Economic impacts of climate change: A micro-level evidence from Nigerian rice agriculture

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Abstract

This study employed the Ricardian approach to test the relative importance of climate normals (average long-term temperature and precipitation) in explaining the value of farm land used for rice production under irrigation and dry land conditions. A survey was done by interviewing 1200 rice farmers from 20 rice producing states in Nigeria. The states cover all the six geopolitical zones in the country. The results indicate that increase in temperature will reduce land rent per hectare for dry land rice farms while it increases the land rent for irrigated rice farms. Increase in precipitation on the other hand will cause a rise in land rent for both dry land and irrigated rice farms. The results clearly demonstrate irrigation as a significant techniques used by the farmers to adapt to the climate change.

JEL CODES: Q12, Q25

Keywords: Climate change, Irrigation, Land value, Rice, Nigeria.

1. Introduction

Climate change through extreme temperature, frequent flooding and drought and increased salinity of water supply used for irrigation has become a recurrent subject of debate globally. When the United Nations Framework Convention on Climate Change (UNFCCC) was opened for signature in June 1992, Nigeria was among the first set of 154 countries that signed the convention which entered into force on 21 March 1994. Nigeria ratified the Convention in August 1994. Like other developing countries, the challenge of climate change and global warming is enormous in Nigeria due to widespread poverty, prevailing slash-and-burn agriculture, erosion and burning of firewood and farm residues. Though climate change is a threat to agricultural and socioeconomic development, agricultural production activities are generally more vulnerable to climate change than other sectors (IPCC 1990, Derresa et.al. 2005) and quite substantial works has been done in respect at national, regional and global aggregate level (Mendelsohn et.al 1994, Adams 1989; Chang 2002, Nhemachena and Hassan 2007, Eid et. al. 2006 and Kurukulasuriya and Mendelsohn 2007). According to Deressa, 2005, such assessments tend to hide important spatial variations in severity of climate change impacts. Though, evidence exist that developing countries are more likely to be negatively affected by climate change than developed (IPCC, 1996). More efforts have been made to quantify the economic impact of climate change on agriculture in developed countries than developing countries. Even then, there has been no major research carried out in Nigeria to study the economic effects of Climate Change on agriculture.

A recent research has shown that rice can be used to offset the major impacts of climate change because of its potentials and unique properties as a food crop for urban poor and rural rice-growing populations (Manneh et. al. 2007). Rice is a major cereal in Nigeria in terms of its output and land area. The crop is currently grown in more than 70% of the states in the country. In spite of availability of cultivable land area, the current level of demand for rice in Nigeria is about 5 million metric tones which is more than twice the quantity produced (2.2 metric tones). At present about 4.9 millions hectares are suitable for rice production but just about 1.8 (37%) are currently utilized for cultivation. To amend the problem, WARDA, IITA and ministry of agriculture are frequently improving adaptation measures in rice agriculture in Nigeria. In addition, Nigeria governments have invested more to increase rice production than other cereals. In 2009, the nation stakes more than 10 billion Naira in public-private partnership schemes to improve the irrigation systems and set up about 17 new rice processing mills. The major problems associated with rice production include drought, flooding, salt stress and extreme temperatures, all of which are expected to worsen with climate change. Drastic changes in rainfall patterns and rise in temperatures will introduce unfavourable growing conditions into the cropping calendars thereby modifying growing seasons which could subsequently reduce the crop productivity. So far, there has not been any study to address the economic impacts of climate change on rice farming and farm level adaptations that rice farmers make to mitigate the potential impact of climate change.

The main objective of this study therefore is to analyze the economic impact of Climate Change on rice agriculture in Nigeria. Specifically, the study (i) estimates a Ricardian model to assess the potential impacts of climate on Nigerian rice agriculture; (ii) evaluates importance of irrigation as an alternative course of action to mitigate the likely impact of climate change on rice farming in Nigeria. The distinction between irrigated and non-irrigated rice cultivation is very relevant in Nigeria since irrigation is necessitated by prolong drought effects. As at 2005, irrigated rice production accounted for up to 20% of total rice area in the country. Other inputs normally altered in rice agriculture include the use of fertilizer, insecticide and herbicide. Varying amount of nitrogeneous fertilizer are required to take full advantage of carbondioxide effects or decrease to minimize input costs. The timing of application can also be altered depending on the pattern of precipitation. This paper is organized as follows: section two discusses the Ricardian approach adopted including specification of the empirical model and estimation procedures. The results and discussion are presented in section three while section four gives the summary and conclusion.

2. Literature review

Several studies have empirically examined the economic impacts of climate change on agriculture from various points of view (Jain,2007; Maddison et al.,2007; Buys et al.,2007;Mendelsohn,2007; Mendelsohn and Seo, 2007, Asseldonk and Langeveld, 2007; Deressa, 2005; Anderson,1979; Dixon,1994; Eid et al.,2006). Anderson (1979) reviewed the approach of divide and conquer commonly used to address the pervasive effects of instability and uncertainty that emanate from climate on agriculture. He showed that effects of climatic variation are investigated and measured at farm, regional, industrial, sectoral and national levels and that low rainfall is the dominating climatic variable. Where possible, sensitivities to climate are measured by production elasticities with respect to rainfall indexes.

Following previous researchers such as Gallagher (1986) and Huff and Neill (1980), Dixon (1994) used a single equation framework to estimate a crop response model. In his empirical specification, yield per acre was specified as a linear function of a set of independent variables including weather and weather- related variables such as temperature, precipitation, soil moisture, solar radiation and planting date. Using crop reporting district as the observational unit, sample consists of annual time series and cross-sectional observations. In Mendelsohn et al., (1994), a regression of farm land prices and net revenues were carried out on climate, soil and other variables, in the United States. Using country with averages and spatial statistical technologies, county with averages were constructed. The result indicated a non linear relationship between farm and climate. Kumar and Parith (1998), in their analysis of the climate sensitivity of initiation agriculture, using a Ricardian approach, regressed district level estimates of annual net revenues on climate and other socio-economic variables. Some farms were at the subsistence level and this made the analysis of the input and output prices very cumbersome. A major weakness of the study is that the effect of climate was captured only on the marketed farm sector.

Sanghi et al., (1998), used district average for net revenues and land values in a Ricardian study constructed for Brazil. In their findings, the impact of climate change on agricultural productivity is negative, with the most prominent impacts being felt in the central and western region. Maddison (2000), also constructed a Ricardian study for England and Wales. It was an uncommon study because it is obviously the only study that have, up till then, used actual sale prices at the level of the individual farm to determine the value of climate. The importance of frost days in winter period to agriculture was earmarked by the results of the study. He found a strong dependence of the price per hectare of land on the size of the farm (Maddison et al., (2007). The Ricardian approach seeks to provide a quantitative solution to economic damage to agriculture owing to climate change. It has an advantage over the other approaches because it provides a way to address issues of farmer adaptation.

Generally, in Ricardian studies, agricultural performance is regressed on various structural and environmental characteristics of land. This attempt is to infer the implicit value of each attribute. Either the net revenues or the values of land can be used as the dependent variable. One of the weaknesses of the Ricardian approach which must not be brushed aside while interpreting the results is the fact that the approach essentially assumes that the level of technology and knowledge remains unchanged, even though the farmer's adaptation is addressed to a certain reasonable extent. Another deficiency is that in the developing country situation farms may face budgetary or awareness constraints which may be found to hinder efficient adaptation. The interesting, part of the Ricardian approach is that the limitations are not sufficient enough to prevent the emergence of the importance of climate in determining agricultural performance from the result.

Mendelsohn et al., (1994), Dinar et al., (1998), the Ricardian approach assumes that farm value has a quadratic relationship with climate variables such as temperature and precipitation. The aim of the approach is to create more understanding into how agricultural practices can be sustainable. Reinborough (2003) used census data to examine to which extent climate explains variation in farm values and farm net revenues for Canada. The fact that the Canadian agriculture stands to be favoured by global warming makes the result to be particularly an interesting one. Reinsborough finds a statistical significant of climate variables along with latitude and population density, although no degree of precision can accurately be ascertain. Mendelsohn and Dinar (2003), considered the impact of water availability an agricultural outcomes across the US. They wanted to know whether the inclusion of variables which capture the availability of ground water and surface water to the standard Ricardian model will produce a change on the climate sensitivity of agriculture. It was discovered that if land is irrigated, then, a valuable buffer will be provided against adverse climatic conditions.

Kurukulasuriya and Ajwad (2004), used the Ricardian approach on farm level data from Srilanka. The authors were able to control for a host of individual household and farmers' characteristics, such as the farmer's human and physical capital, all based on the additional level of the detailed data. They found that when precipitation increases, it results in a positive and significant impact on the revenues, whereas temperature has a strong negative impact. The level of education of the household head and land tenure status were other important variables. The assumption of the Ricardian technique is that trade in agricultural produce is enough for the equalization of the returns on differentiated factors of production in all locations. However, if the prices for land of similar quality are to be equalized, especially for land in different countries, some impediments to the movement of goods may have to be surmounted. For situations in developing countries, data on prices of land are seldom available, hence, net revenue are often used as alternatives. It is also of paramount need to account for the fact that in any given year, only a very small fraction of farmland is likely to be put on the market in a situation where individual farm sale prices data is available. Sample selection problems may arise where sales take place in farms which are unrepresentative Koundouri and Pashardes (2003). All the more recent works (Deressa, 2005; Eid et al, 2006; Mendelsohn, 2007 e.t.c.) are based on Ricardian approach developed by Mendelsohn et al.(1994). In line with recent methodology, this study will employ the Ricardian theoretical and empirical framework to assess the economic impacts of climate change on rice agriculture in Nigeria.

Theoretical Framework

As this study deals with one crop, the approach proposed draws heavily on the conceptual contributions and empirical application of Deressa et al. (2005). The econometric approach is based also on the Ricardian method to assess economic impacts of climatic changes, which allows for capturing adaptations farmers make in response to climate changes. The model is based on a set of well- behaved (twice continuously, differentiable, strictly quasi-concave with positive marginal products) production functions of the form:

$$Q_i = (K_j, E) \tag{1}$$

Where, Q_i is quantity produced of good i, K_j is a vector of production inputs *j* used to produce Q_i and *E* defines a vector of exogenous environmental factors such as temperature, precipitation, and soil, characterizing production sites. Given a set of factor prices w_j , *E* and *Q*, cost minimization gives the cost function:

$$C_i = C_i(Q_i, W, E) \qquad (2)$$

Where C_i is the cost of production of good *i* and $W\ (w_1, w_2 \ldots w_n)$ is the vector of factor prices. Using the cost function C_i at given market prices, profit maximization by farmers on a given site can be specified as:

$$Max\pi = \left[P_iQ_i - C_i(Q_i, W, E) - P_LL_i\right] \qquad (3)$$

Where P_L is annual cost or rent of land at that site, such that under perfect competition all profits in excess of normal returns to all factors (rents) are driven to zero

$$P_iQ_i^* - C_i^* = (Q_i^*, W, E) - P_LL_i^* = 0 \qquad (4)$$

If the production of good *i* is the best use of the land given *E*, the observed market rent on the land will be equal to the annual net profits from the production of the good. Solving for P_L from the above equation gives land rent per hectare to be equal to net revenue per hectare.

$$P_L = (P_iQ_i^* - C_i(Q_i^*, W, E))/L_i \qquad (5)$$

The present value of the stream of current and future revenues gives the land value.

$$V_L = \int_0^\infty P_Le^{-rt}dt = \int_0^\infty \left[(P_iQ_i^* - C_i(Q^*, W, E)/L_i\right]e^{-rt}dt \qquad (6)$$

in welfare induced or caused by the changing environment from a given state to the other. Economic welfare change is measured in terms of change in the capitalized value of the land or alternatively in net farm income. Consider an environmental change from the environmental state *A* to *B*, which causes environmental inputs to change from *EA* to *EB*. The change in annual welfare from this environmental change is given by:

$$\Delta W = W(E_B - W(E_A) =$$

$$\int_0^{Q_B}\left[(P_iQ_i - C_i(Q_i, W, E_B)/L_i\right]e^{-rt}dQ - \int_0^{Q_A}\left[(P_iQ_i - C_i(Q_i, W, E_A)/L_i\right]e^{-rt}dQ \qquad (7)$$

If market prices do not change as a result of the change in E, then the above equation reduces to:

$$\Delta W = W(E_B) - W(E_A) = \left[PQ_B - \sum_{i=1}^{n} C_i(Q_i, W, E_B)\right] - \left[PQ_A - \sum_{i=1}^{n} C_i(Q_i, W, E_A)\right] \qquad (8)$$

Substituting for $P_LL = P_iQ_i{*} - C_i\,(Q_i{*},\ W,\ E)$ from (5)

$$\Delta W = W(E_B) - W(E_A) = \sum_{i=1}^{n} P_{LB}L_{Bi} - P_{LA}L_{Ai}) \qquad (9)$$

Where P_{LA} and L_A are at E_A and P_{LB} and L_B are at E_B. The present value of the welfare change is thus:

$$\int_0^{Q_B}\Delta We^{-rt}dt = \sum_{i=1}^{n} V_{LB}LB_{Bi} - V_{LA}L_{Ai}) \qquad (10)$$

The Ricardian model takes either (9) or (10) depending on whether data are available on (6) annual net revenues or capitalized net revenues (land values V_L). The model in (9) will be employed for this research, as data on land prices for the selected samples are hardly available. This is the same approach followed by Sanghi *et al* (1998) and Kumar and Parikh (1998) for India

3. Materials and methods

The econometric approach used in this study is based on the Ricardian method to assess economic impacts of climatic changes, which allows for capturing adaptations farmers make in response to climate changes. The method was named after David Ricardo (1772 – 1823) because of his original observation that land value would reflect its net productivity. The principle is shown explicitly in the following equation:

$$LV = \sum P_i Q_i (X, F, H, Z, G) - \sum P_x X \quad (11)$$

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). It is assumed 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). Following previous works such as Molua, (2005), Eid et. al (2006) and Mendelsohn et. al (2007), the standard Ricardian model relies on a quadratic formulation of climate:

$$LV / ha = \beta_0 + \beta_1 F + \beta_2 F^2 + \beta_3 Z + \beta_4 G + \mu \quad (12)$$

Where LV / ha is the land value measured by rent per hectare, F is vector of climate variables, Z is a set of soil variables, G is a set of socio-economic characteristics, μ is the error term. Farm-level data on land value and its determinants are collected from 1200 randomly

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

$$E[dLV / df_i] = b_{1,i} + 2 * b_{2,i} * E[f_i] \quad (13)$$

The signs of the linear terms indicate the uni-directional impact of the independent variables on the dependent variable, the quadratic term reflects the non-linear shape of the net revenue of the climate response function. When the quadratic term is positive, the net revenue function is U shaped and when the quadratic term is negative the function is hill-shaped. Agronomic studies reveal that crops consistently exhibit a hill-shaped relationship with annual temperature, although the maximum of that hill varies with the crop.

Ordinary least square (OLS) estimation procedures using STATA 10.0 software were used to fit the models. To overcome the problems of heteroscedasticity and multicollinearity, a robust estimation of the standard error was undertaken and identified correlated variables were dropped from the models. Variables were dropped from the model on the basis of low significance level and low contribution in improving the overall significance of the estimation models. The marginal impact of seasonal climate variables was estimated for each of the models.

Following Kurukulasuriya and Mendelsohn (2008) this study explicitly estimates the model separately for dryland and irrigated rice farms.

Data and Empirical Analysis

selected rice farmers spread all over the agro-ecological zones. The survey covered 20 states in the country, which were selected to represent the major rice producing regions in the country, namely, Kano, Niger, Benue, Yobe, Kaduna, Anambra, Ebonyi, Kwara, Edo, Taraba and Kebbi states, Zamfara, Jigawa, Borno, Adamawa, Ondo, Ogun, Cross River, Ekiti, and Kogi states. There are significant variations in temperatures and precipitations of the states. The differences are driven by elevations. A sample of 60 rice farmers was randomly selected from each state, making a total of 1200 respondents. The data were collected with the use of a structured questionnaire administered to the rice farmers between September 2008 and January 2009.. The questionnaire comes from Yale University and the University of Pretoria. The questionnaire has two main parts and six sections. Part 1 focuses on crop production and Part 2 on livestock. Sections 1 and 2 ask about household characteristics and the household head's employment. The questions in Section 3 are about the household's land under farming activities (both crops and livestock), and about the labor used for various farm activities and about their costs. In Section 4 detailed questions are asked about crop farming activities: the type of crops grown, the area of land planted, the quantities of crops harvested and sold, and various costs such as seeds, fertilizer and pesticides; light, heavy and light and heavy machinery and animals used in agricultural work; and farming related buildings. Section 4 asks about the types of animals farmed and how many are purchased, lost and sold during the growing season, and about livestock and poultry products, such as milk, beef, wool and eggs. Section 5 asks about the farmers' access to information on farming activities and the sources and cost of this information, and Section 6 asked for an estimate of the farm household's total income (for both farming and non-farming activities), taxes paid and subsidies received. Finally, Section 7 contains questions on farmers' perceptions of short- and long-term climate change and their adaptation strategies in response to these.

January to December monthly means for precipitation and average temperature from 1970 to 2007 were specifically obtained from Nigeria Meteorological Agency at Oshodi in Lagos Nigeria and International Institute for Tropical Agriculture (IITA) in Ibadan, Nigeria. There are 32 stations in the country. Given significant variation in temperatures across geographic locations (driven primarily by elevation the study accounted for seasonal temperatures and precipitations.

The soil data for the 20 states producing rice in Nigeria are obtained from the Food and Agricultural Organization. The FAO provides information about the major and minor soils in each location, including the slope and texture. In all there exists 5 types of soil in the states and all of them were used in the analysis. The distributions of the soil by the states are shown in Table 1. Run offs data for various regions in the country were obtained from Global Centre for Hydrological Data in Germany. Runoff is defined as excess precipitation, which is not absorbed by soils. It runs on the soil surface and eventually joins a stream. Runoff takes away soil nutrients. Excessive runoff may have a negative impact on farm yield.

It is abundantly clear from literature that irrigation and water availability are important to rice production in Nigeria. Irrigated lands are generally of higher value when compared to farms that rely solely on rain. Farms that rely only on rainwater are classified as dry land.

Table 1: State soil Variable

	State	Soil type
1.	Kano	(Gb)- Brown and Reddish Brown soil of Arid and Semi arid Regions (not differentiated)
2.	Niger	(Jc)- Ferruginous Tropical Soils on Crystalline Acid Rocks
3.	Benue	(Ln)- Ferrallite Soils, Dominant Colour Red (not differentiated)
4.	Yobe	(Gb)- Brown and Reddish Brown soil of Arid and Semi arid Regions (not differentiated)
5.	Kaduna	(Jc)- Ferruginous Tropical Soils on Crystalline Acid Rocks
6.	Anambra	(Li)- Ferrallite Soils, Dominant Colour Red on Loose Sandy sediments.
7.	Ebonyi	(Ln)- Ferrallite Soils, Dominant Colour Red
8.	Kwara	(Jc)- Ferruginous Tropical Soils on Crystalline Acid Rocks
9.	Edo	(La)- Ferrallitic Soils, Dominant Colour Yellowish – Brown, (not differentiated)
10.	Taraba	(Jc)- Ferruginous Tropical Soils on Crystalline Acid Rocks
11.	Kebbi	(Jc)- Ferruginous Tropical Soils on Crystalline Acid Rocks
12.	Ekiti	(Jc)- Ferruginous Tropical Soils on Crystalline Acid Rocks
13.	Kogi	(Jc)- Ferruginous Tropical Soils on Crystalline Acid Rocks
14.	Zamfara	(Jc)- Ferruginous Tropical Soils on Crystalline Acid Rocks
15.	Jigawa	(Gb)- Brown and Reddish Brown soil of Arid and Semi arid Regions (not differentiated)
16.	Borno	(Gb)- Brown and Reddish Brown soil of Arid and Semi arid Regions (not differentiated)
17.	Adamawa	(Jc)- Ferruginous Tropical Soils on Crystalline Acid Rocks
18.	Ondo	(Jc)- Ferruginous Tropical Soils on Crystalline Acid Rocks
19.	Ogun	(Li)- Ferrallite Soils, Dominant Colour Red on Loose Sandy Sediments.
20.	Cross River	(La)- Ferrallitic Soils, Dominant Colour Yellowish – Brown, (not differentiated)

Those that depend at least on surface water resources, groundwater or stored water in any season of the survey year are assumed to be irrigated.

In addition to the climate and soil variables, the study collected information about the farmer characteristics. These include the household head's education level to capture effects such as ability of households to adopt new technologies, as well as ability to better optimize on farming and marketing practices. The survey also obtained information about the farmer's experience, which is expected to have a positive impact on farm profitability.

The socio-economic data obtained from the survey also include the gender of the household head, household size, farm size, educational status, access to public extension services, access to credit, amount of crop consumed, amount of crop sold by type of markets, the use of machinery, cost of labour used, the values in kilometers of variables distance to market from where inputs were purchased and output sold.

The key response variable used in this paper is the per hectare land value. The land value was measured in terms of rent paid by the farmer. The dependent variable is regressed on climate and other important control variables, such as soils and socioeconomic data.

After estimating the model above, simulations was undertaken using different climate scenarios to determine how rice production will be affected under the scenario. For instance, how will rice production be affected if temperature or precipitation falls or varies by certain proportion?

4. Results and discussion

Descriptive Statistics

The basic summary statistics of the dataset for the relevant variables of the study are presented in Table 2. On the average, the net farm revenue per hectare for both irrigated rice and dry land farms were N31382.63 and N23432.59 respectively. The mean value of land rent per hectare for irrigated rice farms was also greater that of dry land rice farms. The values were N3523.67 and 2580.76 respectively. This paper considers two climate data namely temperature and precipitation and their mean values in January, April, July and October. The mean rainfall and temperature vary across the two category of farms considered in this study. As expected, irrigated rice farm regions were generally warmer than dry land rice farms in all the months due to lower level of precipitation (Table 2).

The soil type on which the farmers operated is a function of geographical location. These soil types are (Gb)- Brown and Reddish Brown soil of Arid and Semi arid Regions (not differentiated); (Jc)- Ferruginous Tropical Soils on Crystalline Acid Rocks; (Li)- Ferrallite Soils, Dominant Colour Red on Loose Sandy Sediments.; (Ln)- Ferrallite Soils, Dominant Colour Red (not differentiated); (La)- Ferrallitic Soils, Dominant Colour Yellowish – Brown,(not differentiated). More than half of the irrigated rice farmers (55%) plant on Jc soil type. The same set of farmers that use Gb, Li, Ln and La are in the proportion of 17%, 12%, 3%,and 0% respectively. On the other hand, about 44% of dry land rice farmers plant on Jc soil while 6%, 8%, 15% and 25% used Gb, Li, Ln, and La respectively. The average total area devoted to rice cultivation is 3.76 Hectares.

Table2. Descriptive Statistics: Variables for net revenue regression model

	All farms		Irrigated farms		Dry land farms	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Net revenue per hectare	26632.48	26354.91	31382.63	26348.53	23432.59	25890.21
Land rent per hectare	2963.27	2879.08	3523.67	2923.16	2580.76	2847.00
January rain	5.95	7.04	1.11	2.16	9.22	7.30
April rain	90.80	64.41	44.68	32.12	121.86	62.06
July rain	223.91	71.36	194.06	29.58	244.02	83.25
October rain	123.95	95.60	56.19	42.93	169.60	94.23
January temperature	32.86	1.75	32.51	2.07	33.10	1.44
April temperature	36.14	2.86	37.98	2.05	34.90	2.65
July temperature	30.24	1.68	31.05	1.47	29.69	1.59
October temperature	32.51	1.98	33.54	1.69	31.82	1.85
Squared January rain	84.93	161.02	5.88	17.16	138.18	190.16
Squared April rain	12388.84	13557.17	3026.17	3888.29	18695.91	14093.86
Squared July rain	55222.32	40474.30	38530.87	11263.18	66466.36	48407.65
Squared October rain	24495.51	30591.43	4996.63	6321.16	37630.74	33331.34
Squared January	1082.78	113.29	1060.96	133.90	1097.48	94.27
Squared April	1314.27	207.54	1446.58	153.58	1225.14	191.01
Squared July temperature	917.17	103.51	966.30	91.55	884.08	97.86
Squared October	1060.89	130.94	1127.86	114.15	1015.78	121.96
Gb soil	0.10	0.30	0.17	0.37	0.06	0.23
Jc soil	0.49	0.50	0.55	0.50	0.44	0.50
Ln soil	0.10	0.30	0.03	0.16	0.15	0.36
Li soil	0.10	0.30	0.12	0.33	0.08	0.28
La soil	0.15	0.36	0.00	0.00	0.25	0.43
Mean flow	1884.22	1647.58	1296.37	755.82	2280.22	1941.90
Farm area	3.76	2.37	3.56	2.24	3.90	2.44
Credit	0.43	0.59	0.59	0.57	0.32	0.57
Irrigated	0.40	0.49	1.00	0.00	0.00	0.00
Urban market	0.57	0.50	0.61	0.49	0.54	0.50
Non-farm job	0.60	0.50	0.65	0.49	0.57	0.51
Market distance	53.85	27.26	48.98	24.69	57.12	28.41

Rice farming experience	18.02	11.74	16.54	11.68	19.02	11.68
Family size	5.70	4.99	6.88	5.10	4.91	4.76
Extension contact	1.77	2.17	1.64	2.39	1.86	2.00
Livestock keeping	0.54	0.93	0.28	0.53	0.71	1.09
Educational status	10.05	6.79	10.79	7.66	9.55	6.09
Observations	1200		483		717	

This suggests that rice farming in Nigeria is still predominantly on small scale level. More land area on the average was devoted to dry land rice farming (3.90) than irrigated (3.56). Access to credit also varied widely across the two categories of rice growers. On the average, about 59% of the irrigated rice farmers had access to formal credit. Whereas less than one third (32%) of dry land rice farmers had access. The sales of produce to urban market followed the same pattern, about 61% of irrigated rice farmers sold their rice at urban market while the proportion was about 54% for dry land rice farmers. Accessibility to land depends mostly on whether a farmer is a native of a particular location or not. There are four main mode of land acquisition identified by the farmers. About 41% of the farmers rented their crop land, While 59% got their land through other means such as leasing and communal land tenure system. In order to reduce the side effects of unfavourable climatic conditions, about 65% and 57% of the irrigated rice farmers and dry land rice farmers respectively engage in various off-farm works. These include civil service, artisan, teaching and other vocational activities. The average distance of market place to the farm is about 49km for irrigated rice farmers and 57.12km for dry land rice farmers.

The summary of the personal characteristics show that on the average, irrigated rice farmers were more educated than dry land rice farmers The average farming experience however did not follow that pattern. Their average farming experience was 16.54 and 19.02 for irrigated rice farmers and dry land rice farmers respectively. The average number of extension visits also differs by categories of rice farms. Quite interesting, the extension agents visited dry land rice farmers than irrigated rice farmers perhaps because they were less educated and therefore required more attention. In respect of livestock farming, it was far more prevalent among dry land rice farmers (71%) than irrigated rice farmers (28%) as a climate adaptation option.

The Regression Results

Land rent as a measure of the value of agricultural land was available for 491 (About 41%) out of 1200 respondents. Out of the 491 farmers, about 48% of them irrigated their farms. Since the complete data set comprises a survey of 1200 rice farms from 20 states in Nigeria, the analysis of the data at this stage was truncated. This is because the dependent variable – land rent per hectare - was not observed for 709 out of 1200 farmers. The usual approach for dealing with this kind of incidental truncation is to include an explicit equation for the population of interest. Generally, sample selection is only problematic from an econometric point of view if the error term from the sample selection equation is correlated with the error term from the equations of primary interest.

Table 3: Heckman Sample Selection Model: Dependent Variable = Land Rent/ha

	All farms		**Irrigated**		**Dry**	
Variable	A	T	A	T	A	T
Constant	126538.8	0.29	596546.7	9.14	610946.5	1.33
January rain	-1317.584	-2.63			-5272.48	-2.20
April rain	-83.384	-1.13	-3041.778	-8.62	-1019.09	-1.96
July rain	23.597	0.50	832.488	5.94	600.44	1.87
October rain	97.117	1.25	3712.8	8.67	846.41	2.37
January temperature	791.628	0.04				
April temperature	-3092.433	0.30			-32572.93	-1.32
October temperature	-12093.04	-0.72				
Squared January rain	31.249	1.39	736.984	9.68	238.94	2.12
Squared April rain	0.0068	0.03	12.389	8.91	3.05	2.18
Squared July rain	-0.044	-0.40	-3.119	-6.63	-1.51	-1.96
Squared October rain	-12093.04	-0.72	-20.764	-8.58	-1.56	-2.56
Squared January temperature	18.135	0.07	265.902	8.65	7.48	0.35
Squared April temperature	25.427	0.18	47.844	7.56	409.17	1.33
Squared July temperature	82.607	4.03	322.587	6.94	46.14	1.07
Squared October temperature	-243.663	-0.96	-968.370	-8.18	-62.86	-1.23
Gb soil	3164.803	0.86			11100.29	1.42
Jc soil	-1317.421	-1.70	-659.410	-1.46	-2624.4	-1.37
Ln soil	3052.072	1.92			229.72	0.12
Li soil	-1462.877	-1.08			9030.25	1.81
La soil						
Mean flow	-0.412	-2.28	2.185	6.37	-2.46	-1.46
Farm area	22.552	0.54	5.883	0.18	26.87	0.46
Credit	-231.217	-1.16	123.314	0.93	-488.46	-1.47
Irrigated	1371.003	5.26				

Table 4: Heckman Sample Selection Model: Selection equation

	All farms		Irrigated farms		Dry land farms	
Variable	**A**	**T**	**A**	**T**	**A**	**T**
Constant	0.41	2.59	0.30	1.31	0.58	2.71
Mean flow	0.00	0.33				
Farm area	-0.02	-0.96	-0.013	-0.51	-0.02	-1.03
Credit	0.03	0.37	0.10	0.85	-0.08	-0.84
Irrigated	0.04	0.51				
Urban market	0.01	0.16	0.18	1.45	-0.11	-1.12
Non-farm job	-0.06	-0.73	-0.12	-0.98	-0.03	-0.32
Market distance	0.00	0.58	0.01	2.40	-0.00	-1.11
Rice farming experience	-0.01	-2.67	-0.01	-2.61	-0.01	-1.53
Family size	0.00	0.30	-0.01	-0.82	0.01	1.05
Extension contact	0.03	1.35	0.03	1.47	0.02	0.77
Livestock keeping	0.01	0.20	0.13	1.07	-0.01	-0.20
Educational status	-0.01	-1.57	-0.02	-1.94	-0.00	-0.45
N	1200		483		717	
Censored observation	491		191		300	
Wald chi2	209.30		462.04		64.46	

Heckman's method for correcting this source of bias was used in this study. This involves identifying variables that could be included in the selection equation but which do not appear as independent variables in the primary equation (Heckman 1979). The regression results for the Heckman sample selection model are shown in Table 3. The variables used to identify the model include among others, whether the respondent worked off farm, family size, education of the respondents in year, whether the respondent sells at urban market and the farming experience of the respondents.

The results in Table 3 showed that the climate variables in dry land rice farms were not significant when compared with the results for irrigated rice farm model. The second order temperature had positive and significant effect on land rents. A U-shaped relationship was observed for precipitation in January and April for dry land rice farms.

The results showing relevance of various soil types show that none of them was significant for both dry land and irrigated farms. The run-off variable was negative and significantly related to land rent per hectare for all rice farm and irrigated rice farms. This indicates that the implicit value of land is lower in areas characterized by high level of runoff.

Turning to the selection equation (Table 4), educational status of the respondents, farming experience in years and market distance significantly affected land rent for irrigated rice farms. Apart from market distance, the variables were positive.

Surprisingly, none of the variables significantly affected land rent for dry land rice farms. The Wald test however, readily rejects the hypothesis that the regression equation and the selection equation are independent of one another, justifying the use of the Heckman model.

Elasticities of Climate Factors from Land Rent Model

The results of the elasticities calculated from the land rent model are shown in Tables 5 and 6). A percentage rise in January and July temperature would cause a rise in the land rent. On the contrary, a percentage change in October temperature would cause a decline in rent for both farm types.

Table 5: Monthly and annual temperature elasticities evaluated at the sample mean for irrigated farms

	Land rent function	
Month	**Irrigated**	**Dry land**
January	159.513	6.351
April	39.172	-56.142
July	176.524	31.520
October	-618.304	-49.324
Annual	-243.093	-67.595

Table 6: Monthly and annual precipitation elasticities evaluated at the sample mean for irrigated farms

Month	**Land rent function**	
	Irrigated	**Dry land**
January	0.516	-3.097
April	-24.532	-13.025
July	-20.821	-12.907
October	21.996	20.896
Annual	-22.841	-8.133

The precipitation elasticities from land rent function varied largely in the same direction across farm types. For instance, increasing April precipitation on irrigated rice farms by 1 percent would decrease land rent by 24% per annum and dry land farms' by about 13%. In similar fashion, a 1% rise in July precipitation would decrease land rent by about 21% and 13% on irrigated and dry land rice farms respectively.

Impacts of Forecasted Climate Scenario on Rice Land Rent

The simulation results for land rent models are shown in Table 7. Increasing precipitation will decrease the value of land for both irrigated and dry land farm whereas it will increase irrigated farm revenue.

In similar fashion, simultaneously changing both temperature (+2^{o}C) and precipitation (-5%) will have harmful effect on land rent for both irrigated and dry land rice farming. On the other hand, the scenario will have positive effect on irrigated farm net revenue but negative effect on dry land farm net revenue.

Table 7: Impact of changing only temperature or rainfall on rice land rent in percentage %

Climate Variable	Climate Scenarios	Irrigated	Dry
Temperature	+2 °C	-2.68	-21.04
Rainfall	-5%	-11.6	-17.11
Both temperature and rainfall	+2°C and 5% reduction in rainfall	-18.34	-29.18

5. Conclusion and implication

The empirical results from this study provide certain evidence that climate change is significant to rice agriculture in Nigeria. The results showed that land rent per hectare is sensitive to marginal change in climate variables (temperature and precipitation). The degree of sensitivity however depends on whether the farm is irrigated or not.

Generally, both irrigated and dry land farms are more sensitive to marginal changes in temperature than precipitation. The results have some implications for the relevance of irrigation as an adaptation technique and the use of land value in estimation of Ricardian models.

a. The results suggest that the use of irrigation has proved to be an effective adaptation measure to reduce the harmful effects of climate change on rice agriculture. However, most river basins in the country are under-performing. They are ineffective in meeting the demand of rice farmers in Nigeria. Further investments are therefore required to resuscitate the irrigation systems both in terms of facilities and manpower.

b. Since land rent is sensitive to marginal changes in climate variables, efforts should be geared towards having a well functioning land market in the nation. The on-going review of the nation's land use and reforms for instance should give this utmost consideration.

c. By and large, given the increasing investment of Nigeria government to increase rice production, wider research and deeper analyses of climate change on its agriculture should be encouraged.

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