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An Empirical Analysis of Climate Change Effects on Selected Cereals Acreage in Nigeria: A Ricardian Approach

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Abstract:

This study examined the relationship between the acreage of selected cereal crops and climate variables for the period 1995 – 2021 in Nigeria. The study was based on maize, rice, millet and guinea corn for all the states in Nigeria for the period of study. Data for acreage of selected cereal crops for all the time period were collected from the Nigeria Bureau of Statistics (N.B.S) while data on the two important climate variables required for crop growth – temperature and precipitation – used for the analysis were obtained from the Nigerian Metrological Agency. The results indicated positive response of the acreage of the cereal crops to increase in temperature which is possibly due to other factors that serve in cushioning the effect of the temperature such as irrigation; rainfall has mixed relationship with the acreage of the cereal crops except; the negative coefficient of trend variable shows a negative relationship with the acreage of selected cereal crops. The results of the elasticity of cereals acreage to climate variables show that the acreage of rice is inelastic to rainfall but elastic to temperature. However, maize, millet and guinea corn acreage are all appreciably elastic to precipitation and temperature changes. These results also reveal that with the passage of years and climate factors running contrary to agricultural productivities, cereal crops farmers in Nigeria were adopting new measures to cope with the negative effect of climate change. Climate adaptation measures which include the use of drought or heat resistant varieties, early sowing, mixed cropping, tillage system alteration and the utilization of land that has been considered too marginal for agricultural cultivation reduces the negative effects of climate change on cereal crops acreage and enhances the positive factors.

Keywords: *Climate change, Agriculture, Cereal crops, Ricardian, Nigeria.*

Introduction

The role of agriculture remains significant in the Nigeria economy despite the strategic importance of the oil sector. Farming systems in Nigeria, which are mostly small in scale, are predominantly subsistence - based and for the most part depend on the vagaries of the weather. Rain-fed farming dominates agricultural production in Nigeria and exposes agricultural production to high seasonal rainfall variability. Since agriculture in Nigeria is mostly rain-fed, it follows therefore that any change in climate is bound to impact its productivity in particular and other socio-economic activities hi the country (Ayinde et al, 2010).

Like other developing countries, climates change still has a strong impact on Nigerian agriculture. The challenge of climate change and global warming is enormous due to wide spread of poverty, prevailing slash-and-burn agriculture, erosion and burning of firewood and farm residue. Though climate change is a threat to agricultural and socio-economic development, agricultural production activities are generally more vulnerable to climate change and other sector (Ajetomobi et al., 2011). Fluctuation on climatic variables such as temperature, precipitation, humidity makes the farmers conduct their activities under the risky environment, resulting in variation in farmers' income (Orhan et al., 2011).

The impacts of climate change have been experienced globally, especially in the tropics (Idowu et al., 2011; Williams et al., 2018) and it have triggered a wide variety of physical and biological changes across the world with negative effects on agriculture, humans, and the environment (IPCC, 2014). The continuous rise in temperature which is one of the major drivers of climate change and its concomitant effect on livelihood has put sustainable development as the top priority in international discourse (IPCC 2018). Many nations have also continuously look for avenues to address climate change in order to deal with its obvious consequences.

Climate change threatens to exacerbate existing threats to food security and livelihoods due to a combination of factors that include the increasing frequency and intensity of climate hazards, diminishing agricultural yields and reduced production in vulnerable regions, rising health and sanitation risks, increasing water scarcity, and intensifying conflicts over scarce resources, which would lead to new humanitarian crises as well as increasing displacement (IPCC, 2007).

Two most important issues impacted on by climate change are food security and human health. Food security and human health both have a direct and essential impact on human existence. Poor diet has been adjudged to be a major cause of mortality and morbidity (Afshin et al., 2019; Micha et al., 2020). Currently, about 690 million people are hungry and the number is expected to surpass 840 million by 2030 (FAO, 2020). As of 2020, 149.2 million children under 5 years of age were stunted and 45.4 million were wasted, partially due to poor diets. Simultaneously, 38.9 million children below 5 years of age were overweight in 2020 (WHO, 2021).

A direct negative impact of climate change on unsustainable food systems has been established (IPCC 1990, Derresa et al., 2005). . Specifically, climate change adversely affects food systems directly by impacting soil fertility, rain patterns, crop yields and food production, food-nutrient and anti-nutrient composition, and nutrient bioavailability (Niles et al., 2017; Von Braun, 2018). This vicious cycle leads to food insecurity and malnutrition in all its forms, environmental damage, water scarcity, and the emergence of new human, plant, and animal diseases (Tirado et al., 2009; Niles et al., 2017; Von Braun, 2018; Popkin, et al., 2020). It has also led to changes decrease macro and micronutrients available in the global food supply.

Evidence has shown that climate change has already affecting crop yields in many countries (IPCC, 2007; Deressa et al, 2008). This is particularly true in low-income countries, where climate is the primary determinant of agricultural productivity and adaptive capacities are low (SPORE, 2008; Apatae et al, (2009). Many African countries, which have their economies largely based on weather-sensitive agricultural productions systems like Nigeria, are particularly vulnerable to climate change (Dinar et al, 2006). Climate change may also change the types, frequencies, and intensities of various crop and livestock pests; the availability and timing of irrigation water supplies; and the severity of soil erosion (Silayo et al, 2008).

Generally, cereals are tropical crops classified based on their life cycle, life form, uses, growth habit and family. Based on this classification, cereals can thus be expressed as an ephemeral, corn, non-woody crop which belong to the member of the grass family-Graminceae. Examples include maize, rice, sorghum, guinea corn, millet, barley, and wheat, pearl. They are cultivated for their edible seed which are high hi carbohydrate with considerable amount of proteins and some vitamins. They also have multiplicity of end uses. They provide a staple (basis of diet) of the world's human population; serve as feed for livestock and for industrial uses. Cereals are easy to cultivate, they have compact and dry grains that are easy to handle and to store, and they also give good yield with a small amount of labour inputs (Akanbi et al., 2009).

Despite the fact that cereal products constitute the major staples, and climatic factors are main determinant of its production in Nigeria, not many studies have estimated the relationship between climatic factors and cereal acreage. The production of cereal is associated with constraints such as drought, flooding, salt stress and extreme temperature, of all which are expected to worsen with climate change. To what extent this will be, in Nigeria has not received much research interest.

Cereal farming also faces bio-physical and economic constraints; these include frequent flood, irregular pattern of rainfall, water shortage, low soil fertility and past menace. The economic constraints are the high cost of production, low productivity, price instability, shortage in agricultural labour and higher wage due to high opportunity cost of labour in other activities. In addition, technological constraints are likened to low yielding varieties of cereal crops and other major threats. Furthermore, production has been reducing in recent years as a result of aging of farmers and inefficiency in the use of resources by farmers. The implication of this has been reduced cereal production at the time when there are more processing industries and the increased demand for Nigeria cereals.

Subsistence or cereal crops like maize and rice, which provide a third of the national daily calorific intake and are grown by half of the farmers, could be particularly affected by climate change National Adaptation Programme of Action (NAPA) (URT, 2007) indicated that with an increase in temperature and reduced rainfall, as well as change in rainfall patterns, the average yield would decrease by 33% countrywide. Ajetomobi et al, (2010) found that increase in temperature due to extreme climatic events may undermine any positive effects by reducing the net revenue for dry land rice farms, whereas increase revenue for the irrigated rice farms due to the fact that, irrigation buffers the crop from rainfall shortages. Precipitation had similar effects on rice net revenue in dry land and irrigated production systems or hilly regions in semi-arid regions (Ajetomobi et al, 2010).

Despite the great potential of Nigeria in cereal production, the frequent occurrence of drought occasioned by erratic rainfall distribution and/or cassation of rain during the growing season is the greatest hindrance to increased production and this is more serious in the northern part of country where most of the cereals are produced. The vulnerability of the Nigerian agricultural sector especially the food sub-sector to climate change is of particular interest to policy makers. This study therefore examined the impact of climate change on cereal acreage in Nigeria. The goal is to assist in formulating appropriate climate- related policies relating to cereals production and as well contribute to the body of literature.

Methodology

The Study Area and Climatic Description

Nigeria is located on the southern coast of West Africa between 2° and 15°E longitude and 5° and 15°N latitude. The Republic of Benin boarders Nigeria to the west, Niger to the North, Chad and Cameroon to the east while the south of Nigeria is boardered by the Gulf of Guinea. Nigeria covers an area of over 923,773 square kilometers extensively within the tropical zone. It extends north wards from the coastline for over 140km. Nigeria's area of land is about 98 million hectares, with about 75 percent suitable for cultivation of almost all typical crops, out of which only 14 percent is under cultivation in any form; 1.4 million hectares is estimated to be irrigable; only 0.05% of the cultivated hectares are presently under irrigation, most of the irrigable and irrigated land are the Northern states of the country (Fabiyi, et al, 2011).

Surface water resources total about 193 billion cubic meters based on annual flow of the country's rivers and streams. The figure (193 billion m^3) excludes soil moisture and ground water. It is estimated that about 95% of surface water in the Northern states can be controlled. The climate of the country studies from a fairly wet coastal area with annual rainfall greater than 3500m to the Sahel region in the northwestern and northeastern parts with annual rainfall of less than 600mm (Ajetomobi 2010).

By virtue of Nigeria's location primarily within the lowland humid tropics, the country is generally characterized by a high temperature regime almost through the year. In the far south, mean maximum temperature is between 30°C and 32°C while in the north it is between 36°C and 38°C. However, the mean minimum temperature is between 20°C and 22°C in the south and under 13°C in the north which has a much higher annual range. The mean temperature for the country is between 27°C and 29°C.

In the absence of altitudinal modifications, the diverse nature of the country's climate consequently give rise to a high degree of biological diversity mainly in six vegetation zones; the mangrove swamps, Sudan savanna, the salt water and fresh water swamps, tropical lowland rainforests, guinea savanna and Sahel savanna. Salt and fresh water swamps are along the coast of Nigeria. The salt-water swamps stretch inland for 1-2 km in the Lagos area to over 30km in the Sapele area. Further inland beyond the reach of tidal waters, mangroves give way to fresh water plants, the most important of which is the raffia palm. From a water balance perspective, the country experiences large spatial and temporal variations in rainfall, and less variation in evaporation and evapo-transpiration. Consequently, rainfall is by far the most important element of climate in Nigeria and thereby becomes a critical index for assessing agricultural and water resources potential in the country.

Nigerian cereal cropping dominates crop production in the northern part of the country; while the dominant crops in the south are cassava, yam, palm produce, rubber and cocoa. Agriculture in Nigerian economy has the same general characteristic as the country's economy those of a giant with feet of clay. While production has leap considerably over the past twenty-five years, demand has also risen, accentuating the federation's dependency on foreign cereal products and making it vulnerable to internal and external shocks. The significance of this sector in the economy follows, therefore, that any change in climate is bound to impact on the agricultural sector in particular and the socio-economic activities in general.

Data and Sources

All variables used in the regression model were time series covering the time period of 1995-2021. The dependent variables is land area while the explanatory variables are weather data namely, annual mean temperature - measured in centigrade, the annual rainfall-measured in millimeters and a time trend. The analysis was based on all the state producing maize, rice, millet and guinea corn in Nigeria for the main period 1995-2021.

Data for the total agricultural area per state for each crop were collected from the Nigeria Bureau of statistics (N.B.S). The climate variables temperature and rainfall were obtained from the Nigerian meteorological agency as reported in the annual abstract of the central Bank of Nigeria statistical Bulletin, covering the period of 1961-2021. There are some cases where values of temperature and rainfall were missing for some of the sates. In such cases, interpolations were made by using the average value of state close to such state in terms of climatic characteristics. Annual rainfall is measured in millimeters while temperature is measured in centigrade.

Meteorological data used in the analysis were arranged according to phonological periods of the cereal investigated according to the examined period. All the data used in the study was related to the period 1995-2021.

Analytical Techniques

The econometric approach used in this study is based on the statistical model that relates yield per hectare to meteorological data to assess economic impacts of climatic changes, which allows for capturing adaptations farmers make in response to climate changes. The study assumed a quadratic relationship between yield per hectare (Y) and temperature (I), Rainfall (R) and time trend (T). The general form for the quadratic regression model used in this study is specified as follows:

$$Y = \beta_o + \beta_1 T + \beta_2 Pi + \beta_3 P_i^2 + \theta_4 T + e_i \quad (1)$$

Where 1, 2, 3 and 4 are the state index

i is the time index denoting annual observations from 1995 to 2021.

e_i is the error term

The estimated parameters are β_0, β_1, β_2, β_3, β_4 and θ

A time trend has been included in the model; this serve as a proxy for the non-inclusion of some non- climate variables which are important in agricultural productivity. Such factor include technological change and innovations (improvement in agricultural inputs/and or practices and/or changes in production patterns), increased productivity due to other climate variables and a fertilizer effect from increased CO_2 concentration in the atmosphere. Although, sunlight is another important weather variable necessary for crop growth; it was not possible to include it in the analysis because the meteorological stations did not have the data or its proxy for the period of the study.

Secondly, land area was regressed on the climatic variables. The land area was the dependent variable of the regression model respectively. The independent variables were temperature (°C), rainfall (mm), square of temperature (°C), square of rainfall (mm) and time trend.

The A-Priori Expectation of the Regression Model

R_i, rainfall is theorized to affect crop production positively. The basis for this theoretical expectation is justify with the fact that rainfall increase affects crop yield positively (IPCC, 2001, Rosenzweig and Hillel, 1995) by readily dissolving the nutrients for easy soil absorption by plants.

T_i, Temperature is hypothesized to be positively related to crop production. The basis for this is that temperature benefits crop production by enhancing photosynthesis there by increasing crop yield as it increases (Sombroek and Gommes, 1996; Rosenzweig and Hillel, 1995).

The linear term introduced into the model is expected to indicate the unidirectional impact of the independent variables on the dependent variable while the quadratic term is expected to reflect the impact of increased in the independent variables on the dependent variable as well as the non-linear shape of the yield as they respond to climate function. When the quadratic term is positive, the yield function is U shaped and when the quadratic term is negative, the function is hill-shaped. Agronomic studies has revealed that crops consistently exhibit a hill-shaped relationship with annual temperature, although the maximum of that hill varies with the crop.

Results and Discussion

The Regression Results

The regression analysis that was employed to estimate the impact of climate change on cereal crop yield for this study was a linear (quadratic) model for ease of interpretation.

The regression results for selected cereal crops acreage are presented in Table 1. The value in each parenthesis represents the t-ratio of the corresponding explanatory variables respectively.

Estimate of the Parameters

On the basis of land variability to climate change in regards of cereal cultivation, it was observed that rainfall has a significant and negative relationship with maize cultivation, millet cultivation and guinea corn cultivation except for rice cultivation which has a positive correlation with rainfall but not significant. On a more explicit term, a percentage decrease in amount of rainfall on land will increase cultivation of maize by 0.71 percent, millet by 3.98 percent and guinea corn by 2.21 percent respectively.

It was also observed that temperature has a positive and significant relationship with rice cultivation as well as guinea corn cultivation millet cultivation is positively correlated with temperature while maize has a negative correlation with temperature respectively but not significant at 5% level. The table also reveals that time trend has a negative and significant relationship with millet and guinea corn cultivation respectively; it also has a negative and insignificant relationship with rice cultivation, in the case of maize cultivation it is positively correlated though insignificant

Table 1. Results of Ricardian Analysis of Acreacge of Seleted Cereal Crops

Crop	C	R	T	R²	T²	Trend	R²
Rice	-539.12* (-1.87)	0.22 (1.15)	31.29* (1.92)	-0.01* (12.57)	-0.41* (-1.75)	-0.23 (-0.28)	0.10
maize	898.80** (2.27)	-0.71* (-2.77)	-35.20 (-1.57)	0.02 (0.72)	0.39 (1.20)	0.35 (0.31)	0.10
Millet	-989.73 (-1.25)	-3.98*** (-7.74)	71.37 (1.59)	0.01*** (5.70)	-0.81 (-1.25)	-4.81** (-2.13)	0.40
Guinea Corn	-926.68 (-1.33)	-2.21*** (-4.87)	67.06* (1.70)	0.05** (2.49)	-0.85 (-1.50)	-3.41* (-1.72)	0.28

Source: Data Analysis, 2021

Table 2 present the report of land elasticity to climate change. It was revealed that rice land is inelastic to rainfall but there is a strong elasticity between rice land and temperature. This suggest that increase in temperature will increase land productivity for rice cultivation equal to the elasticity of the temperature in the same direction as temperature changes, were as, one percent decrease in the amount of rainfall will improve land quality and increase rice cultivation by 0.67 percent.

The table also reveals that maize land is elastic to rainfall and temperature. One percent decrease in the amount of rainfall and temperature will increase land productivity for maize cultivation by 1.06 and 13.51 percent respectively.

In the case of millet and guinea corn land, it was revealed that they were elastic to precipitation and temperature. This implies that percent increase in the amount of temperature will improve land quality and increase millet and guinea corn cultivation by 20.09 and 18.35 percent respectively, as for precipitation; a decrease in precipitation will increase their cultivation by 4.35 and 2.34 percent respectively.

Table 2. Elasticities of Cereal Land Area to Climate Change

Land area	Value
Rice rainfall	0.67
Rice temperature	25.33
Maize rainfall	-1.06
Maize temperature	-13.51
Millet rainfall	-4.35
Millet temperature	20.09
Guinea corn rainfall	-2.34
Guinea corn temperature	18.35

Source: Data Analysis, 2020

Conclusion and Recommendations

The study conducted an econometric analysis of climate change impact on cereal crop for land area using data from Nigeria Bureau of Statistic and the country's meteorological data. All the data used in the study was related to the period 1995-2006. The quadratic regression model was used to determine relations between yield, production, and land area respectively and the climatic variables (explanatory variables) temperature and rainfall. The analysis was done using an econometric panel data approaches.

The regression result indicated that the climate variables have significant impacts on the acreage of selected cereals crops in Nigeria. The study therefore suggests that the use of effective adaptation measures to reduce the harmful effect of climate change on cereal agriculture.

Crop rotation practices should be sought as an important tool of integrated management of cereal production; the rotation management should maintain soil condition, minimize risk of nitrite leaching and reduce pest development in order to optimize crop health. The use of Integrated Pest Management (IPM) System should be encouraged.

Training and services by extension agent and field demonstration should be encourage as this will significantly boost their output and income after all; establishment of plant clinics with competent pathologist, entomologist and soil scientist to give technical assistance to the farmers in terms of diagnosis, control, correct use of pesticides and the use of disease free planting materials.

Above all, agro-metrological stations should be made available at district, local and regional level to help fanners in weather forecasting through crop performance in terms of (planting dates, yield, densities of sowing, location and acreages of planting), estimating probabilities of occurrence of potential hazards (frost, fire, hail, severe rainfall) as this will help agriculture to make the most complete and rational use of climatic and weather data; to operate economically, produce high and consistent yields and to maximize their productivity. Through these adaptive measures discussed above, the negative effect of climate change on cereal agriculture could be reduced and the positive influences enhanced.

Finally, wider research and deeper analyses regarding to climate change on agriculture should be encouraged.

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