TEMPERATURE AND RAINFALL VARIABILITY STUDIES WITHIN SOUTH-SOUTH REGION OF NIGERIA

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Abstract: The annual rainfall and temperature variables from 1978-2017 for South-South region of Nigeria was retrieved from the records of NiMet in order to ascertain the recent extent of the variation in the climatic conditions of the region. The methods used for the analyses are: simple approach, coefficient of variability (CV), anomaly approach, trend evaluation using parametric and non-parametric methods and the data homogeneity test. The results show that the differences between 1978-1997 and 1998-2017 revealed variability of; -7.0 mm, -0.3°C and -0.3°C for rainfall, maximum and minimum temperatures respectively. The overall CV of the maximum temperature, minimum temperature and annual rainfall are 0.026, 0.036 and 0.145 respectively. From the anomaly results it was unveiled that 21 years recorded higher rainfall whereas 19 years recorded lower rainfall. Moreover, 24 years were warmer than normal, 13 years were less warm than normal while 3 years were having normal temperature. The Sen's estimator slope of the annual rainfall recorded a downward trend of -94.0 mm/yr during 1978-1987 decade with a slope of -3. There were upward trends of 90.0 mm/yr with a slope of 1, 30 mm/yr with a slope of 1 and 118.0 mm/yr with a slope of 1 for 1988-1997, 1998-2007 and 2008-2017 decades respectively. While, the maximum temperature recorded downward trend of -0.1°C/yr with a slope of -1 in 1978-1987 decade. It recorded rising trend of 0.1°C/yr with a slope of 0 in 1998-2007 decade. The remaining two decades recorded no trend in the maximum temperature with a slope of 1 and 0 respectively. Similarly, the minimum temperature recorded upward trend of 0.1°C/yr with a slope of 0 in 1988-1997 periods, while 1978-1987, 1998-2007 and 2008-2017 decades recorded no trend with a slope of 2, 0 and 1 respectively. This study has again unveiled the fact that there is variation in the climate. Accordingly, there is a conceptual need to keep the general public on alert due to its vicious impacts so as to take the appropriate measures and adaptation opportunities for its mitigation.

Keywords: Agriculture, Climate, Global warming, Rainfall, Temperature

1. INTRODUCTION

Research in climatic studies are becoming more pertinent mainly due to weather related environmental hazards that have affected agricultural activities and caused a lot of harms to lives and properties as a result of climate change and variability (Ukhurebor et al., 2017a-d; Ukhurebor and Abiodun, 2018; Nwankwo and Ukhurebor, 2019a-b; Nwankwo and Ukhurebor, 2020; Nwankwo et al., 2020a-b; Ukhurebor and Nwankwo, 2020; Ukhurebor et al., 2020).

Climate change according to the Intergovernmental Panel on Climate Change (IPCC) is a statistically significant variation in either the mean state of the climate or in the variability of the mean state of climate, occurring for a long period. It has to do with a change of climate that is caused either by natural internal processes or external factors by human direct or indirect activities. These changes are constituent of the atmosphere, coupled with the usual variation in the climate observed over longer period (Field et al., 2014; IPCC, 2014). Climate Variability on the other hand is the change in the average state and other statistics of the climate on all temporal and spatial scales, beyond individual weather events. It is mostly used to denote nonconformities of climatic statistics over a given short period of time (month, season or year) when compared to long-term statistics for the same calendar period. Climate variability is measured by these deviations, which are usually termed anomalies.

According to the Food and Agricultural Organisation of the United Nations (FAO, 2018) the 20th century and the beginning of the 21st have been the warmest period ever in the world measurement of temperature records, which commenced around the middle of the 19th century. Greenhouse gasses (GHGs) such as Carbon (IV) Oxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O). These gasses which are mainly from the utilisation of fossil fuels as a source of the world's greater energy source, permit solar radiation to pass through the atmosphere but do not allow the reflected heat from going back into space which leads to the rise in the earth's temperature may cause variations in climate which may result to global warming (UNFCCC, 2007; FAO, 2018). Global warming is now a treat in most parts of the world, Nigeria inclusive (Ukhurebor and Abiodun, 2018; Nwankwo and Ukhurebor, 2019a-b; Ukhurebor et al., 2020; Nwankwo et al., 2020a-b).

In Nigeria and most parts of the world the release of GHGs have increased tremendously as a result of human activities, agriculture inclusive (Odjugo, 2010; Field et al., 2014; IPCC, 2014; Nwankwo and Ukhurebor, 2019a-b; Ukhurebor et al., 2020). In the next coming decades or so, it is estimated that several persons, especially those in developing regions will encounter deficit of water and food with negative effect to health due to climate change. Consequently, global action is required to withstand these impacts that are occurring continuously. However, because of global warming, the type, rate and magnitude of extreme events are anticipated to rise even with little rise in temperature (UNFCCC, 2007; Meehl et al., 2007; Ukhurebor et al., 2020). It is obvious that human activities have altered atmospheric features, such as temperature, rainfall, levels of CO_2 and ground level ozone. As rightly highlighted by IPCC, that there are several uncertainties about changes in the climate They highlighted that warming of the climate system is now unambiguous and it is obvious that global warming is higher because of the man-made emissions of GHGs, particularly CO_2 (Field et al., 2014; IPCC, 2014).

According to Okoro et al., (2014), what is deemed as the most cause of climate variability especially rainfall variability in West Africa is the West African Monsoon. They highlighted that there is now a major paradigm shift, in that it is now well-known that inter-annual variability is connected to changes in higher-level features like the African Easterly Jet (AEJ), the Tropical Easterly Jet (TEJ) and the Low-Level Westerly Jet, the African Westerly Jet (AWJ) over the continent and the West African Westerly Jet (WAWJ) over the Atlantic. Each of these features has its climatic importance particularly with respect to inter-annual variability. However, continual increase in fossil fuel burning and changes in land use due to agricultural activities have caused the amount of heat from the sun to increase in the earth's atmosphere. This heat was ideally supposed to be radiated back into space. The emission of greenhouse gases and the radiation effects have led to climate change. The current population pressure and poverty has led to certain human activities such as deforestation and bush burning to increase the level of CO_2 in the atmosphere, which invariably increase global warming. The effects of climate change have really affected the development and have made the achievement of the Millennium Development Goals (MDGs) significantly more tedious in Nigeria. This again affirm the report of the United State Agency for International Development (USAID, 2007), that the impacts of the changes in the climate have higher effects in less privileged unindustrialized countries than those of more developed nations.

Variations in any of the climatic variables have significant implications economically with a strong connexion to agriculture and food security (Muluneh et al., 2017; Ukhurebor and Abiodun, 2018; Ukhurebor et al., 2020). This affirmed the result of Muluneh et al., (2015), that changes in the climate would reduce agricultural produce in the sub-humid or humid and the semi-arid regions like the Central Rift Valley of Ethiopia (Muluneh et al., 2015; Muluneh et al., 2017). According to them, the general anticipated changes in the climate will affect agricultural yields undesirably. They also anticipated that these impacts could push several persons into food shortages and the number of persons facing water scarcities would tremendously increase. Change in the climate also affects the components that made up the atmosphere, invariably have significant effect on the electromagnetic waves that propagate through the atmosphere (Ukhurebor et al., 2018; Ukhurebor and Umukoro, 2018; Ukhurebor and Azi, 2019; Nwankwo and Ukhurebor, 2019a-b; Ukhurebor and Odesanya, 2019; Ukhurebor et al., 2019; Ukhurebor and Nwankwo, 2020).

Specifically, South-South region of Nigeria is vulnerable to climate variability because of the dependence on rain-fed agriculture which relies directly or indirectly on climate variables (Ukhurebor and Abiodun, 2018). Subsistence agricultural activities from planting to harvesting are dependant either directly or indirectly to climate variability. This study would attempt to evaluate the annual rainfall and temperature variables of forty years (1978-2017) for South-South region of Nigeria. These variables were retrieved from the records of the Nigerian Meteorological Agency (NiMet). The implications and rationale of this study is that it will again bring to the consciousness of individuals about the existence of in the changes in the climate and its impact on agriculture as well as other aspects of human lives so as to take the necessary mitigation measures as well as the adaptation options.

2. MATERIALS AND METHODS

2.1 Area of Study

South-South region of Nigeria is one of the six geopolitical zones in Nigeria which comprises of six states (Akwa Ibom, Bayelsa, Cross River, Delta, Edo, and Rivers). The region experiences the humid tropical climate, which is characterized by wet and dry seasons. This region is rich with crude oil which provides the major economic lame stream of the country. It also constitutes a reasonable number of Nigeria's population (Ukhurebor and Abiodun, 2018).

The map of South-South region of Nigeria is shown in Figure 1.

2.2 Materials Used for the Study

The materials used for this study are:

Monthly rainfall, maximum and minimum temperatures data of forty years (1978-2017) retrieved from the records of NiMet Synoptic Weather Stations in six cities; one from each of the six states that comprises the region. These are weather stations are managed by professional and the standard meteorological instruments which assist in measuring the most conventional meteorological variables such as temperature and rainfall, are installed in the stations. The common meteorological instruments of measure are thermometer and rain gauge.

I. Each of the six cities used for this research work covers a large area of the entity in the following locations across South-South region of Nigeria:

- Owot Uta Ibesikpo, Uyo, Akwa Ibom, State; located within Latitude 5.0513° N and Longitude 7.9335° E of the Greenwich Meridian.

- Amarata, Yenagoa, Bayelsa State; located within Latitude 4.9212° N and Longitude 6.2748° E of the Greenwich Meridian.
- Magret Ekpo International Airport Calabar, Cross River State; located within Latitude 4.9690°N and Longitude 8.3470°E of the Greenwich Meridian.

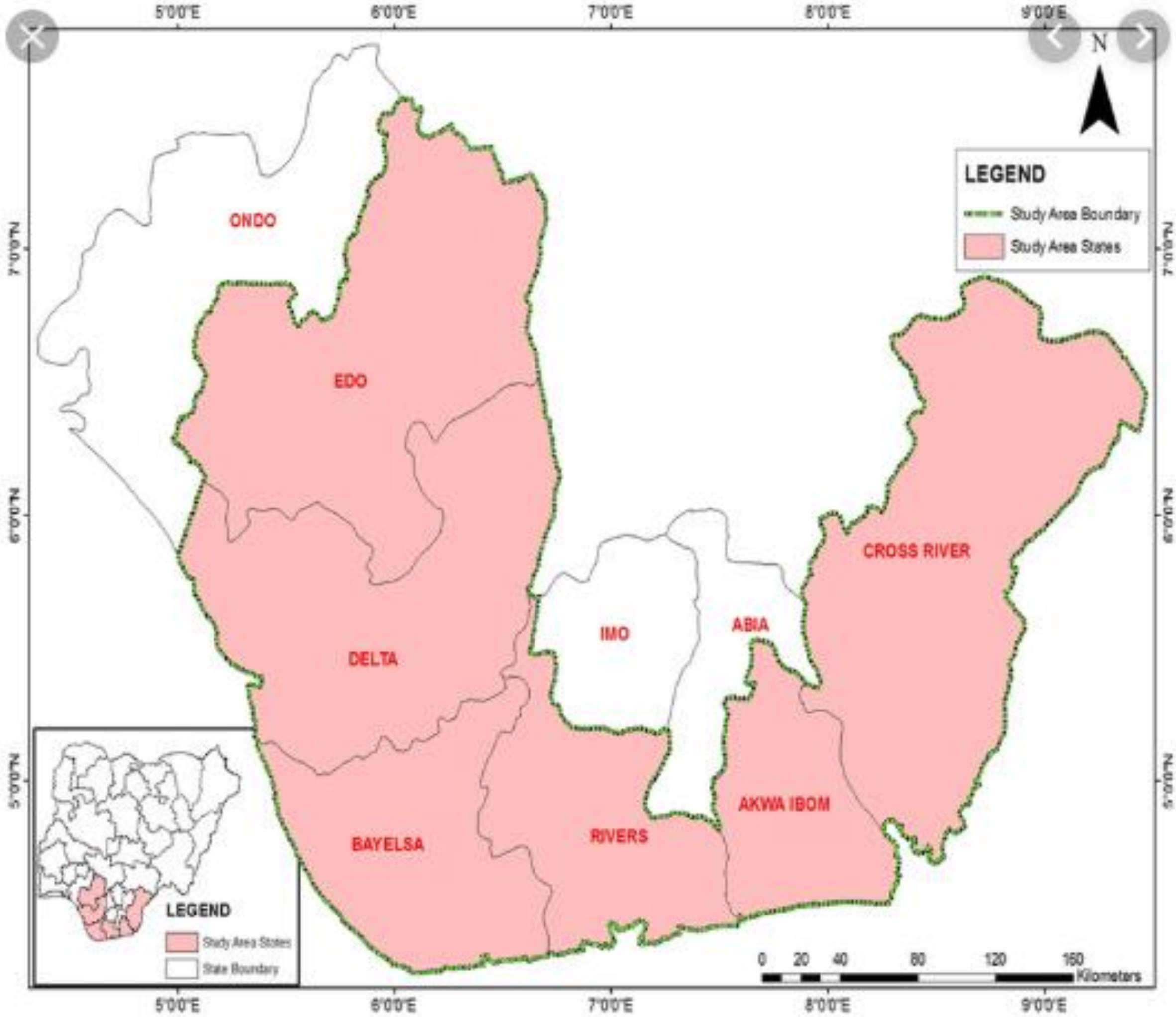

Figure 1: Map of South-South Region of Nigeria

- Federal Secondary, Okpamam, Asaba, Delta State; located within Latitude 6.2059° N and Longitude 6.6959° E of the Greenwich Meridian.
- Benin Airport, Benin City, Edo State; located within Latitude 6.3350° N and Longitude 5.6037° E of the Greenwich Meridian.
- Port-Harcourt International Airport, Omagwa, Port-Harcourt, Rivers State; located within Latitude 4.4721 ° N and Longitude 6.5954 ° E of the Greenwich Meridian.

II. Some mathematical and statistical packages (IBM SPSS Version 20 and Microsoft Excel).

2.3 Method of Analysis

The methods that were employed in the analysis of the collected weather data are:

- Simple Approach
- Coefficient of Variability (CV) and
- Anomaly Approach
- Trend Evaluation using Parametric and Non-Parametric Methods
- The Data Homogeneity Test.

2.3.1 Simple Approach

This method measures the climate variability by dividing the climatic time series into two equal periods as recommended by World Meteorological Organization (WMO, 2012). The two equal length time scales used are; 1978-1997 and 1998-2017. The differences between their means *(X)* and standard deviations (***δ***) were computed and the climate variability is obtained by Eqns. 1 and 2 accordingly;

$$C_V = X_1 - X_2 \qquad (1)$$

$$C_V = \delta_1 - \delta_2 \qquad (2)$$

Where C_V is the climate variability, X_1 is the mean of the first-time scale, X_2 is the mean of the second time scale, $\boldsymbol{\delta}_1$ is the standard deviation of the first-time scale and $\boldsymbol{\delta}_2$ is the standard deviation of the second time scale

The statistics for the skewness (g_1) and kurtosis (g_2) were obtained using Eqns. 3 and 4 respectively.

$$g_1 = \frac{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \mu)^3}{\delta^3} \qquad (3)$$

$$g_1 = \frac{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \mu)^4}{\delta^4} \qquad (4)$$

Where x_i is the climatic variable and n is the sample size.

2.3.2 Coefficient of Variability (CV) Approach

This was another method that was employed in analysing the climate variability for this study. It compares the size of standard deviation relative to the mean of the climatic data. It was obtained using Eqn. 5:

$$C_V = \frac{\delta}{\mu} \qquad (5)$$

Note: ($C_V < 0.1$) indicates low variability, ($0.1 < Cv < 0.4$) designates that moderate variability, ($0.4 < Cv < 0.9$) indicates high variability and ($Cv > 0.9$) designates that variability is very high [22,23].

2.3.3 Anomaly Approach

The anomaly approach was also used for this study. It enables the determination of rainfalls that are higher than normal (wet) which are designated by positive values and rainfalls lower than normal (dry), designated by negative values. With respect to mean temperature, it enables the determination of mean temperature that are higher than normal (hot), designated by positive values and mean temperature lower than normal (cooling) designated by negative values for the years over the period of study. In this method, the average value of the climatic weather variables over a period of thirty years was computed. The climate normal (30 years) used was the mean of 1978-2007 climatic periods as recommended by NiMet, (2010). The anomaly was obtained by subtracting the climate normal from yearly mean of each climatic weather variable as shown in Eqn. 6:

$$A = X_i - \mu_{30} \tag{6}$$

Where A is the anomaly, μ_{30} is the climate normal and X_i is the average value of the climatic weather parameter.

Decadal variability of rainfall, maximum and minimum temperatures were obtained by using the deviation of the decadal mean (ten years mean) of each climatic variable from the climate normal of the climatic variable as presented in Eqn. 7:

$$D_a = \mu_{10} - \mu_{30} \tag{7}$$

$$D_a = \frac{\mu_{10} - \mu_{30}}{\mu_{30}} \times 100 \tag{8}$$

Where D_a is the decadal anomaly, μ_{10} is the decadal mean.

2.3.4 Trend Analysis

Trend analysis was used to determine the change of the random variables during the period under consideration (1978-2017) in statistical terms. The estimate of the extents of the trends in the annual rainfall, annual maximum and minimum temperatures of the forty years and their statistical significances were obtained. The methods employed in detecting the trend of the climatic variables were both parametric and non-parametric tests (Attah, 2013; Durdu, 2009). The parametric test employed is the Student's *t*-test, while the non-parametric tests used were the Mann Kendall and Sen's estimator slope methods (Karabulut et al., 2008). The non-parametric test is more reliable and better when the distribution data are skewed and it is a function of ranks of the observations. However, unlike the parametric test, non-parametric test it is not affected by the outliers (Oke and Ismai'l, 2012).

2.3.5 Student's *t*-test

This method was performed by regressing climatic variable (y) on the time (x). The method assumed a linear trend in the time series. The regression analysis was carried out by considering time as the independent variable, while the annual rainfall, annual maximum and minimum temperatures as the dependent variables. The general statistical model uses to represent linear regression is shown as Eqn. 9:

$$y_i = \beta_o + \beta_{xi} + \varepsilon_i \tag{9}$$

Where y_i is the *ith* observation of the dependent variable (response), x_i is the *ith* value of the independent variable (years), $\boldsymbol{\beta o}$ is the intercept (constant), $\boldsymbol{\beta}$ is the gradient of the regression line (trend of the climatic variables), $\boldsymbol{\varepsilon i}$ is random error. The regression analysis was carried out using IBM SPSS version 20 software. It is expected that the statistics follows student's t-distribution that has $n - 2$ degrees of freedom:

$$t = \frac{\beta \Big/ \sum_{i=1}^{n} (y_i - Y)^2}{(n-2)\sum_{i=1}^{n} (x - X)^2} \tag{10}$$

Where t is the student's t value, $\boldsymbol{\beta}$ is the slope (trend), n is the sample size, y_i-Y is the error, X is the mean of the independent variable x and n-2 is the degrees of freedom. The term Y is given as:

$$Y = \beta_0 + \beta_{xi} \tag{11}$$

H_o; that the trend in the climatic variables is not statistically significance is obtained when the computed t < the critical value. H_a is obtained if the calculated t > the critical value.

2.3.6 Sen's Estimator Slope

The Sen's estimator slope is applicable for the determination of the extent of the trend in the time series climatic variable. In this method, the slopes (T_i) of all the data pairs were computed using Eqn.12:

$$T_i = \frac{x_j - x_k}{j - k} \tag{12}$$

Where i = 1, 2, …, N in which N is the number of observations $\boldsymbol{x_j}$ *and* $\boldsymbol{x_k}$ are values of the climatic data at times j and k respectively, for which j-k. The median of these values of T_i is regarded as the Sen's estimator slope, which is calculated in Eqn. 13:

$$\beta = \begin{cases} T\left(\frac{N/2}{2}\right) \ldots\ldots\ldots\ldots\ldots\ldots N, odd \\ \frac{1}{2}\left[T\left(N/2\right) + T\left(\frac{N+2}{2}\right)\right] \ldots\ldots\ldots N, even \end{cases} \tag{13}$$

If β has positive value, it implies an inclining trend, but if negative it implies declining trend in the climatic time series. The statistical significance of the trend is ascertained using the Mann Kendall test.

2.3.7 Mann Kendall Test

This test was used in determining the presence of trend or otherwise in the climatic variables and the statistical significance of the trend. The Mann Kendall identified the H_0 of the presence of trend versus the H_a that there is no trend. The Mann Kendall test can be applied to non-normal distribution that has seasonality, missing values and unusual data (Attah, 2013). The climatic data were divided into four decades; 1978-1987, 1988-1997, 1998-2007 and 2008-

2017. The trends for the climatic data were then obtained. The Mann Kendall (*S*) statistics is defined by Karabulut, et al., (2008) as:

$$S = \sum_{i=1}^{n} \sum_{j=i+1}^{n} sign\left(x_j - x_i\right) \tag{14}$$

Where *n* is the number of data points, *x* is the observed climatic variable, $\left(x_j \succ x_i\right) taking \left(x_j - x_i\right) = 0$, the value of *Sign* (*θ*) was calculated by:

$$Sign\ (\boldsymbol{\theta}) = \begin{cases} +1 & if\ \theta > 0 \\ 0 & if\ \theta = 0 \\ -1 & if\ \theta < 0 \end{cases} \tag{15}$$

The *Z* statistics was estimated using [24] Eqn. 16;

$$Z = \begin{cases} \frac{s-1}{\sqrt{V(s)}} & if\ s > 0 \\ 0 & if\ s = 0 \\ \frac{s+1}{\sqrt{V(s)}} & if\ s < 0 \end{cases} \tag{16}$$

Where the variance, *V(s)* is calculated using Eqn. 17:

$$V(s) = \frac{n\left(n-1\right)(2n+5) - \sum_{q=1}^{p} tq^{(tq-1)(2tq+5)}}{18} \tag{17}$$

Where *p* is the number of tied groups (zero differences between the compared values of the climatic data), *tq* is the number of the data points in the *qth* tied group.

H_0 is rejected and H_a is accepted when the calculated value of $Z > Z_{\propto/2}$ at ∝ level of significance, otherwise H_0 is accepted and H_a rejected at $\propto = 0.05$, $Z_{\propto/2} = 1.96$ and at $\propto = 0.01$, $Z_{\propto/2} = 1.65$ (Attah, 2008).

2.3.8 Homogeneity Test

The data homogeneity test is important in identifying the reliability as well as the suitability of the time series data for climate change and variability studies (Tuomenvirta, 2002). The non-parametric Thom's homogeneity test was performed on the climatic variables used for this study and show that they were homogenous. The *Z*-statistics result signified that, the homogeneity of all the climatic variables were statistically significant at 95% confidence level as the computed *Z*-value was less than 1.96 for all the climatic elements considered and this ascertained that the weather data used for this study were good and reliable for climate variability studies.

3. RESULTS AND DISCUSSION

3.1 Descriptive Statistics of the Climatic Variables

The statistical parameters used for the descriptive statistics of the climatic variables during the forty years (1978-2017) under investigation are; maximum (*Max*), minimum (*Min*), mean (X), median (*med*) and standard deviation ($\boldsymbol{\delta}$). It was observed that the annual rainfall recorded the *Max* of 1349 mm and *Min* value of 686 mm, with the corresponding X, *med* and $\boldsymbol{\delta}$ of; 1018 mm, 992 mm and 148 mm, respectively. For that of the annual maximum temperature, the *Max* value was 34.6ºC and the *Min* value was 30.8ºC with the corresponding X, *med* and $\boldsymbol{\delta}$ of; 31.9ºC, 31.8ºC and 0.815ºC, respectively. On the other hand, the minimum temperature had the *Max* value of 20.1ºC and *Min* value of 17.7ºC, with the corresponding X, *med* and $\boldsymbol{\delta}$ of; 19.0ºC, 20.0ºC and 0.684ºC, respectively. Rainfall have the highest variability during the period under consideration as it can be seen to have the highest $\boldsymbol{\delta}$ value of 148 mm compared to the other climatic variables. It is obvious that the climate variability to an extent is harmful to plants, animals and humans. The variations in climatic variables have great consequences on reliable crop yields and agriculture in general (Ramirez et al., 2003; Bhandari, 2013; Muluneh, 2015).

3.2 Variability of the Climatic Variables

The variability of the climatic variables used for this study for the period under consideration is shown in Table 1. The variability was in terms of the differences between the mean (X), standard deviation ($\boldsymbol{\delta}$), coefficient of variability (*CV*), skewness (g_1) and kurtosis (g_2) of two the equal-length time scales of 1978-1997 and 1998-2017 respectively. The overall (1978-2017) X, $\boldsymbol{\delta}$, *CV*, g_1 and g_2 are also shown in Table 1.

Table 1: Variability of the Climatic Variables

Statistical Parameters	Periods	Maximum Temperature	Minimum Temperature	Rainfall
X	1978-2017	31.900	19.000	1018.000
	1978-2007	31.600	18.900	1009.000
	1988-2017	19.200	19.200	1016.000
	Variability	-0.300	-0.300	-7.000
δ	1978-2017	0.816	0.684	148.000
	1978-2007	0.542	0.688	147.000
	1988-2017	0.853	0.455	149.000
	Variability	-0.311	0.233	-2.000
CV	1978-2017	0.026	0.036	0.145
	1978-2007	0.017	0.036	0.145
	1988-2017	0.027	0.024	0.146
	Variability	-0.010	0.012	-0.001
g_1	1978-2017	1.545	-0.293	0.072
	1978-2007	0.765	-0.172	0.196
	1988-2017	1.591	-0.850	-0.164
	Variability	-0.826	0.678	0.360
g_2	1978-2017	2.784	-0.662	-0.363
	1978-2007	1.591	-0.643	0.248
	1988-2017	2.820	0.708	-0.593
	Variability	-1.229	-1.351	0.841

It was shown that the climatic variables recorded some level of variability using the differences between the averages of the equal-length time scales of 1978-2007 and 1998-2017 of; -0.5^{o}C, -0.3^{o}C and -7 mm for maximum temperature, minimum temperature and annual rainfall respectively. The negative sign implies that the mean of base line first time scale for 1978-2007 is lower than the mean of the second time scale for 1998-2017; which signifies climate change. However, using the differences between the standard deviations of the equal-length time scales of the climatic variables, the variability of; -0.311^{o}C, 0.233^{o}C and -2 mm for maximum temperature, minimum temperature and annual rainfall, respectively were obtained. On the other hand, the CVs of the climatic variables using the time scales of 1978-2007 also recorded some changes. The values are; 0.017 (1.7%), 0.036 (3.6%) and 0.145 (14.5%) respectively for maximum temperature, minimum temperature and annual rainfall; while for the 1998-2017 time-scale, the CVs are; 0.027 (2.7%), 0.024 (2.4%) and 0.146 (14.6%), respectively. The overall coefficient of variability (CV) of the maximum temperature, minimum temperature and annual rainfall for the period under investigation are; 0.026 (2.6%), 0.036 (3.6%) and 0.145 (14.5%) respectively; signifying low variability and that rainfall recorded the greatest climate variability amongst the climatic variables used. Similarly, the differences in the skewness of the two equal-length time scales for maximum temperature, minimum temperature and annual rainfall are; -0.826, 0.678 and 0.360 respectively. While, the differences in the kurtosis of the two equal-length time scales for maximum temperature, minimum temperature and annual rainfall are; -1.229, -1.351 and 0.841 respectively, signifying that the climatic variables were skewed. Furthermore, the analysis of the distribution of the historic data (skewness) for the 1978-2017 showed that the maximum temperature, minimum temperature and rainfall had the positive values of 1.545, 0.525 and 0.072 respectively; implying that they were right skewed and this is in perfect agreement with the result of Attah, (2013) and NiMet, (2010) observation of the late commencement of and initial cessation of rainfall since 1911. Undoubtedly, affecting the hydrologic characteristics of an area as the water availability can be impaired and have vicious effects on the entire environment.

3.3 Anomalies of the Climatic Variables

In order to ascertain the deviation of each climatic variable from the established normal climate for the period under investigation (1978-2017), the anomalies of the climatic variables were computed and are shown in Figure 2 for rainfall, maximum and minimum temperatures respectively. The established normal for rainfall, maximum and minimum temperatures are; 1009 mm, 31.6^{o}C and 18.9^{o}C respectively, any deviation from this established normal climate signifies climate variability.

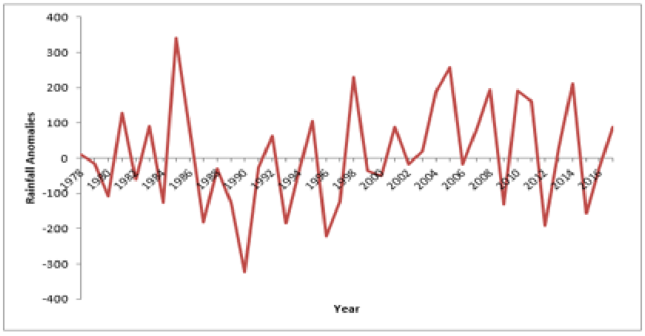

Figure 2a: Annual Rainfall Anomalies

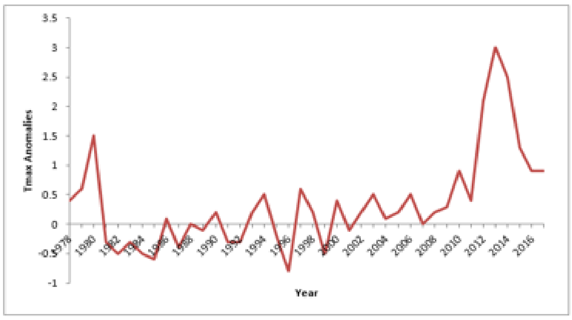

Figure 2b: Annual Maximum Temperature Anomalies

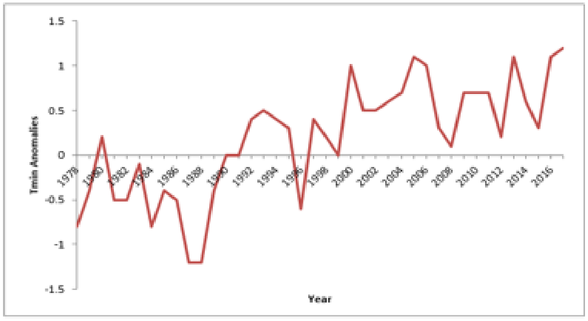

Figure 2c: Annual Minimum Temperature Anomalies

Figure 2: Anomalies of the Climatic Variables

Figure 2a shows the rainfall anomaly. The line corresponding to zero is the base line, which signifies the average rainfall of thirty years and the normal rainfall value of 1009 mm. The base line as can be observed in the Figure is the line that correspond to zero and it is the average rainfall record of thirty years which also implies the normal rainfall (1009 mm). The positive values (above zero) signify rainfalls that were higher than normal (wet); while the negative values (below zero) imply rainfalls that were lower than normal (dry). It is observed that 19 years representing 47.5% recorded wet due to the fact that the rainfalls that occurred in those years were greater than the normal rainfall; while 21 years representing 52.5% recorded dry due to the fact that the rainfalls that occurred in these years were below normal rainfall. It can be said that the wet that occurred from 1978-2017 in these areas ranged from 9 mm – 340 mm; while the dry ranged from 15 mm – 323 mm.

In Figure 2b the anomalies of the maximum temperature are shown. The reference line represents the mean value of the climatic variable over thirty (30) years and which in turn implies the climate normal. However, any yearly mean value that is above the reference line (positive) signifies that the year is warmer than normal; while any yearly average value of the climatic variable that is below the reference line (negative) signifies that the year is less warm than normal. It was observed that twenty-five years representing 62.5% recorded higher maximum temperature than normal; thirteen years representing 32.5% recorded lower maximum temperature than normal; while only two years representing 5% recorded normal maximum temperature. In Figure 2c the anomalies of minimum temperature are shown. The reference line in the figure represents the mean value of the climatic variable over thirty years and which in turn implies the climate normal. However, twenty-five years representing 62.5% recorded higher minimum temperature than normal; twelve years representing 30% recorded lower minimum temperature than normal; while three years representing 7.5% had normal minimum temperature.

These anomalies revealed that climate change signal is stronger and steadily increasing by the year. This again affirms the fact that Nigeria like most part of the world is experiencing the basic features of climate variability (Odjugo, 2010). Climate variability poses a great challenge not only to agriculture but to all human endeavours. It is a limiting factor especially in agriculture (Bhandari, 2013; Muluneh et al., 2015; Muluneh et al., 2017; Ukhurebor and Azi, 2018; Ukhurebor et al., 2019).

Table 2 extracts the years in which the rainfalls were higher than normal (wet) or lower than normal (dry) in relation to increase in the temperature (higher than normal), decrease in temperature (lower than normal) or normal temperature.

Table 2: Comparisons of the Years of Occurrence of Wet/Dry in Relation to Increase, Decrease or Normal Temperature

Years	Wet/dry	Increase/Decrease/Normal Temperature
1978	Wet	Decrease
1979	Dry	Normal
1980	Dry	Increase
1981	Wet	Decrease
1982	Dry	Decrease
1983	Wet	Decrease
1984	Dry	Decrease
1985	Wet	Decrease
1986	Wet	Decrease
1987	Dry	Decrease
1988	Dry	Decrease
1989	Dry	Decrease
1990	Dry	Increase
1991	Dry	Decrease
1992	Wet	Normal
1993	Dry	Increase
1994	Dry	Increase
1995	Wet	Normal
1996	Dry	Decrease
1997	Dry	Increase
1998	Wet	Increase
1999	Dry	Decrease
2000	Dry	Increase
2001	Wet	Increase
2002	Dry	Increase
2003	Wet	Increase
2004	Wet	Increase
2005	Wet	Increase
2006	Dry	Increase
2007	Wet	Increase
2008	Wet	Increase
2009	Dry	Increase
2010	Wet	Increase
2011	Wet	Increase
2012	Dry	Increase

2013	Wet	Increase
2014	Wet	Increase
2015	Dry	Increase
2016	Dry	Increase
2017	Wet	Increase

It was observed that nineteen years recorded higher rainfall and twenty-one years that recorded lower rainfall. For the nineteen years that recorded higher rainfall, twelve years were associated with increase in temperatures; five years were associated with decrease in temperatures; while the remaining two years were associated with normal temperature. Similarly, out of the twenty-one years that recorded lower rainfall, twelve years were associated with increase in the temperatures; eight years were associated with decrease in the temperatures; while the remaining one year was associated with normal temperature. The occurrences of wet or dry during the forty years under investigation had no definite pattern. It can therefore be said, inferentially, that the occurrence of higher rainfall or lower rainfall could be associated with increase in temperature, decrease in temperature or normal temperature. The pattern based on the results obtained is that a year of lower rainfall or higher rainfall is predominantly accompanied by increase in temperature.

3.4 Decadal Variability of the Climatic Variables

The decadal variability for rainfall, maximum and minimum temperatures for the period under consideration (1978-2017) are presented in Table 3. The decadal mean and percentage changes are also contained in the Table accordingly.

Table 3: Decadal Variability of the Climatic Variables

(a) Decadal Variability of Rainfall

Decade	μ_{10} (mm)	μ_{10}- μ_{30} (mm)	Percentage Change (%)
1978-1987	1024	15	1.50
1988-1997	920	-89	-8.80
1998-2007	1083	74	7.30
2008-2017	1045	36	3.60

(b) Decadal Variability of Maximum Temperature

Decade	μ_{10} (°C)	μ_{10}- μ_{30} (°C)	Percentage Change (%)
1978-1987	31.6	0	0
1988-1997	31.6	0	0
1998-2007	31.8	0.2	0.6
2008-2017	32.9	1.3	41.1

(c) Decadal Variability of Minimum Temperature

Decade	μ_{10} (°C)	μ_{10}- μ_{30} (°C)	Percentage Change (%)
1978-1987	18.4	-0.5	-2.7
1988-1997	18.9	0	0
1998-2007	19.5	0.6	3.2
2008-2017	19.6	0.7	3.7

Table 3a shows the decadal variability of the rainfall, the decadal mean and percentage changes in the rainfall accordingly, using the established normal rainfall of 1009 mm. The positive sign signifies much rainfall (wet); while the negative sign signifies less rainfall (dry) for the particular decade under consideration. It was observed that three decades (1977- 1987, 1998-2007 and 2008-2017) representing 75% were associated with much rainfall; while the remaining one decade (1988-1997) representing 25% was having less rainfall. The result affirms the report of Attah, (2013) that the rainfall in lower Kaduna catchment increased by 100mm per decade from 1971-2006.

Table 3b shows the decadal variability of the maximum temperature, the decadal mean and percentage changes in the maximum temperature accordingly using the established normal maximum temperature of 31.60^{o}C. The positive sign signifies higher maximum temperature than normal; while the negative sign signifies lower maximum than normal. It was observed that 1978-1987 and 1988-1997 had normal maximum temperatures; while 1998-2007 and 2008-2017 were higher than the normal maximum temperature by 0.2 (0.6%) and 1.3^{o}C (4.1%), respectively. It can then be said that the maximum temperature over the last two decades (1998-2007 and 2008-2017) was on the increase. However, 2008-2017 recorded the highest maximum temperature which was above the normal by 1.3^{o}C. Table 3c shows the decadal variability of the minimum temperature, the decadal mean and percentage changes in the maximum temperature accordingly using the established normal maximum temperature of 18.90^{o}C. It was observed that 1978-1987 decade was associated with less minimum temperature of 0.5^{o}C (2.7%); while 1988-1997 was normal. The remaining two decades (1998-2007 and 2008-2017) have much minimum temperature of 0.6 (3.2%) and 0.7^{o}C (3.7%) respectively. This implied that the temperature was on the successive increase during the last two decades with each decade having higher mean temperature than the previous decade. These results affirm the report by IPCC (2014) and WMO (2012), that the global trends of most countries now experience their highest national temperatures from 2001 upward and this can affect plant growth and development (Ramirez et al., 2003; Bhandari, 2013). This implies that all other areas of human endeavours could also be affected by this trend.

3.5 Trend Analysis

3.5.1 Parametric Test

From the results of the regression and the corresponding *t-test* values it was observed that there was upward trend of 1.68mm/decade, 5.34^{o}C/decade, 7.59^{o}C/decade and 7.20^{o}C/decade for rainfall, maximum temperature and minimum temperature respectively.

3.5.2 Non-Parametric Test

From the Sen's estimator slope of the annual rainfall, annual maximum and minimum temperatures for the period under investigation. It is observed that the rainfall recorded a downward trend of -94.0mm/yr during 1978-1987 decade with a slope of -3, while there were upward trends of 90.0mm/yr with a slope of 1, 30mm/yr with a slope of 1 and 118.0mm/yr with a slope of 1 for the remaining three other decades (1988-1997, 1998-2007 and 2008-2017) respectively. On the other hand, the maximum temperature recorded downward trend of -0.1°C/yr with a slope of -1 in 1978-1987 decade, whereas it recorded upward trend of 0.1°C/yr with a slope of 0 in 1998-2007 decade. The remaining two decades (1988-1997 and 2008-2017) recorded no trend in the maximum temperature with a slope of 1 and 0 respectively. Similarly, the minimum temperature recorded upward trend of 0.1°C/yr with a slope of 0 in 1988-1997 periods, while 1978-1987, 1998-2007 and 2008-2017 decades recorded no trend with a slope of 2, 0 and 1 respectively.

The Mann Kendall test was carried out to further ascertain the trend in the climatic variables and also to determine its statistical significance using the *Z*-statistics. From the Mann Kendall test for the annual rainfall, maximum and minimum temperatures. It was observed that the annual rainfall recorded Mann Kendall of -3.0, 1.0, 1.0 and 1.0 during 1978-1987, 1988-1997, 1998-2007 and 2008-2017 decades respectively. This signified a downward trend in the 1978-1987 and upward trends in 1988-1997, 1998-2007 and 2008-2017 periods, but they are not statistically significant at 95% confidence level as the computed *Z*-value is < 1.96. Similarly, maximum temperature had Mann Kendall of 1.0 and 1.0 in 1978-1987 and 1998-2007 respectively implying decreasing and increasing trends respectively but they are not statistically significant at 95% confidence level. Moreover, the minimum temperature recorded Mann Kendall of 2.0 in 1988-1997 decade but it was not statistically significant at 95% confidence level.

This result signifies that the area recorded upward trend in rainfall during the last three decades and also upward trend in temperature for all the decades during 1978-2017 periods, implying that the area is becoming warmer. Accordingly, this could impair with the growth and development of plants, reduces soil water availability, thereby affecting agricultural yields and possibly have vicious effects on the entire environment (Ramirez et al., 2003; Durdu, 2009; Araya et al., 2012; Audu et al., 2012; Bhandari, 2013; Muluneh et al., 2015; Van Eck et al., 2016; Muluneh et al., 2017).

4. CONCLUSION

The climate variability for South-South region of Nigeria was analysed using some mathematical and statistical packages from two weather variables (rainfall and temperature) data of forty years (1978-2017) retrieved from the records of NiMet.

The methods employed for the evaluations are: simple approach, coefficient of variability, anomaly approach, trend evaluation using parametric and non-parametric methods and the data homogeneity test. The results show that there is variability in the two essential climate variables used within the study area.

The variations in rainfall have significant effects on agricultural activities as most local (subsistence) farmers depend on favourable weather condition during agricultural activities from sowing to harvesting. This also play a crucial role in determining agricultural yields (Araya et al., 2012; Audu et al., 2012; Bhandari, 2013; Rasul et al., 2014; Muluneh et al., 2015; Van Eck et al., 2016; Muluneh et al., 2017). It also has effects on other human activities. The implication is evident in the destruction of some plants, soil erosion, difficulty in cultivating land due to water logging of soils and have significant implications economically and could also lead to environmental hazard (Field et al., 2014; IPCC, 2014; Muluneh et al., 2015; Van Eck et al., 2016; Muluneh et al., 2017).

Increase in temperature can cause impairment to soil-water availability and also capable of resulting to respiration to prevent photosynthesis processes thereby having negative influence on agricultural yields and this could also lead to environmental hazard [6,7,28,33]. It is also reported that the raise in temperature affects the physiological processes needed for plant growth and development (Field et al., 2014; IPCC, 2014; Rasul et al., 2014; Muluneh et al., 2015; Van Eck et al., 2016; Muluneh et al., 2017).

Inferentially, it can be concluded that variation in these climatic variables have significant implications on plants, animals, humans and the environment economically and otherwise. The results obtained from this study have further revealed that there is climate variability. It is therefore paramount to urgently keep the general public on alert due to its vicious impacts on agriculture and other aspects of human lives in order to take the appropriate measures and adaptation opportunities in mitigating and controlling its impacts. Ultimately, it is recommended that further studies on climate variability should be carried out specifically in other geopolitical zones of the country considering more updated meteorological variables using recent statistical tools in discussing whether the observed trend is in line with climate model projections.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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