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ECONOMIC IMPACT OF CLIMATE CHANGE ON VALUE OF IRRIGATED RICE FARMS IN NIGERIA: THE RICARDIAN APPROACH

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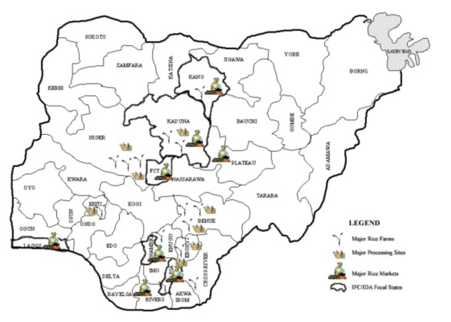
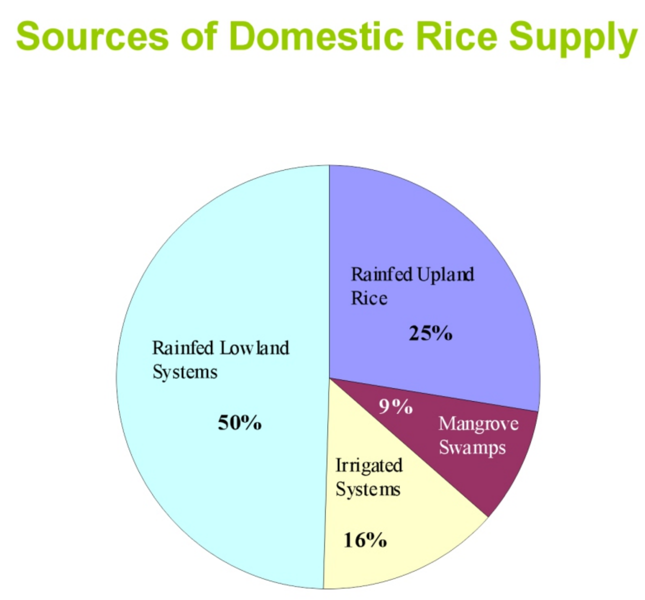
Introduction

The vulnerability of Nigerian agricultural sector to climate change could be of particular interest to policy makers because agriculture is a key sector in the economy. Like other developing nations, Climate Change affects Nigerian agriculture in a number of ways. For example, uncertainties in the onset of the farming season, due to changes in rainfall characteristics can lead to an unusual sequence of crop planting and replanting which may result in food shortages due to harvest failure. Extreme weather events such as thunderstorms, heavy winds, and floods, devastate farmlands and can lead to crop failure. Pests and crop and diseases migrate in response to Climate Changes and variations (e.g. the tsetse fly has extended its range northward) and will potentially pose a threat to livestock in the drier northern areas. It is estimated that by 2100, Nigeria and other West African countries are likely to have agricultural losses of up to 4 % of GDP due to climate change (Mendelsohn, et al, 2000). Parts of the country that experienced soil erosion and operate rain-fed agriculture could have decline in agricultural yield of up to 50 % between 2000 – 2020 due to increasing impact of climate change (Agoumi, 2003; IPCC, 2007).

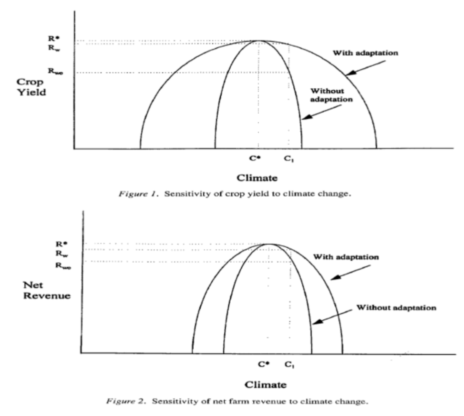
A recent research has shown that rice can be used to offset the major impacts of climate change because of its potentials and unique properties as a food crop for urban poor and rural rice-growing populations (Manneh et. al. 2007). Rice is a major cereal in Nigeria in terms of its output and land area. The crop is currently grown in more than 70% of the states in the country.

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 (Akpokodje et.al. 2002 and FAO, 2004). 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 land value and hence the crop productivity. So far, there has not been any nationwide study in Nigeria that address the economic impacts of climate change on value of land for rice farming and farm level adaptations that rice farmers make to mitigate the potential impact of such climate change.





The main objective of this study therefore is to analyze the economic impact of climate change on value of land for rice production in Nigeria. Specifically, the study (i) estimated a traditional Ricardian model using land rent as the dependent variable unlike previous works which used net revenue; (ii) evaluated the importance of irrigation as an alternative course of action to mitigate the likely impact of climate change on value of land for rice farming in Nigeria.



Materials and Method

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 principle is shown explicitly in the following equation:

$$LV = \sum P_i Q_i(X, F, H, Z, G) - \sum P_x X \quad \ldots\ldots (1)$$

Where
LV is the value of land,
Pi is the market price of crop i,
Q_i is the quantity of crop i produced,
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).

Following Mendelsohn et. al (2007), the standard Ricardian model relies on a quadratic formulation of climate:

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

Where *LV/ha* is land value measured by rent per hectare respectively, *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.

In this study, land rent as a measure of the value of agricultural land was available for 491 (About 41%) out of 1200 respondents. Heckman's sample bias method was used to correct this source of bias. The expected marginal impact of a single climate variable on the land value was evaluated at the mean as follows:

$$E[dLV/df_i] = b_{1,i} + 2 * b_{2,i} * E[f_i] \quad \ldots\ldots (3)$$

Response variable

The first measurement of net revenue (NR1) is gross revenue less the cost of fertilizer and pesticides per hectare of cropped area. The second one (NR2) is where hired labor cost per hectare was deducted from NR1. The third one is NR3, where total machinery cost per hectare is deducted from NR2. The fourth (NR4) is obtained when other crop farming costs are deducted from Nr3.

EXPLANATORY VARIABLES

Climate variables. This study relies on monthly rainfall and temperature data from 1970 – 2007. We use climate data from available weather stations in Nigeria. There are 32 stations in the country. We specifically collected January to December monthly means for precipitation and average temperature for the period from Nigeria Meteorological Agency at Oshodi in Lagos Nigeria and International Institute for Tropical Agriculture (IITA) in Ibadan, Nigeria.

Soil variables: 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.

Hydrological variables: 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. At present we use geopolitical zone dummy as a proxy. The hydrological data (runoff) were obtained from global centre for hydrological data in Germany

Socioeconomic variables: 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.

Results and Discussion

Descriptive Statistics of Variables for the Ricardian model

The mean value of land rent per hectare for irrigated rice farms was greater than that of dry land rice farms. The values were N2879.08 and 2685.76 respectively. As expected, irrigated rice farm regions were generally warmer than dry land rice farms in all the months due to lower level of precipitation. The soil type on which the farmers operated is a function of geographical location. 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.

Variable	All farms Mean	All farms Std. Dev.	Irrigated farms Mean	Irrigated farms Std. Dev.	Dry land farms Mean	Dry land farms Std. Dev.
Land rent per hectare	2682.05	2879.08	2824.98	2923.16	2585.76	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 temperature	1082.78	113.29	1060.96	133.90	1097.48	94.27
Squared April temperature	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 temperature	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

Table 1. Descriptive Statistics

Table 2. Heckman Sample Selection Model: Dependent Variable = Land Rent/ha

Variable	All Farms Coefficient	All Farms t-value	Irrigated coefficient	Irrigated t-value	Dry Coefficient	Dry t-value
Constant	1340408	2.65	-209956.3	-1.50	610946.5	1.33
January rain	-660.86	-1.16			-5272.48	-2.20
April rain	139.33	1.66	1179.09	1.56	-1019.09	-1.96
July rain	42.58	0.79	-468.13	-1.56	600.44	1.87
October rain	-86.72	-0.98	1555.59	1.67	846.41	2.37
January temperature	-57291.43	-2.84				
April temperature	19765.51	1.66			-32572.93	-1.32
July temperature						
October temperature	-45693.86	-2.39				
Squared January rain	19.82	0.77	208.87	1.28	238.94	2.12
Squared April rain	-0.47	-1.64	-4.33	-1.45	3.05	2.18
Squared July rain	-0.10	-0.80	1.66	1.65	-1.51	-1.96
Squared October rain	2775663	1.32	-8.86	-1.71	-1.56	-2.56
Squared January temperature	871.60	2.82	-107.46	-1.63	7.48	0.35
Squared April temperature	-286.66	-1.80	-40.52	-2.98	409.17	1.33
Squared July temperature	-27.24	-1.16	-156.05	-1.57	46.14	1.07
Squared October temperature	731.15	2.52	429.33	1.69	-62.86	-1.23
Gb soil	-10186.14	-2.43			11100.29	1.42
Jc soil	-1274.03	-1.43	-615.44	-0.64	-2624.4	-1.37
Ln soil	-3688.11	-2.03			229.72	0.12
Li soil	-3160.79	-2.02			9030.25	1.81
La soil						
Mean flow	-0.62	-3.05	-1.39	-1.89	-2.46	-1.46
Farm area	26.55	0.59	-1.12	-0.02	26.87	0.46
Credit	-369.77	-1.69	-98.58	-0.34	-488.46	-1.47
Irrigated	554.74	1.92				

Table 3. Heckman Sample Selection Model: Selection equation

Variable	All farms coefficient	All farms t	Irrigated farms coefficient	Irrigated farms t	Dry land farms coefficient	Dry land farms 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	-0.01	-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	140.65		94.03		64.46	

More climate variables were significant in dry land rice farms than in irrigated rice farms. Apart from October temperature which was positive, and significantly related to land rent for irrigated rice farms, other temperature variables were insignificant. They were however significant for dry land rice farm model. The second order temperature had positive and significant effect on land rent for irrigated rice farms. On the contrary, 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 showed that none of them was significant for both irrigated and dryland rice model. The run-off variable was however negative and significantly related to land rent per hectare for all rice farm and irrigated rice farms. This showed that the implicit value of land is lower in areas characterized by high level of runoff. Educational status of the respondents, farming experience in years and market distance significantly affected land rent for irrigated rice farms.

The marginal impact analysis shows that dry land rice land rent fell at an average of N4778.31 per 1°C rise in temperature (Table 5). On the contrary, land rent per hectare for irrigated rice farms increase with increase in temperature. A breakdown of the results by various months showed that April and October temperature were harmful to land rent per hectare for dry land rice farming while October temperature was particularly beneficial to irrigated farms. The marginal effects of precipitation on land rent per hectare also varied across farm types. For instance, increasing precipitation on irrigated rice farms by 1 mm would increase land rent by 1991.91 per annum but reduced it by 1035.48 for dry land farms

Temperature	January	April	July	October	Annual
All farms	-9.88	-954.28	-1647.48	1845.51	-766.12
Irrigated	-6987.05	-3077.9	-9690.71	28799.46	9043.80
Dry	495.18	-4012.86	2739.79	-4000.41	-4778.31
Precipitation	January	April	July	October	Annual
All farms	-425	53.98	-2.20	-17.31	-390.53
Irrigated	1642.78	-855.06	2199.87	-995.69	1991.91
Dry	-940.19	-275.74	-136.5	316.95	-1035.48

Table 4. Marginal Effect of temperature and precipitation on land rent per hectare

The simulation results for land rent models are shown in Table 6. Increasing precipitation will decrease the value of land for both irrigated and dry land farm.. In similar fashion, simultaneously changing both temperature (+2°C) and precipitation (-5%) will have harmful effect on land rent for both irrigated and dry land rice farming.

Table 5. Impact of changing only temperature or rainfall on rice land rent in percentage %

Climate Variable	Climate Scenarios	All farm	Irrigated	Dry
Temperature	+2 °C	0.00	8.79	-10.46
Rainfall	-5%	95	-9.6	-13.15
Both temperature and rainfall	+2°C and 5% reduction in rainfall	-9	-34.69	-19.84

Conclusion

The empirical results from this study provide certain evidence that climate change is significant to rice production in Nigeria.
The results showed that land rent per hectare was 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, the value of land used for rice production was more sensitive to marginal changes in temperature than precipitation.
The results have some implications for the relevance of irrigation as an adaptation technique.

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 was 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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