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An Assessment of Climate Variability on Cassava Output in Nigeria: Potential Impacts and Opportunities

Aroyehun Adeyinka Richard[1,]*, Edaba Michael I.E.[1] and Gbassi Iheanyichukwu J.[2]

[1] Department of Agricultural Economics and Agribusiness Management, University of Port Harcourt, Choba, Nigeria
[1] Department of Plant Science and Biotechnology, Rivers State University, Port Harcourt
*Corresponding author's email: richestaro2014@gmail.com

Abstract
Climate variability is perhaps one of the most severe, unpredictable challenge of our time and it widely threatens agricultural productivity globally. Since it affects all regions worldwide; its evidence is seen in decrease in crop yield and consequently results in increase in the risk of food security most especially in Nigeria. Therefore, this study deals with assessment of climate variability on cassava output in Nigeria along with its potential impacts and opportunities. Annual time-series of cassava output, annual average temperature and precipitation from 1991 to 2020 were used. The study used Mann-Kendall (MK) test, Augmented Dickey-Fuller (ADF) unit root test, Johansen Cointegration test and Runs (R) test to analyze the data. MK test result indicates increasing (positive) trend with non-significance level trend with p-value greater than 5% for both temperature (0.8723) and precipitation (0.1868). ADF unit root test result reveals that all variables were exclusively stationary at the first different orders I(1) at both at intercept and intercept with trend at 1% level of significance. Johansen cointegration test result indicates the presence long-run relationship among the variables possessing three cointegrating equations of (r = 2). Autocorrelation function (ACF) and partial autocorrelations function (PACF) shows a good fit and Runs (R) indicates normally distributed of data. The study therefore recommends some measures of adaptation strategies such as planting of drought tolerant cassava stem, irrigation practices and crop diversification; as well as crop insurance on cassava and other crops could be adopted to reduce the risk and losses associated with climate variability.

Keywords: *Cassava Output, Mann-Kendall Test, Precipitation, Temperature, Trend Analysis*

Introduction

Climate change which refers to the significant effect of long term variation in the measures of weather elements such as temperature, rainfall, and wind pattern is worsened by increasing level of uncertainty of its associated risk (Isaiah, Yamusa & Odunze, 2020). Agricultural practice globally is the major vulnerable sector to the threatening consequences of global climate change. Despite the advancements in technology and Green Revolution; weather and climatic factors remain the source and crucial dynamics in determining the level of agricultural output in almost all regions globally. Temperature and rainfall patterns changes with their related effects on availability of water, pests and diseases, and severe weather actions all to a large extent affect the prospective of agricultural production (Sarkar, Begum & Pereira, 2020). In Nigeria, temperature levels of about 0.2-0.3 degrees per decade have been recorded in the various ecological zones of the country. Also, rainfall levels of about 2-3% for each degree of global warming may be expected for the tropical humid zones of the country (Oladipo, 2011). In the northern part, annual rainfall amounts have been on the increase especially from the late 1990s (Abaje, Ati, Iguisi & Jidauna, 2013). Complex interactions in the climate system can give rise to strong feedback mechanisms that may lead to sudden climatic changes (Tang & Zhang, 2018).

Climate change is one of the most pronounced threats to Nigeria agricultural sector and food security because of its sensitivity and vulnerability to high ambient temperature and rainfall fluctuations. Many cassava farmers in the southern part of Nigeria are already suffering from the negative effects of climate change on their crops. Henri-Ukoha (2020) stated that climate change-induce flood has destroyed cassava crops in the low lying tidal coastal communities of Nigeria. Climate change leads to high incidence of pests and diseases which in turn feeds on cassava leaves. Consequently, it impairs photosynthesis as well as impedes tuberization of cassava root thereby making processing of tubers difficult. Food and Agriculture Organization (2020) projected that due to climate change, crop yield in Sub Sahara Africa may fall by 50% by 2050. It is reported that higher temperatures lower the yield of desirable crops while favouring weeds and pests' proliferation (Abaje *et al*, 2016). Climate change promotes extreme weather events such as heat intensity and floods and the increased risks of droughts with its corresponding crops yield lose (Henri-Ukoha, 2020). Global and regional climate changes are affecting all economic sectors to some degrees but the agricultural sector is perhaps the most sensitive and vulnerable, because agricultural production remains very dependent on climatic resources.

Cassava as a crop originated from South America and it's extensively propagated as an annual crop in the tropical and sub-tropical regions due to its tolerance to extreme stress conditions, its low production resource requirements, its biological efficacy in the production of food and fuel energy, and its availability throughout the year (Echebiri & Edaba, 2008). Cassava is very tolerant crop and has the ability to grow on marginal land where other food crops cannot grow well, but for a better performance and productivity, moderate climatic condition and best soil properties such as light, sandy loam soil of medium fertility and good aerations or drainage are all essential (Akanbi & Olabode, 2004). Hence, extreme weather conditions such as prolonged drought and excessive amount of rainfall that leads into flood may negatively influence its general performance and yield. Nigeria stands as one of the largest producer of cassava in the world with recorded production capacity of 34 million tones. Cassava is regarded as the third largest source of carbohydrates for human food and animal feed in the tropics, after maize and rice, it's a major staple food crop in Africa and it's also grown in several other countries of Asia and North America (Siwabhawo *et al*, 2020), providing a basic diet for over 800 million people worldwide.

Previous studies found that cassava crop production can be affected by several other factors, including climate change which influences harvested area and crop yields with its corresponding impact via increasing temperature, changing patterns of rainfall, or indirect impact via soil, nutrient and increasing pests damage (Siwabhawo, Witswana & Somskaw, 2020). However, increasing temperatures and flooding are serious threats for traditional cassava farms in both Asia and Africa. The implications of these especially in agricultural production are numerous and diverse in nature; decrease in yield, reduced marginal gross domestic product (GDP) from agriculture, increase in cost of food items, increase in the population of people at risk of hunger, increase in level of food insecurity, migration and civil unrest among others. This study therefore aimed at analyzing the climate change impacts on cassava production derived from changes in harvested area and yield of cassava in Nigeria, a major global producer and exporter of cassava products, using yearly time-series data from 1991 to 2020.

Materials and Methods

Nigeria is a West African country that is Sub-Saharan African region. Nigeria is situated within the tropical zone, with land area of about 923,768km^2 and 850km as the aggregate coastline in length (Allu & Ochedi, 2015). Nigeria is bordered by Niger Republic in the North, Chad Republic in the North-East, Cameroon in the East, Atlantic Ocean in the South, and Republic of Benin in the West. Nigeria is located between the latitudes 4ºN and 14ºN of the Equator and between longitudes 3ºE and 15ºE of the Greenwich meridian. Nigeria elongation from north to south is about 1100km and width of 1300km from east to west (https://classhall.com/lesson/location-and-position-of-nigeria/). This however, describes the Nigeria's variations in climatic factors and the disparities on the magnitude of climate variability effects being experienced across Nigeria.

The study used yearly time-series data from 1991 to 2020. The data were collected from Food and Agriculture Organization (FAO) statistics database. The Mann-Kendall (MK) test was used to examined the trends of temperatures and precipitation on cassava output. MK is a non-parametric test, which has no precondition requirements on the data to be generally distributed (Gadedjisso-Tossou, Adjegan & Kablan, 2021). The MK test is established on a null hypothesis (H_0), which shows that there is no trend; the data are independent and extensively efficiently ordered. This is validated against the alternative hypothesis (Ha), which assumes existent of trend (Koudahe, Djaman, Kayode, Awokola & Adebola, 2018). The lag-1 serial correlation coefficient r1 for a two-tailed test at 5% significant level as used by Gadedjisso-Tossou *et al.*, (2021) is expressed as:

$$r1 = \frac{\sum_{i=1}^{n-1}(X_i-\bar{X})(X_{i+1}-\bar{X})}{\sum_{i=1}^{n}(X_i-\bar{X})^2} \quad (1)$$

Where;

Xi = value of observation of time series data

$\bar{X}$ = mean of the sample of time series data
n = sample size
overall S-statistic is stated as;

$$S' = \sum_{j=1}^{p} S_j \quad (2)$$

Where; S' is S-statistic in the Mann-Kendall test for the period j ($j = 1, 2, 3, \ldots, p$)
The overall tau (τ) estimated of the p period is stated as;

$$\tau = \frac{2S}{N(N-1)} \quad (3)$$

The z-statistic for the jth period is estimated as;

$$Z_j = \frac{S_j}{(Var(S_j))^{1/2}} \quad (4)$$

The null hypothesis (Ho) states no trend in any period (year) affecting cassava output in relation to climate factors (temperature and precipitation) in Nigeria.

Results and Discussion

The first measure in time series assessment is visually studying the data. Substantial variations in the level or slope are normally evident. The annual average series of cassava output, temperature and precipitation in Nigeria are shown below:

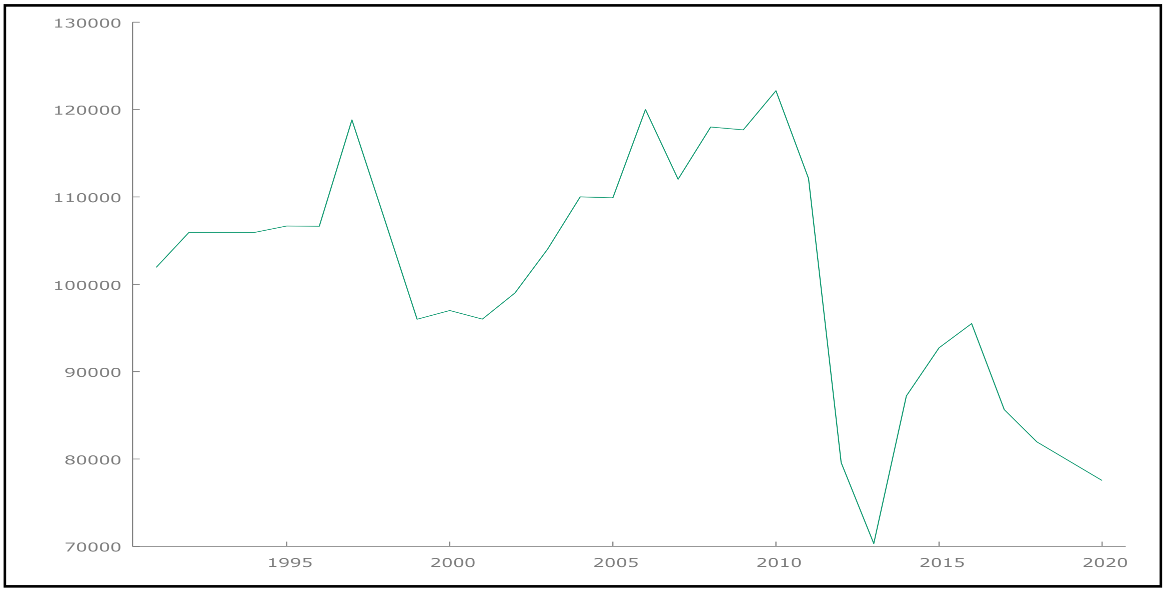

Figure1(a)

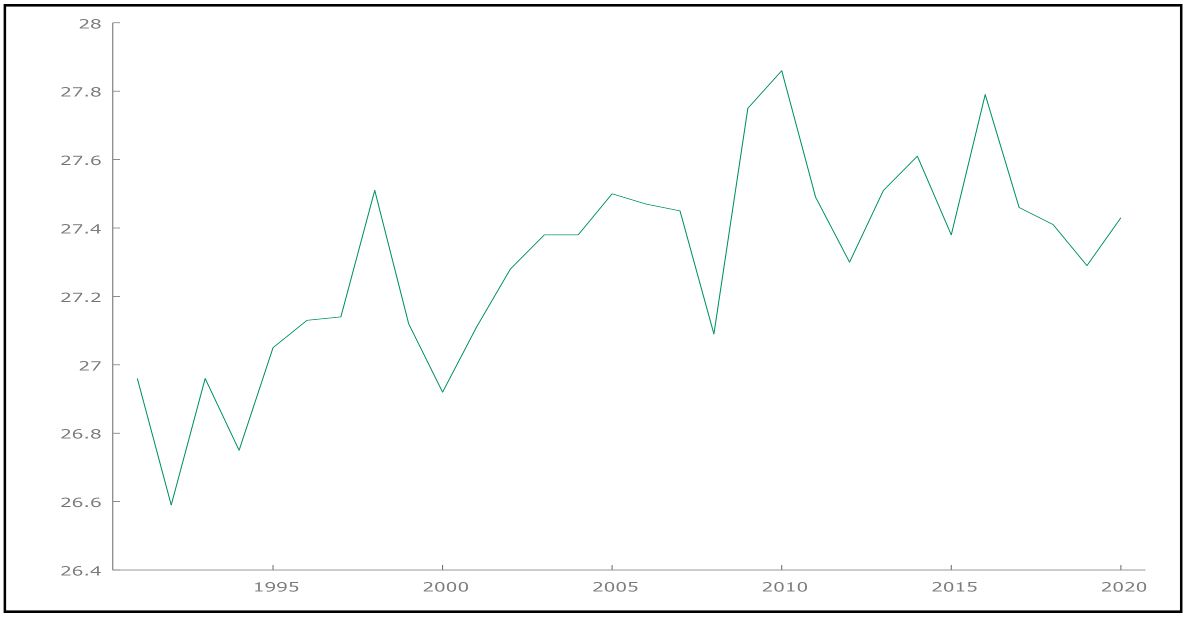

Figure 1(b)

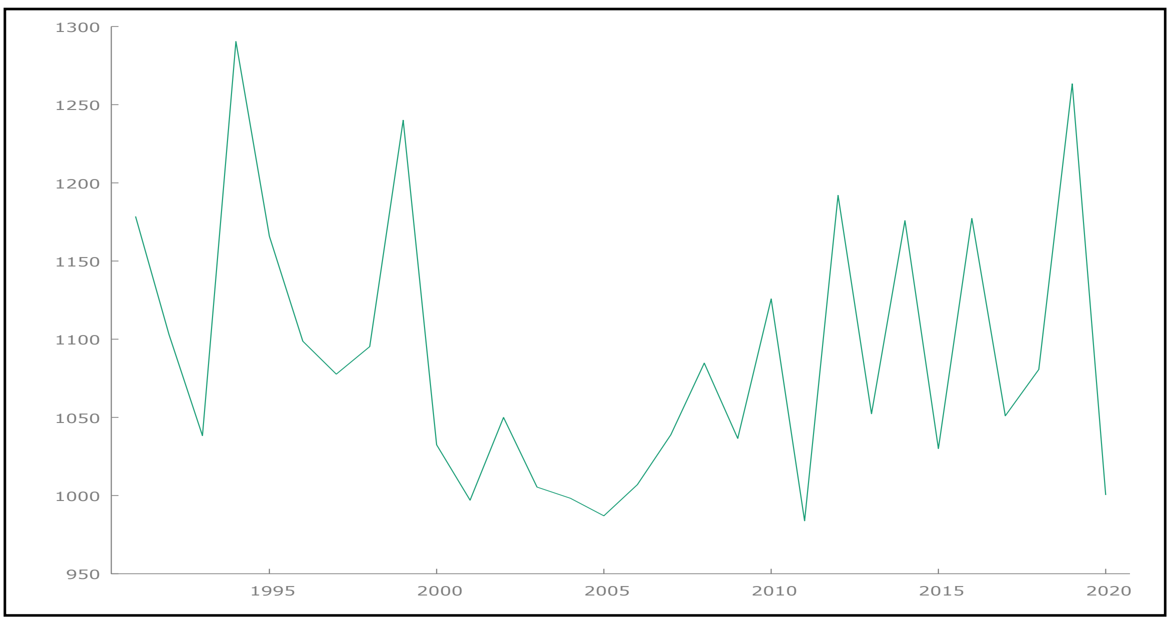

Figure 1(c)
Figure 1: Trend of (a) cassava output, (b) annual average temperature and (c)annual average precipitation
Source: Authors computation, 2022

From the visual assessment in the Figure 1 above, it seems temperature and precipitation affects cassava output. Figure 1a shows an increasing trend in the yield of cassava from 1991 to 2010, when drastically a reduction in output occurred. This occurrence may be attributed to several agricultural related factors affecting farming operations in which variability in climatic such as temperature and precipitation inclusive. Precipitation (Figure 1c) exhibits erratic or downward trend and temperature (Figure 1b) also shows upward trend. This implies that precipitation and temperature actually has a great potential on cassava output in Nigeria.

Table 1: Mann-Kendall (MK) result

Variables	Tau	Z statistic	p-value
Temperature	0.02312	0.1607	0.8723
Precipitation	0.1678	-1.32024	0.1868
Null hypothesis: tau = 0			

Source: Authors computation, 2022

Table 1 shows the Mann-Kendall (MK) test result of the trend of annual temperature and precipitation (rainfall) time series, which shows increasing positive trend with non-significance level trend. The result agrees with the visual assessment heuristic result in Figure 1 above. The annual average temperature under the period (1991-2020) considered varied from 26.59^{o}C to 27.86^{o}C. while the annual average precipitation under the period (1991-2020) considered varied from 987.03mm to 1290.42mm. A non-significant increase in trend in the annual average temperature (0.8723) that's p-value greater than 5% (i.e 0.8723 > 0.05) was observed, which shows uneven distribution pattern trend in the long-run. A non-significant increase in trend in the annual average precipitation (0.1868) that's p-value greater than 5% (i.e 0.1868 > 0.05) was also observed, which shows erratic rainfall pattern trend in the long-run, as seen in Table 3. The finding agrees with Gadedjisso-Tossou (2015), and Gadedjisso-Tossou *et al.,* (2021) who reported long-run trend in rainfall in norther region of Togo. The erratic precipitation pattern observed in Nigeria via this study could results in drought during growing season. While high temperature could similarly lead to reduction in the output if coincided with vegetative stage, which will result price of cassava escalation. As a consequence, food security is jeopardized and the livelihood of the farmers is at a great risk as well. The single raining season in Nigeria does not give farmers more opportunity to meet up with cassava production. This scenario compels the able body farmers to migrate to other places for non-agricultural jobs opportunities particularly when raining season is not favourable for them.

Table 2: Stationarity: Augmented Dickey-Fuller (ADF) unit root test

Variables	Level			First Difference		
	t-value	*p*-value	Remarks	*t*-value	*p*-value	Remarks
Intercept:						
LnCassYd	-1.4136	0.5618	NS	-4.2073	0.0028	S
LnTemp	-2.7428	0.0792	NS	-7.7771	5.29e-007	S
LnPrecip	-5.5397	8.651e-005	S	-10.429	2.17e-008	S
Intercept and trend:						
LnCassYd	-2.0875	0.5309	NS	-4.1773	0.0109	S
LnTemp	-3.9550	0.0223	NS	-7.8419	1.113e-006	S
LnPrecip	-5.4529	0.0006	S	-10.2045	1.044e-012	S

Note: NS = Non stationarity; S = Stationarity

Source: Authors computation, 2022

Table 2 above shows the stationarity test result of the ADF unit root test of the variables. The presence of unit root indicates that the variables under consideration were non-stationary. Variable LnCaasYd (cassava output) and LnTemp (temperature)are non-stationary at level I(0) both at intercept and intercept with trend, yet became totally stationary at the first different orders *I(*1) at both at intercept and intercept with trend. While LnPrecip (precipitation i.e rainfall) is both stationary at level *I*(0) and at first different order *I*(1) at both intercept and intercept with trend. Completely estimated at level of significance of 1%. This implies that the variables are of the mixed order zero and one orders, i.e *I*(0) and *I*(1). Therefore, the null hypothesis of dominating a unit root is thus rejected and accepted the alternative hypothesis.

Table 3: Johansen Cointegration test result

Rank	Eigenvalue	Trace test	p-value	Lmax test	p-value
0*	0.84447	105.29	0.0000	52.106	0.0000
1*	0.75619	53.188	0.0000	39.518	0.0000
2*	0.38628	13.670	0.0002	13.670	0.0002

Note: * indicates rejection of the hypothesis at the 5% level

Source: Authors computation, 2022

Table 3 shows the Johansen Cointegration test result, which is used to assessed the long-run relationship between the variables. The result shows that both Trace test and Lmax test reveals 3 co-integrating equations respectively at 5% level. This insinuates that the null hypothesis (Ho) of no cointegrating equation of (r = 0) is rejected and the alternative hypothesis (Ha) of possessing three cointegrating equations of (r = 2) is accepted. This implies the existence of a long-run relationship among the variables used in the study.

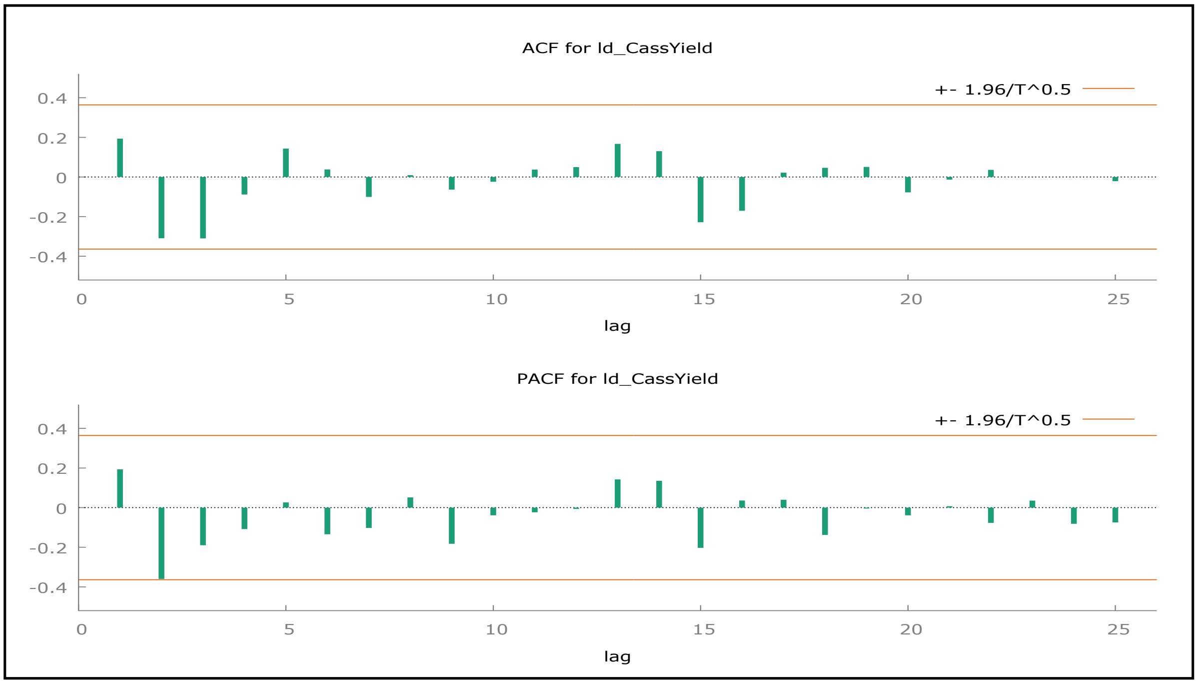

Figure 2a: Autocorrelation function (ACF) and partial autocorrelations (PACF) of cassava output
Source: Authors computation, 2022

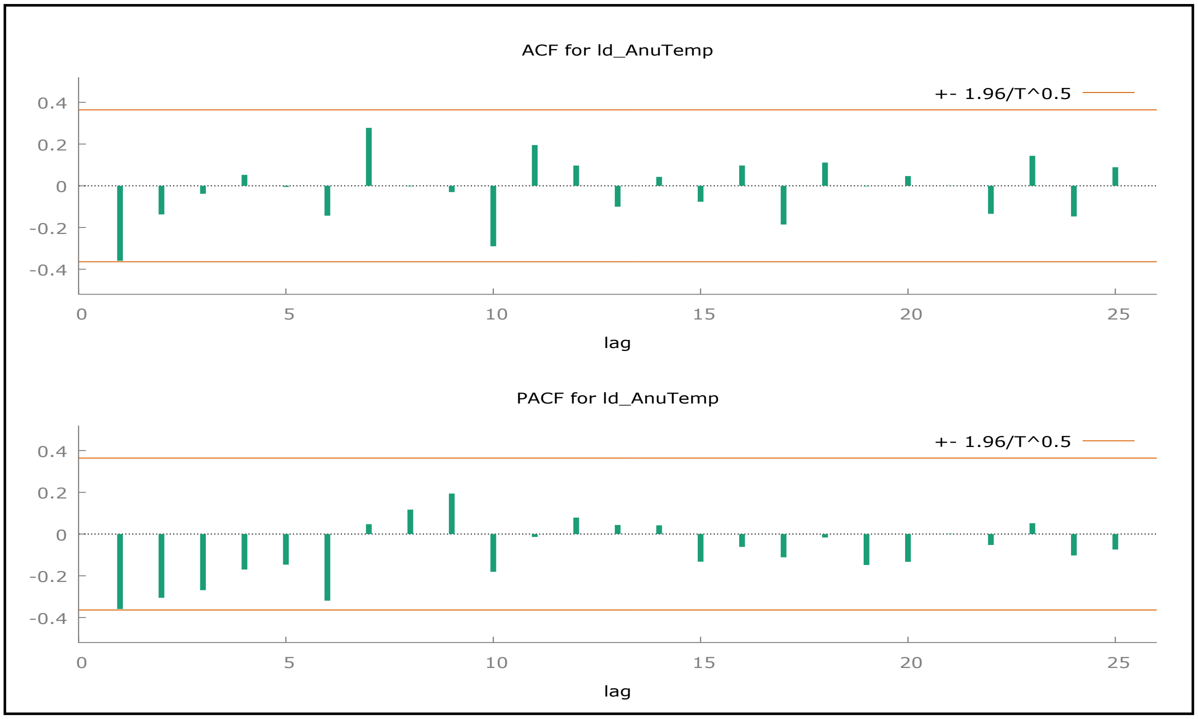

Figure 2b: Autocorrelation function (ACF) and partial autocorrelations (PACF) of temperature
Source: Authors computation, 2022

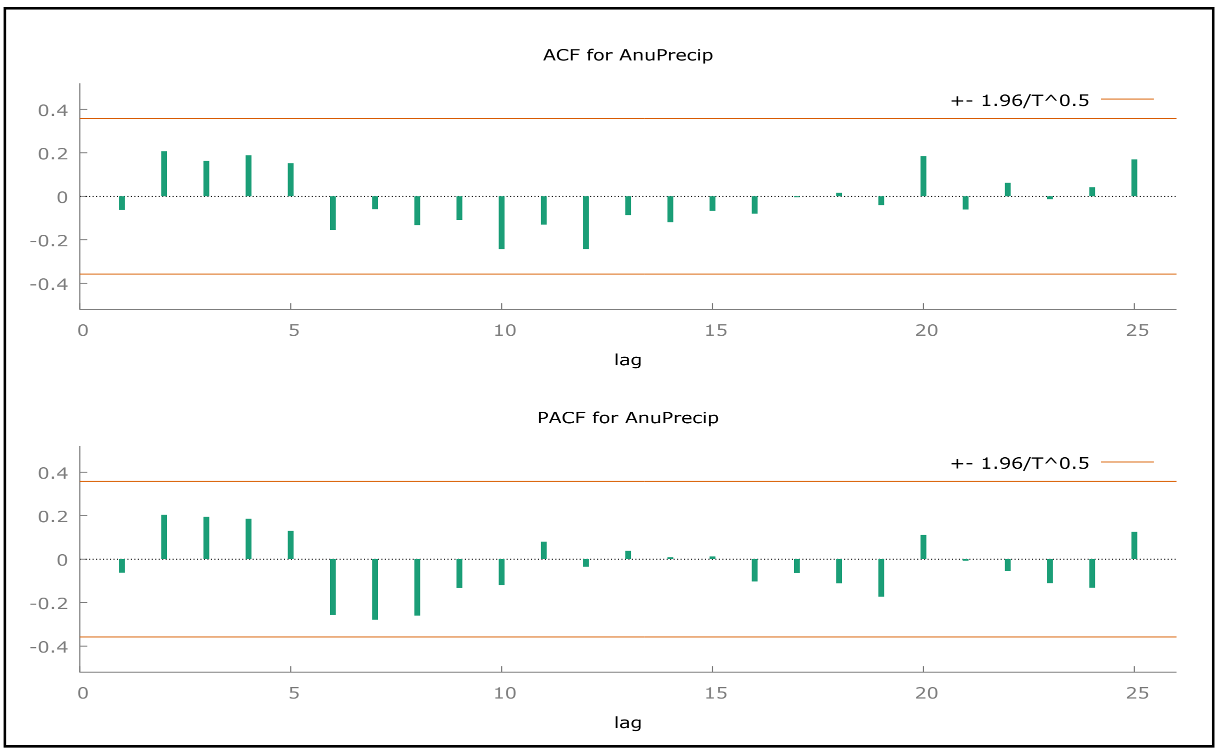

Figure 2c: Autocorrelation function (ACF) and partial autocorrelations (PACF) of precipitation
Source: Authors computation, 2022

Figure 2 (a, b and c) shows the autocorrelation function (ACF) and partial autocorrelations function (PACF). The values of the autocorrelation function (ACF) for series, which may be specified by name or number. The values are defined as ρ(ut, ut-s) where ut is the tth observation of the variable u and s denotes the number of lags. The partial autocorrelations function (PACF, calculated using the Durbin–Levinson algorithm) are also shown: these are net of the effects of intervening lags. This was used to test the null hypothesis that the series is "white noise"; it is asymptotically distributed as chi-square with degrees of freedom equal to the number of lags used. Since the data used fall within the boundary of 5%, it implies that the tool used to assessed the data is a good fit model.

Table 4: Runs (R) test result

Variables	Z statistic	p-value
Cassava output	0.953211	0.3404
Annual temperature	0.195865	0.8447
Annual precipitation	1.39792	0.1621

Source: Authors computation, 2022

Table 4 shows the Runs (R) test result. Runs test was used to examined the randomness of the variable used. "First difference" option was selected to examined R. The p-value obtained for cassava output, annual average temperature and precipitation (0.3404, 0.847 and 0.1621) respectively were greater than alpha ($p > 0.05$). This implies that that variables under consideration were normally approximately distributed.

Conclusion and Recommendations

This study assessed the potential effect of climate variability on cassava output in Nigeria using Mann-Kendall test, Augmented Dickey-Fuller (ADF) unit root test and Johansen cointegration test. The Z statistics of Mann-Kendall test indicates increasing trend of both temperature and precipitation. The trend of annual average for both temperature and precipitation was found out to be at increasing (positive) magnitude with level of non-significance trend. Hence, it can be concluded that there could be a potential effect on climate variability, contributing to poor or low output of cassava in Nigeria. ADF unit root test was used to test the stationarity of the data, which were mixed of level $I(0)$ and first difference order $I(1)$. While Johansen cointegration test was used to test the long-run relationship and the result shows a long-run relationship among the variable considered, Autocorrelation function (ACF) and partial autocorrelations function (PACF) shows good fit of the model used in the study. The study, therefore, recommends that: Since the variation in both temperature and precipitation shows increasing positive trend effecting on cassava output. Then, there is a need for farmers to adopt some measures of adaptation strategies like planting of drought tolerant cassava stem, adoption irrigation practices in an extreme condition of drought or dryness, avoid sole cropping system to avert the risk of losses, crop diversification, armed with agrometeorological information, and involved in decision-making procedures for sustainable cassava production in Nigeria.; This study focused on climate variability (temperature and precipitation), which is our principal concern and interest. This study can further include other non-climate such as socio-economic characteristics, farmland and government policy to make it more comprehensive and gain more insights of the climate dependence crop (cassava) output potential effects in Nigeria.; Policymakers should raise awareness about the severity of climate change impacts on cassava production to farmers, institutions and the private sector that uses cassava as a raw material. Also, crop insurance programme for cassava and other crops may be needed to reduce the risk of farmers from climate change and its variability.; Over the past decade, the overall agricultural research expenditure in Nigeria has been diminished, and past research studies focusing on issues related to climate change adaptation options are limited for cassava. There is therefore an urgent need to improve on research based funding in Agriculture, especially to develop a new drought-tolerant cultivar and explore the optimal adaptation strategies.

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