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Climate Change and Plantation Agriculture: A Ricardian Analysis of Farmlands in Nigeria

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Abstract

This study used the Ricardian approach that captures farmer adaptations to varying environmental factors to analyze the impact of climate change (CC) on plantation agriculture in Nigeria. By collecting data from 280 farm households in seven different agro-ecological zones of Nigeria (Cross River, Abia, Edo, Ondo, Ekiti, Oyo and Ogun States), the quantity of crops produced over time and land value proxied by net revenue per hectares (NR), were regressed on climate, household and soil variables. The results suggest that these variables have a significant impact on the net crop revenue per hectare of farmlands under Nigerian conditions. Specifically, seasonal marginal impact analysis indicates that increasing temperature during summer and winter would significantly reduce crop net revenue per hectare whereas marginally increasing precipitation during spring would significantly increase net crop revenue per hectare. Furthermore, the net crop revenue impact of predicted climate scenarios from three models (CGM2, HaDCM3 and PCM) for the years 2020, 2060 and 2100 suggest drastic decline in future net revenue per hectare for plantation crops in Nigeria. However, these marginal impacts are not uniformly distributed across the different agro-ecological zones in Nigeria.

Keywords: Nigeria, CC, plantation agriculture, Ricardian Analysis, CC simulations.

1. Introduction

There is a growing consensus that the earth is warming and will continue to warm as the concentration of greenhouse gases rises in the future (Mendelsohn 2009). However, there remains considerable debate about how harmful climate change (CC) will actually be (ICCP 2007a). Sufficient empirical evidences also suggest that the world has witnessed long-term changes in climate patterns and variability with rapid acceleration in recent decades (Hassan 2010). Considerable shifts in long-term temperature and rainfall averages, sea levels, frequency and intensity of draughts and floods, and their variance have been observed (IPCC 2007b, 2007c). This may obviously have implications for plantation crops across the globe including Nigeria.

This paper examines the climate sensitivity of plantation crops in seven different agro-ecological zones of Nigeria namely: Cross River, Abia, Edo, Ondo, Ekiti, Oyo and Ogun States. This is because most plantation tree crops are very sensitive to CC. For instance, cocoa for example, develops under optimal temperatures of 15^0 and 30^0C and annual rainfall between 1200 to 2000 mm, levels. Far above or below these ranges would obviously reduce productivity (Ajewole & Iyanda 2010). The same could be said for palm kennels, rubber and plantains.

Prior to 1960, Nigeria was the world's second largest producer of cocoa, largest exporter of palm kernel and largest producer and exporter of palm oil. However, ever since, the outputs of these major plantation tree crops have consistently declined. This is spite of several policy interventions that have tried to promote the return to agriculture. For example, the structural adjustment programme (SAP) that was introduced between 1986 and 1994 was designed to encourage the production of agricultural export commodities. Yet, plantation production output has consistently declined. One of the possible reasons for this may be the nature of investment in plantation production, as some worry that the returns from these crops are being threatened by climatic factors. Generally, if investment in these crops were attractive, farmers/investors would allocate more scarce resources to producing such crops. However, the problem is that most individual investors and even the government have only a vague idea, of the climatic effects of the industry and as such, are sometimes slow in committing investment funds into production. Besides, beyond this, information on how the dynamics of climatic changes on crops vis-à-vis different management systems has scarcely been documented. The aim of this study is to therefore explore how climate change affects plantation agriculture in Nigeria using a Ricardian Cross-sectional model (RM).

1.1 Theoretical Framework

The theoretical basis of the RM is deeply rooted in the famous theory of 'economic rents' by David Ricardo (1815). However, much of its application to climate-land value analysis draws extensively from Mendelsohn *et al.* (1994). The RM simply examines how climate in different places affects the net revenue or value of land. As Seo *et al.* (2005) pointed out; by doing so, the RM accounts for the direct impacts of climate on yields of different crops as well as the indirect substitution of different inputs, introduction of different activities, and other potential adaptations by farmers to different climates. Hence, the greatest strength of the model is its ability to incorporate the changes that farmers would make to tailor their operations to CC (Mendelsohn and Dinar 1999). Notwithstanding, despite these major advantages that the RM has over alternative climatic impact models such as the Production Function Model (PFM), the Agronomic-Economic Models (AEM) and the Agro-Ecological Zone Model (AEZM), it has been extensively criticized on grounds that (i) crops are not subject to controlled experiments across farms as the case with the AEM and AEZM (Note 1), (ii) it does not account for future changes in technology, policies and institutions, (iii) the model assumes constant prices which is really the case with agricultural commodities since other factors determine prices; and, (iv) it fails to account for the effect of factors that do not vary across space such as carbondioxide concentrations that can be beneficial to crops (Hassan 2010).

In spite of its major short comings, the RM has been extensively applied in both the developed and developing countries to predict the damages from CC with remarkable success. These include Easterling (1993), Mendelsohn and Nordhaus (1996), Sanghi *et al.* (1999), Mendelsohn and Dinar (1999 & 2003), Mendelsohn (2000), Kumar and Parikh (2001), Sohngen *et al.* (2002), Chang (2002), Reinsborough (2003), Gbetibouo and Hassan (2005), Hassan and Nhemachena (2008), Deressa *et al.* (2005), Deressa (2006), Seo *et al.* (2005), Seo and Mendelsohn (2006), Sene *et al.* (2006), Ouedraogo *et al.* (2006), Mano and Nhemachena (2006), Seo and Mendelsohn (2008a, 2008b, 2008c), Hassan (2008), and Mendelsohn *et al.* (2009).

1.1.1 Empirical Model

To measure the economic impact of CC on plantation crops in Nigeria, the standard RM (Mendelsohn *et al.* 1994) was adopted. However, the specification follows Seo *et al.* (2005) due to its simplicity and most importantly, because the study assessed the effect of climate change on plantation agriculture in Sri-Lanka for different climate zones. This makes it similar to the current application. We begin by assuming that the revenue maximizing function of plantation farmers in Nigeria is derived from the cost function, production (output function) and the cost of land as follow.

$$C_i = C_i(Q_i, P_R, E) \qquad (1)$$

Where Q_i represents the quantity of plantation crops, $C_i(.)$ is the relevant cost function associated with production, $\mathbf{P}_R$ represents the vector of prices of inputs associated with crop production except land, and $\mathbf{E}$ reflects a vector of environmental characteristics of the farmer's land including climate (i.e., temperature and precipitations). Given the cost function in equation 1, under the assumption of perfect competition in the market for plantation crops production, the farmer will maximize net revenue as:

$$Max \;\; NR = P_c * Q_i(R, E) - C_i(Q_i, P_R, E) - P_l L_i = 0 \qquad (2)$$

Where *NR* represents the net revenue per hectare proxied for farm land value, P_c is crop price, P_l is the rent and L_i the land. If we assume that a plantation farmer chooses inputs, *R*, to maximize *NR*, then we can express the resulting outcome of *NR* in terms of ***E*** alone as:

$$NR = f(E) \qquad (3)$$

And, the resulting welfare value of a change in the environment from state A to B as:

$$W = \sum f(E_{iE})^* L_i - \sum f(E_{iA})^* L_i \qquad (4)$$

Where, L_i is the amount of land of type *i* (Seo *et al.* 2005). Equation (4) indicates that the welfare value of change in environment is equal to the difference in the net revenue given the two states of nature. However, since most plantation crops grow and develop very well under preferred temperatures and rainfall. Thus, levels far above or below the optimal ranges would obviously reduce productivity. This suggests that the relationship between *NR* and these climate variables should be hill-shaped as has been extensively discussed in the literature (Pradeep & Robert 2006 and Seo *et al.* 2010). To capture this hill-shaped relationship, we specify *NR* for plantation crop production in Nigeria using the model of equation (3) as:

$$NR_i = \beta_0 + \sum(\beta_1 T_1 + \beta_2 T_2^2 + \beta_3 P_3 + \beta_4 P_4^2) + \sum \lambda_i S_i + \sum \phi_i E_i + \sum f_i Z_i + \varepsilon \qquad (5)$$

where T_i and P_i represent normal temperature and precipitation in each season, S is the set of soil variables, E is the set of economic variable like access to market and capital, Z_i stands for the other relevant social characteristics shown in table 1, and ε represents the error term. Equation (5) represents the empirical model to be estimated for Nigerian plantation farmlands. To estimate the marginal impacts of a climate variable say T_i or P_i on net farm revenue at the mean of that variable, we partially differentiating equation (5) with respect to the variable as follows.

$$\frac{\partial NR_i}{\partial T} = \beta_1 + 2\beta_2 T_2 \quad and \quad \frac{\partial NR_i}{\partial P} = \beta_3 + 2\beta_4 P_4 \qquad (6)$$

1.1.2 Data Description

The data for the analysis was drawn from a random sample of 280 plantation farmers in seven different agro-ecological zones of Nigeria namely, Cross River, Abia, Edo, Ondo, Ekiti, Oyo and Ogun States. The questionnaire instrument was adapted and modified from the Global Environmental Fund (GEF) Regional Climate, Water and Agriculture Project of the Centre of Environmental Economics and Policy in Africa (CEEPA), University of Pretoria, South Africa (see, www.ceepa.co.za/Climate_Change/index.html). The survey lasted for over two months (i.e., September to October 2010), and focused mainly on large scale plantation crop growers with a production record of more than 10 years. Temperature and precipitation data were obtained from the Nigerian Meteorological Agency (NMA), Oshodi, Lagos, and Cocoa Research Institute of Idi Ayunre, Ibadan, Nigeria. A total of 4 Enumeration Areas (EAs) were used in each state. From each EA, 10 farmers were purposely selected, starting from Southeastern region to the West. The enumerators were all drawn from the Nigeria National Bureau of Statistics (NBS) with extensive fieldwork experiences.

Average value of the needed variables for each of the regions were computed and used for the regression of the Ricardian model (equation 5) together with the temperature and precipitation data for each region. Following Sung-no *et al.* (2005), the climate data were collected for different climatic seasons in the country. March represents the hot dry season, July represents the moderately hot but heavy rain season while, December represents the cold dry season *(harmattan*). These months were chosen to represent the various combination of temperature and rain season in Nigeria.

Finally, net revenues per hectare was calculated using NR equals to gross revenue minus total variable costs, minus cost of machinery and less total cost of household labour on crop activities in Naira. Dummy variables were used for nominal variables like gender, marital status, source of water, mixed farming, nature of market, keeping livestock and the soil variables. The soil variables were obtained from the Soil Science Department, University of Nigeria, Nsukka and FAO data base. Depending on the soil characteristics, the soils in the sample area were classified into three categories namely, Ferric Acrisol, Dystric Nitrosol and Cambic Arenosol.

2. Empirical Results

Before presenting the empirical findings of the study, first we report the descriptive statistics of the sampled households. This is reported in table 1 with the mean and standard deviation of key variables used in the analysis. As observed (Table 1), the average household size in the sample was seven persons with a total farmland area of about 2.4 hectares. The estimated yearly net revenue of cocoa production was calculated at 458, 644.7 Naira (US$ 3,057.6), palm fruits at 196,600 Naira (US$1,310) and plantain fruits at 91,200 or US$608 (Note 2). Males head 95% of the farms across the study areas. The average education of the head of households was about 9 years with an average of 22 years of experience in plantation farming. Also, the average quantity of plantation output sold yearly was estimated at about 3 tones with total farm revenue of approximately 1.2 million Naira or about US$ 8,000. In terms of fertilizer usage, the yearly average of the sample was about 776kg while also about 93% of the sample reported using pesticides as farm control mechanism. In terms of agricultural subsidy received, less than 14% of the sample reported having received farm subsidy in the last one year while the average farm visit from agricultural extension workers were less than 2. However, more than 66% of the sample farmers reported having received advice from agricultural extension workers.

There are several other facts about the sample that are worth mentioning. For example, more than 72% of the farmers used multiple farmlands for plantation cropping while about 74% practiced mixed farming and only about 39% made used of irrigated farmlands. Also, more than 52% of the farmers reported selling their produce in urban areas with an average market distance of about 90 km.

Finally, in terms of soil types, about 36% of the plantation farmlands were located on dystric nitrosol soil type, 45% on ferric acrrisol and less than 19% on Cambic Arenosol soil. For temperature and precipitation, the mean annual temperature corresponding to the months of March (hot dry season), July (the moderately hot but heavy rain season), and December (the cold dry season or harmattan period) were 32.4^{o}C, 25.7^{o}C and 19.5^{o}C, while that for precipitation were 1,870 mm, 2,500mm and 750 mm respectively. For the average temperature and precipitation data across the different climatic zones, the summary statistics are presented in figures 1 and 2. This clearly indicates that temperature and precipitation play a key role in plantation farming in Nigeria.

2.1 Ricardian Analysis

The empirical results of the economic impact of CC on plantation agriculture using the Ricardian model specified in equation (5) is reported in Table 2. Average values of the required variables for each of the different agro-climatic zones across the country were computed and used for the regression of the Ricardian model (equation 5) together with the temperature and precipitation data for each region. Following Sung-no *et al.* (2005), the climate data were collected for different climatic seasons in the country. March represents the hot dry season, July represents the moderately hot but heavy rain season while December represents the cold dry season *(harmattan*). Five different measures were used to calculate net revenues per hectare. However, NR defined as gross revenue minus total variable costs, less the cost of machinery as well as total cost of household labour on crop activities gave the best fit to the model and was therefore adopted. Dummy variables were used for nominal variables like gender, marital status, soil types and source of water. Marital status turned out to be non-significant even at 10 % level and was consequently dropped from the model. The questionnaire had spaces for many plantation crops. However, only the most significant economic plantation crops in Nigeria such as cocoa, palm fruits and plantains were filled by the sampled farm households. Additionally, because plantain is grown as an adaptation strategy to cover young cocoa plants from intensive sun, it was dropped from the analysis. Thus, the analysis focused on cocoa and palm fruits as shown in Table 2.

The regression results indicate that most of the climatic, household and other variables have significant impacts on the net revenue per hectare. The table shows that for cocoa, the coefficients of the March and July temperatures are both negative and significant at 5 % level while that of December is positive but non-significant. Still for cocoa, the coefficient of precipitation is negative for July but positive for March and December respectively. This is in line with the findings of Kurukulasuriya & Mendelsohn (2008) in their study of the impact of CC on African cropland and that of Lawal & Emaku (2007) on their evaluation of the impact of CC on cocoa production in Nigeria. Contrary to a priori expectation, farm managers' experience in terms of years has a negative but non-significant impact on net revenue per hectare of cocoa farm. Total farm area as expected, has a strong positive and significant impact on net revenue per hectare. This according to Ajewole & Iyanda (2010), may be due the fact that the larger the farm, the more the efficient use of equipment as they will be used to full capacity. Market distance as expected has a negative impact on Net revenue per hectare. The impact of number of visits of extension workers though positive, is very small and non-significant even at 10 per cent level. Another variable that showed a strong positive impact on Net revenue per hectare of cocoa is the main source of water, the coefficient of 48,673.8 shows that the net revenue per hectare for cocoa farms that use irrigation as their main source of water is NGN48, 673.8 or US$324.5 more than that of those which rain is their main source of water. The explanation for this is implied in Omolaja *et al.* (2009) which explains the impact of timely rain on the flowering and pollination of cocoa trees. Other significant variables in the model included the soil type were plantation crops are grown and fertilizer usage. The F-statistics is significant, showing the significant of the joint impact of the variables included in the model. The R^2 adjusted of 0.42 shows that 42% of the variation in net revenue per hectare across the study area is explained by variations in the variables included in the model.

The fourth and fifth column of table 2 contains the Ricardian regression result for palm fruits, the coefficients of the March and December temperature are both negative and significant at 5 % level while that of July is positive but non-significant. The coefficients of precipitation are negative for the three periods though that of July is not statistically significant. Unlike for cocoa, the experience of the farm manager in years has a positive and significant impact on net revenue per hectare. Market distance representing access to market and gender has a significant impact on net revenue per hectare of oil palm fruits.

2.1.1Marginal Impact Analysis

The marginal impact analysis was undertaken to observe the effect of small changes in temperature and rainfall on farm net revenues for cocoa and oil palm fruit. The results are reported in Table 3. As observed, increasing temperature during the March and December seasons significantly increase the net revenue per hectare for cocoa farm. High temperatures during December enhance the processing of the pod and that of March facilitates flowering. Marginal increase in July temperature however, reduced the net revenue per hectare. The annual marginal impact of temperature on net revenue is -5,771.94, meaning that within the area under study an infinitesimal increase in temperature decreases the net revenue per hectare per annum by over NGN5,771.94 or US$38.5. Similarly, increase in precipitation has a negative marginal impact on cocoa net revenue for all the seasons. For a year, an infinitesimal increase in precipitation decreased the net revenue of cocoa farm by NGN86, 731.3 or US$578.2. The combined marginal impact of temperature and precipitation (climate) on net revenue of cocoa farm is approximately NGN92, 503.3 or US$616.7 decrease per hectare per annum.

Column four of table 3 shows that for oil palm, increase in temperature generally decreases net revenue per hectare of palm plantation. The annual marginal impact of an infinitesimal increase in temperature is a decrease in net revenue per hectare of about NGN32, 238.22. March and July precipitation has a positive marginal impact while that of December has a negative marginal impact. The annual marginal impact of precipitation on net revenue per hectare of palm plantation is a decrease of NGN102.17. Though this is small, its combination with that of temperature gives a decrease of NGN32, 340.39.

2.1.2 The impacts of forecasted climate scenarios

The impact of future climate change occurrence on net revenue per hectare was analysed using the climate scenarios from the Special Report on Emission Scenarios (SRES). The SRES was a report prepared on future emission scenarios to be used for driving climate change models in developing climate change scenarios (IPCC 2001). Future climate change scenarios from climate change models are commonly used to analyse the likely impact of climate change on economic or biophysical systems (Xiao *et al.* 2002 & Kurukulasuriya *et al*. 2006). Predicted values of temperature and rainfall from three climate change models (CGM2, HaDCM3 and PCM) were applied to help understand the likely impact of climate change on plantation farmlands in Nigeria. Through parameters from the fitted net revenue model, the impact of changing climatic variables on the net revenue per hectare is analysed as:

$$\Delta NR = NR - NR_c \quad \text{and} \quad NRh = \sum_{1}^{n} \frac{\Delta NR}{n} \tag{7}$$

where NR' is the predicted net revenue per hectare from the estimated net revenue model under the future climate scenario, NR is the predicted value of the net revenue per hectare from the estimation model under the current climate scenario, ΔNR is the difference between the predicted value of the net revenue per hectare under the future climate scenarios and the current climate scenario, NRh is the average of the change in the net revenue per hectare and n is the number of observations.

Table 4 shows the predicted values of temperature and precipitation from the three models for the years 2020, 2060 and 2100. As observed, all the models forecasted increasing temperature levels for the years 2020, 2060 and 2100. With respect to precipitation, while the CGM2 predicted decreasing precipitation for the years, both HaDCM3 and PCM predicted increasing precipitation over these years. The results of the predicted impacts from the SRES models are presented in Table 6. The table shows that all the predicted values used from every SRES model result in the reduction of the net revenue per hectare by 2020, 2060 and 2100 for both the cocoa and oil palm farm. For the CGM2 scenario, the reduction is NGN41, 184.5 (8.98%) for the year 2020, NGN 24,500 (12.5%) for the year 2060 and NGN120, 010.3 (26.17%) for the year 2100 for cocoa and NGN41, 184.5 (8.98%) for the year 2020, NGN 57,385 (29.2%) for the year 2060 and NGN105, 888 (53.8%) for the year 2100 for oil palm.

In the case of the HADCM3 scenario, the net revenue reduction amounts to NGN57,438.8 (12.5%) for the year 2020, NGN 96,101.17 (20.9%) for the year 2060 and NGN147,309.7 (32.1%) for the year 2100 for cocoa and NGN29,223.4 (14.8644%) for the year 2020, NGN 37,900.5 (19.2%) for the year 2060 and NGN50, 000.6 (25.4%) for the year 2100 for oil palm. The reduction in the net revenue per hectare in the case of the PCM scenario amounts to NGN88,258.8 (19.2%) for the year 2020, NGN 101,671.2 (22.2%) for the year 2060 and NGN134, 289 (29.3%) for the year 2100 for cocoa and NGN27, 834.6 (14.2%) for the year 2020, NGN 39,856.2 (20.3%) for the year 2060 and NGN43, 850.3 (22.3%) for the year 2100 for oil palm.

As would be closely observed, although the net revenue reduction is common for all models and years, it keeps increasing as we move from 2020 through 2060 to 2100. This indicates that the level of damage due to climate change continues to increase in the future, unless adaptation is undertaken to reduce this negative impact of climate change. This result is also in line with the fact that future climate change is damaging to African agriculture (Hassan & Nhemachena 2008 and Kurukulasuriya & Mendelsohn 2008). Also, a closer look at table 6 reveals that the impact of climate change increases significantly for both cocoa and oil palm fruits. In fact, for CGM2 model, the reduction in net revenue impact of climate change is higher for oil palm through out the forecasted years. These rules out the likelihood of substituting oil palm for cocoa as an adaptation to climate change within the cocoa producing state.

As a further step, the marginal impact analysis was carried out across the states to ascertain how the impact of climate change is distributed across the states. The results for the calculation are reported in table 5. The result show that small increase in temperature increases net revenue per hectare in Abia, Ekiti and Oyo and decrease net revenue per hectare in Edo, rivers, Ogun and Ondo, with the greatest impact in Ondo. Marginal increase in precipitation decrease net revenue per hectare of cocoa in all the seven states. However, the impact is highest in Rivers state and lowest in Ekiti state. The total annual impact shows that the climate change decreases net revenue per hectare in all the seven states with Rivers and Ondo having the worst marginal impact and Ekiti and Oyo having the least marginal impact.

3. Conclusion and Policy Implications

This study is based on the Ricardian approach that captures farmers' adaptations to varying environmental factors to analyse the impact of climate change on Plantation agriculture in Nigeria with emphasis on cocoa plantations. A total of 280 farm managers from seven cocoa producing states in the country were surveyed for this study. Net revenues per hectare of cocoa plantation were regressed on climatic and other control variables. The independent variables include the linear and quadratic temperature and precipitation terms for the March, July and Dec, household variables and other farm activity data were collected from the survey and other sources. The regression results indicated that the climate change, social, adaptation and soil variables have significant impact on the net revenue per hectare of cocoa, oil palm and plantain.

The marginal impact analysis showed that increasing temperature marginally during March and December increases net revenue per hectare, whereas increasing temperature marginally during July decreases net revenue per hectare for cocoa.

Forecasts from three different climate models (CGM2, HaDCM3 and PCM) were also considered in this study to see the effects of climate change on plantation farmers' net revenue per hectare in Nigeria for the years 2020, 2060 and 2100. The results indicated that, climate change reduces the net revenue per hectare in all the years and under all scenarios from the SRES models. The reduction in the net revenue per hectare is more in the year 2100 than the other two under all scenarios. Furthermore, the marginal impact of climate change were computed across the cocoa producing states in Nigeria and the result show that although changes in climatic conditions (temperature and precipitation) decreases net revenue in all the states, the impact is more in Rivers and Ondo and least in Ekiti and Oyo.

The above analysis shows the magnitude and direction of impact of climate change on plantation agriculture in Nigeria. Most of the results show that climate change is damaging to net revenue. The damage is also not uniformly distributed across different states. This has a policy implication worth thinking about and planning before further damage occurs. The Nigerian government must consider designing and implementing adaptation policies to counteract the harmful impacts of climate change. The adaptation policies should target different states based on the constraints and potentials of each state instead of recommending uniform interventions.

A closer look at the results reveals adaptation options, which could be appropriate for different states. For example, in Ondo, Ogun and Rivers, increasing precipitation increases the incidence of Black Pod disease and most of the farmers from the survey result adopt late planting. This however requires irrigation facilities. Government should therefore include investment in irrigation technologies in their intervention in such regions. For the states where the climatic impact is minimal, government should give incentives such as subsidization of input materials to reduce cost and expand the farm area.

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Notes

Note 1. To account for this weakness, other important variables such as soil quality, market access are included in the model (Mendelsohn & Dinar 1999)

Note 2. At the time of the survey, 1US$ was equivalent to NGN150

Table 1: Summary Statistics of the Sample

Variable Definition	***Mean***	***Std. Dev.***
Socio-Demographic		
Household Size	7.5	3.83
Age of household head (years)	55.3	12.72
Education of household head (years)	9.1	4.11
Total years spent as cocoa farmer	22.18	10.19
Agricultural variables		
Household farm size	2.9	2.09
Total area of cocoa farmland (in hectares)	2.4	0.96
Cocoa farmland value (in million Naira)	24.2	12.81
Cocoa quantity sold (in tones)	3.1	1.96
Net revenue of cocoa per year (in Naira)	458,644.70	244,951.90
Net revenue of palm fruits per year (in Naira)	196,600	114,984.60
Net revenue of plantains per year (in Naira)	91,200	48,561.10
Total revenue (in million Naira)	1,245,600	802,312.70

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Total cost of cocoa (in million Naira)	568,987.70	356,899.90
Fertilizer use (in kg/year)	776	493.67
Distance to market (in Km)	90.5	142.67
Visit from extension worker (number)	2.5	2.63
Aggregate measures (proportions)		
% of household headed by male	95%	
% of household with electricity	81%	
% of household practicing mixed farming	74%	
% of household using pesticide	93%	
% of household that received farm subsidy	14%	
% of household with livestock	47%	
% of household that received advice from extension worker	66%	
% of household that use irrigation as main water source	39%	
% of household selling cocoa in urban market	52%	
% of household that use single land area for cocoa farming	28%	
% of farmland on soil type dystric Nitrosol	36%	
% of farmland on soil type Ferric Acrrisol	45%	
% of farmland on soil type Ferric Acrrisol	19%	
Climate variable		
March Temperature (in Celsius)	32.4	2.5257
July Temperature (in Celsius)	25.7	2.045
December Temperature (in Celsius)	19.5	3.126
March Precipitation (in mm)	1,870	435.85
July Precipitation (in mm)	2,500	160.23
December Precipitation (in mm)	750	301.62
Sample Size	280	

Description of variables used in the Ricardian model.

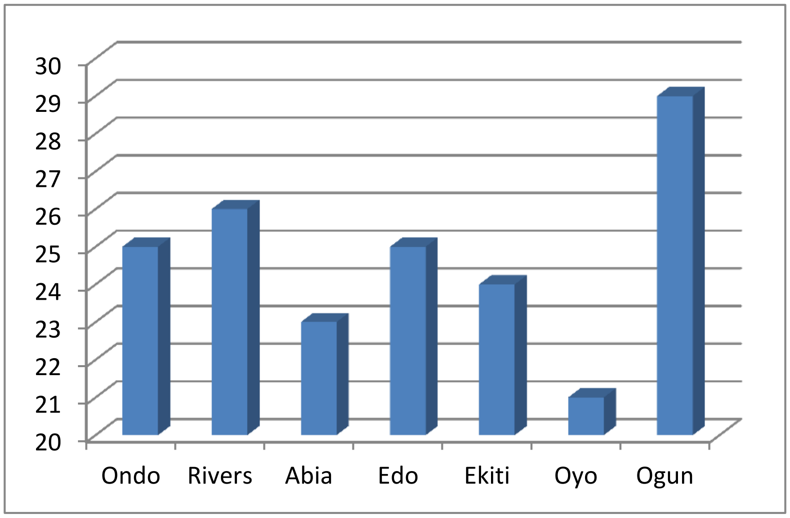

Figure 1. Annual Mean Temperature in Degree Centigrade

Showing the annual mean temperatures plotted for the seven different agro-ecological zones sampled during the fieldwork exercise across Nigeria.

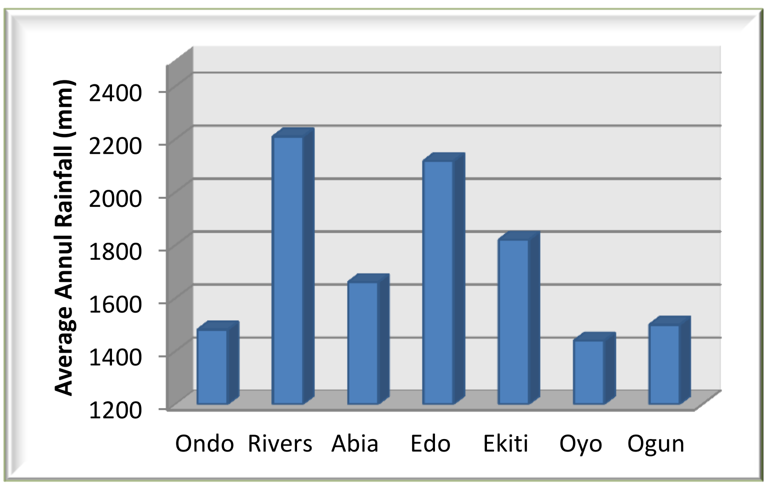

Figure 2. Average Annual Rainfall in mm

Showing the average annual rainfall plotted for the seven different agro-ecological zones sampled during the fieldwork exercise across Nigeria.

Table 2: Regression result of the Ricardian model

	Net Revenue from Cocoa Per Hectare(in Naira)		Net Revenue from Palm Fruits Per Hectare(in Naira)	
Variables	Coefficient	t-value	Coefficient	t-value
March Temperature	407.8	3.66*	-512.5	-2.005*
March Temperature Squared	32.19	-4.653*	-271.8	-2.74*
July Temperature	-230	2.011*	40.2	1.894

July Temperature Squared	-189	3.67*	-59	-5.01**
Dec Temperature	2252	1.77	-6753	-3.2*
Dec Temperature Squared	-15.087	12.87**	-134.5	4.15*
March Precipitation	330	-15.08**	-1178.4	2*
March Precipitation Squared	-255.3	-2.67*	44.2	2.9*
July Precipitation	-370	-1.988	-873	1.2
July Precipitation Squared	-151.78	-20.12**	-14	-3.7*
Dec Precipitation	54.67	4*	-28.37	5.22**
Dec Precipitation Squared	-12.6	-1.22	-201.06	2.33*
Experience in Years	-12.44	-0.56	8800	2.7*
Household farm size	0.453	1.08	927.7	0.004
Total farm area (Hectare)	33,500.09	7.998**	270,888.56	11.5**
Market Distance (Km)	-4461	2.85*	-1503	-2.34*
Number of visit by ext worker	0.3346	1.004	3978.9	1.28
Main water source	48,673.8	17.912**	98.004	0.95
Gender	112.56	1.33	6,475.78	3.7*
Education in years	33.2	1.443	4465	0.01
Soil (Ferric Acrisol)	149.6	5.1***	123.5	3.7**
Soil (Dystric Nitrosol)	10.9	10.21**	8.4	11.3***
Main water source	12,586.0	4.5*	8,746	3.4*
Constant	13,001.89	2.5*	430	1.4
F-Statistics	21.78		8.99	
R- Adjusted	0.42		0.44	

Results from the Ricardian estimation procedure and note that 1 and 0 were used for dummy variables in the estimation.

Table 3. Climate predictions of SRES models for 2020, 2060 and 2100

Model	Temperature				Precipitation			
	Current	**2020**	**2060**	**2100**	**Current**	**2020**	**2060**	**2100**
CGM2	26.4	27.9	28.9	32.4	1626	1466	1350	1200
HADCM3	26.4	28.3	39.66	32.7	1626	1758	1790	1800
PCM	26.4	26.9	27.69	29.13	1626	1695	1740	1805

CC predictions using the climate scenarios from the Special Report on Emission Scenarios (SRES). The SRES was a report prepared on future emission scenarios to be used for driving climate change models in developing climate change scenarios by IPCC in 2001.

Table 4. Forecasted average NRh impacts from SRES Climate Scenarios (in Million Naira)

Impacts	CGM2			HADCM3			HADCM3		
	2020	**2060**	**2100**	**2020**	**2060**	**2100**	**2020**	**2060**	**2100**

Cocoa	Δ in NRh	-41.2	-78.1	-120.0	-57.4	-96.1	-147.3	-88.3	-101.7	-134.3
	Percent	-8.9	-17.0	-26.2	-12.5	-20.9	-32.1	-19.2	-22.2	-29.3
Palm	Δ in NRh	-24.5	-57.4	-105.9	-29.2	-37.9	-50.0	-27.8	-39.9	-43.9
Fruits	Percent	-12.5	-29.2	-53.9	-14.9	-19.3	-25.4	-14.2	-20.3	-22.3

Showing forecasted average NRh impacts using the climate scenarios from the SRES. Δ represents change

Table 5. Marginal impact of CC on NRh of cocoa (in Million Naira)

State	Temperature	Precipitation	Total
Abia	11,236.1	-39,876	-28,639.9
Edo	-10,143	-134,050	-144,193
Ekiti	9,487.7	-9,563	-75.3
Rivers	-10,030.12	-204,004	-214,034.12
Ogun	-21,879	-87,722	-109,601
Ondo	-20,873.56	-138,653.1	-159,526.66
Oyo	5,498	-13,438	-7,940

Marginal impacts analysis for the different agro-ecological zones in Nigeria