic and agronomic variables among the agro-ecological zones but not among the years covered by the study (see Table 6). Also, there were significant variations in the cassava output, size of land cultivated and yield among the agro-ecological zones and the years under consideration. This may be attributed to the variations in suitability of different agro-ecological zones to cassava production and the importance of cassava to the nutrition of the inhabitants of each agro-ecological zone.

The results of the test for stationarity show that the variables behaviour was typical of time series data in terms of stationarity. The results of the Johansen test revealed that there exists a long-run relationship between the dependent variable and independent variables in all the agro-ecological zones. The need for the use of co-integration regression analysis, as confirmed by the Johansen test, was a result of the non-stationarity at the level of most of the variables in the agro-ecological zones. The result is explained based on the agro-ecological zones. Generally, the adjusted R^2s were low across the agro-ecological zones. This may be attributed to the fact that the values accounted for only the effects of climatic and agronomic factors captured in the

Table 6. Two-way ANOVA test results for climatic and agronomic variables among the agro-ecological zones and the years

Climatic/agronomic variable	Sum of squares	Degree of freedom	Mean square error	F^{cal}	P-value
Annual rainfall (mm)	15 707 407	4	3 926 852	151.5	0.000***
Among the years	524 718.7	20	26 235.94	1.01	0.46ns
Annual temperature (°C)	562.14	4	140.53	134.86	0.000***
Among the years	8.02	20	0.40	0.38	0.99ns
Annual relative humidity (%)	24 837.28	4	6 209.32	1509.6	0.000***
Among the years	98.24	20	4.91	1.19	0.28ns
Annual solar radiation (W/m²)	174.64	4	43.66	1 522.57	0.000***
Among years	0.09	10	0.01	0.31	0.97ns
Annual cassava output (MT)	7.57E+15	4	1.89E+15	205.3	0.000***
Among the years	3.73E+14	20	1.87E+13	2.02	0.014**
Annual land area cultivated (Ha)	5.73E+13	4	1.43E+13	98.98	0.000***
Among the years	1.03E+13	20	5.15E+11	3.56	0.000***
Annual Yield (MT/Ha)	1 311.60	4	327.90	82.48	0.000***
Among the years	294.14	20	14.71	3.70	0.000***

Source: result of data analysis, 2017.

model. There are other important factors (like frequency of weeding, application of agrochemicals, the variety planted, farmers' contact with extension agents, access to credit, extent of compliance with new technology and experience of farmer in cassava cultivation among others) influencing cassava production. The Durbin Watson values show that there were no positive autocorrelations. The probability of the F-statistic of the results indicate that the models had a good fit ($p < 0.01$). The positive significance of annual farm size cultivated among the agro-ecological zones means that an increase in farm size leads to increase in cassava annual output. In the long-run, this is not encouraging because it is the only increased productivity that can justify farmers' investment and guarantee sustainable livelihood from farming. According to Ayinde et al. (2012), cassava production over the last half a century has largely been driven by land area expansion as opposed to improved cassava productivity. Table 7 shows that farm size (ha) and solar radiation were the factors that positively influenced cassava output in rainforest zone.

Two significant variables accounted for 23% variation in cassava output in the zone. The significance of the farm size is in agreement with Nwachukwu et al. (2012). In the Guinea savannah zone, the size of land cultivated (ha) was significant and positively influenced cassava output ($p < 0.01$), while annual rainfall was also significant but negatively influenced cassava output contrary to a priori expectations. This may be attributed to the limited number of variables (factors) captured in the model which is line with the research. There are other factors influencing cassava production in Nigeria. In the montane zone, the size of land cultivated positively influenced cassava output, while solar radiation

Table 7. Co-integration regression results for the agro-ecological zones

Variable	Agro-ecological zones				
	Rainforest	Guinea Savannah	Montane	Sudan Savannah	Sahel Savannah
Constant	17.198	15.439	13.236	−11.0587	−120.720
	(2.591)	(2.401)	(6.104140)	(11.638)	(60.0966)
Land size (ha)	2.50E–07***	2.33E–07***	2.98E–06***	5.16E–06***	0.750***
	(3.88E–08)	(6.48E–08)	(5.53E–07)	(1.11E–06)	(0.0953)
Annual temperature (°C)	−0.0385	0.0639	0.0697	0.000124	−0.000944
	(0.0595)	(0.0845)	(0.115)	(0.00104)	(4.450)
Annual rainfall (mm)	5.97E–05	−0.00285***	0.00116	0.388*	2.0692**
	(0.000226)	(0.000850)	(0.000675)	(0.194)	(0.910)
Annual relative humidity (%)	−0.0147	−0.0107	−0.0749	0.0355	6.634
	(0.023)	(0.0180)	(0.0450)	(0.0938)	(6.240)
Annual solar radiation (W/m^2)	0.0126*	0.00411	−0.0271**	−0.00220	−0.154
	(0.00526)	(0.00585)	(0.0105)	(0.0129)	(0.145)
Annual maximum temperature (°C)	0.0375	0.00101	0.0231	0.269	24.318
	(0.0343)	(0.0845)	(0.214)	(0.276)	(14.736)
R^{-2}	0.23	0.30	0.26	0.36	0.22
Probability of F-statistic	0.0000	0.000013	0.005	0.004926	0.0000
DW	1.99	1.89	1.77	1.81	2.0

Dependent variable: cassava output (metric tonnes).
*, **, ***indicate statistical significance at 10%, 5% and 1% levels respectively.

negatively influenced cassava production. The negative relationship may be attributed to an increase in transpiration and abiotic stress as a result of increased solar radiation. Ferrante and Mariani (2018) revealed that abiotic stresses directly affect plant growth and development. In agriculture, sub-optimal values of temperature, light intensity, and relative humidity can limit crop yield and reduce product quality. Temperature has a direct effect on whole plant metabolism, and low or high temperatures can reduce growth or induce crop damage. In Sudan savannah and Sahel savannah zones, size of land cultivated (ha) and annual rainfall were the factors that positively influenced cassava output. However, an increase in the land cultivated should be guided by improved productivity. According to Spore CTA (2015), an arable land expansion approach has been the source of increase in food production as against increase in productivity that can enhance the farmers' commitment and give good returns to their efforts.

CONCLUSIONS AND RECOMMENDATIONS

The study showed that climatic factors influenced cassava output in Nigeria. The effect of the variable(s) differs from one agro-ecological zone to the other. This also translates to the output of cassava which was also agro-ecological zone specific, as it decreases northwards. However, the implementation of a positive relationship between farm size and cassava output across the agro-ecological zones should be guided by improved productivity to justify the resources utilised. There is a need for extension agents to monitor and make available to farmers information on the weather (through collaboration with the Nigerian Meteorological Agency) and recent technology in terms of high yielding cassava varieties. Increasing farm sizes guided by improved productivity through the use of improved cultivars and adoption of modern agronomic practices is recommended for the rainforest and Guinea savannah zones (suitable for cassava production) to enhance the returns on farmers' investment; utilisation of affordable irrigation (occasional flooding of farmland with the right quantity of water) and the adoption of climate-smart agriculture by cassava farmers to boost production in Sudan savannah and Sahel savannah is advised. Additionally, the increase of farmland should be guided by improved cassava productivity driven by the use of improved and drought resistant cultivars, and appropriate agronomic practices should be midwifed by committed agricultural extension agents.

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