Analysis of Climatic Strength through Temperature and Rainfall in the North Eastern Nigeria

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Abstract **— This paper examined the climatic strength by studying the relationship between the monthly average rainfalls and temperatures in three randomly selected major states (Bauchi, Adamawa and Bornu States) in North-Eastern Nigeria. Long time meteorological data on rainfall and temperature were examined as obtained on these states over 30 years period (from 1986 to 2015) and they were compared to other states in the North-Easter region Nigeria. The descriptive statistics were computed from the data sets while Canonical Correlation Analysis was performed to investigate the relationship between the two the two datasets. Wilk's Lambda test was also employed to test the statistical significant of the relationship between the canonical variates. On the descriptive statistics showed that, the lower the mean and variance of the temperature the higher the mean and variance of the rainfall, indicating the lower the temperature the higher the rainfall. Results from canonical correlation analysis identified thw following two sets: Set – A_T = {$BAUC_T$, $ADAM_T$, $BORN_T$} and Set – B_R = {$BAUC_R$, $ADAM_R$,$BORN_R$}. However, two Canonical roots were obtained and only one is statistically significant (r_1= 0.7414,p= 0.0074) with r-squared value of 0.5497 showing a strong positive correlation coefficient between the datasets.**

Keywords - *North East Nigeria, Climatic strength, Temperature, Rainfall, Descriptive statistics, Canonical Correlation Analysis.*

I. INTRODUCTION

Climate is concerned with the weather condition of a particular area over a period of 30 years. Temperature and Rainfall are regarded as the major elements of climate [21]. Climate change seems to be the foremost global challenge facing humans at the moment, even though it seems that not all places on the globe are affected [17]. However, Rainfall and temperature pattern in the semi-arid region of north eastern Nigeria are very important for continuous description of the climate change condition in the area, because the rainfall as it is useful for domestic purpose is always determined by the temperature level [9]. The temperature leads to the hotness and coldness of the region while the rainfall leads to surface and sub-surface recharge, and for rain-fed agricultural production [5]. Inconsistent rainfall over years may include repeatedly late onset of rainfall, short dry spells, and sometimes droughts lasting several years. These events are the main factors determining the water scarcity, poor crop germination and extreme hotness in North East region of Nigeria. Large inter-annual variations in rainfall amounts and prolonged periods of droughts have been recorded in 1967–1973 and 1983–1987 [2], with a negative impact on the region's agricultural output and severe consequences for the socio-economic situation of the people [11]. Perhaps, temperature and Rainfall are one of the elements of Climate. The amount and frequency of rainfall in Nigeria generally increases from southwest to northeast with some variations over short distances [16]; however, the Rainfall in North eastern Nigeria is controlled by the West African Monsoon [13].
However, in this study; we made use of Descriptive Statistics to analyse the mean and variance of the data set, while Canonical correlation analysis to verify the relationship between the monthly average temperature and

rainfall data set of the states (Bauchi, Adamawa and Borno) in the North East region, Nigeria.

The Descriptive statistics used in this paper describes the behaviour and pattern of the data set towards mean and variance. According to [12]; used mean, variance, coefficient of variation and Pearson's correlation to study the characteristics of air temperature and rainfall for effective planning of farming operation; claiming that temperature and rainfall are two important environmental factors in agricultural uses.

While the canonical correlation analysis deals with the association between composites sets of multiple dependent and independent variables (says: Set – A_T and Set – B_R variables, is by creating the combinations). In doing so, it develops a number of independent canonical function that maximize the correlation between the linear composites, known as canonical variates; which are sets of dependent and independent variables. [3]. According to [1]; used Canonical Correlation Analysis on science production. Their result shows that; the relationship between the sets of data {Set-A (School output) and Set-B (School input and Environmental input)} are statistically significant at the first canonical variate, indicating the impact of the School and Environmental inputs on the school output. However, [10]; analyzed the effect of rainfall and temperature on maize yields using Multiple regression analysis. Their study shows that variation in both rainfall and temperature were found not to directly relate to the variation noticed in the output and yield of maize during the ten year period.

The Descriptive analysis of this study shows that; the lower the temperature, the higher the rainfall while there is a strong relationship between temperature and rainfall based on the canonical correlation analysis. This result may be helpful for decision makers to develop the strategies for planning and development under different climatic scenarios to overcome their adverse impact on life and Agriculture.

II. RESEARCH METHODOLOGY

1. Descriptive Statistics

Basic descriptive statistics are calculated to 64 bit decimal precision avoiding any of the pocket calculator formulae that led to unnecessary lack of precision [15].

$$\text{Mean} = \bar{x} = \frac{\sum_{i=1}^{n}(x_i)}{n} \quad (1.1)$$

$$\text{Standard deviation} = S = \sqrt{\frac{\sum_{i=1}^{n}(x_i-\bar{x})^2}{n-1}} \quad (1.2)$$

2. Canonical Correlation Approach Model

The first step in canonical correlation analysis; is to inspect the correlation matrix of the given set data.

Let S denote the data such that: S = {Set-A, Set-B}

Where:

Set – **A** = {**BAUC$_T$**, **ADAM$_T$**, **BORN$_T$**}

Set – **B** = {**BAUC$_R$**, **ADAM$_R$** ,**BORN$_R$**}

Proper analysis begins with a simple examination of the correlation significance [6].

[4] gave a detailed Mathematical concept of canonical correlation analysis. Let X be a q-dimensional random vector and Y be a p-dimensional random vector. Suppose that X and Y have means μ and v respectively and that

$$E[(x-\mu)(x-\mu)] = \Sigma_{11} \quad (2.1)$$

$$E[(y-\mu)(y-\mu)] = \Sigma_{22} \quad (2.2)$$

$$E[(x-\mu)(y-\mu)] = \Sigma_{12} = \Sigma_{21} \quad (2.3)$$

Let us now consider the linear combinations

$$g = a'x \quad (2.4)$$

and

$$f = b'y \quad (2.5)$$

The correlation between g and f is defined as show below

$$\rho(a,b) = \frac{a\Sigma_{12}b}{[(a'\Sigma_{11}a)(b'\Sigma_{22}b)]^{1/2}} \quad (2.6)$$

3. Tests for Significance using Wilk's Lambda Test.

The Wilk's Lambda test of hypothesis is given as:

$H_0 : \Sigma_{XY} = 0$ i.e. there is no relationship between the canonical variates.

$H_1 : \Sigma_{XY} \neq 0$ i.e. there is relationship between the canonical variates.

Test statistic:

$$\lambda_1 = \frac{|R|}{|R_{YY}||R_{XX}|} \quad (2.7)$$

Where:

R is the correlation between $x's$ and $y's$

R_{XX} is the correlation between $x's$

R_{YY} is the correlation between $y's$

Significance Level:

$\alpha = 0.05$

Decision rule:

Reject H_0 if $p < 0.05$ and otherwise accept [20].

4. Data Used for the Analysis

The data used for the Analysis were obtained from the Metrological centre which covers 30 years data on the

average temperature and rainfall based on the monthly temperature and rainfall gathered at each particular year of studies. The selected states with the required nature of data on temperature and rainfall data is symbolized as **$BAUC_T$** = Bauchi State Temperature. **$ADAM_T$** = Adamawa State Temperature. **$BORN_T$**= Bornu State Temperature. **$BAUC_R$** = Bauchi State Rainfall. **$ADAM_R$** = Adamawa State Rainfall and **$BORN_R$**= Borno State Rainfall.

II. Results and Discussion

The Table 1 below shows the mean values and standard deviation of each variable as considered in the analysis. It is clear that the mean scores for the average temperature in the three states is around 30; since most of their temperature values fall around 30 and a little bit more than 30 degree Celsius. While their corresponding Standard deviation reads the higher the value of the mean the higher the temperature. But Borno with $\mu = 35.3129$and $\sigma = 2.5794$ records the highest mean temperature value indicating the extreme hotness of the state; next to Adamawa; which is around $\mu = 34.8486$and $\sigma = 0.6497$, then; Bauchi with $\mu = 32.3968$and $= 0.5877$. However, the highest mean and standard deviation value in the monthly average rainfall came from Bauchi state with $\mu = 87.5325$and $\sigma = 17.5887$; this indicates that, the state experienced the highest rainfall within the years of Study compare to other states, while the next states is Adamawa with $\mu = 74.1784$and $\sigma = 11.9418$ then Borno $\mu = 50.5495$and $\sigma = 11.5913$; which recorded the lowest mean rainfall and standard deviation. From this descriptive statistics outcome; it is clearly understood that, the lower the temperature the higher the amount of rainfall experienced within the years of study in the randomly selected states in Northern Eastern region Nigeria.

Table 1: Descriptive statistics

Variable	Frequency	Mean	Standard deviation
Average Temperature			
$BAUC_T$	360	32.3968	0.5877
$ADAM_T$	360	34.8486	0.6497
$BORN_T$	360	35.3129	2.5794
Average Rainfall			
$BAUC_R$	360	87.5325	17.5887
$ADAM_R$	360	74.1784	11.9418
$BORN_R$	360	50.5495	11.5913

Table 2: Canonical correlation coefficient of Set – A and Set – B .

Canonical Functions	Canonical Correlation	Eigen values	% of Variance Explained
1	**0.7414**	**0.5497**	**83.04**
2	**0.3351**	**0.1123**	**16.96**

Table 2 shows the Canonical correlation of the two canonical variates and their corresponding Eigen values (that is r-squared). Wilk's Lambda test criterion is used to test for the significant of the Eigen values of the canonical variates, Rencher (2002).

Hypothesis:

$H_0 : \Sigma_{XY} = 0$ *Againsnt* $H_1 : \Sigma_{XY} \neq 0$ *at* $\alpha = 0.05$

Reject H_0 *if* $p < \alpha = 0.05$, we have the following table:

Table 3: Shows the Wilk's Lambda test

S/NO	N	P	Q	Df	p-value	$\alpha - value$
1	360	3	3	9	0.0074	0.05
2	360	2	4	4	0.5541	0.05

From table 3 above, the canonical correlations tested is significant at the first canonical correlation coefficient with p_1 – value = 0.0074 $\prec \alpha = 0.05$, since the p-value of the first canonical variate is less than the alpha value (0.05), it implies that the null hypothesis is rejected (which stated that; there is no relationship among the set of the data). This indicates that; one of the two canonical correlation coefficients is significantly different from zero. **'P'** is the number of variables considered in a certain canonical variate, while **'Q'** is the number of variables considered in the opposite canonical variate and **'df'** is the degree of freedom used at each level of canonical function.

We therefore consider the first canonical variate pair U_1 and V_1 with canonical correlation Coefficient r_1= 0.7474 as it is significant and possesses the highest degree of

canonical correlation coefficient, so that the proportion of variance common to the first canonical variate pair is $r_1^2 = 0.5497$ showing about 54.97% of the proportion of variance captured by the first canonical variate.
Similarly $r_2 = 0.3351$ is the canonical correlation coefficient between the second canonical variate pair and so $r_2^2 = 0.1123$ which indicates about 11.23% of the proportion of variance captured.

Table 4: Canonical loading for Set –A and Set – B

Sets	Variables	r_1	r_2
Set – A_T	***Average Temperature***		
	$BAUC_T$	0.8887	0.6257
	$ADAM_T$	0.8766	0.3792
	$BORN_T$	0.3681	0.3928
Set – B_R	***Average Rainfall***		
	$BAUC_R$	0.7115	0.2493
	$ADAM_R$	0.6980	0.0147
	$BORN_R$	0.2510	0.8951

Table 4 shows the canonical loadings that provide information about the relative contribution of variables to each independent canonical relationship, the first pair of canonical variates can be written as follows:
$U_1 = 0.8887BAUC_T + 0.3681BORN_T + 0.8766ADAM_T$

$V_1 = 0.7115BAUC_R + 0.2510BORN_R + 0.6980ADAM_R$

$\emptyset = 0.7474$

The correlation ($\varnothing_1$) between U_1 *and* V_1 is called the first canonical correlation coefficient.
Looking at the contribution of the individual variable used in the analysis, in Set-A; $BAUC_T$ is loading the heaviest value 0.8887, followed by $ADAM_T$ (0.8766) and $BORN_T$ (0.3681), while in Set-B; $BAUC_R$ loading heaviest with the value (0.7115), followed by $ADAM_R$ (0.6980), and $BORN_R$ (0.2510),however, $BORN_T$ (0.3681) and $BORN_R$ (0.2510) are values less than 0.5 indicating their lower contribution and impact to the first canonical coefficient (that is, their low significant impact on the relationship between the temperature and rainfall in the North East Nigeria.)
Thus, the values attached to each variable in Set-A and Set-B are their partial correlation to their corresponding canonical variables and indicating the individual contribution to the canonical pair.

Table 5: Canonical cross loading for Set-A and Set-B

Sets	Variables	r_1	r_2
Set-A_T	***Average Temperature***		
	$BAUC_T$	0.3670	0.2849
	$ADAM_T$	0.3378	0.2397
	$BORN_T$	-0.3239	-0.1170
Set-B_R	***Average Rainfall***		
	$BAUC_R$	0.4662	-0.1721
	$ADAM_R$	0.5434	-0.0584
	$BORN_R$	0.1209	-0.3255

Table 5 shows the Canonical Cross loading of the two canonical functions. In the first canonical function, Set A_T, $BAUC_T$ with (0.3670), $ADAM_T$ (0.3378) and $BORN_T$ (-0.3239) are having a slightly lower correlation with the independent canonical variate. From Set-B_R, $ADAM_R$ with 0.5434 followed by $BAUC_R$ with 0.4662 followed by $BORN_R$ with 0.1209 [22].

III. Conclusion

From the descriptive statistics, it is observed that the lower the mean and standard deviation of the monthly average temperature the higher the mean and standard deviation of the monthly average rainfall in each selected states in the region (North East Nigeria) this is an indication that, the lower the temperature the higher the rainfall in the region. So also; from the output of the Canonical correlation analysis carried out on the entire data, it is observed that the correlation between Set-A_T (Monthly Average Temperature) and Set-B_R (Monthly Average Rainfall) is a strong positive correlation at the first canonical variate and it is significant with a measure of correlation of 0.7414 with the proportion of variability of about 54.97% with ($p = 0.0074 < \alpha = 0.05$)due to the strong contribution of Monthly Average Temperature and rainfall in Bauchi and Adamawa, the Monthly Average Temperature and Rainfall in Borno posses a weak contribution to the first canonical variate. Thus, the first canonical variate indicates that there is a strong relationship between the monthly average

temperatures and the monthly average rainfalls in the selected states as a case study; this describes the strength and consistent pattern of the climatic condition during the year of study in the Region (North East Nigeria)

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