Analysis of Climate Change Impact on Yam Production in Nigeria

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***Abstract*: The study was designed to investigate the relationship between climate variables (rainfall and temperature) and yam production across Nigeria. The objectives of the study were to estimate the impact of climate change on yield, and net revenue of yam agriculture in Nigeria and to investigate the potential impact of climate change on yam agriculture in 2050 and 2100 using Parallel Climate Model and the Canadian climate change Model. Data for 1200 yam farming households were sourced from general household survey wave 4 and that of climate variables from 1981 to 2019 collected from Nigeria Meteorological agency. Feasible generalised least square and Ricardian regression models were used to determine the relationship between climate variables, yield and net revenue of yam agriculture. Simulated Ricardian regression models were used to investigate the potential impact of climate change on yam net revenue in 2050 and 2100. The result showed that rainfall had a positive relationship with both yield and net revenue while temperature had a negative relationship with the yield and net revenue, and the infinitesimal change in temperature reduced net revenue while the infinitesimal change in rainfall increases the net revenue. The potential impact of climate change on yam agriculture showed a detriment on the net revenue of yam agriculture by 2100**

***Key words*: Climate, Ricardian, regression, yam, Nigeria, Impact.**

I. INTRODUCTION

Climate change is not a new phenomenon to many people in the sense that the subject has attracted significant attention in recent years due to its venomous effects on ecosystem. Until recent time, the effects of man's activities on climate variability were perceived as insignificant and so climate change was largely taken for granted. Conversely, it has been evidently established that climate change is not an issue to be trivially managed; its veracity is seriously affecting the earth already, especially challenging agricultural productivity and food security across the globe even the developed countries are not exempted and thus, it requires urgent attention. However, the climate change impact on agricultural productivity may either be positive or negative; nevertheless, several empirical studies show that the latter outweighs the former Nzeh and Oboh (2011), Enete *et al*. (2011). In Nigeria and Africa as a whole, the pattern of rainfall has already been altered, affecting the commencement of the planting season and resulting in poor harvest yields. The unreliable rainfall (changes in variance and seasons of rainfall) has been observed since 2012; it is now very common for south western part of the country to receive rainfall that is not sufficient for crop production (drought), while the northern part receives too much rainfall than the normal crop requirement, which leads to floods. Some parts in the east experience early or late seasons of rainfall which differ from the usual seasons; both conditions (flood and drought) are not good for agricultural practices. According to Ajetomobi *et al*. (2011), 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 productivity will have economic consequences on farm profitability, agricultural supply and demand, trade and price.

Agriculture which includes crop production, livestock production and forestry still remains the backbone of Nigeria economy, its contribution to the country's GDP makes it essentially important to the growth of the country. It is the main sector accountable for providing income and employment to rural dwellers employing 90% of the rural poor and nearly 70% of the total labour force, and generates 90% of non-oil export revenues (Federal Ministry of Agriculture and Water Resources (FMAWR), 2008). The recent GDP analysis shows that the agricultural contribution to the Nations GDP is on decline, In 2005 41.2 percent of the Nations GDP was contributed by Agriculture, a sectorial scrutiny in 2006 of the real GDP showed that the agricultural sector contributed to about 41.7 percent of the GDP compared with 41.2 percent in 2005, analysis of the real GDP performance in 2007 shows that agricultural sector contributed the largest share, 42.2%, compared to 41.7% in 2006 (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 several factors in which variation in climate could be major. The Nigerian Agriculture cultivates eleven major crops which are usually grown in many parts of Nigeria, which are: yam, cassava, sorghum, millet, rice, maize, beans, dried cowpeas, groundnuts, cocoyam, and sweet potatoes, out of which yam was chosen for this study .

Yam is an annual tuber and monocot plant, it is widely cultivated as food and cash crop in Nigeria, It belongs to the genus "Dioscorea" and the family "dioscoreacea". The food plant comprises of 600 species out of which ten species produces edible tubers and only six are cultivated in Africa

(Musa *et al.* 2011). Yam is a major staple food for the majority of Nigerians, as a root crop, it plays major role in the diet of the people in West Africa generally and in Nigeria in particular. Though, there has been a decline in yam production relative to cassava and rice in Africa, yam is such a preferred staple food that, bearing in mind population increases, demand will remain and the absolute production will rather increase (Srivastava and Gaiser, 2008).

Babaleye (2003), observes that yam contributes over 200 dietary calories per capita daily for more than 150 million people in West Africa and also serving as an important source of income to the people. Yam can also be used for livestock feed and industrial starch manufacture, however, Yam production in Nigeria seems to be the most vulnerable by the deleterious effects of climate change. it is becoming more expensive and relatively high-priced in urban areas as production growth has not kept pace with population growth which has caused demand to exceed supply Elijah *et al.*, (2018). Furthermore, the production of yam like every other crop is affected by factors like climate among many others. Climate is the most crucial factor, which determines the flora of the natural vegetation, the characteristics of the soils, the crops that can be grown, and the type of farming that can be practiced in any region. Therefore, ability to meet the future demand may centre on proper assessment of medium- and long-term yam production vulnerability to climate change and the adaptation measures taken by the concerned stake-holders. This study estimates the impact of climate change on yam agriculture across Nigeria using both yield and net revenue, the potential impact of climate change on yam agriculture in 2050 and 2100 using both Parallel climate model and the Canadian climate change Model which had not been done in previous studies. This study also reveals the distribution of the net revenue generated from yam production across the 36 states of the federation.

II. MATERIALS AND METHODS

Study area

This study on the impact of climate change on cassava was carried out in Nigeria, it is located in the tropics and it's one of the countries that are severely affected by the change in climate change because of its location. 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. Land cover 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

The dependent variables for this study are yield and the net revenue per hectare while the climate independent variables are; the mean temperature measured in centigrade and mean rainfall in millimeter for the growing season of yam are the main variables of interest. Other variables that were used for the study include the socioeconomic attributes and the farm level attributes used for yam production. The independent variables used in the regression models were monthly mean rainfall and temperature for the growing season of yam 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 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. The yield and the net revenue per hectare (dependent variables) used for the study were obtained for the entire yam producing state in Nigeria for the selected period of study 2018-2019. Data for the total production of yam per state and the total agricultural per hectare was obtained from the General Household Survey data (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 yam farming households selecting 200 yam farming households per state from wave 4 GHS data which covered the 2018 and 2019 pre and post planting activities was used for this research work.

Analytical Approaches

Two main analytical approaches were used for this study. The feasible generalised least square and the Ricardian cross section approach. The feasible generalised least square approach was 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 yam production, the regression models have the potential flexibility to integrate both socioeconomic factors and the physiological determinants of yield and climate together. Going by this approach, 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 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:

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

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 $[f(X,\beta)]$signifies 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

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

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

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

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

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

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 yam, 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 choses 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 include household attribute, soil types, level of education of household head, distance to input market, types of farming system, climate variables, farming experience, and 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, and 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, and

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:

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

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 dome-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)

III. RESULTS AND DISCUSSION

Description and Summary Statistics of Model Variables

The summary statistics of the model variables used for this study is presented in Table 1. Data for 1200 farming households planting yam solely were used for this study, the yield and net revenue generated from yam production were the dependent variables for this study. The mean yields for yam production is 3248.04kg/ha/year while the mean net revenue generated from yam production is ₦ 64985.64 per ha. Five input variables (fertilizer, pesticide, herbicide, hired labour and machinery) indicating use of farm inputs were selected and use as independent variables (Table 1). This category of non-climate variables are hypothesized to have positive effect on yam yields and net revenue since enhanced use of fertilizers, pesticides, herbicide, hired labour and machinery are likely to increase yam yield. This study shows that yam farmers in Nigeria do not effectively use farm inputs for various reasons which financial position may be the major. The average expenditures on farm inputs are ₦ 2405.22, ₦ 2672.36, ₦ 3618.47 and ₦ 7841.26 per hectare 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. Age and education is assumed to have positive effect on yam yield. Average age of cassava farmers in Nigeria is about 43 years who are mostly male; farmers have average of 9 years of formal education which is hypothesized to assist their methods of farm operations. Though yam is widely grown by food crop farmers across the country, farmers cultivate on minimum of an average of 8 hectares, while the maximum land used for cultivation was 80hectares. Average temperature during the effective growing season of yam for this study is 27.73 ℃, this shows the level of warmness of the country. It was speculated that high temperature will have negative impact on yam production. Normal rainfall during effective growing season for yam was about 741.43mm per month, since yam production needs wet conditions up to a certain threshold, it is expected that rainfall would have positive effect on the yields of yam.

Table 1: Description and Summary Statistics of Model Variables

Variables	Mean	Std. Dev.	Min	Max
Dependent variables				
Yield(Kg)	3248.04	10103.16	0.345	243000
Net Revenue(₦)	64985.64	51464.17	-38200	689900
Independent Variables				
Rain(mm)	733.18	242.32	186.06	1199.45
Temp(℃)	27.73	1.39	21.85	29.86
Age(yrs)	43.99	13.84	25	81
Education(yrs)	9.27	4.71	.01	18
Pesticide(₦)	2405.22	1933.09	.01	26000
Herbicide(₦)	2672.36	2545.48	.01	33000
Fertilizer(₦)	3618.47	4302.49	.01	35500
Labour(₦)	7841.26	10780.56	.01	75000
Farm size(Ha)	5.28	8.37	.01	80
Distance to Road(Km)	6.37	7.31	.01	47.5
Distance to Market(Km)	76.56	37.66	2.9	214.3
Elevation(m)	185.48	145.17	10	1280
Latitude (°)	6.76	1.110	4.66	11.26
Longitude (°)	7.54	1.33	2.97	12.64

Source: Authors 2020. Computed from GHS wave 4

Distribution of Net Revenue from Yam Production in Nigeria by States

The spatial representation of average net revenue generated from Yam production by each state is shown in Figure 1. The States depicted with white colour represent states that did not generate any net revenue from yam production according to the data used for this study. This covers the northern parts of Nigeria these States includes Kebbi, Sokoto, Zamfara, Kaduna, kano, Jigawa, Bauchi, Gombe and Borno states. The variation in climate has basically affected those states producing yam. Soil temperature which is determined by rainfall and temperature is a major determinant of yam growth and it's important to yam production than the air temperature. The increase in temperature has really affected the production of yam in the core north where temperature is known to be on the high side.

The study showed that yam is majorly produced by 24 states in the country. Osun, Ondo, Bayelsa, Imo, Akwa Ibom, Abia, and Enugu states, and generated mean of twenty-two Naira (₦ 22,000) from yam production per hectare per annum, their net revenue from yam production was below forty-two Naira (₦ 42000). The average net revenue of farmers in Kogi, Cross River, Kaduna, Ebonyi and Pleateau, States varied from forty-three thousand to seventy thousand naira (₦ 43000 - ₦ 70000) with the mean of fifty-six thousand Naira (₦ 56,000). The portion of the map represented with light green colour shows states where farmers had their average net revenue within the range sixty-nine thousand and ninety-eight thousand naira (₦ 69000- ₦ 98000). Adamawa state had the highest net revenue from yam production in Nigeria, the average net revenue above ₦ 200,000 per annum.

Figure 1: Spatial distribution of Net revenue generated from Yam production in Nigeria

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

Trends of Climate Variables during the Growing Season of Yam Production from 1981-2019

Figure 1 reveals the trends of climate variables used for the study. The trends of the two climatic variables shows instability in the climate; there was a drastic fall in the level of rainfall around 1998 and rose to the peak (about 33 mm) in the year 2000 while there was an increase in temperature. The peak temperature for the period of years reviewed is 28 ℃ around year 2002, while the peak rainfall was above 300mm around year 2012. Elijah *et al.* (2018) stated that yam production in Nigeria seems to be the most vulnerable by the deleterious effects of climate change; **s**oil and air temperatures affect the developmental stages of yam more than any other factor because yam is a tuber crop. The consistent increase in temperature may reduce the rate of germination of the yam set and therefore reduces the yield of the yam tubers. Yam requires an annual temperature of 30 ℃ and an annual rainfall of between 1177.2 mm and 1202.6 mm. The yam seed requires about 25 ℃ to 30 ℃, long day light favours vine growth while day-light tends to favour tuber formation. Which means that yam seeds should grow better in the years with temperature around 30℃ .The trends of the climate variables shows that rainfall for the growing season of yam is falling and temperature is increasing.

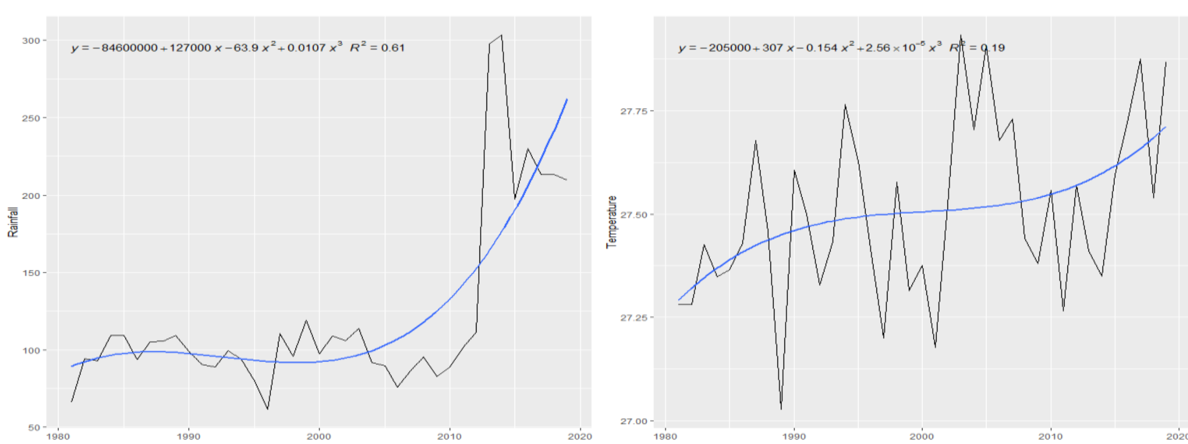

Figure 2 Trends of Temperature and Rainfall during yam growing season from 1981-2019.

Source: Author (Plotted from NIMET data)

Impact of Climate Change on Yield of Yam production in Nigeria

The impact of climate change on the yield of yam production is revealed in Table 2, this was done using the FGLS. The FGLS 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 the crop yield on the sets of independent variables selected for this study. The OLS result revealed that, rainfall has a negative effect on the

unadjusted yield of yam, this implied an inverse relationship with unadjusted yield of yam, while temperature does not affects the yield, farmer's level of education increased the unadjusted yield of yam, the yield also increased as additional land was put into cultivation this is contrary to the findings from the study by Issahaku and Maharjan (2014); their study revealed that increased farm size reduced the yields yam, and that farmers education has no significant impact on the yield of yam. The coefficient of fertilizer is negative yam (p=0.01) respectively this indicates an inverse relationship between fertilizer and the yields; this implied that, the application of additional fertilizer to yam reduced the yield of the crop. This may be because the excessive use of fertilizer may increase the growth of weed at the expense of the crop and also in some cases where fertilizers were wasted during application. Pesticide and Labour input had positive significant input on yam yield the increase in the cost of labour resulted to increase in the yield. Furthermore, the R^2 for the OLS model is 0.225, meaning that the 22% of the variation in the unadjusted mean yield of yam was explained by the explanatory variables. Impact of climate change on crop yield variability from table 3 showed that temperature had a direct relationship with yam; the higher the degree of temperature, the higher the yam yield variability and vice versa, a degree rise in temperature increased by yam yield variability by 3.756 kg/ha. Farmers' age, pesticides, farm size and cost of labour did have any significant relationship with the yam yield variability while increase in the amount of fertilizer used reduced the yam yield variability. The R^2 ranges from 11% for groundnut yield and 31% for yam.

The third stage of the FGLS techniques shoed the climatic effect on the adjusted mean of crop yield was done running the regression of crop yields on the sets of independent variables selected for this study using the estimated error terms from the second model as weight. The explanatory power of the mean crop yield regression improves with stronger goodness of model fit; the R^2 of this model is higher the first two models. Climate variables had mixed impacts on the adjusted mean yield of yam. Temperature had a negative and significant coefficient yam. A unit increase in temperature (1 ℃) reduced the adjusted mean yield of yam by 5.383 kg/ha. Rainfall had a positive and significant effect on the adjusted yield of yam. This is contrary to the findings made by Zakari *et al*. (2014) that rainfall has a weak relationship with yam yield. Farmers' age had an inverse relationship on the adjusted yield of yam which meant that younger farmers who engaged in the cultivation of yam would have more yields than the older farmers; farmers' years of formal education had positive and significant effect on the adjusted yam yield. This meant that the exposure of farmers to education improved farming system which in turn improved yam yields. This is in the same direction with the studies by Etim and Onyenweaku (2013) they concluded that farmers' education had a positive effect on the farm level yam output. Contrary to the findings of Cabas *et al.* (2010), who submitted that there is an inverse relationship between crop yield and farm size, increase in farm size had a positive relationship with the adjusted yield of yam. This study revealed that yam yield will keep increasing as more and more marginal land is put into cultivation, this holds contrary to the submission by Issahaku and Maharjan (2014) who submitted that increase in farm size reduced the yield of farms produce.

This study showed that as additional fertilizer was added the adjusted yield of yam increased, the adjusted yields of yam also increased with additional labour input. The above findings goes with the findings by Shehu *et al.* (2010), they find out that land, labour, education, and fertilizer are the drivers that influence yam production in Nigeria. Also results by Maikasuwa and Ala (2013) indicated that the factors of production such as labour, and material inputs like fertilizer have influenced on yam production. In line with a-priori expectation the use of pesticide on yam production showed a direct relationship with the adjusted yield of yam. The third stage of the FGLS (the adjusted mean yield) had the best goodness of fit compared with the crop yield variability and the ordinary least square.

Table 2: Impact of Climate Change on Yield of Yam Production

Variables	Unadjusted Mean Yield	Yield Variance	Adjusted Mean Yield
Temperature	0.615	3.756***	-5.383***
	(0.999)	(1.299)	(0.098)
Rainfall	-1.480***	-0.141	1.561***
	(0.145)	(0.189)	(0.050)
Age	-0.015	-0.062	-0.379***
	(0.161)	(0.210)	(0.045)
Education	0.094***	0.036**	0.11**
	(0.028)	(0.037)	(0.008)
Farm size	0.217***	-0.030	0.035***
	(0.025)	(0.032)	(0.002)
Fertilizer	-0.033***	-0.017***	0.0403*
	(0.009)	(0.012)	(0.0760)
Herbicide	-0.004	-0.025	-0.0075***
	(0.016)	(0.021)	(0.0071)
Cost of labor	0.023**	-0.018	0.0361***
	(0.009)	(0.012)	(0.0230)

Pesticide	-0.027	-0.006	0.0230*
	(0.019)	(0.024)	(0.0461)
Constant	14.207***	-11.175***	-0.064***
Observations	1,200	1,200	1,200
R^2	0.225	0.314	0.997
Adjusted R^2	0.218	0.236	0.979
Residual Std. Error	1.656 (df = 1190)	2.153 (df = 1190)	3.307 (df = 1190)
F Statistic	35.588*** (df = 9; 1190)	1.688* (df = 9; 1190)	48,958.220*** (df = 9; 1190)

Notes *** means significant at $p < 0.001$, ** means significant at $p < 0.05$ and * means significant at $p < 0.01$; Figures in parenthesis are standard errors of regression estimates

Source: Author's computation 2020

Impact of Climate Change on Yam Net Revenue

The impact of climate change on net revenue from yam production in Nigeria is presented in Table 4. The R^2 and the adjusted R^2 improved as more variables were added to form new models. Model 5 had the best goodness fit; the R^2 revealed that 63.6 percent of the variations in yam net revenue were explained by the explanatory variables. The F statistics for the 5 models were significant at 1% level of significance. Both linear and the quadratic climatic variables had significant impact on yam net revenue in all the five models used. From model 5, linear temperature had a positive and significant impact on yam net revenue at 1% level of significance. The quadratic rainfall had a positive significant impact on yam net revenue while the quadratic temperature had a negative significant impact on the net revenue generated from yam production. This showed that excessive temperature reduced the productivity of the yam tuber; yam needs adequate water for the yam set to sprout and for adequate vegetation. Farmers with higher years of formal education generated more net revenue from yam production than yam farmers with low years of education. This showed education improved the farming system of yam farmers which in turn affected their productivity and net revenue. This study revealed an increase in Net revenue as cost of herbicide, fertilizer and labour increases, this in line with finding by Maikasuwa and Ala (2013), the duo stated that the factors of production such as labour, finance and material inputs like fertilizer have influenced on yam production The cost of pesticide had a negative significant impact on yam net revenue at 5% significant level..

Furthermore, yam net revenue increased as cost labour increases this was contrary to the report by Ayanwuyi *et al* (2011) that "high cost of labour has been among the major constraints to yam production and that it had constrained smallholder yam farmers from enhancing productivity". Farm size had no significant relationship with net revenue in this study, higher elevation reduced yam net revenue (p<0.01), yam productivity increased in the north eastern part of Nigeria than other parts where yam is being produced, this could be majorly traced to the fact that climatic condition there fits the climatic requirement of yam production.

Table 3: Impact of Climate Change on Yam Net Revenue

	Dependent variable:				
	Net revenue				
Variables	Model 1	Model 2	Model 3	Model 4	Model 5
Rain	-191.865***	-190.648***	-160.706***	-137.769***	-206.784***
	(34.483)	(34.769)	(35.822)	(38.391)	(52.314)
Temp	8,029.020***	7,973.990***	5,515.460**	6,699.420**	9,076.900***
	(6,821.020)	(6,946.520)	(2,370.680)	(28,865.660)	(5,917.910)
I(rain2)	0.090***	0.089***	0.073***	0.051**	0.095***
	(0.022)	(0.022)	(0.023)	(0.024)	(0.035)
I(temp2)	-1,468.911***	-1,428.740***	-1,012.975*	-1,159.126**	-3,066.732***
	(515.516)	(517.939)	(526.096)	(554.525)	(696.442)
Age		85.817	76.113	57.791	70.611

		(115.121)	(114.462)	(114.373)	(113.187)
Education		411.529^{**}	405.061^{***}	92.213	6.679^{**}
		(338.105)	(336.970)	(343.697)	(341.644)
Sexmale		1,232.367	855.854	1,509.007	1,455.642
		(3,049.072)	(3,040.175)	(3,023.205)	(2,989.329)
Pesticide			-1.383^{*}	-1.113	-0.927^{**}
			(0.796)	(0.795)	(0.786)
Herbicide			0.248	0.247	0.076
			(0.602)	(0.598)	(0.595)
Fertilizer			0.124	0.149	0.019
			(0.350)	(0.350)	(0.349)
Costlab			0.561^{***}	0.556^{***}	0.452^{***}
			(0.141)	(0.144)	(0.143)
Farmsize			210.594	49.298	98.284
			(186.134)	(187.998)	(189.411)
		Table 2: Impact of Climate Change on Yam Net Revenue(Continuation)			
Latitude				1,547.928	1,879.694
				(2,456.651)	(2,918.756)
Longitude				$2,659.123^{**}$	1,808.177
				(1,270.729)	(1,981.601)
Elevation				-47.194^{***}	-33.591^{**}
				(15.115)	(16.014)
Distoroad				-135.664	-223.677^{**}
				(227.778)	(226.353)
Distomkt				118.971^{**}	74.572
				(49.222)	(53.363)
zoneN_C					$17,374.869^{*}$
					(3,454.314)
zoneN_E					$81,923.840^{***}$

					(15,191.180)
zoneN_W					12,477.060
					(12,980.720)
zoneS_E					-11,267.220
					(7,754.256)
zoneS_S					9,387.771
					(9,862.330)
zoneS_W					14,906.440
					(10,113.590)
Constant	879,220.800***	861,724.700**	602,361.300*	746,615.100**	1,858,162.000***
	(340,374.700)	(341,853.100)	(346,605.100)	(372,791.000)	(446,216.600)
Observations	1200	1200	1200	1200	1200
R^2	0.291	0.451	0.488	0.595	0.636
Adjusted R^2	0.226	0.415	0.478	0.505	0.618
Residual Std. Error	736.920 (df = 1111)	757.650 (df = 1108)	418.880 (df = 1103)	966.490 (df = 1098)	324.350 (df = 1093)
F Statistic	20.697*** (df = 4; 1195)	12.113*** (df = 7; 1192)	8.850*** (df = 12; 1187)	7.862*** (df = 17; 1082)	7.800*** (df = 22; 1177)

Notes *** means significant at p < 0.001, ** means significant at p < 0.05and * means significant at p < 0.01; Figures in parenthesis are standard errors of regression estimates

Source: Author’s computation 2020

Marginal Impacts of Climate Variables on Net Revenue

The marginal impact analysis of climate change on yam net revenue was conducted to evaluate the outcome of an infinitesimal change of temperature and rainfall on yam production in Nigeria. Table 4 displayed the marginal impacts of climate variables on net revenue yam production. The fifth regression model above was used to evaluate the marginal effect using the mean temperature and rainfall for the growing season of yam The climate variables had marked different marginal effects on the net revenue per hectare of yam.

1^0c increase in temperature reduced the net revenue of yam ₦ 28928 per hectare 1mm increased in rainfall increased their net revenue by ₦ 2124. This result agreed with the findings from many studies in literature (Mendelsohn *et al.* 1994; Kurukulasuriya and Mendelsohn, 2006; Kabubo and Karanja, 2007) who reported that temperature is harmful for crop production.

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

Variables	Yam
Temperature	₦ -28928
Rainfall	₦ 2124

Source: Author’s computation 2020

Impacts of Potential Climate Scenario on Yam Net Revenue

The Potential impact of climate change on yam net revenue is revealed in this section. This was done using simulated regression model; Table 5 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 yam using CCC and PCM was shown in Table 5. The result showed marked disparities in the potential net-revenue from yam 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 yam production will reduce by 6.13% in 2050 and reduce by 38.35% 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 yam by 3.50% and 41.23%

In addition, the results for the PCM scenario for temperature (0.6 ℃ and 2.5 ℃) for 2050 and 2100 as presented in Table 5 showed that there would be 0.75**%** increase in the net revenue generated from yam by 2050 and a reduction of 12.70% by 2100. Consequently, the scenario for rainfall for the two years reveals that there would be increase in the net revenue generated per hectare in 2050 by 7.35% and 4.70% by 2100.

Table 5: Impacts of Forecasted Climate Scenario on Yam Net Revenue

Climate variables	Climate scenarios / %change in Net revenue /year	
	2050	**2100**
	Climate Canadian scenarios	
Temperature	+1.6 ℃(-6.13)	+6.7 ℃(-38.35)
Precipitation	3.7mm (-3.50)	-18.4mm (-41.23)
	Parallel Climate Model	
Temperature	+0.6 ℃(0.75)	+2.5 ℃(-12.70)
Precipitation	2.5mm (7.35)	+4.3mm (4.70)

Source: Author's computation 2020

IV. CONCLUSION

The study concluded that temperature is has a detrimental effect on both yield and net revenue of yam production in Nigeria. To improve the level of yam production and ensure food security in Nigeria, constraints to yam production posed by change in climate should be tackled by assisting farmers with a wide range of subsidies and affordable credit facilities to invest on irrigation system in yam production for higher productivity, and giving them access to innovation and technology to move away from labour intensive to capital intensive yam production.

REFERENCES

[1] Ajetomobi, J. O., Ajiboye, A., & Rasheed, H.. (2010). *Economic impact of climate change on irrigated rice agriculture in Nigeria*.

[2] Ajetomobi, J. O., Ajiboye, A., & Rasheed, H. (2011). Impacts of climate change on rice agriculture in Nigeria. *Tropical and Subtropical Agroecosystems*, *14*(2), 613–622.

[3] Ayanwuyi, E., Akinboye, A. O., & Oyetoro, J. O. (2011). Yam production in Offrire Local Government area of Oyo State, Nigeria: Farmer's perceived constraints. *World Journal of Young Researchers*, *1*(2), 16–19.

[4] Babaleye, T. (2003). West Africa: Improving yam production technology. African News Bulletin, 463, 56–59.

[5] Cabas, J., Weersink, A., & Olale, E. (2010). Crop yield response to economic, site and climatic variables. *Climatic Change*, *101*(3–4), 599–616. https://doi.org/10.1007/s10584-009-9754-4

[6] CBN (2012). Central Bank of Nigeria: Statistical Bulletin, 2012 Edition

[7] Enete, A.A., Madu, I.I., Onwubuya, E.A., Onyekuru, A.N., Mojekwu, J.C. & Eze, F. (2011). Indigenous agricultural adaptation to climate change: Study of Southeast Nigeria. African Technology Policy Studies Network WORKING PAPER SERIES/ No. 53. Website: www.atpsnet.org.

[8] Etim, N.A., Thompson, D., & Onyenweaku, C.E. (2013). Measuring efficiency of yam (Dioscorea spp) production among resource poor farmers in rural Nigeria. Journal of Agriculture and Food Sciences, 1(3), 42-47.

[9] Elijah S T., Ogonna, O.O., & Anarah, S.E. (2018). Effect of Climate Change on yam production in Cross River, Nigeria , International Journal of Agriculture and Forestry 2018, 8(2): 104-111.

[10] Eid, H.M., El-Marsafawy, S.M., Ouda, S.A. (2007). Assesing the economic impact of climate change on agriculture in Egypt: A Ricardian approach. The World Bank policy research paper, 4293

[11] Issahaku, Zakaria Amidu, & Maharjan, K. L. (2014). Climate change impact on revenue of major food crops in Ghana: Structural Ricardian cross-sectional analysis. In *Communities and Livelihood Strategies in Developing Countries* (pp. 13–32). Springer

[12] Kabubo-Mariara, J., & Karanja, F. K. (2007). *The economic impact of climate change on Kenyan crop agriculture: A Ricardian approach*. The World Bank.

[13] Kurukulasuriya, P., & Mendelsohn, R. (2007). *A Ricardian analysis of the impact of climate change on African cropland*. The World Bank.

[14] Maikasuwa, M.A., & Ala, A.L. (2013). Determination of profitability and resource-use efficiency of yam production by women in Bosso local government area of Niger State, Nigeria. European Scientific Journal, 9(16), 196-205.

[15] Mendelsohn, R., Arellano-Gonzalez, J., & Christensen, P. (2010). A Ricardian analysis of Mexican farms. *Environment and Development Economics*, *15*(2), 153–171

[16] Mendelsohn, R. O., & Dinar, A. (2009). *Climate change and agriculture: An economic analysis of global impacts, adaptation and distributional effects*. Edward Elgar Publishing.

[17] Musa, Onu, Vosanka & Anonguku (2011). Production efficiency of yam in Zing Local Government Area of Taraba State, Nigeria. Journal of Horticulture and Forestry, 3(12), 372-378.

[18] Nzeh, C.E. & Eboh, O.R. (2011). Technological challenges of climate change adaptation in Nigeria: Insights from Enugu State. African Technology Policy Studies Network Working Paper Series/ No. 52. Website: www.atpsnet.org

[19] Issahaku, Z A, & Maharjan, K. L. (2014). Climate change impact on revenue of major food crops in Ghana: Structural Ricardian cross-sectional analysis. In *Communities and Livelihood Strategies in Developing Countries* (pp. 13–32). Springer.

[20] Kurukulasuriya, P., & Mendelsohn, R. (2008a). Crop switching as a strategy for adapting to climate change. *African Journal of Agricultural and Resource Economics*, *2*(311-2016–5522), 105–126.

[21] Kurukulasuriya, P., & Mendelsohn, R. (2008b). *How will climate change shift agro-ecological zones and impact African agriculture?* The World Ban

[22] Shehu J . F., Iyortyer J. T., Mshelia S. I., &. Jongur A. A. U (2010). Determinants of Yam Production and Technical Efficiency among Yam Farmers in Benue State, Nigeria . J Soc Sci, 24(2), 143-148.

[23] Zakari D.M., Mohammed A.B., Medugu N.I., and Sandra I. (2014). Impact of climate change on yam production in Abuja, Nigeria. International Journal of Science Environment and Technology. Vol 3, No 2, 2014