Climate Change Impact on Cassava Agriculture in Nigeria

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ABSTRACT: This study employed Feasible Generalised least square and structural Ricardian models to investigate the impact of climate change on yield and net revenue of cassava production across the six across the six geopolitical zones in Nigeria using 1200 farming households. The data on climate variables (rainfall and temperature used for the study were obtained by the Nigeria meteorological agency while the data on cassava farmers characteristics and farm level characteristics was obtained from General Household Survey wave 4 data. The results showed that climate variables had varying impact on the yields and net revenue of cassava agriculture. Yield increases as temperature increases and reduces as rainfall increases, the net revenue increases as rainfall increases and reduces as temperature increases. The marginal effect of climate change showed that cassava is more sensitive to the infinitesimal change in climate. The predicted climate scenarios showed that extreme climate condition will be dangerous to cassava and it will reduce the net revenue generated from cassava production.
Key words: Climate change, Net revenue, Yield, Ricardian, FGLS, Cassava

1. INTRODUCTION

Climate change has become a persistent object of debate across the globe and Nigeria is not left out, the effect of this menace caused by the recent change in the climate as reported by IPCC 2007 is going to be severe in the tropical countries like Nigeria because it comprises of developing country where their agricultural system is often weather dependent. At the 10th Session of IPCC WG II and 38th Session of IPCC in Yokohama, Japan, they warned the world that climate change impacts was leading to shifts in yields of crops, decreasing the overall yields and sometimes increasing them in temperate and higher latitudes. (IPCC, 2014). According to Sha, Fischer and van Velthuizen (2009) food production and food security in developing countries with low capacity to cope and adapt to these challenges posed by this change in climate will be faced by its adverse consequences. Nigeria where rain-fed agriculture is the main source of livelihood for about 50-60 per cent of the population and accounts for over 25.5 per cent of the nation's gross domestic product in real terms is not expected be to left out of the severe impact (National Bureau of Statistics, 2017). Majority of Nigeria households have agriculture as the mainstay and the sector is significant in the economy of the Nation. Agriculture helps in the provision of food, employments and raw materials for agro allies industries, it also contributes to gross domestic product and helps in generation of foreign earnings. These contributions can however be undermined by the dangerous impact of climate change. A sectorial scrutiny in 2006 of the real GDP showed that the agricultural sector contributed to about 42 percent of the GDP compared with 41.2 percent in 2005 (CBN, 2012). The growth rate of the contribution of the agricultural sector to the GDP is now on the decrease rather than what it used to be. In 2018, Nigerian agriculture shared 22.12% contribution to total gross domestic product; this could be linked with variation in climate. However, Crop production takes a significant aspect of agricultural production and exports in Nigeria, according to Adams *et al.* (2008), crop yields are directly affected by changes in climatic factors such as temperature and precipitation and the frequency and severity of extreme events like droughts, floods and windstorms. However, according to Verrnier *et al*.2000 climatic factor seems more important both in terms of its variation over space and time than the other requirements for crop growth. In particular, climate has both direct and indirect effect on crop production. The direct effect is displayed by the impact of climatic factor on the other mechanisms of the plant environment, as submitted by Lobell *et al.*,(2013) the Extreme events are expected to effect the instability of yields and are seen as the principle immediate threat to global crop production (Lobell et al.,2013).

Nigeria is located in the tropics with variations in climate across various agro-ecological zones which supported the growth of various crops: cereals, legumes tubers to mention just a few. Cassava (Manihot esculenta) is a hardy crop that could have significant potential to adapt to climate change and soil infertility and drought stress, and this made it possible for its wide cultivation across the country. It is a short-lived perennial crop which is grown mainly for its tuber, it is grown in an environment with warm and humid climate Temperature and rainfall requirement for cassava in Nigeria is between 28 ℃ to 33 ℃ and 1000 and 1400 mm respectively. It is one of the most important crops in Nigeria, playing a dominant role in the rural economy in the southern agro-ecological zones and is increasingly gaining importance in other parts of Nigeria (Ande *et al.*, 2008). Some species can be cooked and consumed as food, they are also been processed into different produce, (Nwaobiala, *et al*., 2009).

Few studies have investigated the impact of climate change on cassava in Nigeria; the objective of this study is to (i)investigate the impact of climate change on yield of cassava production in Nigeria (ii) to analyse the impact of climate change on net revenue of cassava production using Ricardian approach. (iii) to assess the potential impact of climate change cassava production in Nigeria in 2050 and 2100 using both Canadian climate change model and parallel climate mode. The study also reveals the net revenue generated by each state from cassava production for 2018/2019 production year.

2. Material and Methods

Study area

This study on the impact of climate change on cassava was carried out in Nigeria, Nigeria is one of the countries that is severely affected by the change in climate; it is located in the tropical zone of West Africa between latitudes 4°N and 14°N and longitudes 2°2'E and 14°30'E with the total land area of 923 770 km^2. The country's north-south extent is about 1 050 km and its maximum east-west extent is about 1 150 km and estimated population of about 131,859,731 inhabitants. (July 2006 estimate, World Fact book). Nigeria is bordered to the west by Benin, to the northwest and north by Niger, to the northeast by Chad and to the east by Cameroon, while the Atlantic Ocean forms the southern limits of Nigerian territory. Presently, the country has thirty-six states and Abuja as the Federal Capital Territory, the country is presently sub-divided into six agro-ecological zones and six geopolitical zones.

Data Description and Sources

The dependent variables for this study are the yield and the net revenue per hectare while the explanatory variables are the climate variables; the mean temperature measured in centigrade and mean rainfall in millimeter for the growing season of cassava are the main variables of interest. Other variables used include the socioeconomic attributes and the farm level attributes used for production. The explanatory variables used in the regression models were monthly mean rainfall and temperature for the growing season of cassava was obtained from Nigeria Meteorological Agency. The Nigerian Meteorological Agency is the primary source of Meteorological data in the country. The Nigerian Meteorological Agency (NIMET) has a weather station network that is covering almost all the agro ecological zone in the country. Presently there are about 38 meteorological stations located in each state across the country with two locations in Lagos state. The yield and the net revenue per hectare (dependent variables) used for the obtained for all the state producing cassava in Nigeria for the main period 2018-2019. Data for the total production of each crop per state and the total agricultural area per state for cassava was obtained from the General Household Survey (GHS). The (GHS) is the result of a partnership that the Nigeria Bureau of statistics (NBS) has established with the Federal Ministry of Agriculture and Rural Development (FMARD), it survey of over 5,000 households which was carried out annually throughout the country. Data for 1200 cassava farming households from wave 4 GHS data which covered the 2018 and 2019 pre and post planting activities was used for this research work.

Empirical Models

Two economic approaches were used for this study. The first approach is feasible generalised least square approach adopted by Just and Pope (1978) and Cabas *et al.* 2010 which was used to investigate the impact of climate change on the yield of cassava production, Regression models have the potential flexibility to assimilate both socioeconomic factors and the physiological determinants of yield and climate together. Going by this approach, in order to isolate the effects of climate from the effects of other confounding variables including modern inputs and the socioeconomic variables an appropriate production function is specified. Production risk, also known as stochastic production function developed by Just and Pope (1978) is often used by researchers to analyze effect of production inputs on crop yields. More formally, the effect of climate on crop yield is specified as follows:

$$Y = f(X,\beta) + h(X,\alpha)^{\frac{1}{2}}\epsilon \qquad 1$$

Y is crop yield; X is vector of independent variables; $\in$ is stochastic error term which is assumed to be independently and normally distributed with mean of zero and variance of one. The first term $[f(X,\beta)]$represents the effects of inputs on mean of crop output or yield, also known as the deterministic component of crop yield; and second term$[h(X,\alpha)^{\frac{1}{2}}\epsilon]$ represents the effects of inputs on variance of crop output or yield, as known as the stochastic component of crop yield. The symbols β and α represent vector of model μ deterministic and stochastic components respectively. The idea behind the above specification is that the effects of the independent variables on mean crop yield should not a-priori be tied to the effects of independent variables on the variance of crop yield.

The two methods commonly used in estimating the stochastic production function are the Maximum Likelihood (ML) methods and the Feasible Generalised Least Square approach (FGLS). ML method provides more efficient parameter estimates in smaller samples but for large samples as the case of this study the FGLS approach is preferable. The Feasible Generalised Least Square approach earlier used by (Cabas *et al*., 2010) was adopted in this study; it was used in estimating the effects of independent variables on the variance of crop yield

$$Y = f(X, \beta) + \mu \quad 2$$

$$ln\mu^* = h(X, \alpha)^{\frac{1}{2}} + \epsilon \quad 3$$

$$Y^* = f^*(X, \beta) + \mu^* \quad 4$$

$$Y^* = Y/\exp(h(X, \beta)^{\frac{1}{2}}); \; f^*(X, \beta) = f(X, \beta)/\exp(h(X, \beta)^{\frac{1}{2}}); \text{ and } \mu^* = \mu/\exp(h(X, \beta)^{1/2})$$

The symbol μ represents the heteroskedastic (non-constant) error term of the production function; Y^* and μ^* are the values of crop yield and the error term adjusted for heteroskedasticity, and exp. $(h(X, \beta)^{\frac{1}{2}})$ is the exponential function used to find the antilog of the heteroskedastic error term. Going by the procedure of Cabas *et al*. (2010) equation (1) is usually estimated in three steps using FGLS. The first stage of the FGLS estimation procedure regresses crop yield, Y, on the vector of explanatory variables, X, as in equation (2) with the resulting least squares residuals used on the various crop yield. At the second stage to estimate the marginal effects of explanatory variables on the variance of crop yield. In the second stage, the squares of residuals from the first stage are regressed on $h(X, \alpha)$as in equation (3). If equation (2) is not in logarithmic form, it is advisable to use the log of the squared residuals from the first stage rather the untransformed values. The third and final stage uses the predicted error terms from the second stage as weights for generating the FGLS estimates for the mean yield equation as in equation (4) The resulting estimator of β in the final step is consistent and asymptotically efficient under a broad range of conditions and the whole procedure corrects for the heteroskedastic disturbance term (Just and Pope, 1978; Cabas *et al*., 2010).

The second economic approach is based on Ricardian approach. The Ricardian method to evaluate economic impacts of climatic changes on cassava, which allows for capturing adaptations farmers make in response to climate changes. This method was named after David Ricardo (1772 – 1823) who made the original observation that land value would reflect its net productivity. The principle is shown explicitly in the following:

$$LV = \sum P_i Q_i (X_i F_i H_i Z_i G) - \sum P_x X \quad 5$$

Where LV is the value of land, Pi is the market price of crop i, X is a vector of purchased inputs (except land), F is a vector of climate variables, H is water flow, Z is a vector of soil variables, G is a vector of socio-economic variables and Px is a vector of input prices (Mendelsohn *et al.*, 1994).the model is based on the assumption that the farmer chose X so as to maximize land value per hectare given characteristics of the farm and market prices. Depending on whether data are available, the dependent variable can either be the annual net revenues or capitalized net revenues (land values). The annual net revenue was employed for this research, as data on land rent are not readily available because of absence of a well-functioning land market in Nigeria. This was earlier adopted by such as Eid *et al*., (2007) and Mendelsohn *et al*. (2000), Ajetomobi (2010) the standard Ricardian model relies on a quadratic formulation of climate.

Data used includes household attribute, soil types, level of education of household head, distance to input market, types of farming system, climate variables, farming experience, educational status. Five separate models were estimated with the regression analysis. The first model estimated the net revenue with climate variables alone both the linear and the quadratic form was regressed on net revenue. In the second model, socio-economic characteristics were integrated into the first model; the cost of input was added to the second model to make the third model. Sets of soil variables were added in the fourth model and the Zone dummy were added in the fifth model to take care of the soil variability. In this regression, farmers' household size, temperature and distance to input markets are expected to have a negative impact on net revenue per hectare. Variables that are expected to have a positive impact on net revenue per hectare include rainfall, years of education of the farmer, farm size.

$$\frac{NR}{ha} = \beta_o + \beta_1 F + \beta_2 F^2 + \beta_3 G + \beta_4 H + \beta_4 Z + \beta_5 C + \mu \quad 6$$

Where:

NR / *ha* represents net revenue per hectare,

F is a vector of climate variables that is rainfall and temperature

G is a set of socio-economic characteristics such as age, sex, years of formal education

H is a set of farm input variables like pesticides, fertilizers, farm size, and labour.

Z is a set of soil variables, and variables such as latitude longitude, elevation, distance to road, and distance to market

C is a vector of regional dummies to control for heterogeneity e.g. southeast zone dummy, north eat zone dummy,

μ is the error term.

Both linear and quadratic terms for temperature and rainfall are introduced. The expected marginal impact of a single climate variable on the land value and farm net revenue evaluated at the mean is:

$$E\left[\frac{\frac{dNR}{ha}}{df}\right] = b_{1i} + 2 * b_{2i} * E[f_1] \quad 7$$

The linear terms sign indicate the uni- directional impact of the independent variables on the dependent variable, the quadratic term reveals the non-linear shape of the net revenue of the climate response function. The net revenue revealed a U-shaped when the quadratic term is positive, and the function is hill-shaped when the quadratic term is negative. Agronomic studies revealed that crops consistently exhibit a hill-shaped relationship with annual temperature, although the maximum of that hill varies with individual crops. (Ajetomobi *et al.* 2011)

The marginal impact of seasonal climate variables was estimated for the model. This empirical approach includes both direct effect of climate on productivity and the local climate adaptation response taken by farmers. This approach was earlier adopted by Mendelsohn and Dinar, 2003, Kurukulasuriya and Mendelsohn (2008)

3. Results and Discussion

Description and Summary Statistics of Model Variables

Table 1 shows the summary of the model variables that were used for this study. The mean crop yields for cassava production is 1520.12kg/ha/year while the mean net revenue generated from cassava production is ₦ 45,794.24 per ha. The study selected five input variables (fertilizer, pesticide, herbicide, hired labour and machinery) indicating use of farm inputs as independent variables (Table 1). The average expenditures on farm inputs are ₦ 2178.06 ₦ 1914.08, ₦ 3039.64 and ₦ 5383.80 for pesticide, herbicide fertilizer, hired labour respectively. The average number of machinery used was 2 different types which is low. Other explanatory variables obtainable from the survey data are gender, age and years of formal education of farmers. Normal temperature during the effective growing season of cassava is about 27℃, these shows the level of warmness of the country. It was theorized that high temperature will have negative impact on cassava. Normal rainfall during effective growing season for cassava was about 741.43mm per month, since cassava needs wet conditions up to a certain threshold, it is expected that rainfall will have positive effect on the yields cassava.

Table 1: Description and Summary Statistics of Model Variables

Variables	Mean	Std. Dev.	Min	Max
Independent				
Yield(kg)	1520.12	6499.37	5.13	16200
Net revenue (₦)	45794.24	36627.88	-10900	259650
Dependent				
Rain(mm)	741.43	250.33	186.06	199.45
Temperature℃	27.23	0 .94	22.11	29.12
Age	43.83	13.02	25	81
Education|	9.33	4.64	.01	18
Pesticide (₦)	2178.06	2146.63	.01	27000
Herbicide (₦)	1914.08	2381.83	01	18000
Fertilizer (₦)	3039.64	3364.38	.01	24000
Labour (₦)	5383.80	8378.13	.01	48000
Farm size(ha)	6.26	10.29	.01	80
Elevation|	160.33	137.54	10	1070
Latitude	6.52	1.56	4.4	13.20
Longitude	7.27	1.55	2.97	13.63
Distance to road	5.48	6.65	.01	46.70
Distance to market	72.24	36.92	2	195.40

Source: Computed from wave 4GHS data and Nigeria Meteorological Agency data

Description of net revenue from Cassava Production in Nigeria by States

Figure 1 shows the average net revenue generated from cassava production for each state in Nigeria during 2018/19 production year. Cassava is a hardy crop that could have significant potential to adapt to climate change, and this made it possible for its wide cultivation across the country.

This study reveals that 82 percent of the States in the country are into cassava production. Sokoto, Borno and other states represented with dark brown colour are the states that are not into cassava production in Nigeria. The states presented with light brown colour are states that generated net revenue below thirty six thousand (₦ 36,000) Naira and average net revenue of eighteen thousand Naira (₦ 18,000) per annum from cassava production. The States denoted with white colour shows the states that generated net revenue between thirty six and fifty nine thousand Naira on cassava production. Niger and other states represented with light blue colour are states the where farmers generated net revenue that ranges between fifty eight thousand and seventy six thousand naira from cassava production. Nassarawa state as shown in Figure 1 is the only state where farmers generated average net revenue that is above seventy-six thousand from their cassava production.

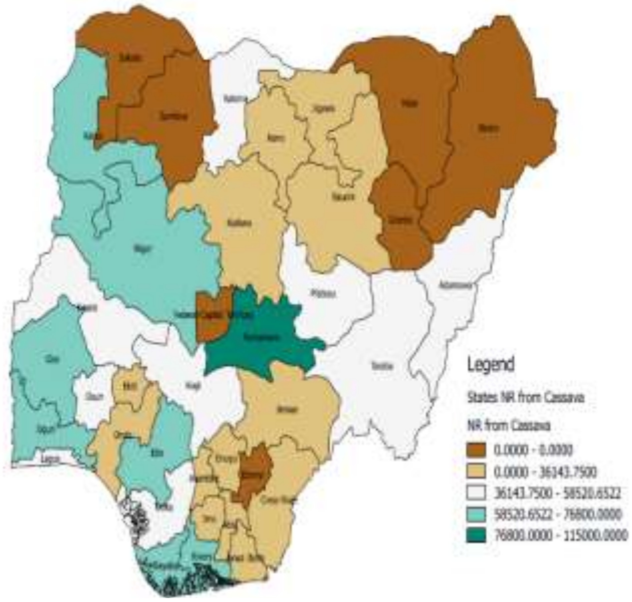

Figure 1: Spatial Distribution of Net revenue generated from Cassava Production in Nigeria

Climate change impact on cassava yield, yield variance and mean yield.

Temperature is observed to have a positive effect on the unadjusted yield and the adjusted yield of cassava, 1℃ increase in temperature will increase the unadjusted yield and the adjusted mean yield by 7.6kg/ha and 1.7kg/ha per year respectively. This is in line with the findings from Ajetomobi (2006), when temperature on the other hand had negative significant impact on the unadjusted yield of cassava and a positive significant impact on the yield variance and rainfall had a negative significant impact on the adjusted yield variance of cassava; however Chukwuone (2015) affirms that climate change affects the yield of cassava in Nigeria. Cassava mean yield increases as farmer's age increases; this is because older farmers will have more farming experience that will assist in the climate change coping strategies which will reflect on their yield. Farmer's years of formal education had an inverse relationship with cassava mean yield; this may be due to the fact that farmers with high level of education may take farming as their secondary occupation, thereby getting little of no attention from the farmer. Farm size has a direct relationship with the unadjusted and adjusted mean yield of cassava, the yield increases as the size of the farm increases. This is in agreement with the a-priori expectation and goes in line with the findings from Ajayi (2015), Nwaobiala and Nottidge (2015). Fertilizer has no significant impact on the yield of cassava, this is contrary to a-priori expectation, fertilizer is meant to boost the yield of cassava. This may because the fertilizer used short supply or got wasted during application which could result in the reduction of yield. The yield of cassava increased as Labor increased, this goes along with the a-priori expectation and in-line with Nwaobiala (2013) and Nwaobiala and Nottidge (2015). The R^2 for the models are 0.173, 0.129 and 0.994 for unadjusted mean, yield variance and adjusted mean yield respectively with the adjusted mean yield having the best goodness of fit. This means that 98% of the total variation in dependent variable (adjusted mean yield) was accounted for by the explanatory variables in the model.

Table 2: Impact of Climate Change on Cassava Yield

Variables	Unadjusted Mean Yield	Yield variance	Adjusted Mean Yield
Temperature	7.609(1.417)	-2.358 (2.376)	1.795***(0.048)
Rainfall	-0.456*** (0.138)	.576**(0.231)	- 0.008**(0.027)
Age	-0.219 (0.168)	-0.074 (0.282)	0.220***(0.041)
Education	0.006 (0.033)	0.043 (0.056)	-0.261***(0.012)
Farm size	0.069*** (0.023)	0.009 (0.038)	0.018***(0.001)
Fertilizer	-0.015 (0.009)	0.024 (0.016)	-0.170 (0.002)
Herbicide	-0.003 (0.009)	-0.032**(0.015)	0.014 (0.060)
Labor	-0.007 (0.010)	0.037**(0.017)	0.430***(0.142)
Pesticide	0.007 (0.011)	0.012(0.019)	-0.030***(0.070)
Constant	35.023***(4.969)	3.063(8.331)	10.056*(5.008)
R2	0.173	0.129	0.984
Adjusted R2	0.162	0.117	0.949
F Statistic	35.588*** (df = 9; 1106)	2.486*** (df = 9;1106)	48,958.220*** (df = 9;1106)

*** means significant at 1%, ** means significant at 5% and * means significant at 10%; the dependent variable is the log of crop yield; and Figures in parenthesis are standard errors of regression estimates. Source: Author's computation

Impact of climate change on Cassava Net Revenue

The impact of climate of climate change on the net revenue per hectare for cassava production is presented in Table 3. This was done using 5 models and added the zone dummy instead of the 3 models used by previous studies; the zone dummy included was to take care of soil variability. The first model estimated the net revenue with climate variables alone both the linear and the quadratic form was regressed on net revenue. In the second model, socio-economic characteristics of the farmers were integrated in the second model; the costs of inputs were added in the third model. In the fourth model geographic data were added while the zone dummy. Model 5 had the best goodness of fit; the climatic were variables showed varying impacts on net revenue for all the models.

In model 5, both linear and quadratic rainfall had a positive significant impact on the net revenue; the linear rainfall was significant at 1% significant level while the quadratic rainfall was significant at 5% significance level. Temperature had a positive significant relationship on the linear form, but the quadratic form had a negative significant relationship with the net revenue generated from cassava production this means that at the long run a degree rise in temperature led to reduction in the net revenue generated from cassava per hectare, this in line with the findings from Mbanasor *et al.* (2015). The socioeconomic characteristics considered for this study did not determine the net revenue generated from cassava production. The cost of pesticides and herbicides reduced the net revenue generated from cassava production; while the increase in cost of labour increased the net revenue which is contrary to expectation.

Farm size increased the net revenue, this is in line with a-priori expectation, the net revenue generated per hectare from cassava production increased as the more land was put into usage, i.e. the larger the farm the larger the net revenue generated. This contrary to stylized fact in the studies from Sridhar (2007) that small farms are more productive than large farms and its in-line with submission made by Cabas *et al*. 2010 . Increased longitude reduced the net revenue while elevation had no significant impact on the cassava net revenue. Contrary to expectation the farther distance of cassava farm to the road increased the net revenue, while far distanced market reduced the net revenue because it may increase the cost of transportation. The R^2 for model 5 is 0.58 which showed that 50.8% of the total variation in dependent variable (cassava net revenue) was accounted for by the explanatory variables in the model. The F - statistic of 9.969 indicated that the model statistically fitted at 1% level of significance and confirms the overall explanatory power of the model.

Table 3: Impact of Climate Change on Cassava Production

	Dependent variable:				
	Net Revenue				
	(1)	(2)	(3)	(4)	(5)
Rain	6.849***	5.705	44.380	27.660	46.123***
	(28.026)	(28.028)	(28.136)	(33.670)	(35.562)
Temp	8,493.491**	10,238.200	5,680.518	-3,093.230***	8,251.400***
	(3,142.230)	(3,109.490)	(3,630.320)	(3,951.770)	(5,550.420)
I(rain2)	0.024**	0.023	0.046**	0.029	0.039**
	(0.019)	(0.019)	(0.019)	(0.023)	(0.024)
I(temp2)	-364.252	-394.164***	-304.458	844.846	-372.691***
	(604.675)	(604.039)	(595.167)	(720.240)	(971.949)
Age		-215.811**	-198.068*	-194.522*	-154.377
		(104.585)	(102.475)	(102.767)	(99.366)
Education		-85.139	-72.233	-108.723	-112.916
		(293.610)	(288.611)	(286.605)	(276.352)
Sexmale		-1,212.712	-850.610	-287.870	-783.392
		(2,641.255)	(2,586.390)	(2,568.994)	(2,484.572)
Pesticide			-1.868***	-2.165***	-2.280***
			(0.594)	(0.592)	(0.572)
Herbicide			-0.911*	-0.898*	-0.948*
			(0.541)	(0.541)	(0.529)
Fertilizer			0.179	0.253	0.218
			(0.384)	(0.381)	(0.371)
Costlab			0.600***	0.559***	0.427***
			(0.151)	(0.151)	(0.148)

Table 3(Continuation)

Farmsize			439.531***	463.819***	401.786***
			(126.024)	(126.022)	(125.019)
Latitude				-43.369	243.059
				(1,257.522)	(1,506.060)
Longitude				-3,284.068***	-6,912.530***
Elevation				-23.665*	3.241
				(14.084)	(14.348)
Distoroad				546.724***	530.715***
				(200.085)	(193.558)
Distomkt				16.199	-41.214**
				(44.646)	(48.128)
ZoneN C					-47,586.830***
					(25,480.128)
Zone N_E					35,281.180***
		-			
Zone N_W					8,879.157
					(8,632.277)
					(10,939.940)
Zone S_E					-19,016.160***
					(6,749.214)
Zone S_S					3,919.403
					(7,130.869)
Zone S_W					-20,748.650***
					(7,542.544)
Constant	94,542.130***	80,049.170***	121,591.700***	894,565.200*	611,211.200**
	(425,475.200)	(424,939.300)	(418,395.800)	(505,283.100)	(652,150.400)
Observations	1116	1116	1116	1116	1116
R^2	0.185	0.291	0.438	0.465	0.531
Adjusted R^2	0.180	0.283	0.414	0.445	0.508
Residual Std. Error	5,125.840 (df = 748)	5,076.790 (df = 745)	4,277.800 (df = 740)	3,858.530 (df = 735)	2,599.820 (df = 730)
F Statistic	17.422*** (df = 4; 748)	10.711*** (df = 7; 745)	9.887*** (df = 12; 740)	8.532*** (df = 17; 735)	9.969*** (df = 22; 730)

Notes *** means significant at 1%, ** means significant at 5% and * means significant at 10%; Figures in parenthesis are standard errors of regression estimates

Source: Author's computation

Marginal Impacts of Climate Variables on Net Revenue

The marginal impact analysis was conducted to evaluate the outcome of an infinitesimal change in temperature and rainfall on cassava production. Table 4 revealed the result for the marginal effect; the fifth regression model in Table 3 was used to evaluate the marginal effect using the mean temperature and rainfall for the growing season of each of the crops.

The climate variables had marked different marginal effects on the net revenue per hectare cassava.. 1^0c increase in temperature reduced the net revenue of cassava by ₦ 5782 per hectare. While increase in rainfall increase the net revenue of cassava production. This result agreed with the findings from many studies in literature (Mendelsohn *et al.* 1994; Kurukulasuriya and Mendelsohn, 2007; Kabubo and Karanja, 2007) who reported that temperature is harmful for crop production.

Table 4: Marginal Effect of climate variables on net revenue per hectare

Variables	Net Revenue
Temperature	₦ -5782
Rainfall	₦ 1392

Source: Author's computation

Impacts of Forecasted Climate Scenario on Cassava Net Revenue

This section reveals the simulated impact of future climate change scenarios on the selected crops using the results from the estimated coefficients for net revenue function. Table 5 and Table 6 presents the simulation results, in these simulations, the climate variables are the only variables that are subject to change, all other variables was assumed to remain the same. Apparently this will not be the case over time. Technology, costs and other independent variables are bound to change with time and this will have incredible impacts on future farm net revenue of the crops. The essence of this exercise therefore is not to predict the future per se but simply examine the role climate may play in the future. In order to examine a wide range of climate outcomes, the approach rely on two sets of climate models; Canada Climate Change (CCC) and Parallel Climate Model (PCM) (Washington *et al* 2000) to examine the consequences of the climate change scenarios for 2050 and 2100.

This study tried several combinations and reports the following combinations; increase in temperature by 1.6 ℃ by 2050 and 6.7 ℃ by 2100 and rainfall reduction of 3.7 mm by 2050 and 18.4 mm by 2100 for CCC and PCM. The study predicted increase in temperature by 0.6 ℃ and 2.5 ℃ by 2050 and 2100 respectively; and increase in rainfall by 12.5 mm and 4.3 mm by 2050 and 2100 respectively. The simulated regression results for the net revenue cassava using CCC was shown in Table 5 while the PCM estimation is presented in table 6. The result showed marked disparities in the potential net-revenue from cassava production.. For CCC scenario, (the increase in temperature by 1.6 ℃ and 6.7 ℃ in 2050 and 2100) the study showed that the net revenue generated from cassava production will increase by 12.6% in 2050 and reduce by 25.48% by 2100. Furthermore, CCC scenario for rainfall by year 2050 and 2100, that is, reduction in rainfall by 3.7 mm and 18.4 mm respectively will cause reductions in the net revenue generated per hectare from cassava by 1.3% and 26.45%

In addition, the results for the PCM scenario for temperature (0.6 ℃ and 2.5 ℃) for 2050 and 2100 as presented in Table 6 shows that there will be 3.40**%** increase in the net revenue generated from cassava by 2050 and a reduction of -7.35% by 2100. Consequently, the scenario for rainfall for the two years reveals that there will be reduction in the net revenue generated per hectare in 2050 by 13.75% and increase by 7.85% by 2100; may be the increase in rainfall predicted may be in excess of the normal requirement of cassava and could lead to the rotting of the tuber and the prediction for 2100 may be the needed requirement for cassava plant.

Table 5: Climate Canadian scenarios

Climate variables	**Climate scenarios / %change in Net revenue per year**	
	2050	**2100**
Temperature	+1.6 ℃(12.6)	+6.7 ℃(-25.48)
Precipitation	3.7mm (-1.3)	-18.4mm (-26.45)

Source: Author's computation

Table 6: Parallel Climate Model

Climate variables	**climate scenarios / %change in Net revenue per year**	
	2050	**2100**
Temperature	+0.6 ℃(3.40)	+2.5 ℃(-7.35)
Precipitation	+12.5mm(-13.75)	+4.3mm (7.85)

Source: Author's computation

4. Conclusion

Having examined the impact of climate change on Cassava production in Nigeria, the study concludes that climate variable has impact on both the yield and net revenue of cassava production. The marginal impact of climate change on cassava production shows that the infinitesimal increase in temperature reduces the net revenue; however, infinitesimal increase in rainfall increases the net revenue

The potential impact of climate change shows that excessive increase in temperature and rainfall by 2100 will reduce the net revenue generated form cassava, it is therefore necessary to emphasize the adoption of appropriate and proactive adaptation along with mitigation measures. These may include planting drought tolerant/resistant varieties, adoption of sustainable land management practices and intensification of campaigns to promote healthy environmental practices among farmers and citizens. Government and other stake holders should assist farmers in promoting these adaptation measures and adopting new adaptation techniques that may be available, adaptation constraints should also be taken care of. The usage of fertilizer and pesticides among cassava farmers should be promoted

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