

# Measuring the Effect of Climate Change and Productivity Factors on Cassava Production in Nigeria: ARDL Approach (1990-2023)

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## Abstract

Agriculture is one of the sectors that are greatly affected by climate. A change in climate would in no small measure impact on agriculture, location notwithstanding. This study examined the effect of climate change and productivity factors on cassava yields in Nigeria. Data were obtained from World Bank's World Development Indicator (WDI), Food and Agricultural Organisation (FAO) and IMF. ARDL method of data analysis was used to analyse the data. The Results showed that TEMP, Rf, LF, CS and AF are statistically significant at 5% and has positive effects on cassava yield. The paper concluded that that cassava significantly depended on temperature, rainfall, labour force, capital stock, and availability of fertilizer. Base on the findings, the study recommend the need for national agricultural policy to prioritize cassava as a climate-resilient crop, Policies to support irrigation infrastructure and rainwater harvesting, inclusive financial policies, such as: subsidized agricultural loans for smallholder cassava farmers, Establishing agricultural credit guarantee schemes and Encouraging microfinance institutions and cooperatives to offer targeted support for cassava producers, It also recommend for more extension officers in order to spread best practices and improve technical efficiency at the farm level, as well as investments in training programs and mechanization instruments for rural workers. Lastly, further analysis using mixed-methods approach (quantitative econometric modeling with qualitative insights) to better explain how farmers perceive respond to climate impacts should be carried out.

**Keywords:** Climate Change, Cassava Yield, Cassava Production, Agricultural Productivity, ARDL Model, Nigeria.

## Introduction

Climate change has emerged as one of the most significant threats to agricultural productivity worldwide, and its impacts are increasingly evident across Sub-Saharan Africa. The economy and rural livelihoods of Nigeria are still largely dependent on agriculture, therefore changes in climatic patterns present significant obstacles. Cassava (*Manihot esculenta*), a staple crop for millions of Nigerians and a key source of food security, has traditionally been resilient to harsh conditions. However, the growing intensity and unpredictability of climate variables including erratic rainfall, warming temperatures, severe droughts, and frequent floods have started to have an impact on cassava output that

necessitates more thorough scientific investigation (Food and Agriculture Organization [FAO], 2023; Intergovernmental Panel on Climate Change [IPCC], 2022).

The effects of climate change are pronounced in Nigeria, where the Food and Agriculture Organization (FAO) estimates that 26.5 million people may experience severe food insecurity in 2024 due to unpredictable weather patterns, flooding, and protracted dry spells. Climate change is no longer a hypothetical threat; it is a current reality that has a significant impact on agriculture in Sub-Saharan Africa, particularly Nigeria.

Cassava production is uniquely sensitive to environmental changes. Although the crop is relatively hardy compared to other staples, it still requires a delicate balance of moisture and temperature for optimal yield. Recent years have seen erratic weather events, including the devastating floods of 2022 and 2023, which submerged thousands of hectares of cassava farms across major producing states like Benue, Kogi, and Delta (FAO, 2023; Olanrewaju et al., 2023). Such extreme events not only lower yields but also disrupt planting and harvesting cycles, increase post-harvest losses, and threaten farmers' incomes and national food supply.

Cassava plays an important role in Nigeria's food system—not only as a staple food for millions but also as a major source of income for rural households. Its ability to grow in poor soils and under varying weather conditions has long made it a dependable crop. However, in recent years, cassava production has been increasingly affected by the changing climate. Farmers are now facing unpredictable rainfall patterns, prolonged dry spells, and frequent flooding, which disrupt planting schedules and reduce yields.

Despite its importance, there is still a limited understanding of how climate change specifically affects cassava production in Nigeria. Most research focuses broadly on agriculture without addressing the unique responses of cassava to climate-related stress. This leaves a gap in knowledge that is crucial for developing effective adaptation strategies tailored to this vital crop. As climate conditions continue to shift, understanding their impact on cassava is essential not just for protecting the livelihoods of farmers, but for ensuring food security for the nation as a whole. This study aims to explore that connection and provide insights that can help farmers, policymakers, and researchers respond more effectively to the challenges ahead.

Measuring the effects of climate change and productivity factors on cassava production in Nigeria is crucial for formulating effective adaptation and mitigation strategies and fight against food insecurity. It involves analyzing key climatic variables such as temperature trends, precipitation patterns, and carbon dioxide emission and linking them to cassava yield performance over time (IPCC, 2022; Nwafor et al., 2022). Empirical studies employing econometric models, GIS tools, and time-series data are increasingly being used to quantify these relationships. Furthermore, understanding regional variations is essential, as the effects of climate change are not uniform across Nigeria's diverse agro-ecological zones. By systematically assessing the extent and nature of climate-induced changes in cassava output, policymakers, researchers, and farmers can work together to develop climate-

resilient farming practices, improve cassava varieties, and strengthen national food security strategies.

This study contributes to the field by conducting a robust analysis of climate change variables and productivity factors in the same empirical context. The study aims to clarify the fundamental causes of cassava production in order to guide the development of policies that can deal with it. Ultimately, understanding the effects of the variables is crucial for developing comprehensive policy interventions aimed at promoting food security.

## Description of Study Area

The study was carried out in Nigeria, which is regarded as the giant of Africa in terms of population, landmass, capital and development of humans, and GDP. Nigeria is divided into three climatic zones, with the southern region experiencing a tropical monsoon climate with an average annual rainfall of roughly 2000 mm and average day and nighttime temperatures of 31 °C and 23 °C; a tropical savannah climate for most of the central regions with an average annual rainfall of greater than 1200 mm; 33 °C and 22 °C temperature for day and night, respectively; a Sahelian hot and semi-arid climatic condition in the northern part of Nigeria with 35 °C and 21 °C temperature for daytime and nighttime, respectively, and a 700 mm mean annual rainfall (IPCC, 2022).

## Empirical Literature Review

In order to further put the discussion in this study on a proper perspective, previous studies on climate change effect on food crops production are reviewed.

Starting with the studies that investigated the effect of climate change on some selected food crops in Nigeria, Ajiere and Nwagbara (2018); Mbanasor, Nwachukwu, Agwu and Onwusiribe (2015) and Edet, et al. (2021) investigated the effect of climate change on maize and cassava production. They used ARDL and ex-post-facto research methodology, among others analytical techniques, to analyse the data that were sourced from various sources and which covered different periods. Their findings revealed that temperature and rainfall influenced cassava productivity negatively both in the short and long run while rainfall reduced the yield of maize and yam, both in the long and short-run. Also Tingem, Rivington, Bellocchi, Azam-Ali, and Colls (2008) assessed the potential effects of greenhouse gas climate change and CO<sub>2</sub> emission on crop yields in Cameroon. They found out that maize and sorghum yields decrease by 14.6 and 39.9% respectively due to climatic change

Chikezie et al. (2015) examined the effect of climate change on maize and yam output in south eastern Nigeria. The study used multi-stage sampling techniques and the result showed that temperature had a positive effect on yam output but a negative one on maize output. Rainfall and relative humidity had negative effect on both yam and maize output. Similar result was obtained by Emaziye (2015), where temperature is reported to have a positive effect on maize and yam yields respectively while rainfall negatively affect maize and yam yields. Ayinde et al. (2018) reported a high incidence of vulnerability to climate risk among maize farmers in Kwara State. Similar studies by Olawususi and Tijani (2013)

revealed that climate variables led to reduction in soil fertility, instability in planting calendar and drying of yam seed after germination due to high temperature. Also, Edet et al. (2018) reported that climatic variables (carbon dioxide, rainfall and temperature) account for 98%, 97% and 96% of the variations respectively in net revenue per hectare of crop production (Daniel, 2020; Ita, 2020).

In related studies, Apata (2011) examined the effects of global climate change on agriculture sector in Nigeria. The study was done, using both primary data consisting of 850 questionnaires and secondary data which was divided into 10-year periods, and production, consumption and storage of grains under different climate scenarios were calculated over a 10-year scenery. The results showed that unfavourable climatic environment negatively affects grain productions, but climate change adaptations have significant effect on farm productivity. Also, Kazi and Abu (2014) examined the effect of climate change on agricultural productivity in 23 regions of Bangladesh, using fixed effects regression equation estimation technique. The result shows a significant positive relationship between rice production and temperature during wet season, but insignificant after controlling for the year specific heterogeneity. Also, fluctuation of rainfall in dry and wet seasons has a positive effect on agricultural productivity, while fluctuation of humidity in the wet season has a negative effect on rice productivity.

Coming to the studies that examine the effects of climate change on aggregate agricultural production instead of individual crops, Akomolafe, Awoyemi and Babatunde (2018), Onuoha (2009), Zhai and Zhuang (2009), Mendelsohn (2009) and Gunther, Mahendra and Harrij (2002), their dependent variables were rural household outputs of rice, wheat corn and soya beans while the climate variables include seasonal mean temperature, annual accumulated precipitation and annual accumulated sunshine hours. Squared climate variables were also introduced into the model to capture possible nonlinear effects of climate variables. The result shows that the aggregate effects of agricultural damages caused by climate change on the global economy are moderate. However, the effects are not evenly distributed across the world. The study also found that developing countries would bear disproportionately large losses arising from climate change.

The study "Climate Change and Food Security in Nigeria: A Case Study of Yam Production" (2022) examined the impact of climate change on yam yields, finding that irregular rainfall and rising temperatures reduced yields by up to 25%, particularly in Nigeria's Middle Belt region. These declines threaten food security, as yam is a staple crop, and have led to higher prices and lower farmer incomes. Farmers adopted strategies like early planting and mulching but faced limited access to resources for effective adaptation. The study recommended climate-resilient yam varieties, improved water management, and policy support to mitigate impacts. It emphasized the need for integrated efforts to ensure sustainable yam production amid climate change (Adeyemi et al., 2022)

Having reviewed so many studies it was discovered that previous studies from within and outside Nigeria has used Cobb-Douglas production function as framework and no studies

examined the effect of climate change variables together with productivity factors on cassava production so, this present study estimates the effects of climate change and productivity factors like government expenditure on agriculture, availability of fertilizer, credit to agricultural sector on cassava production in Nigeria.

## Methodology

### Data Sources and Variable Description

This study utilizes time series data spanning the period from 1990 to 2023. The detailed description, measurement, as well as the justification of the variables are presented in Table 1.

**Table 1**

| Variables                             | Description                                          | Measurement                                                             | Data Source                                                        |
|---------------------------------------|------------------------------------------------------|-------------------------------------------------------------------------|--------------------------------------------------------------------|
| Cassava output                        | This is the dependent variable                       | This is measured in metric tons                                         | Food and Agricultural Organisation (FAO) online publication (2024) |
| Temperature                           | Key explanatory variable representing climate change | This is measured in degrees Celsius (°C)                                | World Bank's World Development Indicator (WDI, 2024)               |
| Rainfall                              | Key explanatory variable representing climate change | This is measured in millimetres                                         | World Bank's World Development Indicator (WDI, 2024)               |
| Carbon dioxide emission               | Key explanatory variable representing climate change | metric tons per capita                                                  | World Bank's World Development Indicator (WDI, 2024)               |
| Government expenditure on agriculture | This represent productivity factor                   | % of total government expenditure                                       | World Bank's World Development Indicator (WDI, 2024)               |
| Credit to agriculture                 | This represent productivity factor                   | % of total bank credit                                                  | Food and Agricultural Organisation (FAO) online publication (2024) |
| Availability of fertilizer            | This represent productivity factor                   | This is measured in metric tons                                         | Food and Agricultural Organisation (FAO) online publication (2024) |
| Capital stock                         | Independent variable                                 | General government capital stock in of constant 2017 billions of naira. | International Monetary Fund (IMF) online publication (2024)        |
| Labour force                          | Independent variable                                 | rural population                                                        | World Bank's World Development Indicator (WDI, 2024).              |

**Source: Authors' construct (2025)**

### Theoretical Framework Underpinning the Specified Model

The theoretical framework that forms the basis of the model specified in this paper is the production function. Production function generally is  $Y = f(X_1, X_2, \dots, X_m)$ , where  $X_1, X_2, \dots, X_m$

denote the factor inputs, and Y denotes the output level. Specifically, this paper adopts the Cobb-Douglas production function as the theoretical framework.

The aggregate production on which the output level relationship is based can be stated as in Equation (1) below base, thus:

$$Y = AX_1^{\alpha_1}X_2^{\alpha_2}\dots\dots\dots X_m^{\alpha_m} \quad (1)$$

where Y = total output,  $X_j$  (j= 1, 2, 3, .....m) = units of factor input j; and each of  $\alpha_1, \alpha_2, \dots\dots\dots \alpha_m$  is the elasticity of factor input j with respect to  $Y_j$ ; while A is the efficiency parameter.

To transform Equation (1) into a linear function, the logarithm of each variable in the equation is taken so as to give Equation (2) thus:

$$\ln Y = \ln A + \alpha_1 \ln X_1 + \alpha_2 \ln X_2 \dots\dots\dots \alpha_m \ln X_m \quad (2)$$

### Model Specification

The econometric model is obtained by substituting for the efficiency factor and introducing natural resources or climate change variables into the above production function in Equation (2).

The economy-wide variables that determine the aggregate crops output level are factors of production like labour and capital. But for this present study, natural resources, in the form of climate variables, are also recognised as factors of production and this is done by splitting them into three components, which are: temperature, rainfall and carbon dioxide, while the three postulated determinants of crop productivity or efficiency variables are government expenditure on agriculture, credit to agricultural sector and availability of fertiliser, as discussed in Sub-section below.

### Determinants of Crop Productivity (A)

There are three postulated determinants of crop productivity and these are government expenditure on agriculture, credit to agricultural sector and availability of fertiliser.

**Government Expenditure on Agriculture (GEA):** Government agricultural expenditure in relation to agricultural output level is considered as one of the determinants of food crop output level in this study, considering the fact that government agricultural expenditure should influence the food crops productivity level. The government expenditure on agriculture is therefore expected to have a positive effect on food crops productivity level.

**Credit to Agricultural Sector (CAS):** Ricardo, as cited in Obianefo et al (2024) observed that agriculture can achieve massive improvement with the increase application of capital to fixed factors of production. However, accumulation of capital in this sector is greatly influenced by the development within the financial system of a nation. Low crop productivity level in Nigeria can be linked to inadequate availability of credit to the farmers. In this study, it is therefore expected that provision of financial support to the local farmers in form of loan should have a positive effect on food crop productivity level.

**Availability of Fertilizer (AF):** In agricultural practices, fertilizers (organic and inorganic) are used so as to increase the accumulation of carbon (C), nitrogen (N), and phosphorus (P) in the soil to improve the soil's ability to supply nutrients to crops. In this study, it is postulated that availability of fertiliser for the farmers will lead to increase in crop productivity level.

### Mathematical Expression of Productivity Relationship

Following the discussion in Sub-sub-section above on determinants of productivity (A), the mathematical equation is given below:

$$\ln A = \alpha_1 GEA + \alpha_3 CAS + \alpha_4 AF \quad (3)$$

where A is productivity, GEA is government expenditure on agriculture, CAS is credit to agricultural sector and AF is availability of fertilizer. Based on the reasons earlier adduced in Sub-sub-section 3.2.1, the direction of the effects of these explanatory variables on productivity is mathematically summarised as follows:  $\alpha_1, \alpha_3, \alpha_4 > 0$

By replacing the factor inputs  $X_1, X_2, \dots, X_m$  in Equation (2) by capital stock (K), labour force (LF), temperature (TEMP), rainfall (RAIN) and carbon dioxide emission (CO<sub>2</sub>) and also by replacing the productivity growth  $\left(\frac{\Delta A}{A}\right)$  with the right handed expression in Equation (3), the model used to analyse the effect of climate variables (temperature, rainfall and carbon dioxide) and the efficiency variables (government expenditure on agriculture, credit to agricultural sector and availability of fertilizer) on cassava production is thus:

$$\ln CSV_t = \alpha_0 + \alpha_1 GEA + \alpha_2 CAS + \alpha_3 AF + \alpha_4 K_t + \alpha_5 L_t + \alpha_6 TEMP_t + \alpha_7 RAIN_t + \alpha_8 CO_{2t} + U_t \quad (4)$$

Equation (4) above is an extension of Equation (2), where CSV = cassava that now replaces y K = capital, L = labour proxied by rural population, TEMP = temperature; RAIN = rainfall, CO<sub>2</sub> = carbon dioxide emission and U is the error time, while subscript is denoted by t. The other acronyms and notations are as are explained in connection with Equation (3).

### Method of Analysis

To understand the nature of the data, descriptive analysis is carried out by examining the mean, medium and mode, as the measures of central tendency, and standard deviation, as the chosen measure of dispersion.

To avoid the problem of spurious regression (meaningless regression result) that may result from the usage of non-stationary time series data for regression analysis, the Augmented Dickey-Fuller test is conducted to examine the presence or absence of unit root in each of the variables. The null hypothesis for the test is that there is unit root. If the calculated test statistic is less than the chosen critical value, then the null hypothesis is to be rejected and it is to be concluded that no unit root is present, but in a situation where by the calculated test statistic is greater than the chosen critical value, then the null hypothesis is not to be rejected and unit root is to be concluded to be present. The non-rejection of the null hypothesis implies the need for appropriate differencing to induce stationarity.

The long-run relationship among the variables (depend and independent) is checked through co-integration tests. If the result from the unit root test were found to be stationary

only after the first difference so that all the series are uniformly I(1) or if there is a mix of I(1) and I(0), then co-integration test will be necessary to test for the existence of long run relationship among the variables. The decision rule is not to reject the null hypothesis if the Mackinnon (1996) p-value is less than or equal to the cut-off level of significance being adopted (which is taken to be 5% in this study) and accepted if otherwise.

## Results and Discussion

### Pre-estimation Analysis

#### Results of Descriptive Analysis

The result of the descriptive analysis is as presented in the Table 2, after which the contents of the table are discussed.

**Table 2: Descriptive Statistics**

| Var.            | Description                                                                             | Mean      | Max.      | Min.      | Std. Dev. | Coef. Of Var. |
|-----------------|-----------------------------------------------------------------------------------------|-----------|-----------|-----------|-----------|---------------|
| TEMP            | Annual temperature - degrees Celsius (°C)                                               | 27.30     | 27.86     | 26.59     | 0.29      | 0.01          |
| RF              | Annual rainfall - millimetres                                                           | 1,181.67  | 1,296.43  | 1,051.33  | 67.10     | 0.06          |
| CO <sub>2</sub> | Green house gas emission - metric tons per capita                                       | 0.68      | 0.92      | 0.49      | 0.12      | 0.18          |
| GEA             | Government expenditure on agriculture - % of total government expenditure               | 6.02      | 7.74      | 3.18      | 1.25      | 0.21          |
| CAS             | Credit to agricultural sector – % of total bank credit                                  | 7.34      | 19.65     | 1.43      | 5.76      | 0.79          |
| AF              | Availability of fertilizer – metric tons                                                | 209,786.6 | 453,000   | 70,115    | 116,293.8 | 0.55          |
| CS              | Capital stock - General government capital stock in of constant 2017 billions of naira. | 650.79    | 639.05    | 567.16    | 192.09    | 0.29          |
| LF              | labour force in agricultural sector - rural population                                  | 8,545,607 | 9,856,707 | 6,701,207 | 1,045,607 | 0.12          |
| CSV             | Annual total cassava production - metric tons                                           | 4,212,307 | 6,056,707 | 1,901,207 | 1,245,607 | 0.23          |

**Author's computation using Stata 14.**

*Explanatory notes: Var = Variable, Max = Maximum, Min = Minimum, Std. Dev. = Standard deviation, Coef. Of Var. = Coefficient of variation while the total number of observations in respect of each variable is 33.*

Starting with the annual temperature, the mean was 27.30 degree Celsius, the maximum and minimum values are 27.86 and 26.59 degree Celsius respectively while the standard deviation is 0.29 degree Celsius, The mean value of the annual rainfall is 1,181.67 millimetres, the maximum is 1,296.43 millimetres, the minimum is 1,051.33 millimetres while the and standard deviation is 67.10 millimetres. Concerning greenhouse gas emission

(CO<sub>2</sub>), the mean is 0.68 metric tons per capita, the maximum is 0.92 metric tons per capita and the minimum is 0.49 metric tons per capita while standard deviation is .12 metric tons per capita.

As for government expenditure on agriculture (GEA), its mean is 6.02 percent of total government expenditure, with a minimum of 3.18 percent and the maximum value of 7.74 percent while the standard deviation is 1.25. Also, the mean for credit to agricultural sector is 7.34 percent of total bank credit, with a minimum of 1.43 and the maximum of 19.65 percent while the standard deviation is 5.76 percent. Also, availability of fertilizer has a mean of 209,786.6 metric tons, with a maximum value of 453,000 metric tons and the minimum value of 70,115 metric tons while standard deviation is 786.6.

In the case of general government capital stock, the mean is 650.79 in 2017 constant billions of naira, with a maximum value of 639.05 and the minimum value of 567.16 while the standard deviation is 192.09 percent. Concerning labour force, its mean is 5,956.5, with the maximum of 7,032 and the minimum 4,756 percent while the standard deviation 731.87. In the case of cassava, the mean is 4,212,307 metric tons, with a maximum value of 6,056,707 metric tons and a minimum of 1,901,207 metric tons while the standard deviation is 1,245,607 metric tons.

In column seven of the table, the coefficients of variation (coeff. Of var.), defined as the standard deviation divided by the mean, are reported. It is the only statistic that is comparable across all the variables because it is independent of the unit of measurement, unlike the other statistics reported in the table, the values of which depend on the units of measurement, thereby making them not to be comparable across different variables. Because of this special character of the coefficient of variation in lending itself to comparability across different variables, it is singled out for the purpose and this paragraph is devoted to that. In the table, the first six variables with the greatest volatility in the ascending order are CS, AF, CAS and GEA, with the coefficients of variation of 0.36, 0.55, 0.79 and 0.86 respectively, while the remaining variables, still in the ascending order, are TEMP, RF, LF, CO<sub>2</sub> and CSV with the coefficients of variation of 0.01, 0.06, 0.12, 0.18 and 0.30, respectively.

### Results of Correlation Analysis

Table 2 presents the correlation matrix, which shows the sample correlations between every pair of the variables employed in the study. The p-values are the numbers reported in the parentheses below the correlation coefficients and each indicates the degree of statistical significance of the affected correlation coefficient between a pair of the variables. A correlation is interpreted to exist in this study if the p-value of the affected correlation coefficient is not more than 5%, i.e. 5% is the chosen significance level adopted in the study.

**Table 3: The Correlation Matrix**

|                       | 1.<br>Temp        | 2.<br>RF          | 3.<br>CO <sub>2</sub> | 4.<br>LF          | 5.<br>CS         | 6.<br>GEA        | 7.<br>AF          | 8.<br>CAS        | 9.<br>CVS |
|-----------------------|-------------------|-------------------|-----------------------|-------------------|------------------|------------------|-------------------|------------------|-----------|
| 1<br>TEMP             | 1                 |                   |                       |                   |                  |                  |                   |                  |           |
| 2.<br>RF              | 0.027<br>(0.882)  | 1                 |                       |                   |                  |                  |                   |                  |           |
| 3.<br>CO <sub>2</sub> | -0.713<br>(0.000) | -0.044<br>(0.811) | 1                     |                   |                  |                  |                   |                  |           |
| 4.<br>LF              | 0.689<br>(0.000)  | 0.126<br>(0.491)  | -0.851<br>(0.000)     | 1                 |                  |                  |                   |                  |           |
| 5.<br>CS              | 0.132<br>(0.471)  | 0.301<br>(0.094)  | -0.206<br>(0.258)     | 0.390<br>(0.027)  | 1                |                  |                   |                  |           |
| 6.<br>GEA             | 0.670<br>(0.008)  | 0.190<br>(0.297)  | -0.801<br>(0.000)     | 0.936<br>(0.027)  | 0.211<br>(0.246) | 1                |                   |                  |           |
| 7.<br>AF              | 0.203<br>(0.265)  | 0.160<br>(0.383)  | -0.363<br>(0.041)     | 0.532<br>(0.002)  | 0.211<br>(0.206) | 0.209<br>(0.085) | 1                 |                  |           |
| 8.<br>CAS             | -0.746<br>(0.000) | 0.012<br>(0.950)  | 0.791<br>(0.000)      | -0.813<br>(0.000) | 0.790<br>(0.000) | 0.741<br>(0.000) | -0.526<br>(0.002) | 1                |           |
| 9<br>CSV              | 0.574<br>(0.001)  | 0.166<br>(0.364)  | -0.753<br>(0.000)     | 0.955<br>(0.000)  | 0.724<br>(0.000) | 0.575<br>(0.001) | -0.740<br>(0.000) | 0.778<br>(0.000) | 1         |

**Author's computation using Stata14.**

*Explanatory Note: Temp = temperature, RF = rainfall, CO<sub>2</sub> = carbon dioxide emission, LF = labour force, CS = capital stock, = government expenditure on agriculture, AF = available of fertilizer, CAS = credit to agricultural sector and CSV = cassava, Probability values are reported in parentheses below the correlation coefficients.*

Based on the above decision rule and the results in Table 2, it can be concluded that quantities produced of cassava are correlated with the independent variables included in the model, just as the other variables are inter-correlated with each one another. However, none of the pairs of the explanatory variables in the study has a high degree of correlation coefficient of up or close to 0.80 in absolute term – which, according to Asteriou and Hall

(2011), is usually taken as a rule of thumb-based benchmark, above which multicollinearity becomes an issue of concern.

### Result of the Unit Root and Cointegration Tests

The results of Augmented Dickey-Fuller and Philips Perron unit root tests that were conducted for ascertaining the stationarity status of each of the variables in the models that were estimated for the 1990 – 2023 data sets are presented in Table 4.

**Table 4: The Result of the Unit Root and Cointegrated Test**

| ADF             |                     |          |           |                      |            | Philips Perron      |          |           |                      |            |                  |
|-----------------|---------------------|----------|-----------|----------------------|------------|---------------------|----------|-----------|----------------------|------------|------------------|
| Var.            | Stationary          | p. value | t. stat.  | Order of integration | Conclusion | Stationary          | p. value | t. stat.  | Order of integration | conclusion | Comparison       |
| TEMP            | At level            | 0.0872   | -2.6897   | I(0)                 | Unit Root  | At level            | 0.1012   | -2.613    | I(0)                 | Unit Root  | Both I(1)        |
|                 | At first difference | 0.0009   | -4.6569   | I(1)                 |            | At first difference | 0.0001   | -16.6847  | I(1)                 |            |                  |
| RF              | At level            | 0.1928   | -2.2535   | I(0)                 | Unit Root  | At level            | 0.0000   | -6.0392   | I(0)                 | Stationary | ADF I(1) PP I(0) |
|                 | At first difference | 0.0000   | -13.5163  | I(1)                 |            |                     |          |           |                      |            |                  |
| CO <sub>2</sub> | At level            | 0.5789   | -1.3803   | I(0)                 | Unit Root  | At level            | 0.6438   | -1.2409   | I(0)                 | Unit Root  | Both I(1)        |
|                 | At first difference | 0.0001   | -5.345    | I(1)                 |            | At first difference | 0.0000   | -7.8382   | I(1)                 |            |                  |
| LF              | At level            | 0.9987   | -0.473738 | I(0)                 | Unit Root  | At level            | 0.0001   | -6.0703   | I(0)                 | Unit Root  | Both I(1)        |
|                 | At first difference | 0.0000   | -6.380939 | I(1)                 |            | At first difference | 0.9270   | -0.210113 | I(1)                 |            |                  |
| CS              | At level            | 0.6198   | -1.2936   | I(0)                 | Unit Root  | At level            | 0.5782   | -1.3818   | I(0)                 | Unit Root  | Both I(1)        |
|                 | At first difference | 0.0013   | -4.4899   | I(1)                 |            | at first difference | 0.0013   | -4.49     | I(1)                 |            |                  |
| GEA             | At level            | 0.2402   | -2.1156   | I(0)                 | Unit Root  | At level            | 0.1982   | -2.2363   | I(0)                 | Unit Root  | Both I(1)        |
|                 | At first difference | 0.0000   | -6.2318   | I(1)                 |            | At first difference | 0.0000   | -6.1894   | I(1)                 |            |                  |
| AF              | At level            | 0.7815   | -0.8772   | I(0)                 | Unit Root  | At level            | 0.4698   | -1.6012   | I(0)                 | Unit Root  | Both I(1)        |
|                 | At first difference | 0.0000   | -8.3995   | I(1)                 |            | At first difference | 0.0000   | -8.7965   | I(1)                 |            |                  |
| CSV             | At level            | 0.186    | -2.2748   | I(0)                 | Unit Root  | At level            | 0.1867   | -2.2725   | I(0)                 | Unit Root  | Both I(1)        |
|                 | At first difference | 0.0000   | -6.7243   | I(1)                 |            | At first difference | 0.0001   | -16.5423  | I(1)                 |            |                  |

**Author's computation using Stata14.**

*Explanatory Note: Temp = temperature, RF = rainfall, CO<sub>2</sub> = carbon dioxide emission, LF = labour force, CS = capital stock, = government expenditure on agriculture, AF = available of fertilizer, CAS = credit to agricultural sector, CSV = cassava. A coefficient is statistically significant if its p-value is equal to or less than the 5% level in the study, which indicates that*

*the null hypothesis is rejected and, hence, variables are stationary, but if otherwise (i.e. the p-value is greater than 5%), the null hypothesis is rejected, meaning that the variable contains unit root*

From the table and, based on the aforementioned decision rule, the results show that all the variables (with the exception of RF), while not stationary at level, become stationary after being first differenced both under the ADF and PP tests, judging from their respective test statistics' p-values that are all greater than 0.05 at the level but less than 0.05 after being first differenced. In the case of RF, the variable was not stationary using ADF but stationary using PP. This means that using the OLS method to estimate the equation is prone to produce spurious results. Therefore, it becomes necessary to carry out a cointegration test in order to check whether a long-run relationship exists among the variables.

A cointegration test is thus conducted in respect of the CSV model using the ARDL Bounds test approach, and the result shows that the computed F-statistic is equal to 9.820, which is greater than the upper bound critical value at 5% significance level. This implies that the explanatory variables featuring in the CSV model are co-integrated with the CSV and, hence, there is a long-run relationship between CSV and its regressors, so that both the short-run and long-run estimates are applicable.

### **Results of the Regression Analysis**

This sub-section presents the ARDL estimates of the equation specified earlier. Table 4 contains regression result for the model. The table is divided into 3 columns. Column 1 is for the coefficients, Column 2 is for the t-statistics and Column 3 contains the p-values. A coefficient is considered to be statistically significant if the p-value of its test statistic is less than or equal to 5% critical significance level. Only the long-run ARDL estimates are reported in the table, with the short-run ones being skipped for the sake of brevity.

**Table 5: Long-run ARDL Estimates of the Effect of independent Variables on cassava**

|                                                              | Coeff  | t-stat | P-value |
|--------------------------------------------------------------|--------|--------|---------|
| TEMP                                                         | 1.163  | 2.97   | 0.014   |
| RF                                                           | 0.007  | 0.02   | 0.026   |
| LF                                                           | 0.013  | 0.93   | 0.025   |
| CO <sub>2</sub>                                              | 0.826  | 1.64   | 0.132   |
| CS                                                           | 0.021  | 0.07   | 0.012   |
| GEA                                                          | -0.130 | -.35   | 0.208   |
| AF                                                           | 0.415  | 2.59   | 0.027   |
| CAS                                                          | -0.003 | -.36   | 0.728   |
| Cons                                                         | -8.493 | -.13   | 0.059   |
| ECT                                                          | -0.468 | -.42   | 0.007   |
| R <sup>2</sup>                                               | 0.76   |        |         |
| F-statistic                                                  | 9.217  | -      | 0.000   |
| VIF Test for Multicollinearity                               | 5.68   |        |         |
| Breusch-Godfrey LM Test statistic for Autocorrelation        | 0.994  | -      | 0.4117  |
| Breusch-Pagan-Godfrey Test statistic for Heteroscedasticity. | 0.512  | -      | 0.899   |
| Jarque-Bera Test statistic for Normality                     | 3.09   | -      | 0.2138  |
| Ramsy Reset Test statistic for Model specification           | 4.86   | -      | 0.0107  |
| Observation                                                  | 33     |        |         |

**Sources: Author's Computation, 2025.**

**Explanatory Notes:** The following are the meanings of the acronyms used for the explanatory variables: TEMP = temperature, RF = rain fall, CO<sub>2</sub> = carbon dioxide, CS = capital stock, LF = Labour force, GEA = government expenditure on agriculture, AF = available of fertilizer, CAS = credit to agriculture sector. Also, "coeff" means coefficient; "t-stat" (reported in the column next to "coeff" column) is an abbreviation for "t-statistic"; and "p-value" reported next to the column for "t-stat" abbreviates the "probability value". A coefficient is considered to be statistically significant if the p-value of its test statistic is less than 5% critical level. The 5 rows for Multico, Autocorr, Hetero, Normal and Ramsy Reset are for recording the test statistic and associated p-value for each of Multicollinearity, Autocorrelation, Heteroscedasticity, Normality and Ramsy Reset respectively.

The result in Table 4 shows that the value of the R<sup>2</sup> is 76%, which implies that variations in the explanatory variables included in the model explained 76% of the variations in the cassava production. Also, the result in the same table shows that the F-statistic for the R<sup>2</sup> value is statistically significant at 5%, as the p-value is much lower than 0.05. This therefore connotes that the model has a high explanatory power and the overall fitness of it is good.

Also, the result of the Variance Inflation Factor (VIF) test conducted to detect multicollinearity problem indicates that the average VIF statistic obtained is not above the rule-of-thumb-based value of 5 that is usually taken to be a cutoff, above which multicollinearity may be a problem (Dimitrios and Stephen, 2016). Similarly, the results of the Breusch-Pagan/Cook – Weisberg test indicates that the model is not suffering from a problem of heteroscedasticity because the p-value is greater than the threshold (which is taken to be 5% in this paper). Also, the result of the Breusch-Godfrey LM test conducted reveals an absence of autocorrelation in the model because the Chi-square test statistic's p-value is greater than the chosen level of significance (which is 5% in this paper). Finally, the results of normality in the distribution of residuals test conducted in order to determine the normality or non-normality of the distribution of the residuals indicates that the residuals are normally distributed, as the test p-value is greater than the predefined significance level.

The performance of each of the specific variables included in the model is now discussed below, having evaluated the outcome of the various diagnostic tests.

The results from the table shows that the coefficients of TEMP, RF, LF, CO<sub>2</sub>, CS, GEA, AF and CAS are 1.163, 0.007, 0.013, 0.826, 0.021, 0.130, 0.415, -0.003, with the respective p-values of 0.014, 0.026, 0.025, 0.132, 0.012, 0.208, 0.027 and 0.728. It can thus be deduced from these results that five (viz: coefficients of TEMP, RF, LF, CS and AF) out of the eight coefficients in the cassava production equation are positive and statistically significant at the 5% level, while the remaining ones (viz: coefficients of CO<sub>2</sub>, GEA and CAS) are insignificant. This means that temperature (TEMP), rainfall (RF), labour force (LF), capital stock (CS) and availability of fertiliser (AF) have the expected positive effects on cassava production, while the lack of effect of carbon dioxide emission, government expenditure on agriculture and credit to agricultural sector are against the expectation.

Furthermore, from the table it shows that the following explanatory variables Temp, Rf, LF, CS and AF are statistically significant given the probability values 0.014, 0.026, 0.025, 0.012 and 0.027 respectively. Given the coefficient of Temp, Rf, LF, CS and AF 1.163, 0.007, 0.013, 0.021 and 0.415 it means that unit percent change in temperature will lead to 1.163 percent increase in cassava output. Similarly, a percentage increase in RF, LF, CS and AF will lead to 0.007, 0.013, 0.021 and 0.415 percent increase in cassava yield.

### Conclusion and Recommendation

On the whole, going by the above findings, it can be concluded that temperature and rainfall, labour force, credit to agricultural sector and availability of fertilizer, which this study investigate their effects on cassava production, have positive effects on cassava yield. It can also be concluded from the findings that carbon dioxide emission and government expenditure on agriculture has nil effect on cassava production.

Based on the findings highlighted above, the paper recommends the following:

- i. The need for national agricultural policy to prioritize cassava as a climate-resilient crop,
- ii. There should be Policies to support irrigation infrastructure, rainwater harvesting systems, and water conservation projects.
- iii. There is also need for inclusive financial policies, such as: subsidized agricultural loans for smallholder cassava farmers, establishing agricultural credit guarantee schemes and Encouraging microfinance institutions and cooperatives to offer targeted support for cassava producers.
- iv. More extension officers should be hired in order to spread best practices and improve technical efficiency at the farm level, as well as investments in training programs and mechanization instruments for rural workers
- v. There is need to further analysis using mixed-methods approach (quantitative econometric modeling with qualitative insights) to better explain how farmers perceive respond to climate impacts.

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