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Research Paper

Combined effect of rainfall and sunshine duration on cassava output in Nigeria

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ABSTRACT

This study examined the combined effect of rainfall and sunshine duration on Casava production in Nigeria from 1988 to 2023 using secondary data obtained from the Nigeria Meteorological Agency (NiMet) and the Food and Agriculture Organization (FAO). Econometric techniques were employed to analyse the relationships between the variables. Regression analysis revealed that cassava yield was significantly negatively related with rainfall (β = -73,133.9; p = 0.000), while sunshine duration was positive and significant (β = 8,755,640.3; p = 0.000). Rainfall and sunshine duration interaction was significant and positive (β = 7,611.8; p = 0.000) and revealed that sunshine duration was mediating the adverse effect of excessive rainfall. The model explained a high explanatory power with R-squared being 0.896 and adjusted R-squared being 0.881. The error correction model (ECM) coefficient (-0.934) showed a high speed of adjustment towards equilibrium, which meant that the deviations in the output of cassava as a result of climate variability were adjusted quickly. Based on the findings of this study, farmers are encouraged to adopt water management practices and improved agronomic practices in an attempt to enhance the positive effects of sunshine duration on cassava yield.

Keywords: Cassava production, Rainfall variability, Sunshine duration, Moderating effect, Climate-smart agriculture, Nigeria

Cassava (*Manihot esculenta*) is food staple crop of Nigerian that is essential to food security, income, and the supply of raw material for industries. Nigeria accounts for the majority of the world's cassava, and more than 60 million metric tons of it are produced annually (FAO, 2023; Eze *et al.,* 2023). Rainfall is imperative for cassava development, impacting soil moisture content, nutrient absorption, and physiological processes. On the other hand, excessive rainfall contributes to waterlogging, root rot, and lowered yields (Sowunmi, 2020). Sunshine duration is equally important since it impacts photosynthesis, root tuber formation, and starch build-up (Ezui *et al.,* 2016). Pandey (2023) in a study also noted that while the sunshine hours are projected to decrease, the present-day crop varieties would not be able to sustain crop production levels under a changing climatic scenario. FAO-AquaCrop model has been used to suggest better crop planning cassava in Vietnam (Lee and Dang, 2020; Nguyen and Dang, 2021). Pushpalatha *et al.,* (2021) simulated the Cassava yield in different regions of India using WOFOST model.

The impacts of climate variables on cassava yields in Nigeria have also been examined by numerous studies. Anyaegbu *et al.,* (2022), for instance, studied how climate change had affected cassava yield and ensured that the excess rainfall prevented production through root damage and soil erosion. Oyita *et al.,* (2023) further claimed that rainfall is of utmost importance in the determination of cassava yield, with irregular precipitation leading to yield variability. Additionally, Ezui *et al.,* (2016) highlighted sunshine duration's importance in cassava growth because it has a key role in photosynthesis maximization and carbohydrate deposition.

Despite these observations, there is dearth in empirical examination of the combined effect of sunshine duration and rainfall on cassava yield in Nigeria. Most of the studies have included single climate variables but have not looked at their combined impacts. Towards this end, the study seeks to bridge the knowledge gap by determining the combined effect of sunshine duration and rainfall on cassava yield in Nigeria.

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MATERIALS AND METHODS

Study area and data sources

Nigeria encompasses various agroecological areas beginning from southern humid rainforests progressing toward northern semi-arid regions which encounter distinctive climatic patterns. Secondary sources providing information about the study examined a 36-year timeframe that extended from 1988 to 2023. Rainfall and sunshine duration date obtained from Nigeria Meteorological Agency (NiMet, 2023) [https://nimet.gov.ng/datarequest] whereas cassava output statistics obtained from Food and Agriculture Organization (FAO, 2023) [https://www.fao.org/faostat/en/#data/QCL].

Analytical techniques

The study employed econometric techniques to analyze the moderating role of sunshine duration on the effect of rainfall on cassava output in Nigeria. To examine the relationship between rainfall, sunshine hours, and cassava production, descriptive statistics, mean, and standard deviation were utilized to present and track past trends in data. The Augmented Dickey-Fuller (ADF) test was applied to conduct a unit root test in order to establish stationarity of variables. To determine if there existed a long-run equilibrium relationship among variables, Johansen cointegration test was performed. In inferential analysis, individual contributions of rainfall and sunshine duration to cassava production were estimated using multiple regression analysis. Additionally, moderation analysis with interaction term (rainfall × sunshine duration) was performed to confirm if sunshine duration was moderating the effect of rainfall on cassava production. Diagnostic tests for serial correlation, heteroscedasticity, and autocorrelation were performed to ensure that the model is stable. EViews 13 was used to analyze data to ensure correct statistical modelling and interpretation.

Unit root test

To test for stationarity in the time-series data, the Augmented Dickey-Fuller (ADF) test was applied. The form of the ADF test is specified as:

Where:

$$\Delta Y_t = \alpha_0 + \beta_t + \gamma Y_{t-1} + \sum_{i=1}^{p} \delta_i \, \Delta Y_{t-1} + e_{it} \ldots\ldots\ldots\ldots (1)$$

Y_t = Variable under examination (cassava output, rainfall, or sunshine duration); α = Intercept; β = Time trend coefficient; γ = Unit root coefficient; p = Optimal lag length; δ_i = Coefficients of lagged differences; e_t = Error term

The null hypothesis (H_0 : γ = 0) implies a unit root (non-stationarity), while the alternative hypothesis (H1 : γ<0) implies stationarity.

Cointegration test

The Johansen cointegration test was used in this study because it checks for long-run equilibrium ties between cassava out put and rainfall and sunshine duration variables. Johansen cointegration applies a vector autoregressive (VAR) model through the following specification:

$$\Delta Y_t = \pi Y_{t-1} + \sum_{i=1}^{k-1} \delta_i \, \Delta Y_{t-1} + e_{it} \ldots\ldots\ldots\ldots (2)$$

where:

Y_t = Vector of endogenous variables (Cassava output, rainfall, sun shine duration); ΔY_t = First-differenced values of Y_t; π = Cointegration matrix; = Short-run dynamics; e_t = Error term

Regression model

The regression model was specified as:

$$CAS_{it} = \beta_0 + \beta_1 RAIN_{it} + \beta_2 SSD_{it} + \beta_3 (RAIN_{it} \times SSD_{it}) + e_{it} \ldots\ldots\ldots\ldots (3)$$

Where:

CAS_{it} = Cassava output in metric tons; $RAIN_{it}$ = Mean annual rainfall, measured in millimetres (mm); SSD_{it} = Sunshine duration, measured in hours; β_0 = Intercept; β_1, β_2, β_3 = Coefficients; e_{it} = Error term.

RESULTS AND DISCUSSIONS

Trends of rainfall, sunshine duration and cassava production

Fig. 1 reveals strong trends in rainfall, sunshine hours, and cassava production, with varying patterns for each variable. Rainfall exhibited high year-to-year variability, from a low of 1027.38 mm in 2011 to a high of 1269.15 mm in 2019, with no discernible long-term increasing or decreasing trend. Sunshine hours reflected significant variability from the record low 4.7 hours in the year 2010 to 8.8 hours in the year 2009, record high, but not with consistent rising or falling trend over decades. In contrast to these volatile climatic trends, the production of cassava was consistently high and on an upward trend, rising from 15.439 million tonnes in the year 1988 to 62.69 million tonnes in the year 2023. The most rapid increases occurred in two crucial periods: firstly, between 1990 and 1996, when production nearly doubled from 19.04 to 31.42 million tonnes, and secondly, from 2002 onward, when production consistently exceeded 40 million tonnes, with a peak of 65.35 million tonnes in 2018.

Unit root test

Table 1 shows the unit root test results confirming that all the variables (cassava production, rainfall, sunshine hours, and their interaction term) are non-stationary at level but are integrated to stationarity after first differencing, indicating that they are integrated of order one, I(1).

Lag order selection criteria

From the finding in Table 2, LR test, FPE, and AIC specify the optimal lag to be 2, while SC and HQ select lag 1. Since AIC and FPE are often applied in time-series models, lag 2 is the optimum alternative to take as a measure in capturing the dynamic association among cassava output, sunshine duration, and rainfall.

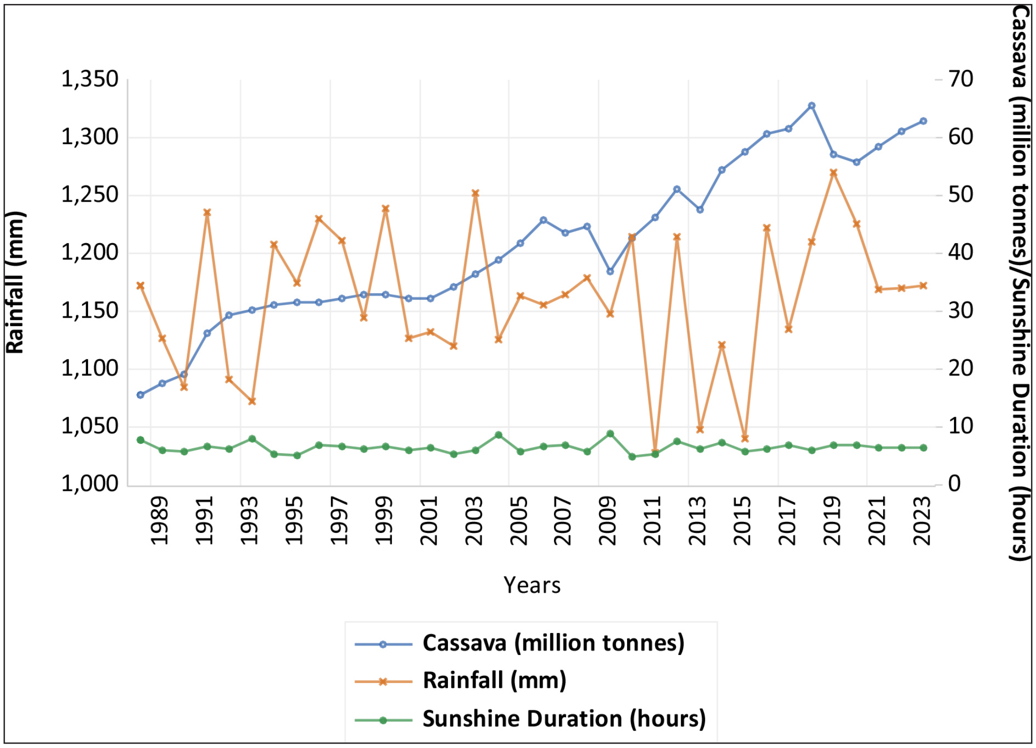

Fig. 1: Trends of cassava production, rainfall and sunshine duration during 1988 to 2023

Table 1: Unit root test

Variable	Level difference	prob	First diff	prob	Order of integration
Cassava	-1.18	0.671	-6.25	0.000	I(1)
Rainfall	-3.30	0.023	-13.0	0.000	I(1)
Sunshine duration	-6.87	0.000	-8.81	0.000	I(1)
Rainfall X Sunshine duration	-8.37	0.000	-7.21	0.000	I(1)

Table 2: Lag order selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1012.7	NA	1.11e+21	59.8	59.9	59.8
1	-950.1	106.8	7.23e+19	57.1	57.9*	57.4*
2	-931.1	27.9*	6.32e+19*	56.8*	58.5	57.4

* indicates lag order selected by the criterion

Cointegration test

The cointegration test presents in Table 3 evidence for long-run connection among cassava production, rain, sunshine hours, and their interaction in Nigeria between 1988 and 2023. The trace test found two cointegrating equations at 5% based on the fact that the test statistics (53.5 and 28.9) exceeded their respective critical values (47.8 and 29.7) at probabilities of 0.003 and 0.012. This shows that these variables move together over the long term, implying that sunshine duration acts to moderate the impact of rainfall on cassava yield over the long term.

Regression analysis

The regression in Table 4 gives significant details on the combined effect of sunshine duration and rainfall on cassava production in Nigeria. The negative coefficient value of rainfall (-73,133.9) and its highly significant p-value (0.000) indicate that excessive rainwfall has a negative effect on cassava production. This means that beyond an optimum level of rain, cassava production decreases, which may be due to waterlogging, leaching of nutrients in the soil, or increased infestation by diseases and pests, all of which are common characteristics of excessive rain. This concurred with Iliyasu *et al.,* (2019), whose research showed that variations in rainfall relate proportionally with variations in cassava production in Owerri, Nigeria. Similarly, Adejuwon and Agundiminegha (2019) found that rainfall did not significantly affect cassava yield in the humid forest agro-ecological zone of Nigeria but that temperature variation had a greater effect. These findings point out that while

Table 3: Cointegration test

No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.
None *	0.524	53.5	47.8	0.003
At most 1 *	0.400	28.9	29.7	0.012
At most 2	0.293	12.1	15.4	0.151
At most 3	0.020	0.678	3.84	0.410

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level

Table 4: Regression analysis

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Rainfall	-73133.9***	10528.5	-6.95	0.000
Sunshine duration	8755640.3***	1940041.9	4.51	0.000
Rainfall X Sunshine duration	7611.8***	1693.2	4.50	0.000
ECM	-0.934***	0.060	-15.5	0.000
C	127915210.3	12057403.4	10.6	0.000
R^2	0.896	F-statistic		62.1
Adjusted R^2	0.881	DW stat.		1.92

Where *** is significant at 1%

cassava requires adequate moisture, too much rain without proper drainage or other favourable conditions such as sunlight can negatively affect its growth and productivity.

On the other hand, the positive coefficient of sunshine duration (8,755,640.3) shows that greater sunshine exposure significantly has an increase in cassava production. Sunshine duration plays a very crucial role in photosynthesis because it increases cassava biomass and tuber growth. The highly significant t-statistic (4.51) and p-value (0.000) also complement the strong contribution of sunshine duration on cassava production. This result agrees with Maduegbuna *et al.,* (2024) that identified the impact of solar radiation on cassava production over a 40-year period in Anambra State. Their publication clearly revealed that the production of cassava showed high variation with respect to change in solar radiation, in agreement with the importance of sunshine in crop production. Besides, the combined variable being significant (7,611.8) indicates that sunshine duration influence the negative impact of excessive rainfall. This means that in years or regions of high rainfall, widespread sunshine can offset waterlogging effects by enhancing evapotranspiration and aeration of the soil, thus maintaining optimum growing conditions for cassava. This combined effect means that cassava cultivation is not controlled by individual climatic factors but by their interactions, which must be considered in agricultural planning.

The goodness of the model overall is confirmed by the high R-squared value (0.896), which suggests that approximately 90% of the variation in cassava yield is explained by rainfall, sunshine duration, and their combination. The adjusted R-squared (0.881) also confirms that the model has high explanatory power even after controlling for the number of predictors. In addition, the error correction model (ECM) coefficient (-0.934) suggests a high adjustment rate towards equilibrium, which infers that cassava output deviations due to climate shocks are strongly corrected quickly. This is corroborated by the evidence of Ekundayo *et al.,* (2021), who determined the long-run cointegration between cassava production and climate change in Southwest Nigeria. Moreover, the result of the test of Durbin-Watson (1.92) presents no significant autocorrelation, hence the estimates are credible.

CONCLUSION

The study revealed negative effect of excessive rainfall and the positive effect of extended sunshine duration on cassava production in Nigeria. The efficiency of photosynthesis and tuber development due to higher sunshine serves to temper negative impacts of excessive rainfall. By employing robust time-series econometric techniques, the work confirms the existence of a long-run equilibrium relation among sunshine duration, rainfall, and cassava production based on high explanatory ability and the rapid adjustment of climatic shocks. The findings highlight the importance of adopting climate-resilient agriculture practices such as improved water management, enhanced meteorological observation, and climate-resilient varieties of cassava to optimize crop yields and ensure food availability in the face of variability in the climate.

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