Consequences of Climate Anomalies on Groundnut Production in Nigeria

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***Abstract*. Groundnut is one of the important oil-bearing leguminous crops that contribute significantly to the food and nutrition security of the poor, particularly in Nigeria where it is widely grown. However, climate has an exquisite role in its production which often varied within the year across the globe. Using data for 1200 groundnut farming households from the General Household Survey wave 4 and historical data for temperature, rainfall and groundnut yield in Nigeria from 1981-2019 gotten from Nigeria Meteorological Agency and Food and Agricultural Organisation respectively; this study assessed the impacts of climate change on mean yield and Net revenue for groundnut production in Nigeria using Feasible Generalized Least Square and Structural Ricardian Approach respectively. This study revealed that 1 ℃ increase in temperature increased groundnut yield and net revenue by 3.316kg and ₦516.800 per hectare respectively while 1mm increase in rainfall reduced groundnut yield and net revenue by 0.505kg and ₦516.800 per hectare. The simulated impact of climate change on net revenue using Canadian Climate Change model revealed that the Net revenue generated from groundnut production will reduce by 8.36% with 6.7 ℃ increase in temperature and reduce by 0.60% with 18.4mm decrease in rainfall by 2100. Therefore, proactive and urgent measures should put in place to aid Nigerian groundnut farmers adapt to the present and looming threats of climate change effects on groundnut production.**

***Key words*: Climate change, Groundnut, Net revenue, Nigeria, Regression, Yield.**

I. INTRODUCTION

The globe is warming, and the climate is changing as demonstrated by upsurge in air and ocean temperatures, increased in ice and snow melt and increasing average sea level. The risk of extreme weather events is rising and these unpleasant trends are expected to continue (Chinwendu *et al*., 2017). The alteration in climate which is attributable to natural climate cycle and human activities had adversely affected agricultural productivity in Africa (Khanal, 2009). The existence of climate change in Nigeria was predicted by IPCC (2001) and established by Odjugo (2010) who confirmed the evidence of the rising in temperature, which was said to be significantly higher than the global mean (14 ℃). He reported that climate change had provoked drought and flood which triggered major land degradation in Nigeria. Several pieces of evidence also showed that each day brings fresh proofs of climate change and these effects include increasing temperatures, decreasing rainfall in the continental interiors, drought, desert encroachment, melting ice, extreme weather, floods, sea level rise, sinking of Islands, water scarcity, health and agricultural problems (Colls, 2008). Excessive increase in temperature results in low agricultural productivity and this may lead to diminution of soil nutrients and destruction of soil structure and organisms which contribute to the fertility of the soil. Ordinarily, rainfall can be considered to have positive effect on agricultural productivity except where it leads to flooding, erosion and leaching (Nelson *et al*., 2009).

The change in climate is caused by factors such as biotic processes, variations in solar radiation received by earth, plate tectonics and volcanic eruptions. This is perhaps the most serious environmental menace confronting mankind worldwide currently (Agawan and Pastiche, 2011; Shikuku *et al*., 2017). The effects of climate change in the Nigeria had been enormous including significant alteration in the rainfall regime and pattern. According to Idowu *et al*. (2011), increasing variation in temperature and humidity had led to increase in pests and diseases infestation, natural disasters like drought, floods and storms which adversely affects crop production which groundnut production is not an exception. Ajetomobi *et al*. (2011) submitted that the drastic changes in rainfall pattern and rise in temperature in Nigeria will introduce unfavourable growing conditions into the cropping calendars thereby altering the growing seasons of crops which could successively decrease crop productivity. Reduction in crop production will have economic consequences on farm profitability, agricultural supply and demand, trade and price.

Groundnut (Arachis hypogaea, L.), also known to as peanut, is one of the world's principal oil seed crops, which originated from South America, and is now widely cultivated throughout the tropical, sub-tropical and the warm temperate climatic zones (Sogut *et al*., 2016). Groundnut was one the popular commercial crop in Nigeria which accounted for 70% of total Nigeria earnings between 1956 and 1967, but earnings declined between 1955 and mid 1980s due to combine effect of drought and disease. Historically, the production of groundnut in Nigeria started about the year 1912 as a response to its high world prices (Salma *et al.*, 2018). Nigeria had since then maintained a prominent place amongst the world producers of it. Nevertheless, Nigeria assumed the prominent position of the world's leading exporters of groundnut in the 1950s (NAMC-DAFF, 2016). In the 1960s, Nigeria being the world's largest groundnut producer and exporter recorded a production of 500 000 metric tons at that period (DFID, 2008)., the production however fell by almost half the 1973 figure in less than a decade, due to a combination of the drought of 1974/75 production season, which brought with it aphid infestation led to huge losses for both farmers and dealers of more than 750 000 hectares in groundnut fields and the incidence of oil boom in Nigeria became a well-known issue about that same time (Ntare *et al*., 2014). Groundnut can also be described as an economic crop due to its diverse economic importance and uses; the plant is a significant soil fertility conserver through its biological activities in nitrogen fixation (Mofya-Mukuka and Shi- pekesa, 2013). The haulms can serve as an important fodder for ruminant live- stock, especially sheep and goat (Li *et al*., 2013). The nuts could be consumed roasted, boiled or processed as confectionary, snack nuts, peanut butter or as cookies. They are therefore consumed primarily when roasted or as oil (Government of Gujarati, 2017). Groundnut agriculture has been perceived over time to be sensitive to short-term changes in weather, as well as to seasonal, annual and longer- term changes and variations in climate (Khanal and Mishra, 2017). Climatic risk and variability in weather, is therefore one of the important factors affecting groundnut production and land allocation (Mofya-Mukuka and Shipekesa, 2013). Eregha *et al*. (2014) also submitted that climate change is regarded as one of the greatest challenges of the 21st century and has posed great threats to agriculturally dependent economies. As a result of changes in the climate variables in Nigeria, the Northeast region of country which is known for large groundnut production is increasingly becoming an arid environment at a very fast rate occasioned by the fast reduction in the amount of surface water, flora and fauna resources on the land (Ayinde et al., 2011).

Furthermore, Iizumi *et al*. (2014) indicated that climate change and variability has an adverse impact on groundnut production, which will by extension affect the global food production and food security, all things remaining equal. However, (Kasimba, 2012) submitted that groundnut production faces several production constraints which include droughts and erratic rainfall patterns, its productivity is also said to be affected by poor local markets, poor pricing structure and lack of lucrative export markets. Nelson *et al*. (2009) submitted that the poor price structure is also a deterrent to increase its productivity because groundnut production is a labour-intensive crop and the low prices means that farmers cannot make much profit and therefore, cannot increase their scale of production. The export market creates demand and hence, drives the production of groundnut (Minde *et al*., 2008). The above submissions motivated this study, previous studies on groundnut production across the globe and within the country were done to investigate groundnut profitability, economic efficiency and so on. Few studies that were conducted on climate change impact on groundnut in Nigeria were often done with other crops and most of the times they were conducted on to cover a state or a zone. This study was carried out to cover the federation and the objectives were to (1) show the trend of groundnut yield from 1981-2019 (2) reveal the net revenue generated from groundnut production by each state (3) analyze the effect of climatic change on yield and net revenue of groundnut production. (4) Investigate the potential consequences of climate change on groundnut production by 2050 and 2100 using Canada Climate Change (CCC) and Parallel Climate Model (PCM)

II. MATERIALS AND METHODS

Study area

This study on the impact of climate change on groundnut was carried out in Nigeria, Nigeria is located in the tropical zone of West Africa and it's severely affected by the change in climate because of its location. Land cover in Nigeria ranges from thick mangrove forests and dense rain forests in the south to a near-desert condition in the north eastern corner of the country. Total cultivable area is estimated at 61 million ha, which is 66% of the total area of the country. Nigeria has different biophysical characteristics, agro-ecological zones, socio-economic conditions and ethnic nationalities. 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

Groundnut yield and the net revenue per hectare are the dependent variables for this study, the climate variables are the independent variables. The mean temperature measured in centigrade (℃) and mean rainfall in millimeter (mm) for the growing season of groundnut are the main variables of interest. Other variables that were used for the study are the socioeconomic attributes and the farm level attributes used for groundnut production.

The monthly mean rainfall and temperature for each state was obtained from Nigeria Meteorological Agency. The Nigerian Meteorological Agency is the primary source of Meteorological data in the Nigeria. The station has a weather station network covering virtually all the agro ecological zone in the country. At present there are about 38 meteorological stations located in each state across the country with Lagos state having two locations. Data for the total groundnut production, cost of inputs, total land area, yield per hectare and so on for groundnut for each state which was used to generate the yield and the net revenue per hectare (dependent variables) used for the study was obtained from the General Household Survey data (GHS). The GHS data 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 5,0000 households which was carried out annually throughout the country. Data for 1200 groundnut farming households which covered the 2018 and 2019 pre and post planting activities was used for this study. The data used for plotting the yield trend was obtained from FAOSTAT.

III. ANALYTICAL APPROACHES

Feasible Generalised Least Square (FGLS) and the Structural Ricardian approach were the two main analytical approaches used for this study. FGLS adopted by Just and Pope (1978) and Cabas *et al.* 2010 was used to investigate the impact of climate change on the yield of groundnut production, the regression models have the potential flexibility to integrate both socioeconomic factors and the physiological determinants of yield and climate together. In order to segregate the effects of climate from the effects of other confounding variables including modern inputs and the socioeconomic variables, an appropriate production function was specified. Production risk, also known as stochastic production function developed by Just and Pope (1978) was used to analyze effect of production inputs on crop yields. More formally, the effect of climate on crop yield was specified as follows:

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

Y is crop yield; X is vector of independent variables; ϵ is stochastic error term which was assumed to be independently and normally distributed with mean of zero and variance of one. The first term $[f(X,\beta)]$signifies the effects of inputs on mean of crop yield, also known as the deterministic component of crop yield; and second term$[h(X,\alpha)^{1/2} + \epsilon]$ 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 groundnut yield.

The Feasible Generalised Least Square approach estimated the effects of independent variables on the variance of crop yield

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

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

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

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

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

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 were regressed on $h(X,\alpha)$as in equation (3). If equation (2) the log of the squared residuals from the first stage was used rather the untransformed values. The third and final stage used 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 was based on Ricardian approach. The method was used to evaluate economic impacts of climatic changes on groundnut, which allowed for capturing adaptations farmers made 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:

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

Where LV is the value of land, P_i 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 P_x 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 were 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*. (2010), Ajetomobi (2010).

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 Precipitation, years of education of the farmer, farm size. The standard Ricardian model relies on a quadratic formulation of climate as stated below:

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

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 were introduced. The expected marginal impact of a single climate variable on the land value and farm net revenue evaluated at the mean is:

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

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, 2009, Kurukulasuriya and Mendelsohn (2008)

IV. RESULT AND DISCUSSION

Description of Net Revenue from Groundnut Production in Nigeria by States.

The description of net revenue from groundnut production in Nigeria by states is revealed in Figure 1. According to Taru *et al.* (2008), major groundnut zones in Nigeria are the Sudan and Northern Guinea Savanna where the soil and agro-climatogical conditions are favourable. It requires 500 to 1600 mm of rainfall, which may last for 70 to 200 days of rainy season in the Sudan savanna. From Figure 1, farmers from 15 States of the 36 states (states depicted with white) were not into groundnut production according to this study. Farmers in Adamawa state generated average net revenue of one hundred and ten thousand Naira from groundnut production (₦ 110, 000) which was the highest among the states

The net revenue varied from eighty two thousand to one hundred and forty-two thousand Naira (₦ 82, 000 - ₦ 142, 000). Groundnut farmers in Kogi, Kaduna, Cross River, Kano, Enugu, and Imo states generated average net revenue of seventy thousand (₦ 70,000), the net revenue varies from (₦ 57,000 and ₦ 83,000). Groundnut farmers in Taraba, Plateau, Gombe, Jigawa, Katsina and Kebbi states generated between thirty one and fifty-seven thousand naira (₦ 31,000 and ₦ 57.000) as net revenue per annum and the average of forty-four thousand naira (₦ 44,000). Farmers in Taraba and other states depicted with teal green colour the farmers generated net revenue below ₦ 31,000 from groundnut production and the least in the country.

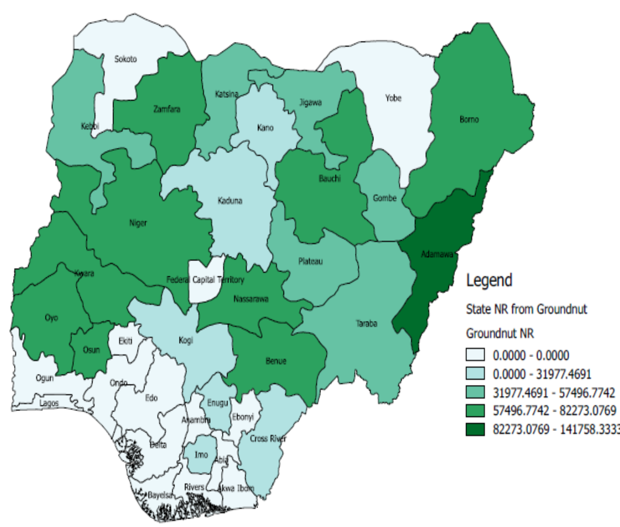

Figure 1: Spatial distribution of Net revenue generated from Groundnut production

Source: Author 2020(computed from wave 4 GHS data)

Trend of Groundnut Yield from 1981-2019 in Nigeria

The yield trend for groundnut production for the years revealed as seen in Figure 2 of the study revealed a bell shape. Groundnut yield rose steadily from 8500 hg/ha in 1981 to 1600 hg/ha in 1990 which was the peak for the trend for the years reviewed for the study. There was a gradual fall in the yield of groundnut from 1990 through 1999 and started rising till it got to the peak in 2006 and then the yield dropped till 2013 after which it there was an increase in yield 2015. Another gradual fall in the yield could be noticed in 2015 till 2019, the fluctuation in the trend of groundnut yield could be linked to the presence of variability in climate which could lead to infestation pest and diseases and eventually reduce production.

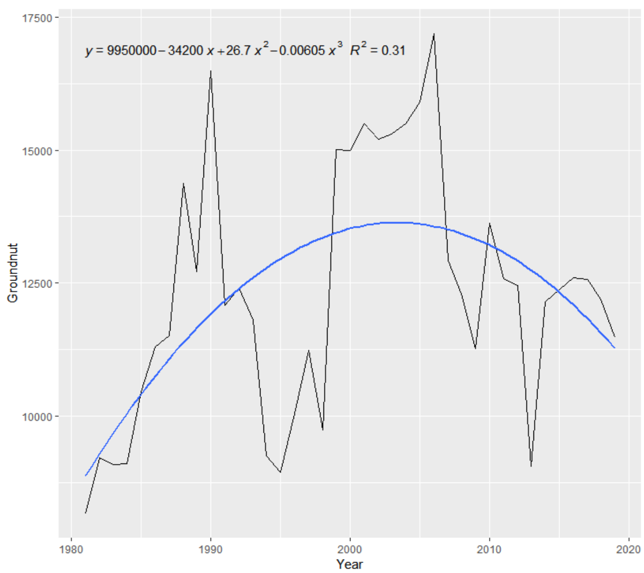

Figure 2: Trend of Groundnut yield in Nigeria from 1981-2019

Impact of Climate Change on Yield of Groundnut Production in Nigeria

The impact of climate anomalies on the yield of groundnut production was revealed in Table 1, this was done using the FGLS. It was estimated in three stages, the ordinary least squared regression (OLS) or the unadjusted mean yield, crop yield variability and the adjusted mean yield. The OLS was done by regressing groundnut yield on the sets of independent variables selected for this study. The OLS result revealed that, rainfall had an inverse relationship with unadjusted yield of groundnut, while a unit increase in temperature increased the unadjusted mean yield of groundnut, increase in the farmers' years of formal education increased the unadjusted yield of groundnut, additional use land put into cultivation increased the unadjusted yield of groundnut. This is in line with the findings from the study by Taru *et al.* 2008); their study revealed that increased farm size increased the yields groundnut, The coefficient of fertilizer is negative groundnut (p=0.01) respectively this indicates an inverse relationship between fertilizer and the yields; this implied that, the application of additional fertilizer to groundnut plant reduced the yields This may be due to the excessive use of fertilizer which may increase the growth of weed at the expense of the crops and also in some cases where fertilizers were wasted during application. Groundnut yield increased as more pesticides were applied. This showed that pest infestation may reduce groundnut yield. Furthermore, the R^2 for the OLS model is 0.209, meaning that the 20% of the variation in the unadjusted mean yield of groundnut is explained by the explanatory variables.

Third stage of the FGLS techniques showed that temperature had a direct relationship with the adjusted yield of groundnut; the higher the degree of temperature, the higher the adjusted mean yield groundnut while rainfall reduced the adjusted mean yield of groundnut. This findings is agreement with the finding by Stanciel *et al.* 2000 and Shwethal *et al.* (2017) that increase in temperature increased plant height, root length, shoot length, stem length, leaf area and total biomass of groundnut. Farmers' age had a negative statistical significant impact on the adjusted yield of groundnut; increase in farmers' years of formal education, farm size and cost of labour and fertilizer caused increase in kg/ha of adjusted yield of groundnut. There was an improvement in the explanatory power of the mean crop yield. The regression improved with stronger goodness of model fit; the R^2 of this model is higher the first two models.

Table 1: Impact of climate change on yield of groundnut in Nigeria

Variables	Unadjusted	Yield Variance	Adjusted
Mean Yield Mean Yield Temperatu re	2.975***	-1.226	3.316***
	(1.074)	(1.896)	(0.085)
Rainfall	-1.273***	0.377	-0.505**
	(0.222)	(0.392)	(0.063)
Age	-0.139	-0.067	-0.578***
	(0.204)	(0.361)	(0.065)
Education	0.062	-0.004	0.025***
	(0.023)	(0.041)	(0.026)
Farm size	0.235***	0.072	0.094***
	(0.033)	(0.058)	(0.005)
Fertilizer	-0.038***	-0.021**	0.0102***
	(0.010)	(0.018)	(0.0201)
Cost of labor	0.007	0.004	0.1702***
	(0.027)	(0.048)	(0.062)
Pesticide	-0.200*	0.066	0.1703
	(0.111)	(0.197)	(0.0184)
Constant	5.612	0.933***	0.149***
Observations	1,200	1,200	1,200
R^2	0.209	0.115	0.899

Adjusted R^2	0.191	0.106	0.848
Residual Std. Error	1.247 (df = 1190)	2.201 (df = 1190)	1.729 (df = 1190)
F Statistic	11.839*** (df = 9; 1191)	0.706 *** (df = 9; 1191)	70,100.600*** (df = 9; 1191)

*** 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 Groundnut Net Revenue**.**

Table 2 showed the impact of climate change on net revenue generated from the production groundnut. Net revenue per hectare was calculated as the difference between gross crop revenue and crop expenses (fertilizer, pesticide, hired labour,) divided by the number of hectares of harvested area. The climate variables are monthly mean temperature and monthly mean rainfall during growing season for different agro-ecological zone across the country. The non-climatic independent variables include age, gender and years of formal education of the farmers, farm size, education, costs of inputs. Five model were used for the analysis

The fifth model has the best goodness of fit; both linear and quadratic temperature had a significant impact on groundnut net revenue. The linear temperature had a positive impact on the net revenue while the quadratic temperature had a negative impact on net revenue which means that temperature has damaging effect on the groundnut net revenue at the long run. Increase in temperature reduced the net revenue by ₦809 per hectare, (P<0.10). This study showed that rainfall had a positive significant impact on the groundnut net revenue; this is contrary to the findings by Eregba *et al.* (2014) and Shwetha *et al.* (2017). Their findings showed that increase in rainfall reduced the net revenue generated from groundnut production in Nigeria.

Increase in farmers' level of education increased groundnut net revenue and vice versa. Farmers' age and gender does not have any significant relationship with groundnut net revenue, this means that either the farmer is young or older is not expected to have effect on the net revenue generated from groundnut production in Nigeria. The result revealed that more net revenue will be generated as additional land is put into use; this agrees with the findings by Taru *et al* (2008). Increase in the cost of pesticide reduced groundnut net revenue; groundnut net revenue increased as the cost fertilizer increases; this explained that additional fertilizer helped to improve groundnut productivity. Distance of the farm to road had a negative significant impact on the net revenue; this showed that the farther the distance of the farm the more the cost to be incurred on transportation. Only the north western dummy had significant impact on net revenue. This means the north western part of the country favours the productivity of groundnut. The R^2 indicates that 75.1% of the variations in net revenue were explained by explanatory variables

Table 2: Impact of Climate Change on Groundnut Net revenue

	Dependent variable:				
	Net revenue				
Variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Rain	-83.893	-62.099	-80.474	-118.499	-313.438
	(78.780)	(78.242)	(78.395)	(78.756)	(190.971)
Temp	592.300*	5,774.290	321.960	477.250	516.800*
	(457.760)	(589.220)	(406.640)	(523.360)	(312.280)
I(rain2)	0.026**	0.008	0.012	0.053***	0.273**
	(0.062)	(0.061)	(0.061)	(0.061)	(0.198)
I(temp2)	-243.143***	-975.239**	-1,056.977	-565.949	-834.020*
	(826.535)	(843.380)	(878.472)	(860.038)	(702.873)
Age		93.447	63.369	-12.252	-97.459
		(220.351)	(219.077)	(215.315)	(212.098)
Edu		1,908.048***	1,697.237***	1,094.147**	824.892**
		(540.033)	(542.281)	(544.581)	(537.882)
Sex		-2,554.378	-4,581.432	-5,271.967	-2,093.436
		(5,681.409)	(5,654.421)	(5,504.555)	(5,485.874)
Pesticide			0.109	-0.302***	-0.341***
			(1.781)	(1.748)	(1.719)

Fertilizer			-1.802**	-2.241***	1.600**
			(0.779)	(0.770)	(0.773)
Costlab			0.231	0.428	0.277
			(0.449)	(0.444)	(0.439)
Farmsize			1,781.771**	1,818.806***	1,294.681*
			(703.298)	(693.908)	(757.061)
Lat				-4,938.892**	-2,740.340**
				(2,359.757)	(2,422.017)
Lon				10,043.660***	9,458.993***
				(2,148.062)	(2,521.865)
Elevation				32.292	15.363
				(24.350)	(24.842)
Distoroad				-505.460	330.887***
				(353.350)	(351.343)
Distomkt				26.513	78.149
				(81.864)	(83.313)
zoneN_C					37,578.130
					(18,342.313)
zoneN_E					-3,561.069
					(14,851.970)
zoneN_W					26,887.180**
					(13,105.320)
zoneS_E					73,733.960
					(47,851.910)
zoneS_S	**Table 2: Impact of Climate Change on Groundnut Net revenue(Continuation)**				-16,223.100
					(14,694.300)
zoneS_W					18,003.090
					(20,819.400)
Constant	135,527.600***	6,008.400***	616,433.900***	288,034.900***	218,522.000*
	(527,264.000)	(539,596.600)	(564,896.700)	(552,194.400)	(362,084.000)
Observations	1200	1200	1200	1200	1200
R^2	0.204	0.405	0.502	0.591	0.751
Adjusted R^2	0.112	0.340	0.492	0.513	0.714
Residual Std. Error	8,080.240 (df = 1196)	7,408.890 (df = 406)	6,844.630 (df = 401)	5,002.520 (df = 396)	3,856.650 (df = 391)
F Statistic	2.130* (df = 4; 1196)	3.049*** (df = 7; 1193)	2.906*** (df = 12; 1188)	4.091*** (df = 17; 1183)	4.299*** (df = 22; 1178)

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 2020

Marginal Impacts of Climate Variables on Groundnut Net Revenue

The marginal impact analysis of climate change on groundnut net revenue was conducted to evaluate the outcome of an infinitesimal change of temperature and rainfall on groundnut production in Nigeria. Table 3 displayed the marginal impacts of climate variables on net revenue groundnut production. The fifth regression model above was used to evaluate the marginal effect using the mean temperature and rainfall for the growing season of groundnut The climate variables had marked different marginal effects on the net revenue per hectare of groundnut.

1^0c increase in temperature reduced the net venue of groundnut ₦ -14180 per hectare 1mm increased in rainfall increases their net revenue by ₦ 2594. This result agreed with the findings from many studies in literature (Kurukulasuriya and Mendelsohn, 2006; Kabubo and Karanja, 2007) who reported that temperature is harmful for crop production.

Table 3: Marginal Effect of Climate Variables on Net Revenue per Hectare

Variables	Groundnut
Temperature	₦ 14180
Rainfall	₦ 2594

Source: Author's computation 2020

Impacts of Potential Climate Scenario on Groundnut Net Revenue

The Potential impact of climate change on groundnut net revenue is revealed in this section. The simulated regression model was used to achieve this; Table 4 presents the simulation regression results. In the simulation model, the climate variables are the only variables that are subject to change, all other variables was assumed to remain the same. This definitely will not be the case over time, Independent variables like technology, costs and others are bound to change with time and this will have incredible impacts on the net revenue in the future. The essence of this exercise therefore is not to predict the future per se but simply to examine the role climate may play in the future. In order to examine a wide range of climate outcomes, the approach relied 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.

Several combinations were tried by this study and the following combinations was reported; 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 groundnut using CCC and PCM was shown in Table 4. The result showed marked disparities in the potential net-revenue from groundnut 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 groundnut production will increase by 9.87% in 2050 and reduce by 8.36% 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 increase the net revenue generated per hectare from groundnut by 3.36% and reduce the net revenue by 0.60%

In addition, the results for the PCM scenario for temperature increase by 0.6 ℃ and 2.5 ℃ for 2050 and 2100 as presented in Table 4 showed that there will be 3.67**%** increase in the net revenue generated from groundnut by 2050 and reduction of 15.65% of net revenue by 2100. Consequently, the scenario for rainfall for the two years reveals that there will be increase in the net revenue generated per hectare in 2050 by 0.62% and reduction by 0.14% by 2100.

Table 4: Impacts of Forecasted Climate Scenario on groundnut Net Revenue

Climate variables	Climate scenarios / %change in Net Revenue /year	
	2050	2100
	Climate Canadian scenarios	
Temperature	+1.6 ℃(9.87)	+6.7 ℃(-8.36)
Precipitation	3.7mm (3.36)	-18.4mm (-0.60)
	Parallel Climate Model	
Temperature	+0.6 ℃(3.67)	+2.5 ℃(-15.65)
Precipitation	+12.5mm (0.62)	+4.3mm (-0.14)

Source: Author's computation 2020

IV. CONCLUSION

With the aid of feasible generalised least square and Ricardian cross-section approaches this study explored consequences of prevailing climate anomalies on groundnut productivities in Nigeria. It was found out that rainfall increase had a negative consequence on the yield and net revenue while rise in temperature increased groundnut yield and net revenue. The simulated future consequence of climate change on the groundnut net revenue revealed that there will be reduction in net revenue generated from groundnut production if the temperature increases. The study therefore recommend that proactive and urgent measures like irrigation, planting of drought resistant groundnut species should be put in place to assist Nigerian groundnut farmers adapt to the present and looming threats of climate change effects.

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