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Temperature variability study for Auchi, Edo State, Nigeria

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Abstract
The study of the variability in temperature is now of great concern not only because of its influence on global warming; which is now a universal threat to humans and its atmospheric environment but also its cruel effects on agricultural activities. In this study temperature variable of four decades (1978-2017) for Auchi, Edo State, Nigeria was collected from the archive of the Nigerian Meteorological Agency (NiMet) so as to ascertain the temperature variability. The three methods that were used for this study are; statistical differences between two the equal-length time scales of 1978-1997 and 1998-2017 respectively, coefficient of variability (CV) and the anomaly approach. The trend analysis using t-test, Sen's estimator slope and Mann Kendall were also carried out in order to determine the trend in the temperature variables. The results show that the differences between the two means of the equal-length revealed variability of: 0.50ºC, 0.30ºC and 0.40ºC for maximum, minimum and mean temperatures, respectively. Similarly, the CV of maximum, minimum and mean temperatures were: 0.026, 0.036 and 0.025 respectively indicating low variability. However, the anomaly results revealed that 24 years (60.0%) were warmer than normal; 13 years (32.5%) less warm than normal; while 3 years (7.5%) had normal mean temperature. This study has further revealed that temperature variability is noticeable. Therefore, it is imperative to sensitize the general public about its existence due to its cruel influence on agriculture and other aspects of human endeavors in order to take the necessary measures and adaptation options to alleviating and controlling its effects.

Keywords: temperature, variability, agriculture, global warming, human activities

1. Introduction

Temperature is a very vital atmospheric weather variable due to its influence on other atmospheric weather variables [1]. The National Oceanic and Atmospheric Administration [2] noted that the 20th century and the beginning of the 21st century have been the warmest period in the whole world measurement of temperature records, which commenced around the middle of the 19th century. The increase in temperature not only affects the physiological processes that are needed for plants growth and development but also on the entire human endeavors [3]. The development and growth of a plant depends upon the exposure of the plant to mean temperature during its growing stage, that is to say that plant growth relies on the degree of hotness or coldness to which the plant is subjected to when it is growing [4].

Variation in temperature is a major component in climate change. Climate change 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 is any change in climate over time whether due to natural variability or as a result of human activity. It has to do with a change of climate that is caused either directly or indirectly by the human activities, which changes the constituent of the atmosphere, coupled with the natural climate variability observed over longer period, Intergovernmental Panel on Climate Change [4, 5], United Nations Framework Convention on Climate Change [6]. Climate changes are caused mainly by greenhouse gasses (GHGs) such as Carbon (IV) Oxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O). These gasses which are from the use of fossil fuels as a source of the world's greater energy source which allow solar radiation from the sun 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. Some of the major features of climate change are: rising in average global temperature; variations in cloud cover as well as rainfall on land; melting of ice caps and glaciers and decreased in snow cover; upward in ocean temperatures and their acidity, because of the absorbing heat of seawater and CO_2 from the atmosphere [7]. Human activities are currently known as the main factors leading to climate change particularly in Africa. Land use changes such as; deforestation, overgrazing and vegetation burning add carbon load and also cause change in energy and moisture fluxes, with devastating result on weather and climate patterns at local and national levels. In the next coming decades or so, it is estimated that billions of people, especially those in developing countries will encounter deficit of water and food with negative effect to health and life due to climate change. Consequently, entire global action is required to make developing countries to withstand the effects of climate change that are occurring now and will continue in the future. However, because of global warming, the type, rate and magnitude of extreme events, such as tropical cyclones (including hurricanes and typhoons), floods, droughts and intense rainfall events, heat waves are expected to rise even with little rise in temperature [7, 8]. The variation in temperature are already been noticed in Nigeria and many parts of the World, [9, 10]. In the report of IPCC [6],

they highlighted many uncertainties about climate change, they stated that; warming of the climate system is now unequivocal and it is obvious that global warming is higher because of the man-made emissions of GHGs, in particular CO_2 and this have altered the atmospheric characteristics such as temperature, rainfall, levels of CO_2 and ground level ozone. However, continual increase in fossil fuel burning and changes in land use have caused rise in the amount of heat from the sun withheld in the earth's atmosphere, which ideally suppose to be radiated back into space. This increase in heat has resulted to the greenhouse effect, which consequently 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 in turn increase global warming. The effects of climate change and variability have really affected the development and have made the achievement of the Millennium Development Goals (MDGs) significantly more tedious in Nigeria; because the impacts of climate change and variability have higher effects in less privileged developing countries than those of more developed nations, the United State Agency for International Development [11].
Specifically, Auchi areas of Edo State, Nigeria are vulnerable to climate change because of the dependence on rain-fed agriculture which relies directly or indirectly on climate change; agricultural activities from planting to harvesting are dependant either directly or indirectly to climate change and variability. The significance of climate change and variability cannot be over emphasized considering its impacts on water availability, quality and quantity, food security, agriculture, health, air quality, species migration and sea level rise. These pose great environmental challenges as well as economic losses to the area, country and the world at large. On the other hand, it is predicted that the impacts of climate change such as sea-level rise, droughts, heat waves, floods and changes in precipitation, could, by 2080 will push 600 million people into food shortages and the number of people facing water scarcities would reached 1.8 billion [12]. It is essential for researchers to take the study of temperature variability very serious not only because it is a major component in atmospheric/climatic studies but its influence on other climatic variables which have great impacts in environmental related hazards that have affected agricultural activities and caused a lot of harms to lives and properties [13]. Although, there have reports of climate change generally in Nigeria as a result in the variation in temperature, precipitation amount and rainfall quantity for quite some time now as observed by [9, 10, 14, 15, 16, 17, 18] and many other researchers. This study is uniquely timely not only because of the importance of temperature but also to the best of our knowledge from existing literatures it is one of the most recent studies specifically on temperature variability in Auchi area of Edo State, Nigeria. This research will be helpful in the sense that individuals will be sensitized about the existence of temperature variability, its influence in all aspects of human endeavors so as to take the appropriate alleviating measures in combating its menace generally.

2. Materials and Methods

2.1 Area of Study

Auchi is in the northern part of Edo State, Nigeria, located within Latitude 7.07°N and Longitude 6.27°E of the Greenwich Meridian. The area experiences the humid tropical climate, which is characterized by wet and dry seasons; the vegetation is that of the Savannah, with mostly open grassland and few scattered fire resistant trees. The topography is relatively undulating and it slopes from the north of the area to the south with an approximate population of 62,907 [19].

2.2 Materials used for the Study

The materials used for this study are:

- Monthly maximum and minimum temperatures data of forty years (1978-2017) collected from NiMet
- Monthly mean temperatures of forty years (1978-2017) calculated from monthly maximum and minimum temperatures
- Statistical Package (IBM SPSS Version 20, Microsoft Excel, MATLAB).

The mean temperature was calculated using;

$$T_{mean} = \frac{Tmax + Tmin}{2} \quad (1)$$

Where T_{mean} is the mean temperature, $Tmax$ is the maximum temperature and $Tmin$ is the minimum temperature.
The non parametric Thom's homogeneity test was used for this study. Homogeneity in climate series is said to occur when its variations are caused by changes in weather and climate [18, 20]. For $N \geq 25$, if the climate series is homogenous, the distribution of the number of runs (R) approximates a normal distribution with the mean (X) and variance, $S(R)$ as:

$$X(R) = \frac{N+2}{2} \quad (2)$$

$$S(R) = \frac{N(N-2)}{4(N-1)} \quad (3)$$

$$Z = \frac{R-E(R)}{\sqrt{S(R)}} \quad (4)$$

For $\alpha = 0.01$ level of significance, the null hypothesis (H_0), that the data is homogenous is accepted if $|Z| \leq 2.58$, otherwise an alternative hypothesis (H_a) is accepted. For $\alpha = 0.05$ level of significance, H_0, that the data is homogenous is accepted if $|Z| \leq 1.96$, otherwise H_a is accepted.

2.3 Methods Used for the Study

Weather data collection and analysis were the methods used for this study. The three methods that were employed in the analysis of the collected weather data:

- Simple Approach
- Coefficient of Variability (CV) and
- Anomaly Approach

Trend evaluation using parametric and non parametric methods was also carried out in order to determine the variations in the climatic variables.

2.3.1 Simple Approach

This method measures the temperature variability by dividing the climatic time series into two equal periods as recommended by World Meteorological Organization [21]. The two equal length time scales used are; 1978-1997 and 1998-2017. The differences between their means *(X)* and standard deviations (δ) are computed and the climate variability is obtained by Eqns. 5 and 6 accordingly;

$$\boldsymbol{C_v = X_1 - X_2} \quad (5)$$

$$\boldsymbol{C_v = \delta_1 - \delta_2} \quad (6)$$

Where C_v is the temperature variability, X_1 is the mean of the first time scale, X_2 is the mean of the second time scale, δ_1 is the standard deviation of the first time scale and δ_2 is the standard deviation of the second time scale. X and δ were obtained using;

$$\mu = \sum_{i=1}^{n} xi \quad (7)$$

$$\delta = \sqrt{\sum_{i=1}^{n}(xi - \mu)^{2}} \quad (8)$$

Where x_i is the temperature variable and n is the sample size. While the statistics for the skewness (g_1) and kurtosis (g_2) were obtained using Eqns. 9 and 10 respectively.

$$g_1 = \frac{\frac{1}{n-1}\sum_{i=1}^{n}(xi-\mu)^3}{\delta^{3}} \quad (9)$$

$$g_2 = \frac{\frac{1}{n-1}\sum_{i=1}^{n}(xi-\mu)^4}{\delta^{4}} \quad (10)$$

2.3.2 Coefficient of Variability (CV) Approach

This is the second method that was employed in analyzing the temperature variability for this study. It compares the size of standard deviation relative to the mean of the climatic data. It was obtained using Eqn. 11;

$$C_v = \frac{\delta}{\mu} \quad (11)$$

Note: C_v value of below 0.1 (10%) indicates low variability, above 0.9 (90%) reveals high variability; while the climate is stable if $C_v \leq 0.4$ (40%), after which it becomes unstable [18].

2.3.3 Anomaly Approach

The anomaly approach is the third method used for this study. It determine the 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 period of study. In this method, the average value of the temperature variables over a period of thirty years was computed. The climate normal (thirty years) used was the mean of 1978-2007 climatic periods as recommended by NiMet [22]. The anomaly was obtained by subtracting the climate normal from yearly mean the temperature variables as shown in Eqn. 12;

$$A = X_i - \mu_{30} \quad (12)$$

Where A is the anomaly, μ_{30} is the climate normal and X_i is the average value of the temperature variable.

The decadal maximum, minimum and mean temperatures were obtained by using the deviation of the decadal mean (ten years mean) of each climatic variable from the climate normal of the temperature variable as presented in Eqn. 13;

$$D_a = \mu_{10} - \mu_{30} \quad (13)$$

$$D_a = \frac{\mu 10 - \mu 30}{\mu 30} \times 100 \quad (14)$$

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

2.4 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 magnitudes of the trends in the annual maximum, minimum and mean temperatures of the forty years and their statistical significances were obtained. The methods employed in detecting the trend of the temperature variables were both parametric and non parametric tests [18, 23, 24]. The parametric test used is the Student's *t*-test, while the non parametric tests used were the Mann Kendall and Sen's estimator slope methods. 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 [20, 24, 25].

2.4.1 Student's *t*-test

This method was performed by regressing temperature 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 maximum, minimum and mean temperatures as the dependant variables [23]. The general statistical model use to represent linear regression is shown as Eqn. 15;

$$y_i = \beta o + \beta xi + \varepsilon i \quad (15)$$

Where y_i is the *ith* observation of the dependant variable (response), x_i is the ith value of the independent variable (years), βo is the intercept (constant), β is the slope of the regression line (trend of the climatic variables), εi is random error. The regression analysis was carried out using IBM SPSS version 20 software. It is expected that the statistics in Eqn.16 follows student's t-distribution that has $n - 2$ degrees of freedom [24];

$$t = \frac{\frac{\beta}{\sum_{i=1}^{n}(yi-Y)^2}}{(n-2)\sum_{i=1}^{n}(x-X)^{2}} \quad (16)$$

Where t is the student's t -value, β 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;

$$Y = \beta o + \beta xi \quad (17)$$

H_o; that the trend in the temperature variables is not statistically significance is obtained when the computed value of t is less than the critical value. H_a is obtained if the calculated value of t is greater than the critical value.

2.4.2 Sen's Estimator Slope

The Sen's estimator slope is applicable for the determination of the extent of the trend in the time series temperature variable. In this method, the slopes (T_i) of all the data pairs were computed using Eqn.18 [23];

$$T_i = \frac{xj - xk}{j-k} \quad (18)$$

Where $i = 1, 2, \ldots, N$ in which N is the number of observations, xj and xk 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. 19 [23] as;

$$\beta = \begin{cases} \frac{T(N+2)}{2} \; if \; N \; is \; odd \\ ½(T(N/2 \; + \; T(N+2)/2 \; if \; N \; is \; even \end{cases} \quad (19)$$

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.

2.4.3 Mann Kendall Test

This test was used to determine the presence of trend or otherwise in the temperature variables and the statistical significance of the trend. The Mann Kendall indentified 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 [18, 23]. The temperature data were divided into four decades; 1978-1987, 1988-1997, 1998-2007 and 2008-2017. The trends for the temperature data were then obtained. The Mann Kendall (S) statistics is defined by [18, 23, 24] as;

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \; sign \; (xj - xi) \quad (20)$$

Where n is the number of data points, x is the observed climatic variable, $(xj > xi)$ taking $(xj - xi) = \theta$, the value of *Sign* (θ) was calculated by;

$$\textbf{Sign} \; (\theta) = \begin{cases} +1 \; if \; \theta > 0 \\ 0 \; if \; \theta = 0 \\ -1 \; if \; \theta < 0 \end{cases} \quad (21)$$

The Z-statistics was estimated using [20, 23, 24] Eqn. 22;

$$Z = \begin{cases} \frac{s-1}{\sqrt{V(s)}} \; if \; s > 0 \\ 0 \; if \; s = 0 \\ \frac{s+1}{\sqrt{V(s)}} \; if \; s < 0 \end{cases} \quad (22)$$

Where the variance, $V(s)$ is calculated using Eqn. 23;

$$V(s) = \frac{n(n-1)(2n+5) - \sum_{q=1}^{p} tq(tq-1)(2tq+5)}{18} \quad (23)$$

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

H_0 is rejected and H_a is accepted if the calculated value of $Z > Z_{\propto/2}$ at $\propto$ level of significance, otherwise H_0 is accepted and H_a rejected at $\propto = 0.05$, $Z_{\propto/2} = 1.96$ and at $\propto = 0.01$, $Z_{\propto/2} = 1.65$ [18, 24].

3. Results and Discussion

3.1 Homogeneity Test

The homogeneity test performed on the temperature variables used for this study is shown in Table 1. The data homogeneity test is important in identifying the reliability as well as the suitability of the time series data for climate variability studies [26].

Table 1: Homogeneity Test for the Temperature Variables

	Climate Weather Variables		
	T_{max}	T_{min}	T_{mean}
Z-value	1.32*	0.69*	1.32*

*Z-value is significant at α = 0.05

This shows that the maximum, minimum and mean temperatures during the forty years (1978-2017) under investigation were homogenous. The Z-statistics is also shown in Table 1, in which the result signified that, the homogeneity of all the temperature variables were statistically significant at 95% confidence level as the computed Z-value was less than 1.96 for all the temperature variables considered. This ascertained that the temperature data used for this study were good and reliable for climate variability studies.

3.2 Variations in the Annual Temperature Variables

The annual variations in the maximum, minimum and mean temperatures during the forty years (1978-2017) under investigation are presented in Figures 1 - 3 respectively. From the Figures it is shown that there were variations in the sense that some years recorded higher values of the temperature variables than other years.

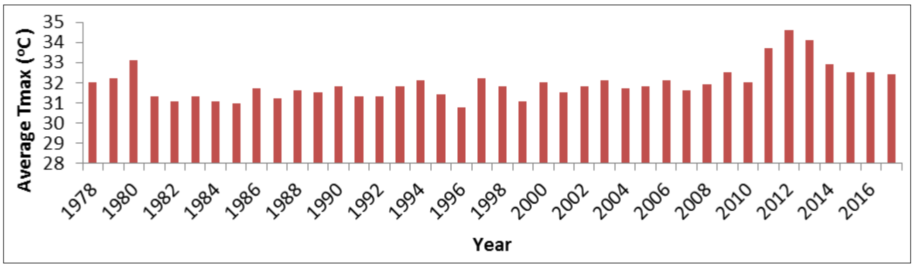

Fig 1: Annual Average Maximum Temperature Variations

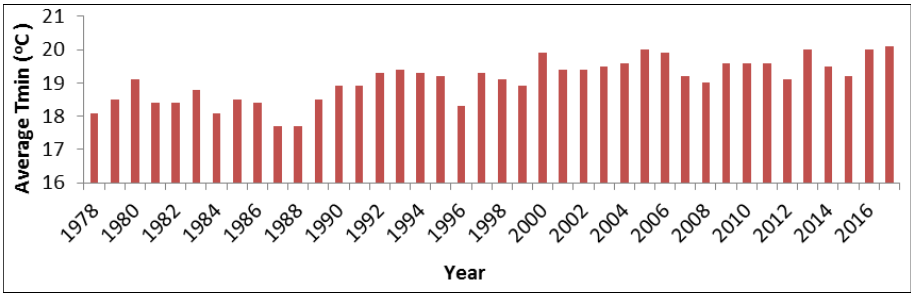

Fig 2: Annual Average Minimum Temperature Variations

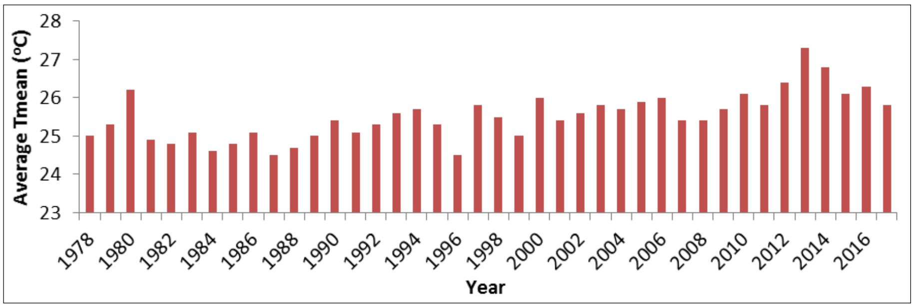

Fig 3: Annual Average Mean Temperature Variations

The annual variations in the maximum temperatures are shown in Figure 1. It was observed that 2013 had the highest maximum temperature value of 34.6ºC; while 1996 has the lowest maximum temperature value of 30.8ºC. This revealed that there were variations in the maximum temperatures. Extremely high temperature can cause impairment to soil-water availability and also capable of resulting to respiration to prevent photosynthesis processes thereby having negative effects on agricultural yields [3, 27, 28] and this could also lead to environmental hazard. The annual variations in the minimum temperatures are shown in Figure 2. It was observed that 2017 recorded the highest minimum temperature value of 20.1ºC; while, 1987 and 1988 recorded the lowest minimum temperature values of 17.7ºC each. This revealed some variations in the minimum temperatures. It is obvious that higher or lower temperatures to an extent are harmful to plants, animals and humans. According to [3] the raise in temperature affects the physiological processes needed for plant growth and development. The annual variations in the mean temperatures are shown in Figure 3. It was observed that the highest mean temperature value of 27.3ºC occurred 2006; while, 1987 and 1996 were the least warm years with mean temperatures of 24.5ºC each. This revealed some variations in the mean temperatures. According to [4, 27], the mean temperature in particular has a significant role in the development and growth of plants especially during the growing stage. It is therefore obvious that variations in the climatic variables to an extent are harmful to plants, animals and humans.

3.3 Descriptive statistics of the temperature variables

The statistical parameters used for the descriptive statistics of the temperature variables during the forty years (1978-2017) under investigation which is presented in the Table 2 are; maximum (*Max*), minimum (*Min*), mean (*X*), median (*med*) and standard deviation (δ).

Table 2: Descriptive Statistics of the Temperature Variables

Statistical Parameters	Climate Variables		
	T_{min} (ºC)	T_{max} (ºC)	T_{mean}(ºC)
Max	17.7	30.8	24.5
Min	20.1	34.6	27.3
X	19.1	31.9	25.5
Med	19.2	31.8	25.5
δ	0.636	0.815	0.629

It was observed that the annual maximum temperature, the *Max* value was 34.6ºC and the *Min* value was 30.8ºC with the corresponding *X*, *med* and δ 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 δ of; 19.0ºC, 20.0ºC and

0.684ºC, respectively. However, the mean temperature was observed to have a *Max* of 27.3ºC and *Min* value of 24.5ºC with the corresponding *X*, *med* and δ of; 25.5ºC, 25.5ºC and 0.629ºC, respectively. The maximum temperature have the highest variability during the period under consideration as it can be seen to have the highest δ value of 0.815ºC compared to the minimum and mean temperatures. It is obvious that the temperature variability to an extent is harmful to plants, animals and humans. As reported by [4, 27], the variations of temperature variables have great consequences on reliable agriculture.

3.4 Variability of the temperature variables

The variability of the climatic variables used for this study for the period under consideration is shown in Table 3. The variability was in terms of the differences between the means, standard deviations, coefficient of variability, skewness and kurtosis of two the equal-length time scales of 1978-2007 and 1998-2017 respectively. The overall (1978-2017) mean (*X*), standard deviation (δ), coefficient of variability (*CV*), skewness (g_1) and kurtosis (g_2) are also shown in the Table.

Table 3: Variability of the Temperature Variables

Statistical Parameters	Periods	T_{max}	T_{min}	T_{mean}
X	1978-2017	31.900	19.000	25.500
	1978-2007	31.600	18.900	25.300
	1988-2017	19.200	19.200	25.700
	Variability	-0.300	-0.300	-0.400
δ	1978-2017	0.816	0.684	0.630
	1978-2007	0.542	0.688	0.512
	1988-2017	0.853	0.455	0.622
	Variability	-0.311	0.233	-0.110
CV	1978-2017	0.026	0.036	0.025
	1978-2007	0.017	0.036	0.020
	1988-2017	0.027	0.024	0.024
	Variability	-0.010	0.012	0.012
g_1	1978-2017	1.545	-0.293	0.525
	1978-2007	0.765	-0.172	0.026
	1988-2017	1.591	-0.850	0.473
	Variability	-0.826	0.678	-0.447
g_2	1978-2017	2.784	-0.662	0.338
	1978-2007	1.591	-0.643	-0.874
	1988-2017	2.820	0.708	1.022
	Variability	-1.229	-1.351	-1.896

It was shown that the temperature variables recorded some level of variability using the differences between the means of the equal-length time scales of 1978-2007 and 1998-2017 of; -0.5ºC, -0.3ºC and -0.4ºC for maximum, minimum and mean temperatures 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 temperature change. However, using the differences between the standard deviations of the equal-length time scales of the temperature variables, the variability of; -0.311ºC, 0.233ºC and -0.110ºC for maximum temperature, minimum temperature and mean temperature respectively were obtained. On the other hand, the CV of the temperature variables using the time scales of 1978-2007 also recorded some changes. The values are; 0.017 (1.7%), 0.036 (3.6%) and 0.020 (2.0%) respectively for maximum temperature, minimum temperature and mean temperature; while for the 1998-2017 time scale, the CVs are; 0.027 (2.7%), 0.024 (2.4%), 0.024 (2.4%) and 0.146 (14.6%), respectively. The overall coefficient of variability (CV) of the maximum temperature, minimum temperature and mean temperature for the period under investigation are; 0.026 (2.6%), 0.036 (3.6%) and 0.025 (2.5%) respectively; signifying low variability. Similarly, the differences in the skewness of the two equal-length time scales for maximum temperature, minimum temperature, mean temperature are; -0.826, 0.678 and -0.447 respectively; while the differences in the kurtosis of the two equal-length time scales for maximum temperature, minimum temperature and mean temperature are; -1.229, -1.351 and -1.896 respectively, signifying that the temperature variables were skewed. Furthermore, the analysis of the distribution of the historic data (skewness) for the 1978-2017 showed that the maximum temperature and mean temperature had the positive values of 1.545 and 0.525 respectively; implying that they were right skewed and this is in perfect agreement with the work of [18] and NiMet [22] observation and this could affect the hydrologic characteristics of an area as the water availability can be impaired and have vicious effects on the entire environment.

3.5 Anomalies of the temperature 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 Figures 4, 5 and 6 for maximum, minimum and mean temperatures respectively. The established normal for rainfall, maximum, minimum and mean temperatures are; 31.6ºC, 18.9ºC and 25.3ºC, respectively, any deviation from this established normal climate signifies climate variability.

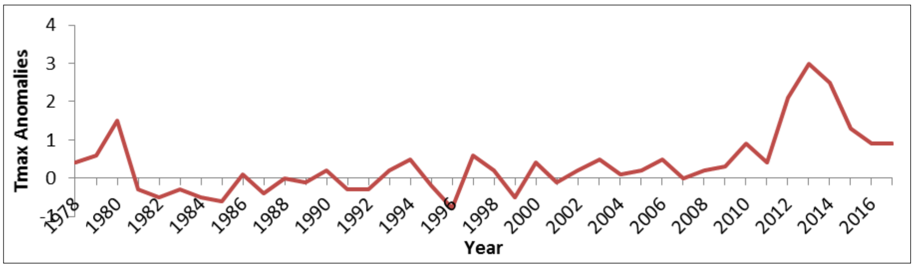

Fig 4: Annual Maximum Temperature Anomalies

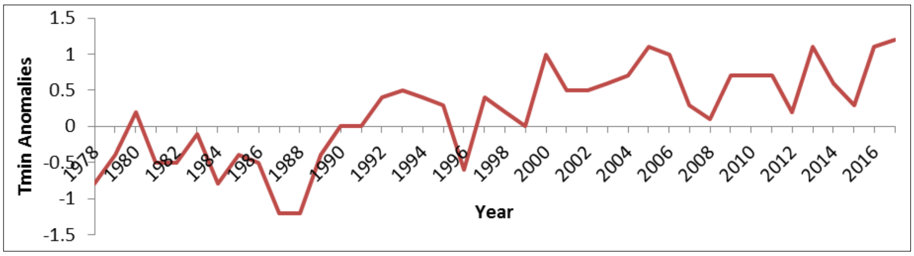

Fig 5: Annual Minimum Temperature Anomalies

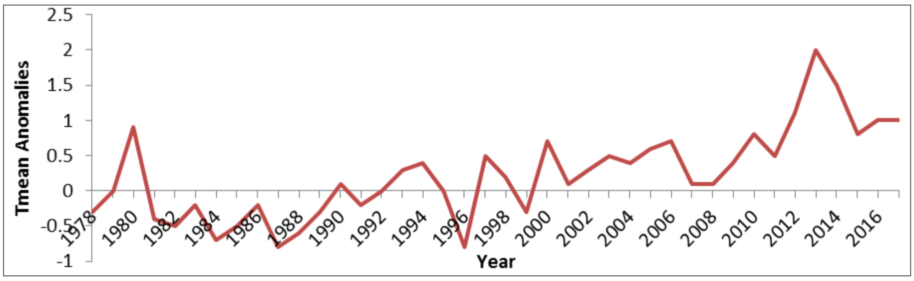

Fig 6: Annual Mean Temperature Anomalies

In Figure 4 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 5 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. Figure 6 shows the mean temperature anomaly. 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 four years representing 60.0% recorded higher mean temperatures than normal; thirteen years representing 32.5% recorded lower mean temperatures than normal; while three years representing 7.5% recorded normal mean temperatures. These temperature 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 [9, 10]. Climate variability poses a great challenge not only to agriculture but to all human endeavors. It is a limiting factor especially in agriculture [27, 29].

3.6 Decadal variability of the temperature variables

The decadal variability for maximum, minimum and mean temperatures for the period under consideration (1978-2017) are presented in Tables, 4, 5 and 6 respectively. The decadal mean and percentage changes are also contained in the Tables accordingly.

Table 4: 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

Table 5: 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 6: Decadal variability of Mean Temperature

Decade	μ_{10} (°C)	μ_{10}- μ_{30} (°C)	Percentage Change (%)
1978-1987	25.0	-0.3	-1.1
1988-1997	25.2	-0.1	-0.4
1998-2007	25.6	0.3	1.2
2008-2017	26.2	0.9	3.6

Table 4 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°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°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 1.3ºC. Table 5 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 18.90ºC. It was observed that 1978-1987 decade was associated with less minimum temperature of 0.5ºC (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 0.7ºC (3.7%) respectively. Table 6 shows the decadal variability of the mean temperature, the decadal mean and percentage changes in the mean temperature accordingly using the established normal maximum temperature of 25.30ºC. It was observed that the first two decades (1978-1987 and 1988-1997) representing 50% were having less mean temperature of 0.3ºC (1.1%) and 0.1ºC (0.4%) respectively; while the remaining two last decades (1998-2007 and 2008-2017) representing 50% also were having much mean temperature of 0.3ºC (1.2%) and of 0.9ºC (3.6%). This implied that the mean 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 [28, 30], that the global trends of most countries now experience their highest national temperatures from 2001 upward and this can affect plant growth and development [4, 27]. This implies that all other areas of human endeavors could also be affected by this trend.

3.6 Trend Analysis

3.6.1 Parametric Test

The results of the regression and the corresponding t test results of maximum, minimum and mean temperatures for the period under consideration (1978-2017) are contained in Tables 8 and 9, 10 and 11, and 12 and 13 respectively. The slope of the regression of these climatic variables represents the trend in the climatic variables.

Table 8: Regression Analysis of Maximum Temperature

Model	Unstd Coefficients		Std Coefficients	T	Significance
	B	Std Error	Beta		
Constant	31.182	0.225		138.602	0.000
Years	0.037	0.010		0.534	0.000

Dependent Variable: Maximum Temperature

Table 9: t test for Maximum Temperature

	Paired Difference					T	Df	Sig (2-tailed)
				95% Confidence Interval of the Difference				
				Lower	Upper			
Years and T_{max}	-11.445	11.277	1.783	-15.051	-7.839	-6.419	39	0.000

Table 10: Regression Analysis of Minimum Temperature

Model	Unstd Coefficients		Std Coefficients	T	Significance
	B	Std Error	Beta		
Constant	18.238	0.135	0.759	135.048	0.000
Years	0.041	0.006		7.197	0.000

Dependent Variable: Minimum Temperature

Table 11: t test for Minimum Temperature

	Paired Difference					T	Df	Sig (2-tailed)
				95% Confidence Interval of the Difference				
				Lower	Upper			
Years and T_{min}	1.415	11.215	1.773	-2.172	5.002	0.798	39	0.430

Table 12: Regression Analysis of Mean Temperature

Model	Unstd Coefficients		Std Coefficients	T	Significance
	B	Std Error	Beta		
Constant	24.735	0.142	0.720	173.608	0.000
Years	0.039	0.006		6.404	0.000

Dependent Variable: Mean Temperature

Table 13: t test for the Mean Temperature

	Paired Difference					T	Df	Sig (2-tailed)
				95% Confidence Interval of the Difference				
				Lower	Upper			
Years and T_{mean}	-5.030	11.246	1.778	-8.627	-1.434	-2.829	39	0.007

The *t*-test result in determining the statistical significance of the upward trend in the maximum temperature is shown in Table 9. Since the absolute computed *t*-value (6.419) obtained is > the critical value of *t*-value (1.685) at 95% confidence level, the upward maximum temperature trend of 5.34ºC/decade in Table 8 is statistically significant at 95% confidence level. The *t*-test result in determining the statistical significance of the upward trend in the minimum temperature is shown in Table 11. Since the absolute computed *t*-value (0.798,) obtained is < the critical value of *t*-value (1.685) at 95% confidence level, the upward minimum temperature trend of 7.59ºC/decade in Table 10 is not statistically significant at 95% confidence level. The *t*-test result in determining the statistical significance of the upward trend in the mean temperature is shown in Table 12. Since the absolute computed *t*-value (2.829 obtained is >the critical value of *t*-value (1.685) at 95% confidence level, the upward mean temperature trend of 7.20ºC/decade in Table 13 is statistically significant at 95% confidence level.

3.7 Non parametric test

The Sen's estimator slope of the annual maximum, minimum and mean temperatures for the period under investigation are shown in Table 14. From the result it is observed that the maximum temperature recorded downward trend of 0.1°C/yr in 1978-1987 decade; while it recorded upward trend of 0.1°C/yr in 1998-2007 decade. The remaining two decades (1988-1997 and 2008-2017) recorded no trend in the maximum temperature. Similarly, the minimum temperature recorded upward trend of 0.1°C/yr in 1988-1997 periods, while 1978-1987, 1998-2007 and 2008-2017 decades recorded no trend. The mean temperature was associated with upward trend of 0.2°C/yr, 0.2°C/yr, 0.1°C/yr, and 0.2°C/yr, respectively during 1978-1987, 1988-1997, 1998-2007 and 2008-2017 decades.

Table 14: Sen's Estimator Slope of the Climatic Variables

Periods	Trends of Climatic Variables		
	T_{max} (°C/yr)	T_{min} (°C/yr)	T_{mean} (°C/yr)
1978-1987	-0.1	0.0	0.2
1988-1997	0.0	1.0	0.2
1998-2007	0.1	0.0	0.1
2008-2017	0.0	0.0	0.2

The Mann Kendall test was carried out to further ascertain the trend in the temperature variables and also to determine its statistical significance using the *Z*-statistics. The Mann Kendall test for the annual maximum, minimum and mean temperatures are shown in Table 15.

Table 15: Mann Kendall of the Climatic Variables

	Climatic Variables		
	T_{max}	T_{min}	T_{mean}
Periods	1978-1987	1978-1987	1978-1987
Mann Kendall	-1.000	0.000	1.000
Z Statistics	0.000	0.000	0.000
Periods	1988-1997	1988-1997	1988-1997
Mann Kendall	0.000	2.000	3.000
Z statistics	0.000	0.092	0.179
Periods	1998-2007	1998-2007	1998-2007
Mann Kendall	1.000	0.000	1.000
Z Statistics	0.000	0.000	0.000
Periods	2008-2017	2008-2017	2008-2017
Mann Kendall	0.000	0.100	0.200
Z Statistics	0.000	0.000	0.174

It was observed that the annual 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 Mann significant at 95% confidence level. On the other hand, the mean temperature recorded positive Kendall values of: 1.0, 3.0, 1.0 and 2.0, respectively in 1978-1987, 1988-1997, 1998-2007 and 2008-2017 decades. This signified that all the decades were associated with upward trend in the mean temperature, but none is statistically significant at 95% confidence level. This result signified that the area recorded upward trend in mean temperature in all the decades during 1978-2017 periods, implying that the area is becoming warmer. According to [4], this could impair with the growth and development of plants, reduces soil water availability, thereby affecting agricultural yields and could have vicious effects on the entire environment.

4. Conclusion

This study is a part of an ongoing study on climate variability where temperature data of forty years (1978-2017) for Auchi, Edo State, Nigeria was collected from the archive of NiMet in order to ascertain the temperature variability of the area. This study has further revealed that temperature variability is noticeable. Therefore, it is imperative to sensitize the general public about its existence due to its cruel influence on agriculture and other aspects of human endeavors in order to take the necessary measures and adaptation options to alleviating and controlling its effects. Finally, it is recommended that further studies on climate variability should be carried out specifically in other parts of the country considering more meteorological variables, such as wind speed, atmospheric pressure, relative humidity, rainfall, etc.

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