INTERNATIONAL JOUNAL OF: AGRICULTURAL RESEARCH AND BIOTECHNOLOGY

TIMBOU-AFRICA ACADEMIC PUBLICATIONS
INTERNATIONAL JOURNAL, MAY, 2021 EDITIONS
VOL. 5 NO. 1 ISSN: 3438-2901

STRENTH OF ASSOCIATION BETWEEN CLIMATIC VARIABLES AND CEREAL CROPS IN PARTS OF NORTH CENTRAL STATES, NIGERIA

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ABSTRACT

The study examined the strength of relationship between climatic variables and yield of three major cereal crops (Rice, Maize and Guinea corn) cultivated in North Central States of Nigeria. Thirty (30) years climatic data of rainfall, minimum temperature, maximum temperature and relative humidity from Climatic Prediction Center Merged Analysis of Precipitation

Introduction

The impact of climatic variability, its related vulnerabilities is an emergent global concern. Climate variability and extreme events are projected to be on the rise in several regions and thus having substantial effects on food productions beyond the effects of changes in climatic means. This reliance is mostly critical for both food and cash crops (Akinseye *et al.*, 2012). In recent time the issue of climate variability and change have been considered to be one of the most prominent universal environmental issues. For the period 1885 to 2013, the mean temperature of the globe increased by 0.84 °C and it is projected to increase further by 1.5 – 5.9 °C by the end of the twenty-first (21st) century (IPCC, 2014). Developing nations are more susceptible to such changes as they have inadequate means of adaptation to the disasters and agriculture plays central role in their national economy (Majumder *et al.*, 2016).

(CMAP) and crop yield data from the Agricultural Development Project (ADP) Offices of the respective states were used. Person Product Moment Correlation and multiple regression methods were used for the analysis. Result shows that rainfall and relative humidity exert more influence on yield of the selected crops when compared to minimum and maximum temperature. The result of the multiple regression analaysis for rice yield and climatic variables shows stronger relationship in Abuja and Lafia with the coefficient of determination R^2 of 54% and 56% respectively, while the other stations show weaker relationships. Maize yield shows weaker relationship with the climatic variable in all the station except in Lafia where a stronger coefficient determination R^2 of 57% was detected. In contrast, guinea corn yield shows weaker relationship with the climatic variables in all the station during the study period. The study concluded that the climatic variables does not exert same influence on all the crops studied, therefore, the general interpretation of the relationship between climatic variables and crop yield should be done with cautiousness and that every variable should be studied on its own merit. The study recommended the adoption of climate smart technologies and innovative practices so as to increase yield and strengthen the farmers' resilience to changing climate

Keywords: Climate Variability, Cereal Crops, Climatic Variables, Relationships, North Central State, Nigeria

Cereals crops is in the family of the monocot 'Gramineae or Poaceae' and they are often grown extensively to get the parts that are edible of their seeds (Ukwuru *et al.* 2018). Cer eal crops provides the main energy needed by the body and also provides substantial quantity of other nutrients needed by the body (Idem and Showemimo, 2004).

West Africa and Nigeria in particular has been identified to be vulnerable to the impact of climate variability and change due to the combination of a highly variable climate which is among the most variable in the world on intra-seasonal to inter-decadal timescales - the high reliance on rainfed agriculture, and the limited economic and

institutional capacity to cope with climate change (Diagne *et al.*, 2013). Recent models show increased rainfall with a range of -1 to +12 percent for Nigeria, heavy rainfall is predicted to intensify and become more frequent by 2050. Without adaptation, rainfed crop production might soon become too risky in the study area, and growing crop will become more and more dependent on irrigation schemes (Sylla *et al.*, 2016).
In regions where rainfed systems dominate, crop yields will especially be affected. Generally, crop production will be highly sensitive to the combination of increased temperature, humidity and rainfall intensity. It will become more vulnerable to pests and disease that thrive in warmer, wetter conditions, such as the rice gall midge, rice weevil, and bacterial leaf blight. In low-lying areas, a relatively small rise in sea level can result in crop land inundation, followed by salinization of the land and the freshwater. It is on the backdrop of this problems that the study investigated the strength of relationship between climatic variables and yield of cereal crops in parts of North Central State, Nigeria.

Materials and Methods

The Study Area

The study area lies between Latitude 7^{o} 48^{1} N and 9^{o} 36^{1} N and Longitude 4^{o} 32^{1} E and 8^{o} 30^{1} E. This includes four stations in central Nigeria namely; Minna, Lokoja, Abuja, Ilorin and Lafia. The study area is grouped into the Guinea Savannah climatic zones of Nigeria. In this zone, the continental north wind and south west monsoon controls the wet and dry period. More often the dry season is from December to March while the raining season is between May to October, with the two seasons regularly separated by somewhat transitional periods in April and November (Olayemi *et al*., 2014).

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ISSN: 3438-2901

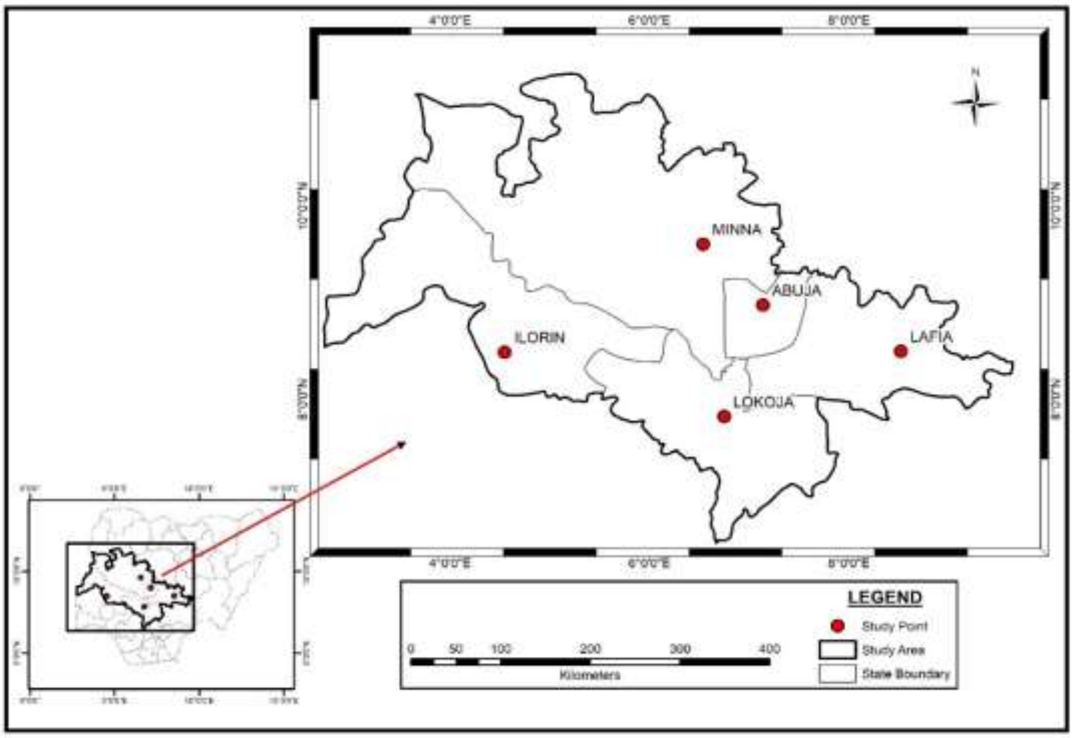

Figure 1: The Study Areas (Minna, Lokoja, Abuja, Ilorin and Lafia)

Data Used

Climatic data of rainfall, minimum, temperature, maximum temperature and relative humidity for the period (1989 to 2018) obtained from Climate Prediction Center Merged Analysis of Precipitation (CMAP) and annual yield per hectares for Rice, Maize and Guinea corn acquired from the Agricultural Development Project (ADP) Offices of the respective states were used.

Correlation and regression analysis was employed to establish the relationship between climatic variables and yield of the selected crops.

Data Analysis

The Pearson Product Moment Correlation was used to measure the linear relationship between the two variables of crop and climatic variables. It is given mathematically as:

$$R = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{n(\sum x^2) - (\sum x)^2}\sqrt{n(\sum y^2) - (\sum y)^2} \quad (1)$$

Where r is the coefficient of linear correlation n = indicate number of data

$\sum x$ = indicates the sum of all x

$\sum y$ = indicates the sum of all y

$\sum x^2$ = indicates the square of each x score and the squares added together

$\sum xy$ = indicates the sum of the product of each x score and its corresponding y score.

$(\sum x)^2$ = indicates the square of the total x score.

Multiple linear regression analysis on crop yield and climatic variables was performed by means of stepwise predictor selection method using version 23 of the Statistical Packages for Social Science (SPSS). This is because there is more than one independent variable (rainfall, maximum temperature, minimum temperature and relative humidity).

The multiple linear regression equation is given as:

$$y = a + b_1X_1 + b_2X_2 \ldots . b_nX_n \quad (2)$$

Where y = is the predicted or expected value of the dependent variable,

a = y-intercept or constant

$X_1 \ldots \ldots X_n$ = independent variable

$b_1 \ldots . b_n$ = regression coefficient

Results and Discussions

Tables 1, 2 and 3 summarized the outcome of the Pearson correlation coefficient between the climatic variables and crop yield during the study period (1989 to 2018) and shows that it is significant at 0.01 and 0.05 (2 tailed).

Table 1, is the result of correlation between rice yield and climatic variables. Result shows significant positive correlation for rice yield and rainfall at alpha value of 0.05 in Minna station. Significant negative correlation at 0.05 and 0.01 alpha values were detected for maximum temperature and rice yield in Lokoja and Lafia stations respectively. The correlation between rice yield and relative humidity shows positive significance at 0.05 alpha value in lokoja station. Generally, finding revealed that rainfall and relative humidity exert more influence on rice yield than minimum and maximum temperature in the study area. This implies that an increasing amount of rainfall and relative humidity is associated with an increase amount of rice yield in most parts of the study area.

Table 1: Summary of Pearson Correlation Coefficients between Rice Yield and Climatic Variable

		Rice Yield	Rainfall	Max Temperature	Min Temperature	Relative Humidity
Minna Rice Yield	Pearson correlation	1	**.394***	.152	.266	.140
	Sig (2 tailed)		.031	.424	.155	.462
	N	30	30	30	30	30
Lokoja Rice Yield	Pearson correlation	1	.348	**-.370***	.169	**.427***
	Sig (2 tailed		.059	.044	.371	.019
	N	30	30	30	30	30
Abuja Rice Yield	Pearson correlation	1	.340	-.541	.220	. 348
	Sig (2 tailed)		.066	.002	.242	.059
	N	30	30	30	30	30
Ilorin Rice Yield	Pearson correlation	1	.216	.134	.165	.040
	Sig (2 tailed)		.251	.480	.382	.833
	N	30	30	30	30	30
Lafia Rice Yield	Pearson correlation	1	.273	-**.693****	-.303	-.341
	Sig (2 tailed		.145	.000	.103	.065
	N	30	30	30	30	30

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

The analysis of the correlation between maize yield and climatic variables is presented in Table 2. On a station by station basis, the Minna station shows significant positive correlation between maize yield and rainfall at 0.05 alpha value while other parameters showed non-significant. Result for Lokoja station shows that maize yield had significant negative correlation with maximum temperature at 0.05 alpha value. Further result shows that the Abuja and Ilorin stations detected non-significant correlation with all the parameters. Result for Lafia station shows non-significant negative correlation between maize yield and maximum temperature at 0.01 alpha value while the other parameters shows non-significance during the study period. The finding implies that rainfall and maximum temperature exert more influence on maize yield in the study area than minimum temperature and relative humidity.

Table 2: Summary of Pearson Correlation Coefficients of Maize Yield and Climatic Parameters

Station		Maize Yield	Rainfall	Max Temperature	Minimum Temperature	Relative Humidity
Minna	Pearson					
Maize Yield	correlation	1	**.389***	.141	-.195	.244
	Sig (2 tailed)		.034	.458	.301	.193
	N	30	30	30	30	30
Lokoja						
Maize Yield	Pearson					
	correlation	1	-.450*	**-.422***	.206	264
	Sig (2 tailed		.013	.020	.274	.158
	N	30	30	30	30	30
Abuja						
Maize Yield	Pearson					
	correlation	1	.029	-.275	.003	.263
	Sig (2 tailed)		.879	.141	.987	.161
	N	30	30	30	30	30
Ilorin						
Maize Yield	Pearson					
	correlation	1	.009	-.231	-.147	-.105

	Sig (2 tailed)		.962	.219	.438	.581
	N	30	30	30	30	30
Lafia Maize Yield	Pearson correlation	1	.230	**.705****	-.300	-.329
	Sig (2 tailed		.220	.000	.107	.076
	N	30	30	30	30	30

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 3, depict the correlation coefficient between guinea corn yield and climatic variables in the study area. Generally, result shows significant negative correlation between guinea corn yield and the climatic variables in most of the station. On a station by station basis, the Minna station shows significant negative correlation for guinea corn yield and relative humidity at 0.05 alpha value. Result for Lokoja station shows significant negative correlation at 0.05 alpha value each for rainfall, maximum temperature and guinea corn yield. Further result shows significant negative correlation at 0.01 alpha value for guinea corn yield and maximum temperature in Abuja station and 0.05 alpha value for rainfall in Ilorin station. The result for lafia station shows significant positive correlation at 0.05 each for minimum temperature, relative humidity while rainfall shows significant negative correlation at 0.05 alpha value in the same station. Finding implies that the climatic variable exert no much influence on guinea corn yield across the station. This means that guinea corn yield may be influenced by other factors apart from climate in the study area.

Table 3: Summary of Pearson Correlation Coefficients of Guinea Corn Yield and Climatic Parameters

Station		Guinea corn Yield	Rainfall	Maximum Temperature	Minimum Temperature	Relative humidity
Minna Guinea corn Yield	Pearson correlation	1	.343	-.006	-.055	**-.448***
	Sig (2 tailed)		.064	.974	.774	.013
	N	30	30	30	30	30
Lokoja Guinea corn	Pearson					

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ISSN: 3438-2901

Yield	correlation	1	**-.450***	**-.422***	.206	.264
	Sig (2 tailed)	.013	.020		.274	.158
	N	30	30	30	30	30
Abuja						
Guinea corn	Pearson					
Yield	correlation	1	-.280	**-.587****	.299	.404
	Sig (2 tailed)		.134	.000	.108	.404
	N	30	30	30	30	30
Ilorin						
Guinea corn	Pearson					
Yield	correlation	1	**-.458***	-.351	-.166	.113
	Sig (2 tailed)		.011	.090	.381	.55
	N	30	30	30	30	30
Lafia	Pearson					
Guinea corn	correlation	1	-.168	**-.658****	**.385***	**.376***
Yield	Sig (2 tailed)		.375	.000	.035	.041
	N	30	30	30	30	30

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

The Tables 4 to 6 summarized the outcome of the regression analysis for the climatic variables and crop yield during the study period (1989 to 2018).

Table 4, shows the model summary for rice yield and climatic variables with coefficient of determination of 23%, 27% and 10% for Minna, Lokoja and Ilorin stations respectively. This indicates weak positive correlation as compared to Abuja and Lafia stations where the coefficient of determination is 54% and 56% respectively, and therefore indicate a strong positive correlation. This implies that 54% and 56% of the variance in rice yield at Abuja and Lafia stations can be explained by the climatic variables having a strong effect on crop yield.

Table 4: Multiple Regression Model Summary (Rice yield)

Station	R	R Square	Adjusted R Square	Std. Error of the Estimate
Minna	.482[a]	.232	.110	.50860
Lokoja	.521[a]	.272	.155	.73377
Abuja	.735[a]	.540	.466	.44778
Ilorin	.330[a]	.109	-.034	.72929
Lafia	.751[a]	.565	.495	1.69669

a. Predictors: (Constant), Rainfall, Max Temperature, Min Temperature, Relative Humidity

The result of the Analysis of Variance is presented in Table 5. Result revealed that there is statistically significant relationship between rice yield and the climatic variables at F (4.25) =7.326, p=0.00 and F (4.25) =8.103, p=0.00 in Abuja and Lafia station. In contrast, Minna, Lokoja and Ilorin station shows non-significance relationship at p>0.05 respectively. This implies that the climatic variables considered for this study have no much effect on rice yield in Minna, Lokoja and Ilorin stations and are considered statistically insignificant.

Table 5: Summary of Analysis of Variance (Rice yield)

Station	Model	Sum of Squares	Df	Mean Square	F	Sig.
Minna	Regression	1.958	4	0.490	1.893	.143[b]
	Residual	6.467	25	0.259		
	Total	8.425	29			
Lokoja	Regression	5.024	4	1.256	2.333	.083[b]
	Residual	13.460	25	0.538		
	Total	18.484	29			
Abuja	Regression	5.875	4	1.469	7.326	.000[b]
	Residual	5.013	25	0.201		
	Total	10.888	29			
Ilorin	Regression	1.623	4	0.406	0.763	.559[b]
	Residual	13.297	25	0.532		
	Total	14.919	29			
Lafia	Regression	93.302	4	23.326	8.103	.000[b]
	Residual	71.969	25	2.879		
	Total	165.271	29			

a. Dependent Variable: Rice Yield; b. Predictors:(Constant), Rainfall, Max Temp, Min Temp, RH P = 0.05%

Analysis of multiple regression for maize yield and climatic variables is presented in Table 6. Result shows multiple regression model summary for maize yield and climatic variables with coefficient of determination of

57% for Lafia station indicating a strong positive correlation while Minna, Lokoja, Abuja and Ilorin stations has 21%, 27%, 15% and 7% respective indicating a weak positive correlation. This implies that 57% of the variance in maize yield in Lafia station is accounted for by climatic variables while the remaining 43% could be as a result of other local factors apart from climate.

Table 6: Multiple Regression Model Summary (Maize yield)

Station	R	R Square	Adjusted R Square	Std. Error of the Estimate
Minna	.467[a]	.219	.093	.50475
Lokoja	.524[a]	.275	.159	.48891
Abuja	.394[a]	.155	.020	.42070
Ilorin	.278[a]	.077	-.071	.20270
Lafia	.758[a]	.574	.506	1.03862

a. Predictors: (Constant), Rainfall, Min Temp, Max Temp, Relative Humidity

Table 7, depict result of the analysis of variance for maize yield and climatic variables. Result shows that there is statistically significant relationship between maize yield and the climatic variables at F (4.25) = 8.425 in Lafia station while Minna, Lokoja, Abuja and Ilorin station shows non-significance relationship at p>0.05 respectively. This implies that the climatic variables considered for this study have no much effect on maize yield in Minna, Lokoja, Abuja and Ilorin stations and are considered statistically insignificant.

Table 7: Summary of Analysis of Variance (Maize yield)

Station	Model	Sum of Squares	df	Mean Square	F	Sig.
Minna	Regression	1.781	4	.445	1.748	.171[b]
	Residual	6.369	25	.255		
	Total	8.150	29			
Lokoja	Regression	2.264	4	.566	2.368	.080[b]
	Residual	5.976	25	.239		

	Total	8.240	29			
Abuja	Regression	.811	4	.203	1.145	.358[b]
	Residual	4.425	25	.177		
	Total	5.235	29			
Ilorin	Regression	.086	4	.021	.522	.721[b]
	Residual	1.027	25	.041		
	Total	1.113	29			
Lafia	Regression	36.352	4	9.088	8.425	.000[b]
	Residual	26.968	25	1.079		
	Total	63.321	29			

a. Dependent Variable: Maize Yield; b. Predictors: (Constant), Rainfall, Tmax, Tmin, RH

Table 8, presents the multiple regression model summary for guinea corn yield and climatic variables with coefficient of determination of 37%, 40%, 27%, 24% and 47% respectively for Minna, Lokoja, Abuja, Ilorin and Lafia stations respectively. This indicate a weak positive correlation across the study area except in Lafia where R^2 value of 47% was detected. This implies that the climatic variables have little or no effect on guinea corn yield across the study area.

Table 8: Multiple Regression Model Summary (Guinea-corn yield)

Station	R	R Square	Adjusted R Square	Std. Error of the Estimate
Minna	.608[a]	.370	.269	.63935
Lokoja	.636[a]	.404	.309	.27465
Abuja	.526[a]	.277	.161	1.21488
Ilorin	.493[a]	.244	.122	.59211
Lafia	.692[a]	.479	.396	.30487

a. Predictors: (Constant), Rainfall, Max Temperature, Min Temperature Relative Humidity

The result of the analysis of variance for guinea corn yield and climatic variables is presented in Table 9. Result shows statistically significant relationship between guinea corn yield and the climatic variables at F (4.25) = 5.749 in Lafia stations while Minna, Lokoja, Abuja and Ilorin station shows non-significance relationship at p> 0.05 respectively. This means that the climatic variables considered for this study have no much effect on Guinea corn yield in the study area and can be considered statistically insignificant.

Table 9: Summary of Analysis of Variance (Guinea-corn yield)

Station	Model	Sum of Squares	Df	Mean Square	F	Sig.
Minna	Regression	6.004	4	1.501	3.672	.017[b]
	Residual	10.219	25	.409		
	Total	16.223	29			
Lokoja	Regression	1.279	4	.320	4.240	.009[b]
	Residual	1.886	25	.075		
	Total	3.165	29			
Abuja	Regression	14.138	4	3.534	2.395	.077[b]
	Residual	36.898	25	1.476		
	Total	51.036	29			
Ilorin	Regression	2.821	4	.705	2.012	.124[b]
	Residual	8.765	25	.351		
	Total	11.586	29			
Lafia	Regression	2.137	4	.534	5.749	.002[b]
	Residual	2.324	25	.093		
	Total	4.461	29			

a. Dependent Variable: Guinea-Corn Yield; b. Predictors: (Constant), Rainfall, Tmax, Tmin, RH,

Conclusion

The study established that a varying direct and inverse relationship exist between climatic variables and crop yield in the study area. The effects of climatic variables on the selected crops was not homogenous across the study area as climate variables (rainfall, temperature and relative humidity) all did not exert the same effect across all crops studied, therefore the general interpretation of the relationship between climatic variables and crop yield should be done with cautiousness and that every variable should be studied on its own merit. The study recommended the adoption of climate smart technologies and innovative practices so as to increase yield and strengthen the farmers' resilience to changing climate.

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TIJARBT
ISSN: 3438-2901