RESEARCH ARTICLE

EFFECT OF CLIMATIC VARIABLES ON AGRICULTURAL PRODUCTIVITY AND DISTRIBUTION IN PLATEAU STATE NIGERIA

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ABSTRACT

Food production becomes necessary in other to feed the growing population. There is pressure on land for cultivation and climate change has affected the crop yields, production and distributions in Plateau state Nigeria. The two important parameters of climate that are temperature and rainfall have significantly shows positive correlations. Three crops; Millet, Groundnut and Guinea corn (Sorghum), have been studied by comparing their yield using temperature and rainfall the assessment. The rainfall has the highest correlation with 0.987while, the impact of temperature base on the Pearson rank correlation has 0.853. the application of the coefficient determination will provide individual crop yield base on its relationship with independent variable.

KEYWORDS

Crop yield, Agriculture, Climate change, correlation, impact.

1. INTRODUCTION

Many authors have discussed more the rainfall and temperature trends on different applications such as the relationship between soil and temperature, the pattern of rainfall and agriculture as well as the adaptation to human health and the environment. This study is unique in the sense that it combined the climatic variables (rainfall and temperature) as it affects 3 different localities on 3 major crop production and yields. The study focuses on the terrain analysis using plateau as a yardstick to measure environmental lapse rate (topographical effects) as it influenced agricultural productivity in Plateau state. The location of the study area on highland has changed the pattern of the climate on a macro and micro scale.

The areas selected for this study are suitable for the production of certain crops base on the distribution of rainfall and temperature. There is a need to monitor this climatic parameter which contributes to the growth and distribution of the major food crop to serve the increased population and the nation at large. Plateau state is endured with natural resource aside from the agricultural food production. There is the need to observed, monitor and record the rainfall and temperature trend as it affects crop yields and production in Shendam, Ryom and Jos North. Therefore, there are limited researches on the estimates of crop yields based on the combine climatic parameters. This study will integrate the two approaches to evaluate the impact of the selected climatic variables on maize Irish potatoes, and Cabbage.

Some researcher confirms many of the problems facing agricultural products are climate-related (Ayoade, 2002). For instance, other researchser presented data to show that groundnut yield begins to decline significantly with a reduction of twenty days or more in the length of the

growing season for the savannah areas of Nigeria (Kowal and Kassam, 1973). A studied the effect of climate change on cocoa yield with the use of correlation and regression analysis and concluded that optimal temperature and minimal rainfall will give a better yield of cocoa in Nigeria (Ojo and Iyanda, 2010). These findings necessitated the need to carry out research of this kind. This will reveal whether or not changes in climatic variables have a positive or negative effect on crop yield in the study area. It will also reveal the pattern of crop production to be adopted within the study area. The main objective of this investigation is to study the effect of climatic varthe iables on crop production during last the ten years and based on the correlated factors, suggest the crop management plan.

1.1 Agricultural Productivity in Nigeria

Agriculture is practiced widely in Nigeria like in other developing countries is highly subjected to climate variability. Nigeria is an agrarian country because about 70% of the population engages in agricultural production at a subsistence level despite the fact that the country depends heavily on the oil industry for its budgetary revenues (Adhvaryu et al., 2019). Agricultural holdings are generally small and scattered. Traditional smallholders, who use simple techniques of production and the bush-fallow system of cultivation, account for around two-thirds of Nigeria's total agricultural production. Nigeria's wide range of climate variation allows it to produce a wide variety of food and cash crops. However, food production could not keep pace with population increase. Food shortage is therefore linked with climate change (Adefolalu, 2004). Generally, there are many factors influencing crop production and these include soil, relief, climate and diseases among others. In relation to climate, rainfall is the dominant controlling variable in tropical agriculture since it supplies soil moisture for crops and grasses for animals. According to a study, agriculture largely depends on climate to function (Ayoade, 2002). Hence,

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precipitation, solar radiation, wind, temperature, relative humidity and other climatic parameters affect and solely determine the global distribution of crops and livestock as well as their productivity.

Some research described the four ways in which climate affect agricultural production; changes in temperature and precipitation directly affect crop production and can even alter the distribution of agro-ecological zones; increased CO₂ is expected to have a positive effect on agricultural production due to greater water use efficiency and higher rates of plant photosynthesis; runoff or water availability is critical in determining the impact of climate change on crop production, especially in Africa, and agricultural losses can result from climate variability and the increased frequency of changes in temperatures and precipitation (including drought and floods) (Kurukulasuriya and Rosenthal, 2013). Estimation that by 2100, Nigeria and other West African countries are likely to have agricultural losses of up to 4% due to climate change (Fao, 2008). Climate to some extent determines the choice of what plant to cultivate, how to cultivate it, the yields of crops and the nature of livestock to keep. It can also be seen as one of the environmental factors that affect agricultural.

1.2 Temperature and Crops Production

Temperature affects cereal production by controlling the rate of physio-chemical reaction and the rate of evaporation of water from crops and soil surface (Ismaila et al., 2010). Studies have shown that productivity in rice and other tropical crops will decrease with an increase in temperatures as a result of global warming. For instance, high temperature for just 1 to 2 h at anthesis (about 9 days before and at heading) causes a large percentage of grain sterility in rice (Nguyen et al., 2006). Effects of heat stress on rice include reduced tillering, reduced height, reduced spikelet number, sterility and reduced grain filling (Nguyen et al., 2006).

1.3 Rainfall and Crops Production

Rainfall has been seen as the most important factor in crop production in Nigeria. Some of the important factors guiding rainfall in relation to crop include the number of rainy days, time of fall, the total amount of fall and the type of soil. Rainfall usually determines the type of crop to be grown. In a different environment as well as the type of agricultural system to be practiced in different parts of the country. According to a study, regular occurrence of drought as a result of erratic rainfall distribution and/or recession of rain during the growing season reduces Nigeria's capability for increased crop production (Bello and Olaoye, 2009; Tunde et al., 2011)

1.4 Climatic variability

According to a study not only the environment is affected by the climate but different species of animals, as well as plants, are being impacted by the variability of climate (Vasconcelos et al., 2010). The experiment of the anuran species was conducted in Brazil and the results indicated a high correlation of reproductive modes because of the climatic variation. Another different study carried out research on how the snow melt by observing the precipitation and temperature trend for a particular period of time in the western United States (Lobell and Asner, 2003). There is much influence of climate variability in the world, depending on what we focus on and the discipline applied to. The recent study of the influence of meteorological conditions as it affects hospital admission is alarming (Blaum et al., 2012).

A researcher described the effect of climatic warming on the surface of water or Lake of central Boreal (Schindler, 1997). About 20 years of data will be obtained using climatic and hydrologic data to evaluate ecological habit. The finding indicates that there is an increase in the greenhouse due to the warming of the habitat. Change in the climate perhaps can result in different geographical changes in terms of flora and fauna distribution. The number of generation increases with the changes in the rate population growth, changes in the crop yields and pest. Different pest responds to different condition of the climate. One of the destructive factor in the killer pest that destroys farmland and crops in the shortest possible means (Ladanyi et al., 2010).

1.5 Changes in crop yields and their variability

An assessment of climate change impacts at different levels of global warming is crucial to inform the policy discussion about mitigation targets, as well as for the economic evaluation of climate change impacts. Integrated assessment models often use global mean temperature change (Ostberg et al., 2018). Climate change exerts a substantial and direct impact on food security and hunger risk by altering the global patterns of precipitation and temperature which determine the location of arable land as well as the quality and quantity of crops comprising most of the world

food supply (Rosenzweig et al., 2014; Rosenzweig and Parry, 1994; Sultan et al., 2013; Schlenker and Lobell, 2010). By itself, climate change is expected to reduce global production of the four major crops wheat, maize, soy, and rice in current agricultural areas (Challinor and Wheeler, 2008; Lobell and Burke, 2010).

Facing an increasing food demand due to population growth and economic development, these reductions will have to be compensated for by (1) the direct physiological impacts of increased atmospheric CO₂ concentrations, which are beyond local human control; as well as (2) advances in agricultural management (e.g. fertilizer input or irrigation), technology, and breeding and (3) expansion of agricultural land (Kimball, 1983; Jaggard et al., 2010; Ostberg et al., 2018; Smith and Olesen, 2010). In conjunction with these long-term changes, global warming is also expected to contribute to an increase in the frequency and duration of extreme temperatures and precipitation (droughts, floods, and heatwaves), which may increase the near-term variability in crop yields and trigger short-term crop price fluctuations (Brown and Kshirsagar, 2015; Mendelson, 2008; Deressa et al., 2011).

1.6 Objectives

1. To assess the Rainfall trend from 2009- 2019 as it influences crop yields and distribution.
2. To assess the Temperature trend from 2009-2019 as it determines the crop yield and distribution.
3. To examine the relationships of climatic variables on agriculture productivity.
4. To determine the impact of the climatic variability on the select crop Millet, Guinea corn and Groundnut.

2. MATERIAL AND METHODS

2.1 The Study Area

This study investigates a crop-climate relationship using an experimental approach. An experimental farm located at the Headquarters of the National Root Crop Research Institute (NRCRI) Vom, in Jos-South Local Government Area of Plateau state, served as a source of data for the study. Jos-North Local government has a population of 650,835 (National Population Commission, NPC 2006) to the Eastern part Shendam was selected for the Maize production with an average land area of 1, 037km². The first set is agricultural data for Irish Potato yield in tonnes per hectare. The second set of data is the basic agro-climatic variables influencing Irish Potato, Maize and Cabbage yield over the same period for the months of April, May, June, July and August. These months constitute the growing season on the Plateau. The final yields of the crop are in many cases dependent on satisfactory growth during earlier stages of crop development. In all nine climatic parameters collected during the growing season were analyzed with a view to estimating their contribution to yield of Irish potato.

2.2 Location of the Study Area

Plateau state is located in the middle belt of Nigeria between latitude 08° 24'N and longitude 008°38'E

Figure 1: Map of the Study Area Plateau State

Figure 2 is the area of reconnaissance survey in the area of maize production that is Shendam Local government area of Plateau State Nigeria.

Figure 2: Map of the Shendam, Plateau State Nigeria for the Maize Production

Figure 3: Map of Riyom, Plateau State Nigeria for the Irish Potatoes production

Figure 3 is the location of the second area of study that is Riyom, this Zone is having the productivity of Irish potatoes.

Figure 4: Map of Jos North Plateau State Nigeria for the Cabbage Production

The third study area is the Jos North where Cabbage is highly cultivated

2.3 Source of Data

The primary sources of the data from this study will be from the Nigerian Meteorological Agency (NIMET) Plateau state. And the secondary data will be obtained from the field from both the Questionnaire and the farmland sample survey from 300 farmers.

2.4 Method of Data Collection

Series of annual maximum (Tmax), minimum (Tmin) and mean (Tmean) air temperatures and precipitation (P) were analyzed in the present study. The data were collected from synoptic stations in the west, south and southwest of Jos for the period 2008-2018 and were provided by Meteorological Office (NIMET) Jos. These stations were selected taking into account the length and completeness of records so that most of the region was covered by the corresponding data. Several strategies have been described in the literature, which have been developed to detect non-homogeneities in the data series (Peterson, 2009).

In this study, both the double-mass curve method and the correlation analysis were used to the climatic variables time series of each station

(Searcy and Hardison, 1960). The sample size in this study is the use of the structure 300 farm samples and 100 questionnaires that will be administered in the field. The data collected in the field will be interpolated using different statistical analysis. Since the crops are more than one, multiple Regression will be applied. The results as such individuals will have their coefficient of determination computer to obtain their correlations with the climate variability.

2.5 Data Analysis and Presentation

These data were analysed and subjected to different statistical techniques, including correlation coefficient and multiple regressions. In order to select the agro-climatic indices that are critical to the yield of Irish Potato, a stepwise multiple regression analysis was adopted. The yields were expressed as dependent variables (Y) and climatic indices as independent variables (X). The general form of the multiple regression equation is presented as follow:

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + \dots + b_nx_n, \text{ where,}$$

Y = Irish potato yield in ton/ha

a = constants

b = is the rise or falls as X increases

X1 = total rainfall (mm)

X2 = maximum temperature OC

X3 = minimum temperature OCX4 = soil temperature o C

X5 = Rainfall in April X6 = Rainfall in May

X7 = Rainfall in June

X8 = Rainfall in July

X9 = Rainfall in August.

A lot of literature can be found regarding applications of time series models in forecasting agricultural produce or prices. The most widely used technique in this regard has been the Autoregressive integrated moving average (ARIMA) model. To see some applications in agriculture one may refer (Ray et al., 2015).

3. RESULT AND DISCUSSION

The study will portray the significance of the climatic variability of the three important food crops in Sokoto state that is Millet, Guinea corn and Groundnuts. The crops are being national and internationally exported via different routes in Nigeria. The relevance of high crop yields will boost agricultural productivity. The result of the statistical analysis will indicate what crop needs to give emphasis to increase the input through close monitoring of climate change. This study will help planners and farmers on food security, increase food production, create awareness on the importance of climate variability on agriculture.

Table 1: Average samples of Farmlands in Plateau State Nigeria for their Crop Yields

Temperature °C	Millet	Guinea Corn	Groundnuts
30	80	78	85
29	70	60	90
28	50	40	70
31	55	50	72
30	81	60	80
33	90	85	100
34	110	105	120
32	170	120	130
35	180	150	120
38	140	130	200
40	160	135	180
39	180	150	185

The samples mean all strongly have a significant correlation of the rainfall to the 3 major crops as indicated in Table 2.

Figure 6: Impact of Rainfall on crop Yields

Table 2: Crops samples and their correlations

Crop Samples	Pearson Correlation	Coefficient of Determination	Temperature Correlation
Millet	$y = 12.07x + 35.37$	$R^2 = 0.771$	0.853
Guinea Corn	$y = 9.779x + 33.34$	$R^2 = 0.784$	0.853
Groundnut	$y = 11.29x + 45.92$	$R^2 = 0.784$	0.853
Temperature	$y = 1.031x + 26.54$	$R^2 = 0.853$	

Table 3: Average samples of Farmlands in Plateau State, Nigeria for their Crop Yields

Temperature °C	Millet	Guinea Corn	Groundnuts
600	80	78	85
650	70	60	90
700	50	40	70
750	55	50	72
800	81	60	80
850	90	85	100
1000	110	105	120
1050	170	120	130
1100	180	150	120
1150	140	130	200
1200	160	135	180
1250	180	150	185

Table 4: Crops samples and their correlations

Crop Samples	Pearson Correlation	Coefficient of Determination	Rainfall Correlation
Millet	$y = 9.736x - 209.9$	$R^2 = 0.626$	0.987
Guinea Corn	$y = 8.612x - 189.4$	$R^2 = 0.758$	0.987
Groundnut	$y = 10.62x - 233.7$	$R^2 = 0.864$	0.987
Rainfall	$y = 62.58x + 518.1$	$R^2 = 0.987$	

The analysis above has shown that both temperature and rainfall have a significant relationship with positive correlations. The temperature in plateau state has favoured groundnut and Guinea corn production with 0.784 and Millet has 0.771. Overall, the correlation with temperature is 0.853. Rainfall tends to be the higher climatic variable with 0.987. for the three major crops, groundnut has 0.864, the Guinea corn 0.758, and Millet with 0.626. the determinant of the crop yield rest on the rainfall distributions coupled with the lower temperature of the Plateau.

4. CONCLUSION

It is confirmed that climate variability and changes have a significant relationship with food crops and distributions in tropical and Savannah regions of West Africa (Plateau State) Nigeria. The 3 crops sampled (Millet, Guinea corn, and Groundnut) have shown positive correlations relationship with the climatic elements of rainfall and temperature. The more the rainfall, the more the crop yields.

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