Assessment of the Effects of Climate Change on Cassava Productivity in Southwest, Nigeria

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Abstract
The globally threat to food security and farmers' well-being through climate change and its related issues has exacerbated in recent years. In Nigeria, as also in the global scene, concerns among climate stake-holders have heightened. This paper, therefore, assesses the impact of climate change on cassava productivity in southwest Nigeria using a panel fixed effect approach, 1990 to 2020. Data on market price, output, yield and cultivated area of cassava were obtained from FAO statistical data base while that of rainfall and temperature were sourced from the Nigeria Meteorological Agency (NIMET). The data were analysed with descriptive statistics, graphs and a fixed effect panel regression. The Cassava yield trends revealed a general increase in five states, with Ogun experiencing a notable decline. Land allocation, Growing Degree Days (GDD), and rainfall exhibited an uneven variability among states. Ogun state had the highest mean output values and land area devoted cassava production. The regression results emphasized the significant positive impact of cassava price on yield, challenging the expected negative influence of climate change. Recommendations include formulating climate-resilient policies, encouraging adaptive practices among farmers, and providing support through donor agencies.

Keywords: *Climate Change, Cassava, fixed effect, Southwest Nigeria*

1. INTRODUCTION

Cassava (Manihot esculenta), ranking third in caloric significance after rice and maize, plays a vital role in providing sustenance across tropical and subtropical regions of Africa (FAO, 2020). It is cultivated widely in numerous Sub-Saharan African countries, with Africa currently accounting for half of the world's cassava consumption (FAO, 2020). Nigeria stands out as the primary global producer of cassava, followed by South-East Asia, Brazil, Indonesia, Thailand, and Vietnam (FAO, 2021). Cassava holds immense importance in Nigeria, where over 90% of rural families include it in their diets almost daily. However, the potential expansion of cassava productivity in Nigeria is confronted with myriad challenges one of which is change in climate. Climate change poses a threat, particularly to rain-fed agriculture, which relies heavily on favorable climatic conditions for productivity (Lenis et al., 2020). Presently, adverse seasonal variations and climate change-induced shifts are jeopardizing cassava output. These challenges affect cassava production at global, regional, and local levels (FAO, 2022), necessitating urgent action to safeguard agricultural sustainability and food security. The argument surrounding climate change has deepened, particularly in low income economies like Nigeria, where the impacts are felt most terribly. Nigeria, like many other developing countries, faces a many challenges that are worsening food productivity. These include widespread poverty, unsustainable agricultural practices, and environmental degradation. Slash-and-burn agriculture, greenhouse gas emissions, erosion, and deforestation (Ajetomobi and Abiodun, 2010). Agriculture, as a climate-sensitive sector, is particularly vulnerable to the impacts of climate change. Changes in temperature and precipitation patterns can affect crop yields, water availability, and soil fertility. Additionally, climate change can impact the quantity and quality of feed for livestock, and leads to increased spread of diseases and parasites (Niggol and Mendelsohn, 2008). The extent to which climate change is responsible for variability in agricultural productivity remains a subject of continuing research. While climate variability undoubtedly plays a significant role, other factors such as land use, technology adoption, and socio-economic conditions also influence agricultural outcomes. Understanding the multifaceted interaction between these factors is essential for developing effective strategies so as to allay their negative impacts on agriculture (Chikezie et al., 2010). Evidence from the literature suggests significant variability in rainfall and temperature across Nigeria, with implications for agricultural production. The income and profitability of farmers are significantly influenced by the swift degradation of cassava tubers both while they are still on the farmland and after they have been harvested (Ekundayo et al., 2021). Nigeria's diverse climatic conditions, ranging from tropical rainforests to Sahel climates, present both opportunities and challenges for agriculture. An increase in the number of rainy days creates a conducive environment for the proliferation of pests, insects, and diseases that specifically target cassava plants. This heightened presence of pests and diseases poses a significant threat to the growth and development of cassava, ultimately resulting in poor crop yields. (Adejuwon and Ogundiminegha, 2019). Efforts to stimulate agricultural resilience and innovation need to be put in place. This will eventually leads to cassava farmers adopting new cultivation techniques, fertilizer application methods, and cassava varieties (Ekundayo et al., 2021). At present, the market demand for food has been on the increase and the supply-demand gap can only be bridged by the intensification of cultivating general crops like cassava. This is especially while the Nigerian government has continued the enforcement of food imports. Cassava, being an easy-to-cultivate and a crucial staple crop, is also facing some difficulties at the stages of production. This has significantly impacted on its yields in the face of over bloating population awaiting bumper harvest from the food crop subsector.(Onyeneke et al., 2021). To this effect, this paper assesses the effect of climate change on cassava productivity in Southwest, Nigeria using Fixed Effect model.

2. Materials and Methods

2.1 *Description of the study area and data*

The study area is Southwest geopolitical zone of Nigeria, which is made up of six(6) states namely, Ondo, Oyo, Osun, Lagos, Ekiti and Ogun states with one hundred and thirty seven(137) local governments altogether. Ondo state has eighteen (18) LGAs, Oyo state has thirty three (33) LGAs, Osun state has thirty (30) LGAs, Lagos state has twenty (20) LGAs, Ekiti state has sixteen (16) LGAs and Ogun state has twenty (20) LGAs.

The population of the entire region according to 2006 population census was about thirty eight (38) million people. Apart from agriculture as the mainstay of economic activities for the majority in the rural communities, the zone is also known for its commerce and trading activities with a preponderance of micro, small and medium indigenous industries that are into manufacturing, fabrication and agro-allied produce. Agriculture thrives very well in the area because the zone is endowed with fertile land. The main food crops grown in the zone include, yam, cassava, cocoyam and maize while the cash crops include, rubber, cocoa, banana and various types of fruits. The area lies between longitude 2°311 and 6°001 East and Latitude 6°211and 8° 371N (Agboola, 1979) with a total land area of 77,818 km2 out of the total 923,769 square kilometers in Nigeria. The study employed a panel data that spanned from 1990 to 2020 on these six states of southwest, Nigeria. The climate variables of interest included temperature, average temperature, rainfall, growing degree day, while the non-climate variables were market price, output, yield and cultivated area.

A panel regression model generally takes the form:

$Y_{it} = \beta_0+\beta_1X_{it}+\beta_2Z_i+\gamma_t+\epsilon_{it}$

Where:

Y_{it} is the dependent variable for individual i at time t.

X_{it} is a vector of time-varying independent variables for individual i at time t.

Z_i is a vector of individual-specific variables that do not vary over time.

γ_t represents time-fixed effects or time-specific effects.

ϵ_{it} is the error term.

Where;

Y = Cassava yield

X_1 = cassava price (naira)

X_2 = growing degree day

X_3 = annual rainfall (mm)

X_4 = annual output (tons)

X_5 = harvest area (hectare)

γ_t represents time-fixed effects or time-specific effects.

ϵ_{it} is the error term**.**

2.2 *Data analysis*

2.2.1 Descriptive statistics

The cassava trend was represented graphically, showing annual temperature, average temperature, rainfall, output, cassava yield, growing degree days, and the harvest area. The factors generally believed to be responsible for cassava production were analyzed using descriptive statistics. These variables include land area, output, price, growing degree days, year average and rainfall. The trend of cassava production in the study area was analyzed using trend graph, the trend graph include cassava yield, land area, growing degree days, cassava price and rainfall.

2.3.3 Panel regression model

The impact of climate change in the study area was analyzed using panel regression model. The data were run using (R) statistical software. Ordinary Least Square model (OLS) was first conducted and it showed that the co-efficient of price and rainfall were positive and statistically significant, meaning that a unit increase in price will increase yield by 0.005 tonnes per hectare. State effect was controlled by conducting a Fixed Effect Model. The co-efficient of the fixed effect model showed that it is a bit better than the OLS. Fixed effect model showed that price and gdd are the basic drivers of cassava yield. Contrary to theorectical expectations, the gdd has a U-shaped relationship with the yield instead of an expected hill shape. A unit increase in price will increase the yield by 0.006 tonnes per hectare which is slightly greater than the Ordinary Least Square. Before we can conclude on whether to adopt Ordinary Least Square or Fixed effect model, for the significance effect, there is a need to test for the State Effect and compare OLS with Fixed effect model. To do this, plm (panel linear model) test was conducted, using the Langrage multiplier test for Fixed effect, where our effects were our cross section. The result of the Langrage multiplier test suggested the presence of state effect, with a p-value less than 2.2×10^{-16}. pF-test (pooled F-test) was conducted to compare the significance effect of Fixed effect model and Ordinary Least Square. The result of the pF-test showed that the Fixed effect model is preferred to the OLS.

In addition to State Effect, there could be a number of factors affecting yield that are not specific to individual state. Time fixed effect was modeled using the "effect = time" argument in plm (means that fixed effects were included for each time period in the panel data). The result of the Time Fixed Effect showed that the co-efficient of price is the only statistically significant variable in the time fixed effect model, and it is negative, contrary to theoretical expectation. Plm, using Langrage multipler test was also conducted on the fixed effect model, to verify if time fixed effects are indeed present in the model. It was observed that with a p-value of 0.99, it indicated that there is no time fixed effect in the model. The three models conducted are presented in one table (OLS, FE, TE). Serial correlation in the error term was addressed with Breush-Godfrey test. The result showed a p-value of 1.312×10^{-7}, which confirmed the presence of serial correlation in the fixed effect. This presence of serial correlation was corrected by running a co-efficient test. After correcting for the serial correlation, the result showed that price was no longer significant. What is left were just the climate variables. If the government in the six southwestern states should introduce new specie of cassava, it is probable that the change will definitely affect the results in other 36 states of the federation. Cross section dependence was tested using the Pesaran Cross-sectional Dependence test (PCD), and the result showed Z = 0.56357 and a p-value of 0.573, showing that there is no cross sectional dependence. To prevent spurious regression, we conducted a unit root test on the panel data using the lm-Pesaran-Shin (lPS) test, revealing that the data were stationary at the level. In order to mitigate spurious regression, we examined the presence of a unit root through the lm-Pesaran-Shin Unit Root Test. Utilizing unit root tests, we investigated the stationarity characteristics of variables (Choi, 2001), which enables assessment of homogeneity in autoregressive coefficients and identification of potential unit root issues. While the Im-Pesaran-Shin (IPS) unit root test offers less stringent criteria, it proves more suitable than the LLC (Levin, Lin, and Chu) unit root test due to its accommodation of heterogeneity in autoregressive coefficients.

3. Results and discussions

3.1 Cassava Yield Trend in Southwest Nigeria

Figure 1 shows that, in the year 2013 to 2020, five states of Ekiti, Lagos, Ondo, Osun and Oyo experienced a gradual increase in cassava yield (ranging between 12 tons/hectare to 26 tons/hectare). However, Ogun state has drastically dropped from producing 8 tons/hectare in 2013 to producing 5 tons/hectare in 2020, while other five states maintain between 12 tons/hectare to 28 tons/hectare between 2013 to 2020. This implies an increase in cassava price in the state. The Drastic decreasse in cassava yield in Ogun state might be as a result of cassava farmers leaving cassava cultivation for cultivating other crops.

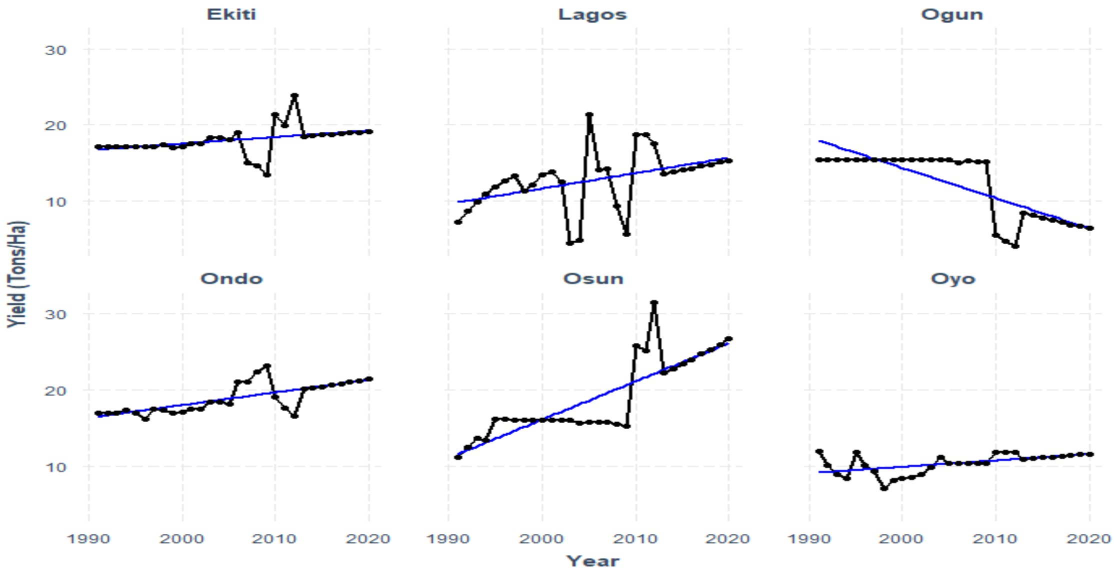

Figure 1: Cassava Yield in Southwestern States: 1990-2020

Land area (hectare)

According to figure 2, no obvious changes in the land area allocated to cassava production in Ekiti, Lagos, Ondo, Osun, and Oyo state, as the area of land allocated to cassava production in these states from 1990 to 2020 was below 400, 000 hectares. However, Ogun state experienced drastic increase in the area of land dedicated to cassava production from 100,000 hectares in 2005 to 800,000 hectares in 2012. Going forward, it reduced to 600,000 hectares in 2013. Ogun state experienced its highest increase of land allocated to cassava production, from 600,000 hectares in the year 2013 to over 1,200,000 hectares in the year 2020, which makes it the state with the highest hectares of land allocated for cassava production.

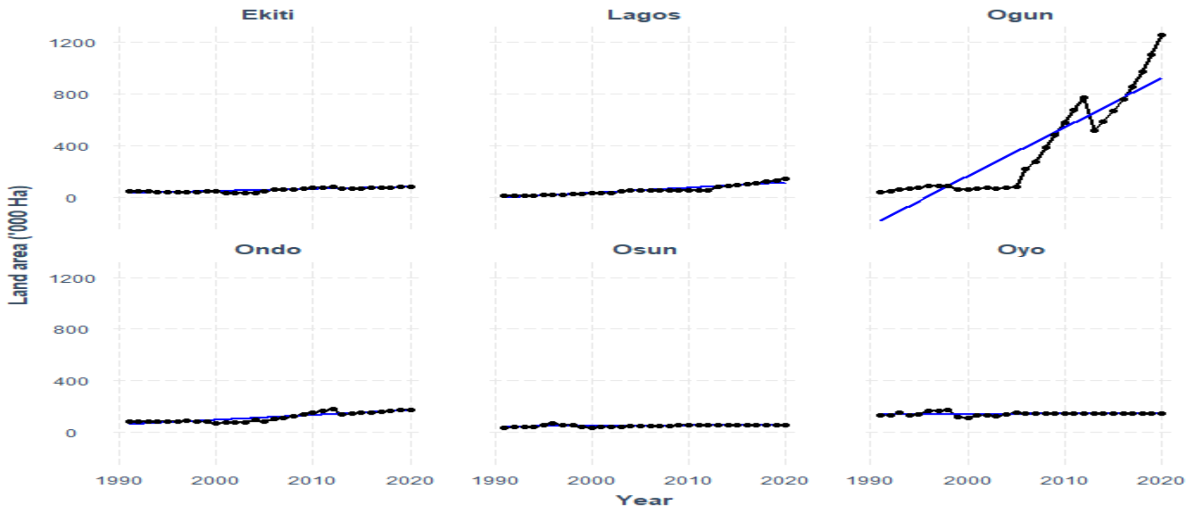

Figure 2: Cassava Land Area in Southwestern States: 1990-2020

Growing Degree Day

There's been fluctuation in the Growing degree days of cassava across the states in the southwest. This implies that, there is no constant measurements of cassava production in Southwest Nigeria, with regards to Growing degree days (GDD).

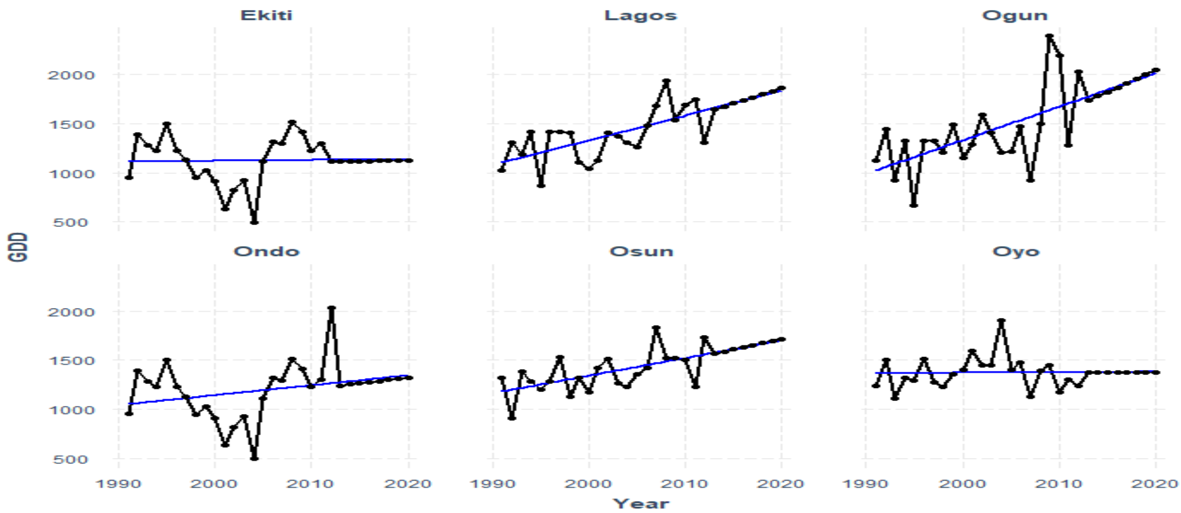

Figure 3: Growing Degree Days for Cassava in Southwestern States: 1990-2020

Cassava Price Trend in Southwest Nigeria

Figure 4 showed the trend for cassava price across the six southwestern states of Nigeria. The six states in Southwest Nigeria have been maintaining the same trend of cassava price from year 2015 to 2017. It was observed that the price of cassava increased from #30 per kg in 2015 to at least #55 per kg in 2017, with lagos having the highest (about #90 per kg) and Ondo state with the least (#55) . This implies that, there is increase in household consumption of cassava from 2015 to 2017, hence the increase in price. The higher the demand for cassava, the higher the price. As at the year 2020, Oyo state has the highest price for cassava (#55 per kg), with Ekiti, Ogun and Osun selling for #50 per kg, Lagos (#45 per kg), and Ondo state selling for #40 per kg (the least price).

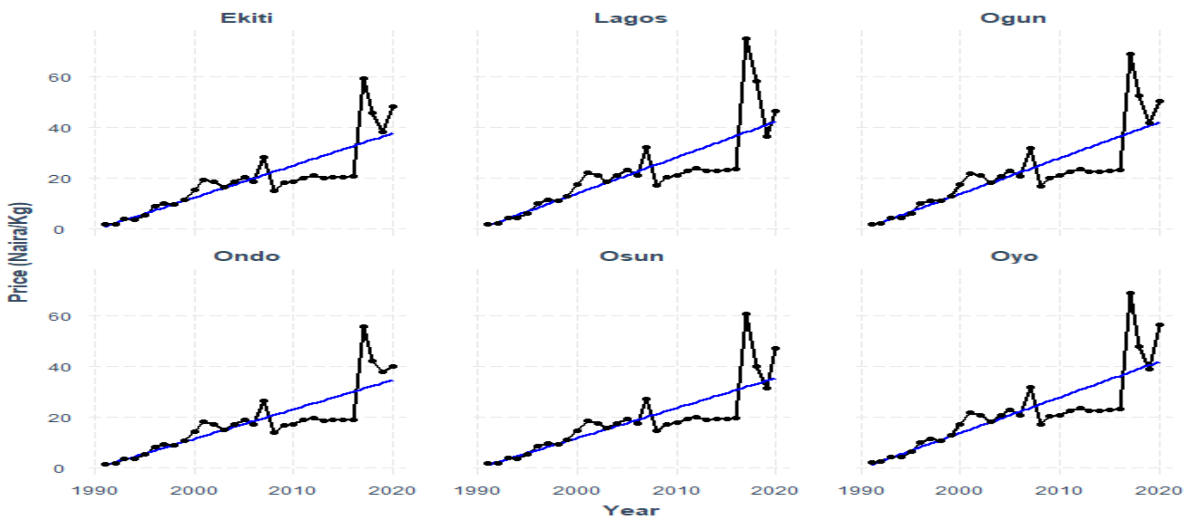

Figure 4: Price of Cassava Fresh in Southwestern States: 1990-2020

Rainfall Trend in Southwest Nigeria

Figure 5 shows the rainfall trend for cassava production across the six states of southwestern, Nigeria. Ekiti state experienced its highest rainfall of about 2,800mm to 3000mm rainfall in 1990 and 1992 respectively. Thereafter, there was drastic depreciation in rainfall pattern from 3000mm in 1992 to about 1500mm in 1993. From 1996 to 2020, the state has experienced below 2000mm annual rainfall. Lagos state is the southwest state with minimum rainfall from 1990 to 2020. The trend also shows that Ogun and Osun states have never experienced above 1600mm of annual rainfall, from 1990 to 2020. Osun state being the state with the least annual rainfall, has produced less than 1100mm from 1990 to 2020. The state has also maintained an annual rainfall pattern of less than 800mm from 2012 to 2020. Ondo state experienced its highest rainfall in 2002 with about 2800mm. After which the rainfall pattern drastically reduced to 900mm between 2005 and 2012. The rainfall rise from 900mm in 2012 to 1100mm in 2013, after which it has maintained between 100mm to 900mm in 2020. Oyo state experienced it highest amount of rainfall in 2012 (2800mm) and dropped to 1500mm in 2013. The rainfall patter was between 1500mm in 2013 and 1800mm in 2020.

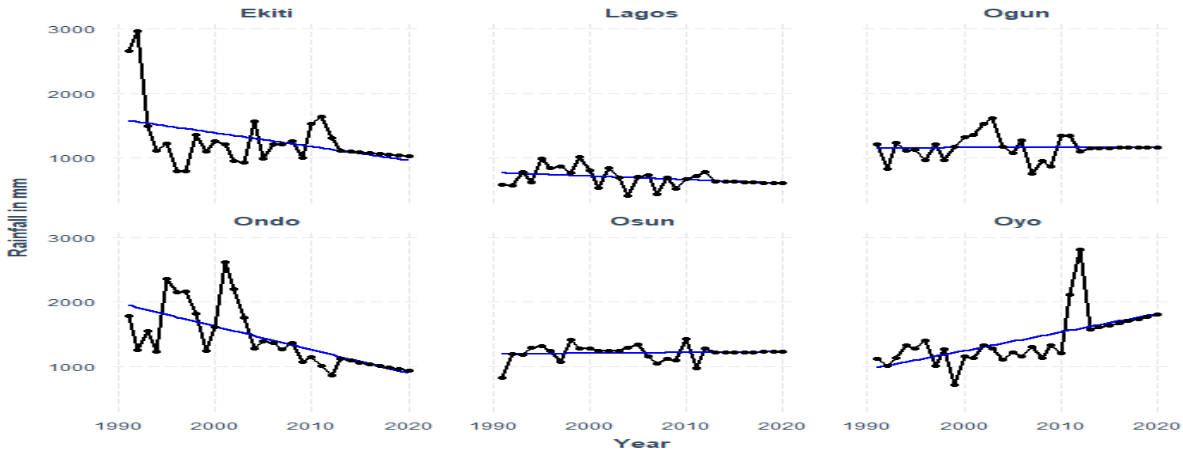

Figure 5: Total Annual Rainfall in Southwestern States: 1990-2020

3.2 DESCRIPTIVE ANALYSIS RESULT OF CASSAVA PRODUCTION

From table 1, the mean cassava yield provides an average production value for each state. Ekiti and Ondo exhibit higher means (18 and 18.9, respectively), indicating above-average yields. Lagos, Ogun, and Osun have lower means (12.8, 12.2, and 18.9, respectively), reflecting comparatively lower average yields. Oyo has the lowest mean (10.3), suggesting the least productive state. The overall mean yield for the study area is 15.2, offering a comprehensive view of the average cassava production.

The mean land area dedicated to cassava cultivation reveals the average size of cassava farms in each state. Ogun has the highest mean (370), indicating larger cassava farms on average. Lagos and Osun show moderate means (53.8 and 50.6, respectively), while Ekiti, Ondo, and Oyo have lower means. The overall mean for the study area is 131, providing an average land area for cassava cultivation across all states. Policymakers can utilize this information to understand the typical size of cassava farms in different regions, aiding targeted agricultural strategies and resource allocation for improved cassava cultivation.

The mean cassava output offers insights into the average production in each state. Ogun has the highest mean output of 3130 kg indicating the largest average cassava yield. Ondo and Oyo also show substantial means of 2230 and 1470 kg, respectively, reflecting significant production. Lagos, Osun, and Ekiti have lower means. The overall mean for the study area is 1600 kg, representing the average cassava output across all states.

The mean temperature values in each state indicate the average temperature levels for cassava cultivation. Lagos stands out with the highest mean temperature 21.9^{0}C, signaling warmer conditions, while Ondo has the lowest mean temperature of 17.8^{0}C, suggesting cooler environments. The overall mean temperature for the study area is 20.1^{o}C, representing the average temperature across all states.

The mean temperatures for cassava cultivation in each state are remarkably consistent, ranging from 27.0^{0}C to 27.4^{0}C. This uniformity is reflected in the overall mean temperature for the study area, which is 27.3^{0}C. The median temperatures also align closely with the mean values, emphasizing the reliability of the average temperature representation. The low standard deviation (ranging from 0.263 to 0.447^{0}C) suggests minimal variation from the mean, indicating a stable temperature distribution across all states.

The mean growing degree days (gdd) for cassava cultivation in each state provides an average measure of heat accumulation. Lagos has the highest mean of gdd (1470), indicating a warmer climate conducive to cassava growth. Ekiti and Ondo have lower mean of gdd values (1120 and 1200, respectively), suggesting slightly cooler conditions. The overall mean of gdd for the study area is 1350, providing a comprehensive average. The median gdd values align closely with the means, indicating a balanced distribution. The standard deviation (307) implies moderate variability around the mean.

The mean rainfall values for cassava cultivation reveal insights into the average precipitation levels in each state. Ondo has the highest mean rainfall (1430), indicating a wetter climate, while Lagos has the lowest mean (689), suggesting drier conditions. The overall mean rainfall for the study area is 1190, offering a comprehensive average across all states. The median rainfall values align closely with the means, indicating a balanced distribution. The standard deviation (411) implies moderate variability around the mean.

Table 1: DESCRIPTIVE ANALYSIS RESULT OF CASSAVA PRODUCTION IN THE STUDY AREA

	Ekiti (N=30)	Lagos (N=30)	Ogun (N=30)	Ondo (N=30)	Osun (N=30)	Oyo (N=30)	Overall (N=180)
Yield							
Mean (SD)	18.0 (1.90)	12.8 (3.98)	12.2 (4.34)	18.9 (2.00)	18.9 (5.26)	10.3 (1.34)	15.2 (4.90)
Median [Min, Max]	17.9 [13.5, 23.9]	13.5 [4.40, 21.4]	15.4 [4.10, 15.4]	18.3 [16.2, 23.2]	16.0 [11.1, 31.5]	10.4 [7.00, 11.9]	15.4 [4.10, 31.5]
area							
Mean (SD)	54.7 (16.6)	53.8 (37.7)	370 (368)	116 (37.3)	50.6 (7.56)	142 (13.2)	131 (188)
Median [Min, Max]	52.0 [32.0, 81.0]	51.0 [11.0, 142]	153 [39.0, 1250]	98.5 [69.0, 178]	53.5 [35.0, 67.0]	144 [111, 171]	75.5 [11.0, 1250]
output							
Mean (SD)	997 (376)	800 (693)	3130 (2430)	2230 (866)	977 (367)	1470 (233)	1600 (1380)
Median [Min, Max]	851 [585, 1940]	452 [79.0, 2450]	2270 [602, 8030]	1960 [1180, 3750]	853 [394, 1800]	1560 [920, 1730]	1330 [79.0, 8030]
price							
Mean (SD)	19.4 (13.5)	21.9 (15.8)	21.7 (15.2)	17.8 (12.4)	18.2 (12.9)	21.5 (15.1)	20.1 (14.1)
Median [Min, Max]	18.8 [1.75, 59.5]	21.1 [2.00, 75.0]	20.9 [2.00, 69.3]	17.3 [1.50, 55.8]	17.5 [1.75, 60.8]	20.8 [2.00, 68.8]	18.8 [1.50, 75.0]
yearAve							
Mean (SD)	27.4 (0.341)	27.2 (0.447)	27.0 (0.377)	27.4 (0.341)	27.3 (0.287)	27.4 (0.263)	27.3 (0.375)
Median [Min, Max]	27.4 [26.7, 28.2]	27.2 [26.6, 28.4]	27.0 [26.4, 27.7]	27.4 [26.7, 28.2]	27.3 [26.8, 27.8]	27.4 [26.6, 28.0]	27.3 [26.4, 28.4]
gdd							
Mean (SD)	1120 (227)	1470 (282)	1520 (413)	1200 (285)	1440 (214)	1370 (150)	1350 (307)
Median	1120	1420	1460	1260	1460	1380	1320

	Ekiti (N=30)	Lagos (N=30)	Ogun (N=30)	Ondo (N=30)	Osun (N=30)	Oyo (N=30)	Overall (N=180)
[Min, Max]	[495, 1520]	[867, 1940]	[662, 2390]	[495, 2030]	[913, 1840]	[1120, 1910]	[495, 2390]
rain							
Mean (SD)	1270 (468)	689 (140)	1160 (184)	1430 (475)	1210 (121)	1400 (399)	1190 (411)
Median [Min, Max]	1120 [795, 2960]	658 [421, 1020]	1160 [762, 1620]	1260 [865, 2620]	1230 [829, 1420]	1300 [715, 2810]	1160 [421 , 2960]

Source: Author's Computation, 2023

Panel Regression Result

In table 2, the statistically significant and positive coefficient of 0.008 indicates that as Growing Degree Days (GDD) increase, cassava productivity in the study area is expected to increase by 0.008 units. This result is consistent with expectations, suggesting that higher but moderate GDD is associated with better cassava productivity. The result clearly showed that climate change does not negatively affect cassava production in the study area. A unit increase in growing degree day actually increased yield of cassava.

Table 2: Regression Between Cassava Yield and Climate Variables

Panel Linear time effect Variables	OLS yield Fixed effect 1	Panel Linear for fixed effect 2	Co-efficient Test 3	Yield for 4
price	0.052*	0.060***	0.060	-1.065***
	(0.027)	(0.019)	(0.038)	(0.138)
gdd	0.003	0.008*	0.008***	-0.0004
	(0.006)	(0.005)	(0.002)	(0.006)
rainfall	0.006*	0.002	0.002	0.0003
	(0.003)	(0.004)	(0.005)	(0.003)
gdd^2	-0.00000	-0.00000**	-0.00000***	-0.00000
	(0.00000)	(0.00000)	(0.00000)	(0.00000)
$rainfall^2$	-0.00000	-0.00000	-0.00000	- 0.00000
	(0.00000)	(0.00000)	(0.00000)	(0.00000)

Regression Analysis Result, 2023

4.0 Conclusion and Recommendation

The research focused on climate change assessment on cassava production in the Southwest Nigeria, analyzing data from 1990 to 2020. The six states in focus, exhibited varying trends in cassava yield, land area, growing degree days, and other factors. Ogun state experienced a drastic drop in cassava yield, potentially due to shifts in agricultural focus. The descriptive analysis provided insights into mean values for cassava yield, land area, output, temperature, and rainfall across states. The Ordinary Least Square and Fixed Effect models revealed the significance of cassava price and growing degree days in influencing yield. The result challenged the expected negative impact of climate change, showing a positive association between growing degree days and cassava productivity. Farmers need to adopt adaptive practices as a boost to cassava production. Extension agents should be equipped with study insights to educate farmers on climate-smart agricultural practices, ensuring widespread adoption. Government and other donor agencies interested in climate change mitigation should consider funding initiatives to support sustainable agriculture in the area.

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