ECONOMIC IMPACT OF CLIMATE CHANGE ON IRRIGATED RICE AGRICULTURE IN NIGERIA

By

AJETOMOBI, JOSHUA OLUSEGUN; ABIODUN, AJIBOYE; and HASSAN, RASHID

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JOSHUA OLUSEGUN AJETOMOBI

DEPARTMENT OF AGRICULTURAL ECONOMICS AND EXTENSION,
LADOKE AKINTOLA UNIVERSITY OF TECHNOLOGY,
PMB 4000 OGBOMOSO, NIGERIA.
E-MAIL: jsegun2002@yahoo.com

AJIBOYE ABIODUN
DEPARTMENT OF AGRICULTURAL ECONOMICS AND EXTENSION,
LADOKE AKINTOLA UNIVERSITY OF TECHNOLOGY,
PMB 4000 OGBOMOSO, NIGERIA.
E-MAIL: realpeggy@yahoo.com

RASHID HASSAN
CENTRE FOR ENVIRONMENTAL ECONOMICS AND POLICY IN AFRICA
UNIVERSITY OF PRETORIA, PRETORIA
SOUTH AFRICA
E-MAIL: rashid.hassan@up.ac.za

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IMPACTS OF CLIMATE CHANGE ON RICE AGRICULTURE IN NIGERIA[1]

Ajetomobi Joshua[a], Ajiboye, Abiodun[b] and Rashid, Hassan[c]

ABSTRACT

This study employed the Ricardian approach to test the relative importance of climate normals (average long-term temperature and precipitation) in explaining net revenue from Nigerian rice agriculture under irrigation and dry land conditions. A survey was done by interviewing 1200 rice farmers from 20 rice producing states in Nigeria. The states covered all the six geopolitical zones in the country. The results showed that increase in temperature will reduce net revenue for dry land rice farms while net revenue rises with increase in temperature for irrigated rice farms. Precipitation had similar effects on rice net revenue. Increase in precipitation will cause reduction in revenue for dry land rice farms whereas it will cause increase in revenue for irrigated farms. The results clearly demonstrate irrigation as a significant techniques used by the farmers to adapt to the climate change. Other adaptation options include Keeping of livestock, engaging in off farm works and the use of different market channels.

JEL CODES: Q12, Q25

Keywords: Climate change, Irrigation, Net Revenue, Nigeria.

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a Reader, Ladoke Akintola University of Technology, PMB 4000 Ogbomoso, Nigeria
b PhD student, Ladoke Akintola University of Technology, PMB 4000 Ogbomoso, Nigeria
c CEEPA Director and Professor, dept of Economics, university of Pretoria, Pretoria, South Africa

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 and Nigeria is one of the countries contributing to global warming. 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 et.al, 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.

The vulnerability of Nigerian agricultural sector to climate change is of particular interest to policy makers because agriculture is a key sector in the economy accounting for between 60-70% of the labour force and contributing between 30-40% of the nations GDP. The sector is also the source of raw materials used in several processing industries as well as a source of foreign exchange earnings for the country. How much one can hold climate responsible for changes in agricultural productivity in Nigeria will, for a long time, remain a subject of research as long as other factors are at interplay in determining agricultural productivity. The production of major export crops in the country such as groundnut, rubber, coffee, cocoa and palm produce in the country have declined in magnitude since the drought of 1972/73 which is the first real evidence of climate change in Nigeria. Though there is evidence of increase in food crop production generally in Nigeria, the nation is not self sufficient in production of any food crop except cassava. The question remains therefore as to whether the production level will ever meet the demand level given the rate of population growth in the country. Also, the proportion of change in production due to impact of climate change will remain an important research focus as well as measures needed to improve the resilience of the farmers to enable them adapt to climate change.

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, West African Rice Development Association (WARDA), International Institute for Tropical Agriculture (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 for instance, the nation spent 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 otherwise called dry land rice 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. MATERIALS AND METHODS

Model Specification

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:

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

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). The former definition was employed for this research, as data on land rent are not readily available because of absence of a well functioning land market in the country. 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:

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

Where

NR/ha represents net revenue per hectare, F is a vector of climate variables, Z is a set of soil variables, G is a set of socio-economic characteristics, and μ is the error term. Both linear and quadratic terms for temperature and precipitation are introduced. The expected marginal impact of a single climate variable on the land value and farm net revenue evaluated at the mean is:

$$E[dNR?ha/df_i] = b_{1,i} + 2 * b_{2,i} * E[f_i] \quad \ldots\ldots\ldots\ldots (5)$$

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 revealed 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 model. Variables were dropped from the model on the basis of low significance level and low contribution in improving the overall significance of the estimation model. The marginal impact of seasonal climate variables was estimated for the model. The advantage of this empirical approach is that the method includes both direct effect of climate on productivity and the adaptation response by farmers to local climate. An observed drawback of the approach however is that its explicit exclusion of irrigation. Cline (1996) and Darwin et.al (2005) both argue in favour of inclusion of irrigation in the analysis. Several researchers (Mendelsohn and Nordhaus, 1999; Mendelsohn and Dinar, 2003) have attempted to address the problem by modeling irrigation. Following Kurukulasuriya and Mendelsohn (2008) this study explicitly examines dry land and irrigated land as well as water flow as a measure of hydrology. The Ricardian analysis in this study clearly does take cognizance of irrigation.

Data and Empirical Analysis

Farm-level data on net-revenue and its determinants were collected from 1200 randomly 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 were significant variations in temperatures and precipitations of the states. The differences were 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 came from Yale University and the University of Pretoria. The questionnaire had two main parts and six sections. Part 1 focused on crop production and Part 2 on livestock. Sections 1 and 2 asked about household characteristics and the household head’s employment. The questions in Section 3 were 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 were 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 asked about the types of animals farmed and how many were purchased, lost and sold during the growing season, and about livestock and poultry products, such as milk, beef, wool and eggs. Section 5 asked 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 contained questions on farmers' perceptions of short- and long-term climate change and their adaptation strategies in response to these with special emphasis on the use of irrigation. According to Erenstein (2003), rice farmers in the tropics including Nigeria engage in other farm and off-farm activities. Other farm activities include growing of other cereals, tuber and tree crops as well as animal husbandry. Examples of their off-farm activities are fishery, hunting, salaried work, commerce, transport and other vocational jobs.

In respect of climate variables, January to December monthly means for precipitation and average temperature from 1970 to 2007 was 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. Their locations are shown in Table 3. Given significant variation in temperatures across geographic locations (driven primarily by elevation as shown in Table 1) we accounted for seasonal temperatures and precipitations.

The soil data for the 20 states producing rice in Nigeria were 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 2. 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. 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, we 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 study defined one key response variable: Per net revenue for rice farming. The net revenue was measured as the gross revenue less per hectare cost of the following variables – fertilizer, insecticide, herbicide, labour, depreciation on machineries, and other farming cost. The dependent variable was regressed on climate and other important control variables, such as soils and socioeconomic data. Following Mendelsohn and Williams (2004), the absence of a well-functioning land market in many African made it difficult for climate response functions to reflect the adjustments made by farmers to normal climate conditions. This explains why net revenue has been selected for this study as the dependent variable as done by previous researchers (Kumar & Parikh 2001, Molua and Lambi, 2007, and Eid, 2007). After estimating the models above, simulations were 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?

RESULTS AND DISCUSSION

Descriptive Statistics

The basic summary statistics of the dataset for the relevant variables of the study are presented in Table 3. On the average, the net farm revenue per hectare for both irrigated rice and dry land farms were N15640.44 and N23432.59 respectively. This paper considered two climate data namely temperature and precipitation and their mean values in January, April, July and October. The mean rainfall and temperature varied 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 3).

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%) planted on Jc soil type. The same set of farmers that used Gb, Li, Ln and La were in the proportion of 17%, 12%, 3%,and 0% respectively. On the other hand, about 44% of dry land rice farmers planted on Jc soil while 6%, 8%, 15% and 25% used Gb, Li, Ln, and La respectively.

The average total area devoted to rice cultivation was 3.76 Hectares. 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 engaged in various off-farm works. These include civil service, artisan, teaching and other vocational activities. The average distance of market place to the farm was about 49km for irrigated rice farmers and 57.12km for dry land rice farmers.

The summary of the personal characteristics showed 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

The analysis explores two principal hypotheses: first, rice farm net farm revenue per hectare is sensitive to climate. Second, irrigated and dryland rice farms have different response to climate (Mendelsohn and Dinar 2003, Schlenkar Hanemann and Fischer 2005). These hypotheses were tested by estimating the following regressions: (i) The net revenues per hectare for all the farms (ii) The net revenue per hectare for irrigated rice (iii) the net revenue per hectare for dry land rice. The net revenue per hectare is the response variables. They are regressed on climate and other control variables (Table 4). A non-linear (quadratic) model was chosen for ease of interpretation.

In the initial runs, different net revenues calculated per hectare were tried. The dependent variable that fitted the model best was net revenue defined as gross revenue less total variable costs less cost of machinery and less total cost of labour on various rice farming activities. Therefore, this definition was chosen for the results presented in this paper. The independent variables include both the linear and quadratic temperature and precipitation term. Three definitions of the climate variables were tried; firstly, they were defined in terms of four seasons: Winter (average for December, January and February), spring (the average for March, April and May), summer (the average for June, July and August) and fall for (September, October and November). Secondly, they were defined in terms of the predominant seasons in the country which are rainy (April to October) and dry (November to March) seasons. Thirdly, they were defined as the middle months for winter, spring, summer and fall, that is, January, April, July, and October. The results for the third definition had the best statistical quality. Hence it is reported and discussed in this paper.

The overall regressions in Table 6 showing net-revenue per hectare models were significant at the 1% level and the adjusted R-squared values were 0.46, 0.42 and 0.47 for all farm, irrigated and dry land rice models. Dry land rice farms had higher average net revenue per hectare than irrigated farms and respond differently to the explanatory variables. For example, the net revenue of irrigated rice farms increased with water flow as expected a priori. More climate variables significantly influenced net revenue per hectare of dry land rice farms than irrigated rice farms. Many of the climate coefficients in irrigated farm model were not significant because the climate variables were highly correlated with each other. The hypothesis that the second order temperature coefficient would be negative when higher temperature is catastrophic was supported by this study for all farms model. The results indicated that temperature was less harmful for irrigated rice farms when compared with dry land rice farms.

In respect of the relevance of various soil types, the coefficients of all the soil except jc affected net revenue significantly as shown in all farms model. However, none of them was significant for both irrigated and dry land rice model. The reductive importance of small farm holding in Nigeria is shown in the results for both irrigated and dry land rice model, as the coefficient of land area allocated to rice was negative and significant.

The household attributes included in the independent variables were livestock ownership, educational status, distance to output markets, household size, sales to urban market, employment in non-farm job and extension contact. As expected a priori, the coefficients of non-farm job, distance to output markets, and extension contacts were positives and significantly related to the net-revenue per hectare for irrigated farm model. They were not significant in case of dry land rice model. Contrary to expectation however, rice farming experience had negative and significant effect on the net revenue per hectare for irrigated rice farm model. This could be because of prevalence of unproductive elderly people in Nigeria rice agriculture who had actually put in many years into rice farming.

Marginal Impact Analysis For Net Revenue Model

The marginal impact analysis was conducted to assess the effect of an infinitesimal change in temperature and rainfall in Nigeria rice farming. Table 5 showed the marginal impacts of climate variables on net revenue per hectare. The climate variables had marked different marginal effects on dry land rice and irrigated rice farms' net revenue per hectare. Dry land rice net revenue per hectare fell at an average of ₦18,155.60 per 1^0C increase in temperature whereas irrigated rice net revenue fell at an average of ₦4864.63 per 1^0C (Table 5). Furthermore, the results showed that higher temperatures in January and October were harmful to dry land rice farming while higher temperatures in April and July were beneficial. On the other hand, higher temperatures in July and October were harmful to irrigated rice farming while higher temperature in January and April were beneficial. Temperature had a less harmful effect on irrigated rice farm partially because irrigation buffers the crop from rainfall shortages.

The marginal effects of precipitation on net revenues also vary across revenue sources; increasing precipitation on dry land rice farm by 1mm will reduce the net-revenue by ₦52421.50 per annum but increase it by ₦2657.03 per annum on irrigated rice farm. Increasing precipitation in January increases net revenue per hectare by ₦3432.92 for irrigated rice farms but harmful to dry land rice farms as it reduced the net revenue per hectare by ₦62910.6

Impacts of Forecasted Climate Scenario on Rice Net Revenue

In this section, the study simulated the impact of future climate change scenarios on Nigeria rice agriculture using the results from the estimated coefficients for net revenue function. In these simulations, the only variables subject to change were the climate variables. All other factors remained the same. Clearly this will not be the case over time. Technology, capital, consumption etc are bound to change over time and this will have tremendous impacts on future farm net revenue of any crop. The purpose of this exercise therefore is not to predict the future per se but simply examine the role climate may play in that future. In order to examine a wide range of climate outcomes, the formal approach rely on sets of climate models such as Canada Climate Change (CCC(and PCM (Parallel Climate Model) (Washington et al 2000) to examine the consequences of the climate change scenarios for 2050 and 2100. In Africa, for instance PCM predicts a 2^0C increase in temperature and 10% increase in precipitation. However, the climate models can only give a gross estimate of what will happen in any place. Consequently, in this paper, we have decided to use a range of scenarios that represent what might happen. The IPCC estimates that by 2100, temperature might rise from 2 to 6^0C and precipitation decline by 5-7% or rise by between 10-15%. Having tried several combinations, we have reported 3 scenarios here namely (i) increase in only temperature by 2^0C (ii) decline in only rainfall by 5% and (3) increase in temperature by 2^0C and decrease in precipitation by 5% simultaneously. Additionally, we explored if moving from rainfall to irrigated agriculture could be an effective adaptation option to reduce the harmful effects of climate change for the crop. The simulation results for net revenue model are shown Table 6. The results showed marked variation in the net-revenues for dry land and irrigated rice farms. While increasing temperature will increase the net-revenue per hectare by 3.9% it will decrease it by 11.7% for dry land rice farms. A 5% reduction in precipitation gave similar result. It will lead to increase in net-revenue for irrigated farms but decline for dry land rice agriculture. The results clearly confirmed that irrigation provided an effective adaptation option to reduce the harmful effects of climate change. Furthermore, the study examined the total effects of simultaneously changing both temperature and precipitation in all seasons on the net-revenue. The results showed harmful effects for dry land rice farms' net revenue but beneficial effects for irrigated farms net revenue.

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 net revenue 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, both temperature and precipitation were more sensitive to marginal changes in dry land farms revenue than irrigated farms. The results have some implications for the relevance of irrigation as an adaptation technique.

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. 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.

REFERENCES

Adams R. M (1989). Global climate change and agriculture: An economic perspective. *American Journal of Agricultural Economics* 71(5):1272-1279.

Chang C (2002). The potential impact of climate change on Taiwan's agriculture. *Agricultural Economics* 27:51-64.

Cline, W. 1996. The Impact of Climate Change on Agriculture: Comment. AmericanEconomic Review 86(5): 1309–1311.

Darwin, R., M. Tsigas, J. Lewabdrowski, and A. Raneses. 1995. World Agriculture and Climate Change. Agricultural Economic Report no. 703 (June). Washington, DC: US Department of Agricultural, Economic Research Service.

Deressa T., Hassan .R and Poonyth .D (2005): “Measuring The Impact of Climate Change on South African Agriculture: The Case of Sugar Cane Growing Regions”. Agrekon , Vol 44, No 4.

Eid, H. M., S. M. El-Marsafawy and S. A. Oudai, (2006). Assessing the economic impacts of climate change on agriculture in Egypt: a Ricardian approach. Research Journal of Agriculture and Biological Sciences, 2(6): 316-322, 2006

Erenstein O (2003). Smallholder conservation farming in the tropics and sub-tropics, A guide to the dissemination of mulching with crop residues, Agriculture, Ecosystem and Environment. (21): 17-37.

IPCC (Intergovernmental Panel on Climate Change) (1990). *Scientific assessment of climate change*. Report prepared by Working Group 1, World Metrological Organization and United Nations Environmental Program, New York.

IPCC (Intergovernmental Panel on Climate Change) (1996). *Impacts, adaptations and mitigation of climate change: Scientific-technical analyses*. Contribution of Working Group II to the IPCC Second Assessment Report, Cambridge University Press, Cambridge, UK.

Kumar K & Parikh J, 1998. Climate change impacts on Indian agriculture: The Ricardian approach. In Kurukulasuriya, P and Mendelsohn, R. 2007. Endogeneous irrigation: The impact of climate change on farmers in Africa. World Policy Research Working Paper 4278.

Kurukulasuriya, P and Mendelsohn, R 2008. A Ricardian analysis of the impact of climate change on African cropland AfJARE 2(1): 1-23

Manneh, B; P Kiepe; M Sie; M Ndjiondjop; NK Drame; K Traore;. J Rodenburg; E. A Somado; L Narteh; O Youm; A Diagne and K Futakuchi 2007. Exploiting Partnerships in Research and Development to help African Rice Farmers cope with Climate Variability" Paper presented at ICRISAT and CGIAR 35th Anniversary Symposium "Climate-Proofing Innovation for Poverty Reduction and Food Security" 22-24 November

Mendelsohn, R. 2007. Measuring climate impacts with cross sectional analysis. Climate Change 18: 1-7

Mendelsohn R, Nordhaus WD & Shaw D, 1994. The impact of global warming on agriculture: A Ricardian analysis. *American Economic Review* 84: 753–771.

Mendelsohn R & Dinar A, 2003. Climate, water, and agriculture. *Land Economics* 79(3): 328–341.

Maddison David, Marita Manley and Pradeep Kurukulasuriya (2007):"The Impact of Climate Change on African Agriculture: A Ricardian Approach". The World Bank Development Research Group Sustainable Rural and Urban Development Team.

Mendelsohn R, Nardhaus W & Shaw D (1994**)**. The impact of global warming on agriculture. A Ricardian analysis. *American Economic Review* 84(88):753-771.

Mendelsohn, R and Williams, L 2004. "Comparing Forecasts of the Global Impacts of Climate Change" Mitigation and Adaptation Strategies for Global Change, 9: 315-333.

Molua, E. L. and C. M. Lambi (2007). The economic impact of climate change on agriculture in Cameroon. The World Bank Policy Research Working Paper 4364

Nhemachema, C and Hassan, R 2007. Micro-Level Analysis of farmers' adaptation to climate change in South Africa. IFFRI discussion paper 00714.

Schlenker, W; W. M. Hanemann and A. C. Fisher 2005. Will US Agrivulture Realy benefits from global warning? Accounting for irrigation in Hedonic approach. American Economic Review 95(1): 395-406

Table 1: Weather Stations in Nigeria

Station	**Elevation**	**Latitude (DD)**	**Longitude (DD)**
Abuja	3440	+09250	+007000
Bauchi	6090	+10283	+009817
Benin city(civ/mil)	790	+06317	+005600
Bida	1430	+09100	+006017
Calabar	630	+04967	+008350
Enugu	1400	+06467	+007550
Gusau	4690	+12167	+006700
Ibadan	2340	+07433	+003900
Ibi	1110	+08183	+009750
Ikom	930	+05967	+008717
Ilorin	3050	+08483	+004583
Jos	12850	+09867	+008900
Kaduna (civ/mil)	6420	+10600	+007450
Kano/mallam aminu	4810	+12050	+008533
Katsina	4270	+13017	+007617
Lagos/ikeja	380	+06583	+003333
Lagos/oshodi	190	+06550	+003350
Lokoja	440	+07800	+006733
Maiduguri	3540	+11850	+013083
Makurdi (mil)	970	+07683	+008617
Minna	2600	+09617	+006533
Nguru	3440	+12883	+010467
Ondo	2870	+07100	+004833
Onitsha	860	+06150	+006783
Oshogbo	3040	+07783	+004483
Port Harcourt	180	+04850	+007017
Potiskum	4880	+11700	+011033
Sokoto	3020	+13017	+005250
Warri	60	+05517	+005733
Yelwa	2430	+10883	+004750
Yola	1740	+09233	+012467
Zaria	6640	+11133	+007683

Source: National Meteorological Agency, Lagos Nigeria

Table 2: 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)

Table 3: 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	20296.25	22021.94	15640.44	13202.41	23432.59	25890.21
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
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	

Table 4: Determinants of Net Farm Revenue Per Hectare

	ALL FARMS		IRRIGATED		DRY	
Variable	coefficient	t-value	coefficient	t-value	coefficient	t-value
Constant	574000000	8.53	509314.6	1.33	18700000	5.12
January rain	45418.08	5.71	4190.86	0.78	23864.32	4.68
April rain	19934.04	8.49	-1517.10	-1.19	4131.92	7.10
July rain	-15254.51	-8.29	-3400.52	-2.02	-4407.27	-5..87
October rain	-10487.89	-7.35	-51.58	-0.03	-2230.20	-4.27
January temperature	-2295305	-8.14	4976.90	0.63	-1112546	-9.52
April temperature	977158	6.02	10632.09	2.85	152028.30	1.53
July temperature	-3080097	-9.05	-1731.83	-0.11	-154214.9	-0.96
October temperature	578629.2	8.37	-18741.79	-0.61	-15975.74	-1.97
Squared January rain	-4151.57	-7.25	-344.52	-1.15	-1632.95	-5.52
Squared April rain	-44.64	-8.07	12.03	3.62	-6.29	-3.05
Squared July rain	36.87	8.17	8.64	1.90	10.46	5.86
Squared October rain	18.10	7.05	-2.09	-0.15	3.18	3.17
Squared January temperature	34637.46	8.14			16656.73	9.56
Squared April temperature	-12281.96	-5.87			-1319.24	-1.03
Squared July temperature	46342.12	8.99			1722.69	0.66
Squared October temperature	-5318.52	-5.92				
Gb soil	-662610.4	-7.67			-12176.65	-0.30
Jc soil	-845.56	-0.42	-2477.70	-1.24	2054.13	0.36
Ln soil	42957.69	6.56				
Li soil	-213835.1	-8.24				
La soil						
Mean flow	-0.67	-1.23	1.51	1.53	-0.94	-1.29
Farm area	-4041.14	-6.97	-3093.96	-3.54	-5065.83	-8.65
Credit	-2349.35	-2.48	-1456.94	-1.41	-2515.80	-1.55
Irrigated	2604.27	1.79				
Urban market	1547.71	1.53	1036.30	0.94	1100.42	0.45
Non-farm job	983.55	0.95	2541.03	3.21	332.58	0.20
Market distance	27.83	1.77	44.85	2.70	13.86	0.55
Rice farming experience	-38.47	-0.74	-154.37	-2.50	29.87	0.39
Family size	-156.37	-0.98	-68.37	-0.48	-282.56	-1.08
Extension contact	547.87	2.82	688.18	2.71	252.50	0.84
Livestock keeping	412.97	0.39	925.66	0.57	1062.10	0.79
Educational status	114.15	1.41	47.47	0.50	244.23	1.67
N	1200		483		717	
R2	0.46		0.42		0.47	
F	32.97		5.88		23.93	

Table 5: Marginal Effect of Temperature and precipitation on net revenue per hectare

Temperature	**January**	**April**	**July**	**October**	**Annual**
All farms	-18931.10	89417.93	-277326	232819	25980.25
Irrigated	4979	10632.09	-1731.83	-18741.80	-4864.63
dry	-10203.60	59945.35	51921.6	-15915.7	-18155.60
Precipitation	**January**	**April**	**July**	**October**	**Annual**
All farms	-44885.5	11827.42	1256.61	-6000.9	-37802.4
Irrigated	3432.92	-442.1	-47.34	-286.45	2657.03
dry	62910.6	1294.12	4964.68	4230.36	-52421.50

Table 6: Impact of changing only temperature or rainfall on rice net revenue in percentage %

Climate Variable	Climate Scenarios	All farm	Irrigated	Dry
Temperature	+2 ^{o}C	-1.4	3.9	-11.7
Rainfall	-5%	0.2	22.63	-65.35
Both temperature and rainfall	2^{o}C rise in temperature and 5% reduction in rainfall	-8.5	20.92	-52.37