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Consequences of Climate Irregularities on Maize Production in Nigeria

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Abstract:

Climate irregularities often characterized by unpredictable rainfall patterns, rising temperatures, and increased frequency of extreme weather events pose significant challenges to agricultural productivity in Nigeria. This study investigates the consequences of climate variability on maize production using time series data on rainfall and temperature from 1971 -2023 obtained from the Nigeria meteorological agency and cross section data on maize production and farm attributes for 3675 farming households obtained from General Household Survey GHS) wave 4. Feasible Generalised least square and structural Ricardian models were used to analyzed the data, while graphical and pictorial presentation was used to present the trend of yield and view of the net revenue. The regression results reveal significant impacts of climate variables Temperature shows a strong negative effect on adjusted mean yield $-4.880,p<0.01-4.880$*,* $p < 0.01-4.880,p<0.01$*, indicating that rising temperatures adversely affect maize productivity. While rainfall positively influences maize yield in the adjusted model* $(1.581,p<0.01)(1.581$*,* $p < 0.01)(1.581,p<0.01$*. The marginal effect of climate irregularities showed that maize is more sensitive to the infinitesimal change in climate while the predicted climate scenarios showed potential reduction of the maize net revenue. Adaptation strategies, such as the promotion of heat-tolerant maize varieties, better water management, and farmer education are therefore recommended to mitigate the adverse effects of excess temperature, region-specific climate-smart interventions are also necessary to cushion the negative effects of irregular rainfall.*

Key words: Climate change, Net revenue, Yield, Ricardian, FGLS, Maize

Introduction: Maize (Zea mays) is a critical food crop in Nigeria. Wossen *et.al.* (2023), it is mostly ranked among the top staple crops cultivated and consumed across the country, Ogunniyi *et.al* 2021). Nigeria happens to be second largest producers of maize in Africa after South Africa, producing over 33milion tons annually (FAO, 2024), with millions of smallholder farmers depending on it for their livelihood. ((Badu-Apraku & Fakorede, 2017). Its significant contribution to the nation's food supply, income generation, and rural employment, especially among smallholder farmers who form the backbone of Nigeria's agricultural sector made maize production highly crucial (Chiaka *et al.* 2022). Despite all the future of maize production is increasingly uncertain against the backdrop of developing climate irregularities (Prasanna *et.al.* 2021). Climate irregularities which is known as unpredictable and extreme variations in weather patterns, which includes erratic rainfall distribution, shift in the onset and cessation of rainy seasons, prolonged droughts, flooding, heatwaves, and incessant rise in temperatures (Mulla *et. al*. 2023). According to Zampieri *et. al* (2019), these anomalies, which are largely driven by climate change, have created extensive uncertainties for maize farmers. Common example is the delayed rainfall which can result to poor seed germination, excessive rainfall which may cause waterlogging and crop failure. Also, Shao *et. al* (2021) noted the unusual temperature spikes during flowering stage of maize growth can reduce pollination success and ultimately lead to lower maize yields. However, most maize farming in Nigeria is rain-fed and highly dependent on stable weather conditions Adikuru *et. al* (2020), these irregularities have made it difficult for farmers to make adequate plans towards managing their production process. (Akano *et.al.* 2021). According to Bekuma Abdisa *et. al* (2022), the traditional knowledge of planting seasons previously known and practiced is becoming increasingly unreliable, and many Nigeria farmers lack access to irrigation facilities, early warning systems, and climate-smart technologies that could help them adapt to these frequent irregularities. Idumah *et. al.* (2016) noted that these changes had previously resulted reduction in maize productivity and could lead to food insecurity and rural poverty the long run. The importance of these subject matter necessitates this study, analyzing the relationship between climate irregularities and maize production in the Nigerian context. Most existing research focuses broadly on climate change and agriculture without zooming in on the specific impacts on maize yield and revenue separately

This study is therefore designed to investigate the consequences of climate irregularities on maize yield and revenue in Nigeria, and also view the potential impact of the irregularities on the revenue under the following objectives. (i) assess trends and patterns of maize yield over time (ii) examine their effects of climate variables on maize yields and net revenue; and (iii) identify the potential impact of climate variables on maize Net revenue in Nigeria in 2050 and 2100 using both Canadian climate change model and parallel climate model. The findings from this research will provide evidence-based recommendations for policymakers, agricultural stakeholders, and development partners to design and implement adaptive strategies that will mitigate the adverse impacts of climate irregularities and support sustainable maize production in Nigeria. The sustainability of maize production in Nigeria has increasingly come under threat due to erratic climate conditions. Climate irregularities have disrupted traditional farming cycles, reduced crop yields, and exposed maize farmers to heightened income volatility. Despite growing awareness of climate change and its broad implications, empirical evidence specifically linking climate irregularities to maize productivity and net revenue in Nigeria remains limited and fragmented. Existing studies often overlook the nonlinear and regionally differentiated impacts of temperature and rainfall anomalies on agricultural outcomes. Furthermore, the lack of integration between climate variables and socio-economic factors—such as education, farm size, and agro-ecological zones—limits the depth of understanding needed to design effective, evidence-based adaptation strategies. This gap in knowledge is particularly troubling given that maize is cultivated across diverse agro-ecological zones in Nigeria, each with varying exposure and sensitivity to climate shocks. Without clear, data-driven insights into how climate irregularities affect maize yield and profitability, policymakers, extension agents, and farming communities are left without adequate tools to respond to these growing threats. Therefore, it becomes imperative to investigate the direct and indirect effects of climate variability on maize production and farmers' yields and net returns in Nigeria.

Study Area: Nigeria, is located in West Africa, and lies between latitudes 4°N and 14°N and longitudes 3°E and 15°E. It is bordered by the Republic of Benin to the west, Chad and Cameroon to the east, Niger to the north, and the Atlantic Ocean to the south. It is endowed with a landmass of about 923,769 square kilometers, and diverse ecological zones ranging from mangrove swamps in the south to Sahel savannah in the far north. Maize is cultivated across all agro-ecological zones in Nigeria, from the humid rainforest regions of the south to the Sudan and Sahel savannah zones of the north. However, some states are primarily on key maize-producing states such as Kaduna, Oyo, Borno, Niger, Plateau, Katsina, Gombe, Bauchi, Kogi, and Taraba, Ondo and so on. These states are known for their substantial contribution to national maize output and have been increasingly impacted by erratic rainfall patterns, prolonged dry spells, and temperature fluctuations which are all consequences of climate irregularities.

Data Description and Sources: The dependent variables for this study - yield and the net revenue per hectare- and the explanatory variables - the mean temperature measured in centigrade and mean rainfall in millimeter for the growing season of maize- are the main variables of interest. Other variables used are the socioeconomic attributes and the farm level attributes used for maize production. Monthly mean rainfall and temperature for the growing season for maize were obtained from Nigeria Meteorological Agency (NIMET). NIMET covers almost all the agro ecological zone in the country with 38 meteorological stations located in each state across the country and two locations in Lagos state. Data for the total production of and the total agricultural area per state for 3675 maize farming households was obtained from the General Household Survey (GHS) wave 4. 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 22,000 households which was carried out annually throughout the country.

Empirical Models: The two economic approaches used for this study are FGLS and Ricardian approaches. The feasible generalised least square approach was adopted by Just and Pope (1978) and Cabas *et al.* 2010 and was used to investigate the impact of climate irregularities on the yield of maize production, Regression models have the potential flexibility to assimilate both socioeconomic factors and the physiological determinants of yield and climate together. 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,

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

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

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

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

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 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 Ricardian method to evaluate economic impacts of climatic changes on maize net revenue, 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:

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

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 researchers like Mendelsohn *et al*. (2000), Ajetomobi (2011), Ajala and Ajetomobi (2021) 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, socioeconomic 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.

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

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:

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

Result and Discussion; Description and summary Statistics of Model Variables: The summary of the model variables that was used for this study is revealed in Table 1. The mean crop yields for maize production is 2720kg/ha/year while the mean net revenue generated from maize production is **N** 44,666.58 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 expenditures on farm inputs on the average are ₦ 2399.72 ₦ 2634.20, ₦ 3397.50and ₦ 6024.25 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. Mean temperature during the effective growing season of cassava is about 27.20, these shows the country is at high degree of warmness. It was theorized that high temperature will have negative impact on Maize. The mean rainfall during effective growing season for was about 584.57mm per month, it is expected that rainfall will have positive effect on the yields maize since maize needs wet conditions up to a certain threshold,

Description of net revenue generated from maize production in Nigeria by States : Maize is widely grown across the country, it either planted solely or as a mixed crop with other crops (Olaniyan 2015). The net revenue of maize depends on the climatic condition of the state where it is planted. Waongo *et al.* (2015) reported that the impact of precipitation on maize yield is stronger than that of temperature, meaning that the impact of climate variability on maize yield could be negative if the change increases temperature but reduces precipitation at the same rate and simultaneously. Figure 1 reveals that maize is widely grown across the country with just three non producing state. The states had varying net revenue generated ranging between ₦ 42,000 and over ₦ 100,000 depending on their geographical location.

Maize Yield Trend Analysis (1970–2023) : Trend Summary: The maize yield trend from 1970 to 2023 in Figure 2 shows a general upward trajectory, with fluctuations in the early decades(1970-2000) and a more stable and accelerated increase in recent years(2000 - 2023). The fitted cubic polynomial model (blue curve) captures this nonlinear growth pattern effectively, with an R^2 value of 0.91, indicating that 91% of the variation in maize yield is explained by the model.The yield remained relatively low and erratic between 1970 and 1985, showing minimal progress. This may be linked to droughts, floods, or erratic rainfall. From the mid-1980s to 2000, yields began to rise but were interspersed with noticeable drops, reflecting possible climate variability or instability in agricultural practices. Post-2000, the yield trend exhibited a significant and consistent increase, indicating improvements in agricultural productivity, technology adoption, and possibly more favorable policies or investments in maize farming.

The fitted regression equation $Y = -7.81 \times 10^6 + 1.18 \times 10^4 \times -5.9x^2 + 0.000988x^3$ $R^2 = 0.91$ supports this interpretation. The positive coefficient of the cubic term (x^3) suggests that the maize yield is not only increasing, but doing so at an accelerating rate in recent years. The shaded confidence band around the fitted curve is relatively narrow, indicating a good level of certainty in the predictions.

Climate change impact on Maize yield, yield variance and mean yield.: Temperature is observed to have a negative statistically significant effect on adjusted maize yield, increase in temperature will yield by 4.8kg/ha. While rainfall increase will increase the yiled by 1.581 ka/ha. This is in line with the findings from Ntat *et. al*. 2018, Lawal and Adesope (2021) Adeagbo *et. al* 2019). Farmer's age and herbicide application has an inverse relationship with maize yield. While farm size, fertilizer application, pesticide application and labour has a statistically significant impact on the maize yield.

Climate Change Impact on Maize Net Revenue.: Table 3 reveals the impact of climate change on the net revenue for maize production in Nigeria. The impacts of climate variable on the maize net revenue was different for each of the models. The goodness of fit of the models improves as more variables are added to make new models. The R^2 improves from 0.168 in the first model to 0.641 in the fifth model. Model 5 reveals that the maize net revenue increased with increase in rainfall, and temperature rise reduced maize net revenue at 5 % and 10 % level of significance respectively. This result indicated that climate exhibited a non-linear relationship with maize net revenue, this findings is in line with findings in literature by Baylie and Fogarassy 2021. Farmers' years education, fertilize and cost labour had a positive impact on the net revenue generated from maize production,. This is line with the submission by Kassie *et. al*. 2018, by Zheng *et. al* (2017) and by Ibitola, *et. al* 2019 respectively. Farmers in south western Nigeria will generate more net revenue than those in southeast, because the climatic condition of the south western part of the country supports the growth of maize. The R^2 and the adjusted R^2 increases as other variables were included to make new models. The R^2 for the models is 0.168, 0.37, 0.47, 0.519 and 0.641 for model 1, model 2, model 3, model 4 and model 5 respectively.

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 net revenue generated from maize production. Table 4 revealed the result for the marginal effect; the fifth regression model in Table 3 was used to estimate the marginal effect using the mean temperature and rainfall for the growing season for maize. Each climate variables had marked different marginal effects on the net revenue per hectare maize production.. increase in temperature reduced maize by ₦ 10,622 per hectare. While increase in rainfall increase the net revenue generated by maize production by ₦ 5581 per hectare. This result agreed with the findings from many studies in literature (Li *et al.* 2022; shao *et.al*, 2021, Zhang et. al. 2018) who reported that extreme temperature is harmful for maize growth.

Impacts of Forecasted Climate Scenario on Maize Net Revenue: 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 were assumed to remain the same. Apparently this is not going to be the case over time, technology costs and other independent variables are inevitably going to change with time and its going to have improbable impacts on future maize net revenue. Therefore this simulation 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 relies 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 ^{O}C by 2050 and 6.7 ^{O}C by 2100 and rainfall reduction of 3.7 mm by 2050 and 18.4 mm by 2100 for CCC and PCM. The increase in temperature by 0.6 ^{O}C and 2.5 ^{O}C by 2050 and 2100 respectively; and increase in rainfall by 12.5 mm and 4.3 mm by 2050 and 2100 respectively was tried. The simulated regression results for the net revenue net revenue generated maize production using CCC is shown in Table 5 while the PCM estimation is presented in Table 6. The result showed marked disparities in the potential net-revenue from maize production. the study showed that the net revenue generated from maize production will reduce by 6.50% in 2050 and reduce by 17.03% 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 28.25% and increase by 20.01% by 2100; the increase in rainfall predicted is adequate for the normal requirement of maize.

Conclusion and Recommendation: This study revealed that maize net revenue per hectare was sensitive to marginal change in climate variables (temperature and rainfall). Temperature had a negative significance on the growth of the maize production in Nigeria, and increase in rainfall increased the yield and net-revenue of Maize in in the country. . Forecasts from two different climate models (CCC and PCM) indicated diverse results. The increased in precipitation for 2050 and 2100 reveals climate change will be harmful for both year. The prediction under PCM scenario shows an increase in the net revenue by 2050 and 2100. Nigeria government should consider focusing on designing and implementing adaptation policies to counteract the harmful impacts of climate change. Climate change centers can be built in Nigeria where there will be bodies who will look into the impact, adaptation and recovery to climate change. Also, this study recommend the government and stakeholder to look into implementing region-specific climate-smart interventions to cushion the negative effects of irregular rainfall, weather based index agricultural insurance should also be invented.

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Table 1 Description and summary Statistics of Model Variables

Variables	Mean	Std Dev.	Min	Max
Independent				
Yield(kg)	2720	17720.63	1.87	544683.30
Net Revenue(₦)	44666.58	53635.97	-9300	720000.00
Dependent				
Rain	584.57	251.70	186.06	1199.45
Temperature	27.20	1.60	20.68	30.20
Age(Yrs.)	43.03	13.37	25	78.00
Education Yrs.	9.05	5.01	0	18.00
Pesticide (₦)	2399.72	1989.34	0	27000.00
Herbicide (₦)	2634.20	2164.56	0	33000.00
Fertilizer (₦)	3397.50	3189.18	0	50000.00
Hired labor (₦)	6024.25	9298.29	0	76000.00
Farm size (ha)	4.02	7.27	0	80.00
Elevation	160.33	137.54	10	1070.00
Latitude	6.52	1.55	4.4	13.20
Longitude	7.27	1.55	2.97	13.63
Distance to road	5.48	6.65	1	46.70
Distance to market	72.24	36.92	2	195.40

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

Table 2: Impact of Climate Change on Maize Yield

Variables	Unadjusted Mean yield	Yield Variance	Adjusted Mean Yield
Temperature	4.180***(0.568)	-3.791(0.807)	-4.880***(0.027)
Rainfall	-1.569***(0.097)	0.896***(0.138)	1.581***(0.011)
Age	-0.1.89(0.130)	-0.054(0.185)	-0.080***(0.017)
Education	0.032**(0.020)	0.050*(0.029)	0.042*(0.014)
Farm size	-0.149***(0.023)	0.063*(0.033)	0.044***(0.001)
Fertilizer	-0.011(0.010)	-0.058***(0.014)	0.020***(0.070)
Herbicide	-0.001(0.022)	0.007(0.031)	-0.017***(0.056)
Labour	0.015*(0.008)	-0.016(0.011)	0.007**(0.002)
Pesticide	0.009 (0.025)	0.001(0.035)	0.028***(0.018)
Constant	2.477(1.980)	6.980(2.813)	-2.154***(1.150)
Observation	3,675	3,675	3,675
R^2	0.182	0.141	0.799
Adjusted R^2	0.177	0.136	0.756
Residual-	(df=3665)	(df=3665)	df(3665)
Std.Error	21.079***	7.878***	20,775.40***
F Statistics	(df=9;3665)	(df=9;3665)	(df=9;3665)

Notes *** means significant at 1%, ** means significant at 5% and * means significant at 10%; the dependent variable is the log of Maize yield; and Figures in parenthesis are standard errors of regression estimates.

Source: Authors' Computation

Table 3: Impact of Climate Change on Maize Net Revenue

	Dependent variable				
	Net Revenue				
Variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Rain	-92.171***	-96.958***	-98.759***	-71.229*	-38.168
	(34.748)	(34.829)	(35.153)	(36.891)	(31.158)
Temp	26,193.900	29,969.920*	30,153.750*	57,956.170***	14,949.610
	(16,765.430)	(16,813.120)	(17,043.870)	(17,628.180)	(12,508.350)
I(rain2)	0.005	0.002	0.001	0.003*	0.033**
	(0.027)	(0.027)	(0.028)	(0.029)	(0.013)
I(temp2)	219.766	-294.632	-295.587	323.579***	-280.501***
	(122.963)	(123.959)	(128.288)	(138.111)	(130.196)
Age		-55.952	-57.153	-31.804	-51.621

	(93.850)	(94.262)	(91.934)		(91.099)
Education	531.467**	562.537**	486.161*		321.168*
	(258.332)	(259.523)	(253.879)		(254.451)
Sexmale	-3,043.943	-2,871.052	-4,239.526		-3,814.126
	(2,449.971)	(2,454.543)	(2,400.471)		(2,378.685)
Pesticide		-0.140	-0.280		-0.240
		(0.733)	(0.715)		(0.708)
Herbicide		1.092	0.352		0.228
		(0.787)	(0.771)		(0.763)
Fertilizer		-0.106***	-0.087**		0.031***
		(0.305)	(0.298)		(0.296)
Costlab		0.202	0.357**		0.301**
		(0.148)	(0.147)		(0.148)
Farmsize		-195.023	40.304		-129.847
		(177.017)	(179.512)		(182.178)
Latitude			665.785		-315.648
			(1,104.414)		(1,496.342)
Longitude			5,405.299***		4,446.463***
			(639.270)		(1,162.411)
Elevation			12.755*		8.576
			(6.741)		(6.799)
Distoroad			-76.983		-67.655
			(160.379)		(160.447)
Distomkt			86.823***		11.937***
			(30.843)		(33.160)
zoneN_C				18,738.859*** (7,133.160)	
zoneN_E					9,206.454
					(6,911.704)
zoneN_W				-2,301.121	
				(6,390.610)	
zoneS_E					20,738.150***
				(7,060.198)	
zoneS_S				-3,085.928	
				(9,170.277)	
zoneS_W					11,520.290***
				(7,250.436)	
Constant	228,227.600***	134,633.300	131,385.500	178,554.100***	68,123.100***
	(212,562.400)	(113,272.300)	(115,977.500)	(124,914.000)	(126,847.100)
Observations	3,675	3,675	3,675	3,675	3,675
R^2	0.168	0.372	0.474	0.519	0.641
Adjusted R^2	0.166	0.368	0.468	0.511	0.631
Residual Std. Error	7,970.570 (df = 1670)	8,913.740 (df = 1667)	4,915.360 (df = 1662)	4,631.120 (df = 1657)	4,037.690 (df = 1652)
F Statistic	4.527*** (df = 4; 3670)	9.397*** (df = 7; 3667)	9.220*** (df = 12; 3662)	7.391*** (df = 17; 3657)	3.843*** (df = 22; 3652)

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

Table 4: Marginal Effect of Temperature and Rainfall on Maize net revenue per hectare

Variables	Net revenue (₦)
Temperature	-10,622
Rainfall	5581

Source: Author's computation

Table 5: Climate Canadian scenarios

Climate variables	**Climate scenarios / %change in Net revenue per year**	
	2050	**2100**
Temperature	+1.6 (-6.50)	+6.7 (-17.03)
Precipitation	- 3.7 (-18.60)	-18.4 (-20.30)

Source: Author's computation 2023

-Table 6: Parallel Climate Model

Climate variables	**Climate scenarios / %change in Net Revenue per year**	
	2050	**2100**
Temperature ^{O}C	+0.6 (-4.30)	+2.5 (-8.30)
Precipitation mm	+12.5(28.25)	+4.3 (20.01)

Source: Author's computation

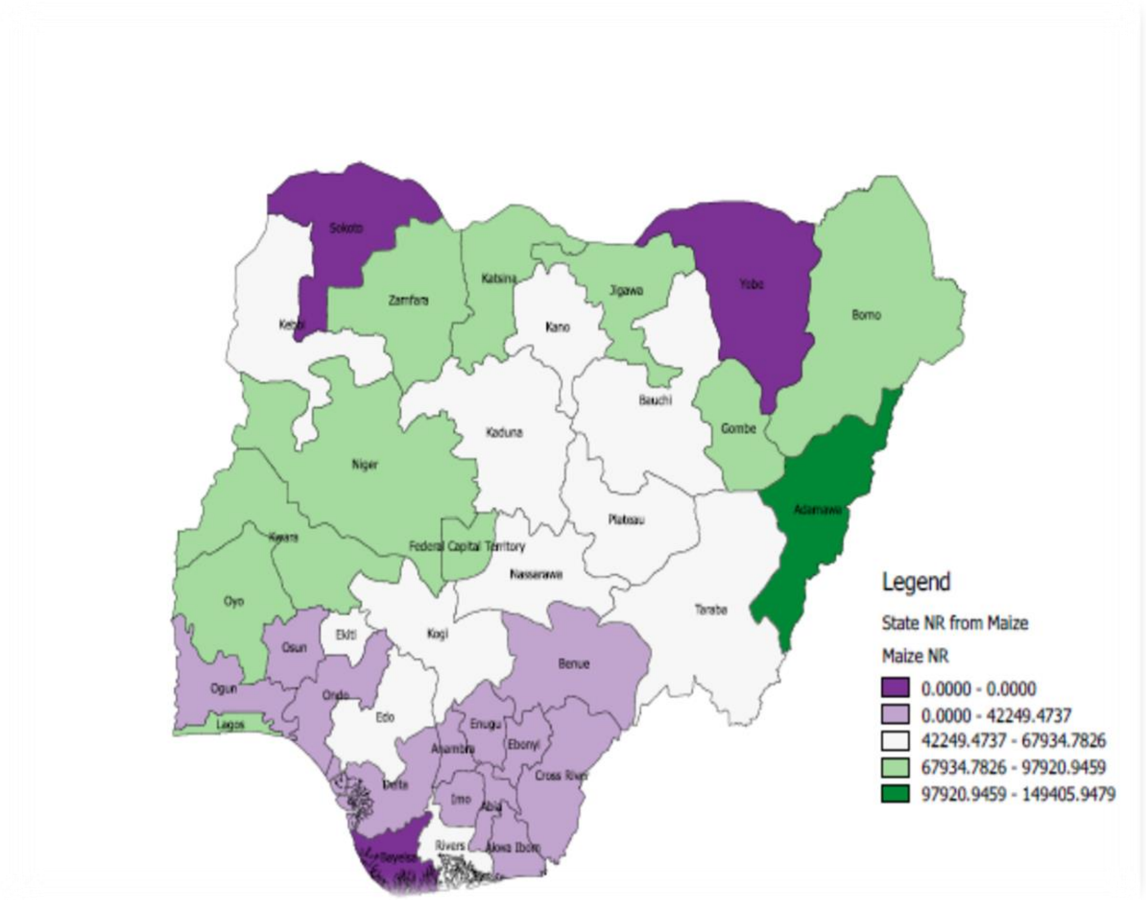

Figure 1: Spatial Distribution of Net revenue generated from Maize production
Source: Author (computed from wave 4 GHS data)

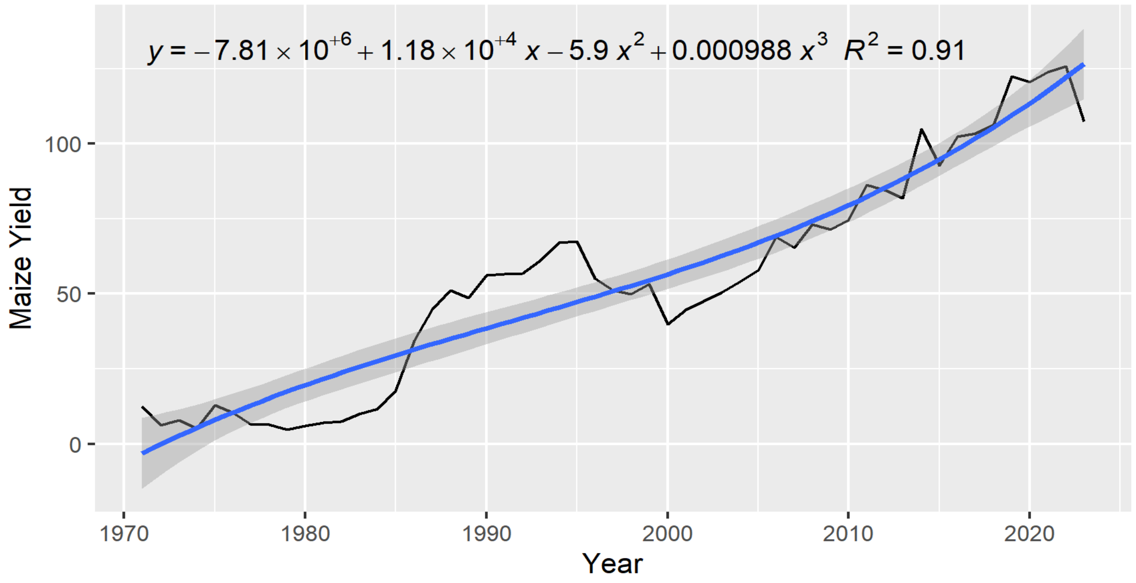

Figure 2. Maize yield Trend.
Source: Authors, Computed from FAO data