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EFFECT OF CLIMATE VARIATIONS ON RICE PRODUCTION IN CROSS RIVER STATE, NIGERIA

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Abstract

The study was carried out in Cross River State, Nigeria to determine the effect of temperature, rainfall, relative humidity, sunshine hours and wind on rice production across the agro-ecological zones of the state as well as to compare rice output per hectare across the zones. Secondary data on climate elements were obtained from the Nigeria meteorological Centres located at Ogoja, Ikom and Calabar AirPort for a period of 23years (1997 to 2020). Also, rice output harvested was obtained within the same period from the state ministry of Agriculture, the three zones of the ADP and the Cross River State Commercial Agriculture Calabar. The study used the multiple regression analysis, correlation analysis and the analysis of variance to analyze the data. The study observed that climate variations influenced rice production in the three agro-ecological zones. Rainfall was significant at ($p < 0.01$). The Northern agro-ecological zone was found to be climatically favored in rice output per hectare than the other two zones.

Keywords: Effect, Climate variations, Rice Production.

1. Introduction

The issue of climate variability has assumed a worldwide dimension cutting across the developed and developing nations. Throughout the world there has been significant concern about the effects of climate change and climate variability on agricultural production (Kaul, 2010). The United Nations Framework Convention on Climate Change (UNFCCC) observed that surface temperature increased from 1.4-4.8^{0}c, while global sea levels rose by 9.88cm in 2008 and as a result there were changes in rainfall pattern, temperature, relative humidity and solar radiation (Spore, 2008).

Food and Agriculture Organization [FAO] (2019) observed that climate variability and climate change are sources of risk to farmers because of the uncertainty surrounding the farm system planning and management. It noted that since 1992, floods, droughts and storms have affected 4.2 billion people and caused USD 1.3 trillion in damage worldwide; United Nations Office for Disaster Risks Reduction [UNISDR] (2012) estimated that floods, droughts and storms have resulted in average global losses of USD 86 billion per year across all economic sectors, with Africa and Asia most affected.

Rice Oryzaglaberrina (African rice) is the seed of grass and it is the second most growing cereal in the world after maize. Rice is the major staple food for majority of the human population with about 2.6 billion people of the world and more than 750 million people in Sub-Saharan Africa depend on it on daily basis, World Health Organization [WHO](2020).Currently, Nigeria‘s population is estimated at 211.8 million people in the first quarter of 2021 with a land area of 923,768 square kilometers, out of which 79 million hectares are under cultivation and of this figure, about 39% of the total land area is used for the cultivation of rice (World Population Review, 2021). Spore, (2008) noted that on global output, the Asian continent accounts for 29 percent production level, 5 percent for the American and the Caribbean, while only 3 percent is attributed to Africa. It reported that in 2002, four out of the six largest countries noted for rice imports in the world then were from the continent of Africa; these countries were Cote d'Ivoire, Nigeria, Senegal and South Africa.

International Institute for Environment and Development (IIED) (2010) forecasted that by 2020 the influence of climate change and climatic variability in Nigeria may result to between 2-11% losses of gross domestic products (GDP) and this may go higher if there are no integrated model adaptations to handle their incidences.

The Food and Agriculture Organization of the United Nations (FAO, 2007) reported that in Mongolia a severe change in climatic condition caused a great loss to farmers in both livestock and crops when temperatures dropped to between -4^0C to -5^0C, killing 1.7 million herds of livestock and 30,000 tons of crops lose, putting many families at risk of hunger.

Edeh, Eboh and Mbam (2011) studied the environmental risk factors affecting rice farming in Ebonyi State and found that the coefficient of the included environmental factors of rainfall, relative humidity and temperature had R^2 of 99.4% which indicated that the included environmental factors accounted for about 99 percent of the total variability in rice yield in the State. This suggests that the intensity and duration of rainfall, relative humidity and temperature constitute some of the environmental factors that affect rice yield in Ebonyi state.

The result of the study by Ngugen (2010) on rice production under global warming indicates that the productivity of rice and other tropical crops decreased as global temperature increases. He observed that variability in the amount and distributions of rainfall is the most important factor limiting yield and production of rain fed rice. He noted that variability in onset of the rainy season leads to variation in the start of planting season and in a freely drained upland environment, moisture stress can severely damage or kill rice plant in an area that receive no precipitation as much as 200mm in a day or no rainfall for up to 20days.

Obioha (2009) reported that changes in climate regime in Nigeria have affected the food production capacity of the nation because the traditional small holder farmers who use simple techniques of production have little or no control over the climatic regimes. This is buttressed by Udoh (2018) that the Nigerian farming households are involved in production without much consideration of the environmental marginal criterion of economic optimality but rather on the decisions of imperatives of survival (subsistence).

Ogbuene (2010) conducted a study to determine impact of meteorological parameters on rice yield in Ebonyi state rice farmlands in Nigeria and found that rainfall, rainy days, relative humidity (RH), maximum and minimum temperature have both positive and negative impacts in the tonnage of rice output and environmental resource sustainability in the study area. It was established that the rainfall intensity and distributions, relative humidity, minimum and maximum temperature impinge much on farming activities and tonnage of rice yield, right from farm planning, clearing of the farm land, planting, growing, harvesting and preservation.

Oniah, Kuye, Ettah and Okon (2017) investigated the effects of climate variation on yam production in Obubra LGA of Cross River State, Nigeria and found that climate variables greatly influenced yam output in the local government area of the state but their study was limited only to yam production. Okpiliya, (2002) studied the effects of climate variation on rice yield in Ogoja Local Government area of Cross River State for 10 years and observed that there was variations in rice yield stimulated principally by the interactions of climatic elements of temperature and rainfall but his study was limited to the area alone.

Ukpai (2011) studied the effects of climatic variability in rice production among small scale rice farmers in Ini Local Government Area of Akwa Ibom State, Nigeria and found that the climate parameter of temperature had an inverse relationship with rice output while the parameters of rainfall and relative humidity had direct relationship with rice output. Fraser (2008) opined that weather prediction has helped to improve significantly varying levels of rice self-sufficiency by the agriculture-based economies of Indonesia, Malaysia, Philippines, and Thailand.

Since there is a paucity of published information on the effects of climate variability on rice production in Cross River State, Nigeria, it becomes necessary to investigate the relationship between climate variables and rice output across the agro-ecological zones in the state, for this will guide rice farmers and stake holders in the rice production industry for areas of greater rice production efficiency for both local consumption and exports.

The study determines the effect of climate variation in rice production in Cross River State, Nigeria. Specifically, the study

i. Determined the effects of temperature, rainfall, relative humidity, sunshine hours and wind on rice production across the agro-climate zones of the state.
ii. Evaluate the strength of relationship of climate parameters on rice output.
iii. Compare rice output per hectare across the agro-climate zones.

2. Research Methodology

The study area

The study area is Cross River State and is situated in the Niger Delta, in the South- South region of Nigeria. It occupies a land mass of about 24,000km^2 comprising of Mangrove swamp forest, tropical rainforest, and Guinea savanna hinterland (Mfam, 2002). It lies between latitudes 5^0 32` and 4$^0$ 27` North and longitudes 7^0 5^{0}` and 9$^0$ 28` East, and is bounded to the West by Abia and Ebonyi States, to the West by Akwa Ibom State, to the North by Benue State, to the East by the Republic of Cameroon and to the South by the Atlantic Ocean. (Cross River State Survey Division, 2004).

Agriculturally, the state is divided into three agricultural zones in line with the agro – climate zones of the state viz, the Northern, the Central and the Southern Agricultural zones (Mfam, 2002, Oniah and Okoye, 2018).

i. The Northern agricultural zone comprises the Local Government areas of Obanliku, Obudu, Bekwarra, Ogoja and Yala.
ii. The Central Agricultural zone has Ikom, Boki, Etung, Obubra, Abi and Yakurr.
iii. The Southern Agricultural zone has Calabar Municipality, Calabar South, Odukpani, Akpabuyo, Akamkpa, Bakassi and Biase Local Government areas.

It has two distinct climatic seasons namely: the rainy season from April to October and the dry season from November to March. Average annual rainfall varies from 1,300mm to 3000mm while the average temperature ranges between 15°C - 30°C (MOFINEWS, 2004). Both rainfed upland and lowland rice are cultivated by small scale farmers depending on the climate regimes experienced in the given environment. This implies that the farming calendars of rice production in the state are dictated by the climate variables which may be favorable or not.

Methods of data collection

Data for the study were from secondary sources obtained from the Nigeria meteorological Centres located at Ogoja, Ikom and Calabar Air Port on the various climate elements of rainfall, temperature (minimum and maximum), relative humidity, sunshine and wind for a period of 23years (from 1997 to 2020). Also, the farm size cultivated, output of rice harvested were obtained within the period under consideration from the Cross River State Ministry of Agriculture Calabar, the three zones of the Cross River State Agricultural Development Project (ADP), Cross River State Commercial Agriculture Development Office Calabar, National Programme for Agriculture and Food Security (NPAFS), Agricultural Production Year Book, Central Bank of Nigeria and Annual Reports of the Federal Ministry of Agriculture and Rural Development on returns on State Ministries of Agriculture and Natural Resources.

Analytical framework

Analytically the study used the multiple regression analysis, correlation analysis and the analysis of variance (ANOVA table) to analyze the data. Correlation analysis was used to test the strength of relationship between rice output and climate variables in the three agro-ecological zones of the study area. The multiple regression analyses were used to estimate relationship between climate variables and rice output. The rice production function was estimated using the ordinary least square model. In this case, three functional models viz; the linear, the Semi log and the double logarithmic functions were fitted and the lead equation (double log) was chosen to explain the results.

The general structure of this model is implicitly expressed as thus:

$$Y = f(X_1+X_2+X_3+X_4+X_5+X_6+e) \quad \ldots\ldots\ldots\text{(i)}$$

Where;

Y = output of Paddy rice in kilogramme
b_o = Intercept
b_1-b_6 = Coefficients
x_1 = maximum temperature (^oC)
x_2 = minimum temperature (^oC)
x_3 = rainfall (mm)
x_4 = relative humidity (%)
x_5 = sunshine (hour/day)
x_6 = wind (m/s)
e = error term

Explicitly, the model is expressed in three forms as thus:

i. **Linear model**

$$Y = b_o+b_1x_1+b_2x_2+b_3x_3+b_4x_4+b_5x_5+b_6x_6 + e \ldots \text{(ii)}$$

ii. **Semi log model**

$$Y=b_o+b_1logx_1+b_2logx_2+b_3logx_3+b_4logx_4 +b_5logx_5+ b_6logx_6 + e \ldots \text{(iii)}$$

iii. **Double logarithmic model**

$$LnY = b_o+b_1lnx_1+b_2xln_2+b_3lnx_3+b_4lnx_4+b_5lnx_5+ b_6Inx_6 + e \ldots \text{(iv)}$$

The result of the production function analysis was used to determine whether these variables influence rice output in the study area. The analysis of variance designated as ANOVA was used to test assumptions of independence. The calculated value was compared to the apriori alpha level (level of significance for the statistic) and a determination was made whether to reject ($p< 0$) or retain ($p> 0$) of the null hypothesis. This statistical tool was used to determine the variation in climate variables effect in rice production across the three agro-ecological zones in the state.

3. Results and Discussion

Effects of climate variation on rice output in the three agro-ecological zones

The general observations from the variables of climate effect on rice production across the three agricultural ecological zones of the state as presented in Table 1 of the regression analysis below showed that, the variables of maximum temperature (x_1)3.963369, rainfall (x_3)10.81317, relative humidity (x_4) 0.10795 and sunshine (x_5) 1.362414 were positive in all the three zones. This reveals that these variables have positive relationships with rice output across the three agro-ecological zones. Rainfall was highly significant at ($p< 0.01$) indicating that rainfall greatly influenced rice output in the state. Meaning that a positive relationship of rainfall in the ecological zone will have increase in rice production and vice versa.

The variables of minimum temperature (x_2) -0.12707 and wind (x_6) -1.644006 were negative in all the three agro-ecological zones. This implies that minimum temperature and wind had an inverse relationship with rice output in the area and it is observed to have critical effects on rice production in the state.

The coefficient of determination (R^2) showed a value of 0.7242 signifying that about 72 % of the Climate Variables fitted influenced rice production across the agro-ecological zone. The F-ratios were significant in all the three zones at one percent level of significant indicating that the climate variables considered in the study area actually influenced rice production.

Table 1: Effect of climate variation on Rice output across the agro-ecological zone of Cross River State, Nigeria

Climate Variables	Linear function	Semi Log Function	Double Log Function (Le)
Constant	-256720	-1225650	-69.6602
Maximum temperature (x_1)	3049.079	91083.45	3.963369
	(0.861251)	(0.858324)	(0.804189)
Minimum temperature (x_2)	-2713.27	-5655.4	-0.12707
	(-0.32397)	(-0.29218)	(0.01414)
Rainfall (x_3)	1212.874	199607	10.81317
	(4.986694)*	(4.500044)**	(5.248992)*
Relative Humidity (x_4)	-16.7024	-1546.21	0.10795
	(-0.02539)	(-0.07498)	(0.11271)
Sunshine (x5)	7548.493	39079.51	1.362414
	(1.514623)	(1.570615)	(1.178994)
Wind (x_6)	22.2612	12149.32	-1.644006
	(0.410804)*	(8.416365)	(1.213131)
R^2	(0.68736	0.62639	0.724286
R^{-2}	0.57912	0.486286	0.620893
F-ratio	0.002146	0.007644	0.000858

*, **, ***, denotes *Significance at 1%, 5% and 10% probability level respectively. (Le) Lead Equation*

Source: Compiled from field data, 2021.

Strength of climate variables with rice output in the Northern, Central and Southern agro ecological zones of Cross River State.

Results of correlation relationship of climate variables with rice output

The results of the correlation relationship of climate variables with rice output as presented in table 2 revealed that rainfall had a coefficient of 0.787786which indicates a strong positive relationship with rice output in all the three agro ecological zones of the state, and was significant at ($p < 0.01$) indicating that rainfall is highly correlated with rice output in the state. Maximum temperature (0.24307) and relative humidity (0.218457) had weak positive relationship with rice output in all the three zones of the state. Sunshine (-0.08025) and minimum temperature (-0.31173) showed a weak negative relationship with rice output across the agro-ecological zones of the state. The disparity in correlation relationship of the climate variables with rice output across the three agro-ecological zones shows the level of sensitivity of the climate element expressed in rice production across the agro-climate zone of the state.

Table 2: Correlation of Rice output with climate variables across the agro-ecological zones of Cross River State.

Variables	Correlation Coefficient	Remark
Minimum temperature and rice output	-0.31173	Weak negative correlation
Maximum temperature and rice output	0.24307	Week positive correlation
Rainfall and rice output	0.787786	Strong positive correlation
Sunshine and rice output	-0.08025	Weak negative correlation
Wind and rice output	-0.000633	Weak negative correlation
Relative Humidity and rice output	0.218457	Weak positive correlation

Source: Compiled from field data, (2021)

Variations of rice output with climate variables across the three agro-ecological zones of Cross River State

The result of the ANOVA analysis on the agro – climate effects on rice output as presented in table 3 for the three agro-ecological zones of Cross River State (North, Central and South) shows that there is high significant difference ($p < 0.05$) of climate effects on rice output across the three climatic zones in the state. From the result of analysis of variance (ANOVA in table 3), the F-calculated had a value of 13.322while F-Tabulated is 9.00 at five percent level. The significant difference in rice output indicates that rice output is determined by the combinations of one or more of the climatic factors such as temperature, rainfall, relative humidity, sunshine and wind that is prevalent in a particular zone. This finding agrees with the work of Edeh *et al* (2011) who found that climate factors influenced the yield and output of rice in Ebonyi state in the South Eastern State of Nigeria.

Table 3: Variations of rice output with climate variables across the three agro-ecological zones of Cross River State

Sources of variation	Degree of freedom (df)	Sum of squares (SS)	Mean sum of squares (mss)	F – ratio F – cal	F- tab 5%
Treatment (agro-climate zones) North,Central & South	3 – 1 = 2	5.437E7	2.719E7	13.322	9.00
Error	217	4.429E8	204082230		
Total	220	9.174E8			

Note: S ** = significant at 0.05

Source: Compiled from field data, (2021).

Mean Comparism of Rice output between the agro-ecological zones of Cross River State

Table 4 shows the mean comparism of rice output per hectare between agro-ecological zones in Cross River State. The result showed that the North and Central zones had a mean difference of 965.3182 with a standard error of 2.13925E2 and was significant at one percent (p< 0.01). This shows that rice output vary significantly between the Northern and Central agro-ecological zones in the State.

The mean comparison between the Northern and Southern agro-ecological zones also indicated a mean difference of 1051.3182 with a standard error of 2.77240E2 and a mean separation of 1.8700E2. This was also significant at 5 percent (p<0.05) and this suggests that rice output between the Northern and Southern agro-ecological zones vary significantly.

The comparison of rice output between the Central and Southern agro-ecological zones gave a mean difference of 86.0000 with a standard error of 2.92438E2 and a mean separation of 9.1300E2. These zones showed no significant difference in rice output between them which implies that rice output did not vary significantly between the two zones.

Generally, the study found that the Northern agro-ecological zone vary significantly on rice output than when compared with the two (Central and the Southern) agroecological zones. This showed that the Northern agro-ecological zone climatically favors rice production and so it will be economically worthwhile to carry out rice production on a large scale in this zone than in the central and Southern agro-ecological zones in the State.

Table 4: Mean comparison of Rice output between agro-ecological zones of Cross River State

Variables	Mean difference	Standard error	Mean separation	Output decision
North and Central zones	965.3182	2.3925E2	1.8783E3	S*
North and South zones	1051.3182	2.77240E2	1.8700E2	S**
Central and North zones	-965.3182	2.13925E2	1.8700E2	S*
Central and South zones	87.0000	2.92438E2	9.1300E2	NS
South and North zones	-1051.3182	2.77240E2	1.8700E2	S**
South and Central zones	-86.0000	2.92438E2	9.1300E2	NS

Note: S*-significant at 1%, S** - significant at 5%, NS – not significant

Source: Compiled from field data, 2021.

Conclusion and recommendations

Conclusion

The study concludes that climate variations influenced rice production in the state. Rainfall was significantly, strongly and positively correlated with rice output in all the three zones; maximum temperature and relative humidity were positively correlated with rice output in all the three agro-ecological zones, while minimum temperature and wind were found to be negatively correlated with rice output across the agro-ecological zones of the state.

The variations in climate parameters gave rise to variations in rice output per hectare across the agro-climate zones of the state with the Northern agroecological zone found to be more significantly favored in rice production than the other two zones (Central and Southern) at 5% level.

Recommendations

Based on the findings of this study, the following recommendations are necessary;

i. Given that the variations in rainfall pattern significantly influenced rice production in all the three zones of the state, proper sources of water supply regime and irrigation system should be provided for regular and adequate water supply in rice farming.

ii. The agro-ecological zones found to be climatically friendly to produce rice should be encouraged to produce more rice both for local consumption and exports by the farmers while other zones not climatically and comparatively favorable for rice production can be involved in other arable crops, vegetable crops and livestock production.

iii. Meteorological information on weather and climate forecasts should be made available to rice farmers in the state on regular basis so as to guide them on the trend in climate and weather conditions in rice farming.

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