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Evaluation of Temperature and Rainfall Variation in Yola, Adamawa State, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This study evaluated rainfall and temperature variation in Yola metropolis, Adamawa State, between 2008 and 2018. The data used was obtained from the Nigerian Meteorological Agency (NiMet). Mann-Kendall's trend test was used to analyse the data on mean temperature (minimum and maximum) and annual rainfall. The results of the study revealed that the minimum temperature is increasing and the maximum temperature is decreasing in the area, while rainfall is increasing. There is also no significant change in the period of onset and cessation of rainfall within the period of study. In this regard, farmers in the region are advised to maintain their normal period of farming activities. Based on these findings, residents of the area are encouraged to build houses that allow for good ventilation to minimize heat stress, keep water drainages clean, and avoid building structures and farming on waterways to prevent flooding and destruction of farm produce during the rainy season.

Keywords: Temperature; rainfall; variability; flooding; Yola Adamawa state.

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1. INTRODUCTION

The global, regional, and local climates of the earth have never remained stable over time. There seem to be different levels of non-stativity, from variability to fluctuations, trends, and rapid to slow shifts. On time scales of 10,000 years or more, analyses of proxy evidence from tidal waves, shifting sea and lake levels, tree rings, pollen counts, and ice-core have demonstrated that climate variations have been substantial [1]. We are aware that the world has gone through and come out of several ice ages. However, what is happening right now is the concern over an unheard-of severe global warming caused by human activities such as the ongoing release of industrial waste products into the atmosphere and widespread deforestation [1].

The Working Group 1 Report of the Inter-Governmental Panel on Climate Change (IPCC) from 1991 confirmed greenhouse gases' role in climate change. (Carbon dioxide ($C0_2$), methane (CH_4), chlorofluorocarbons (CFC – 11, CFC – 12, CFC – 13), nitrous oxide (N_20), ozone (0_3) and aerosol/particulates) contribute significantly to climate change. The fluctuation or trend of variability is thought to be a natural characteristic of climate or weather. It is important to consider the duration and the degree of variation of the climate [2]. The man can quickly adjust to such slight variations, he continued, and minor swings or variations in the climate are little more than "noise" in the climatic series. However, when climatic variations result in notable departures from the norm or persist for an extended period of time to create a new climate state, adjustment issues arise, making man and his activities extremely vulnerable. The sensitivity of man, his society, and his environment is also increased by the speed of climate variations or changes. There is no doubt that the climate system is warming, and tremendous changes have been seen during the decades since the 1950s.The ocean and atmosphere are warming, the amount of ice and snow is declining, and the concentration of greenhouse gases is rising so also sea levels [3]. Emissions of greenhouse gases, which are primarily responsible for human-caused climate change, have been steadily rising since the industrial revolution. The Earth's climate system computer models (natural and human-made) cannot predict current warming without taking anthropogenic causes into account because the rate of emissions is steadily increasing over time. The variations in indices of daily temperature and rainfall extremes for the years 1971–2010 were examined by [4] using climate records from 6 locations in northwest Nigeria. It showed that warm days have increased significantly while cold days have decreased significantly. Compared to the declines in the number of cold days, the rising trends in warm days are far more pronounced. On the other hand, the total amount of precipitation has increased, albeit marginally, with Kaduna being the lone exception. Increased global warming can cause large-scale climatic disturbances, which could ultimately have a significant impact on rainfall in the Sahel [5]. One of the interesting research areas in recent years, particularly for agricultural applications and water resource management, is the detection of trends in temperature and rainfall time series. Temperature variations and rainfall are not equivalent. Between locations with differing climates, there may be significant spatio-temporal differences and considerably bigger variances from one region to the next [6].Several studies have assessed the temperature and rainfall trends in Nigeria at various regional and chronological dimensions [7,8,9,10,11,12]. Most of the research is regional based with varying climatic conditions [13]. Hence, this study aimed at evaluating the trends of rainfall and temperature patterns in Yola, Adamawa State.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 The study area

Yola is the capital of Adamawa state. The city is located at a height of 190.5m and has the coordinates 09°14'N and 12°28'W. On the upper Benue trough is where Yola is situated. Yola has a tropical wet climate, often known as a tropical hinterland climate; locally, the high plateau climate is used to describe the climate in Yola. The climate conforms to Koppen's categorization system. Moderate temperatures are present. The average temperature is 30.5 C. During some months, especially those that fall within the dry season, the temperature ranges from roughly 27.0°C to 42.8°C. Yola experiences about 2954 mean sunlight hours annually. The yearly rainfall ranges from 450 to 1500 mm, and the relative humidity is modest. Every year, the wet seasons last for around six months. Thick vegetation grows on the windward sides, whereas sparse small trees and tiny grasses grow on the leeward sides [14]. Yola has 336648 residents [15] and farmers make up the majority of this population

Fig. 1. Map of the study area

Source: https//www.weather – forcast.com 2015

2.1.2 Data collection

The materials used for this research work are the data on maximum and minimum monthly temperature and rainfall. These data were obtained from the archive of Nigerian Meteorological

2.1.3 Mann-Kendall Test

The Mann-Kendall test is a non-parametric test for identifying trends in time series data. The test compares the relative magnitudes of sample data rather than the data values themselves [16]. One benefit of this test is that the data need not conform to any particular distribution. Moreover, data reported as non-detects can be included by assigning them a common value that is smaller than the smallest measured value in the data set. The procedure that will be described in the subsequent paragraphs assumes that there exists only one data value per time period. When multiple data points exist for a single time period, the median value is used. The non-parametric Mann-Kendall test is commonly employed to detect monotonic trends in series of environmental data, climate data. Mann Kendall test is a statistical test widely used for the analysis of trend in climatology time series. There are two advantages of using this test. First, it is a nonparametric test and does not require the data to be normally distributed. Second, the test has low sensitivity to abrupt breaks due to inhomogeneous time series. The data values are evaluated as an ordered time series. Each data value is compared to all subsequent data value

To measure the significance of trends in meteorological time series, the Mann-Kendall statistical test has been widely used [17] and other studies have tested for trends in rainfall using the conventional Mann Kendall. In this work, mean temperature (minimum and maximum) and annual rainfall time series data during the 11-years study period were subjected to the Mann-Kendal test for trend analysis. $S = \sum_{i=1}^{n-1} \sum_{j=1+i}^{n} sign(x_{j-} x_i)$

Sign (xj - xi) is the sign function, and n denotes the number of data points. xi and xj are the values of the data in the time series i and j, respectively.

The variance is calculated by;

$$Var(s) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{p} t_i(t_i-1)(2t_i+5)}{18}$$

$$Zs = \begin{cases} \frac{S-1}{\sqrt{var(S)}}, for\ S > 0 \\ 0,\ for\ S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, for\ S < 0 \end{cases}$$

Where P is the number of linked groups, t_i denotes the number of data values in the Path group, and n denotes the number of data points. The summation sign (Σ) denotes the summing over all tied groups. Positive Zs values show an increase while negative Zs values show a decrease in trend patterns. Trends are tested with a 5% degree of confidence [18].

3. RESULTS

3.1 Maximim Temperature

Table 1 Monthly mean of maximum temperature (^{O}C) between 2008 and 2018

The following is the summary statistics of Maximum Temperature

The maximum temperature was decreasing though the decrease was not significant because the computed PValue of 0.528 is greater than the confidence level of 0.05.

Table 1. Monthly mean of Maximum temperature (^{O}C) between 2008 and 2018

Months	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Jan	35.2	36.8	36.5	33.5	33.5	36.2	36.1	33.6	33.5	35.9	33.4
Feb	38.0	38.8	39.7	38.7	38.4	39.0	37.6	39.0	31.5	36.4	31.2
Mar	38.9	40.0	40.7	41.2	39.9	41.9	39.8	39.9	40.7	41.1	40.2
Apr	39.8	38.5	42.3	40.9	40.6	40.2	39.2	40.2	41.7	39.6	40.1
May	36.8	35.7	37.3	36.9	35.8	37.9	35.6	39.4	36.6	35.9	35.4
Jun	34.0	33.6	33.5	34.8	32.8	34.7	33.4	35.1	33.7	33.1	33.6
Jul	32.4	32.6	31.4	32.4	30.8	31.5	31.7	33.3	32.1	35.5	32.5
Aug	31.1	31.5	30.9	31.4	30.4	30.8	30.0	31.8	31.5	31.2	31.8
Sep	31.5	31.7	31.1	30.6	31.3	31.5	31.5	30.9	32.0	31.9	31.5
Oct	33.2	33.0	32.6	33.5	33.2	34.1	34.0	33.7	35.0	35.1	35.1
Nov	37.3	35.3	36.3	35.2	37.0	37.8	36.8	36.4	38.1	37.3	36.9
Dec	36.2	36.0	35.5	34.5	35.8	36.1	35.4	34.8	35.8	35.8	33.9

Agency (NiMet)

Table 2. Summary statistics of maximum temperature

Variable	Observations	Obs. with missing data	Obs. Without missing data	Minimum	Maximum	Mean	Std. deviation
Max Temp	11	0	11	34.600	36.000	35.364	1.369

Mann-Kendall trend test / Two-tailed test (MAX TEMP)

Kendall's tau	-0.170
S	-9
Var(S)	160.333
p-value (Two-tailed)	0.528
alpha	0.05

An approximation has been used to compute the p-value

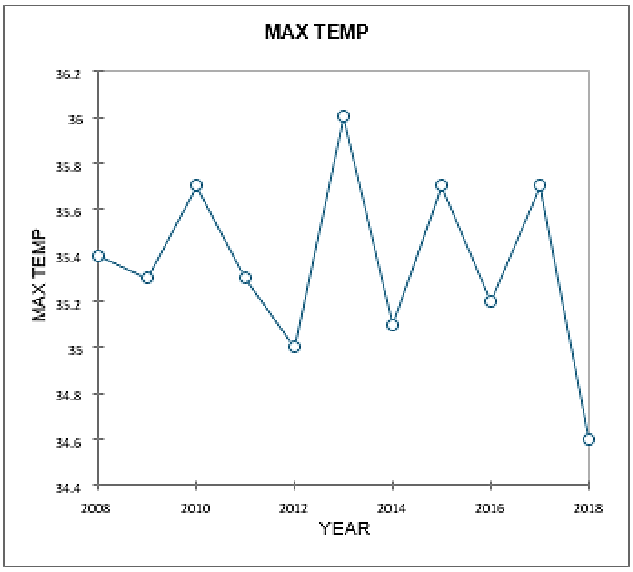

Fig. 2. Graphical illustration of maximum temperature variation

3.2 Minimum Temperature

Table 3. Monthly Means of Minimum Temperature (^OC) between 2008 and 2018

Months	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Jan	19.6	19.3	19.5	19.6	18.2	18.0	17.3	17.7	19.8	18.9	18.5
Feb	23.5	22.8	23.2	23.3	21.7	22.7	23.4	23.1	21.9	21.8	24.2
Mar	24.4	25.2	25.3	25.0	25.0	26.1	24.5	24.8	26.9	26.4	26.9
Apr	30.5	28.6	29.0	29.5	27.4	28.0	27.6	20.5	28.7	27.8	28.8
May	29.1	28.4	28.2	29.0	26.1	27.0	25.7	25.7	26.8	26.2	25.7
Jun	23.3	25.0	23.8	24.4	24.5	24.6	25.1	23.7	25.7	25.1	24.3
Jul	25.1	24.5	24.2	24.0	23.9	23.9	24.2	23.0	24.1	24.5	24.0
Aug	24.7	23.8	24.0	23.8	23.4	23.6	23.9	23.3	24.2	23.8	24.1
Sep	22.9	23.2	23.8	23.6	23.8	23.1	23.4	23.1	23.7	23.7	23.9
Oct	18.0	19.6	20.0	21.6	24.0	24.0	24.2	23.9	24.4	23.9	24.8
Nov	23.8	20.2	20.0	19.4	21.9	21.9	17.7	21.8	21.7	22.5	21.6
Dec	19.5	19.4	19.2	19.2	17.0	17.1	17.3	18.1	20.6	21.5	21.5

The following is the summary statistics of minimum temperature.

The minimum temperature increased in the area though the increase was not significant because the computed PValue of 0.073 is greater than the confidence level of 0.05.

Table 4. Summary statistics of minimum temperature

Variable	Observations	Obs. with missing data	Obs. Without missing data	Minimum	Maximum	Mean	Std. deviation
Min Temp	11	0	11	22.400	25.000	23.491	1.667

Mann-Kendall trend test / Two-tailed test (MIN TEMP)

Kendall's tau	0.073
S	4
Var(S)	164.000
p-value (Two-tailed)	0.815
alpha	0.05

An approximation has been used to compute the p-value.

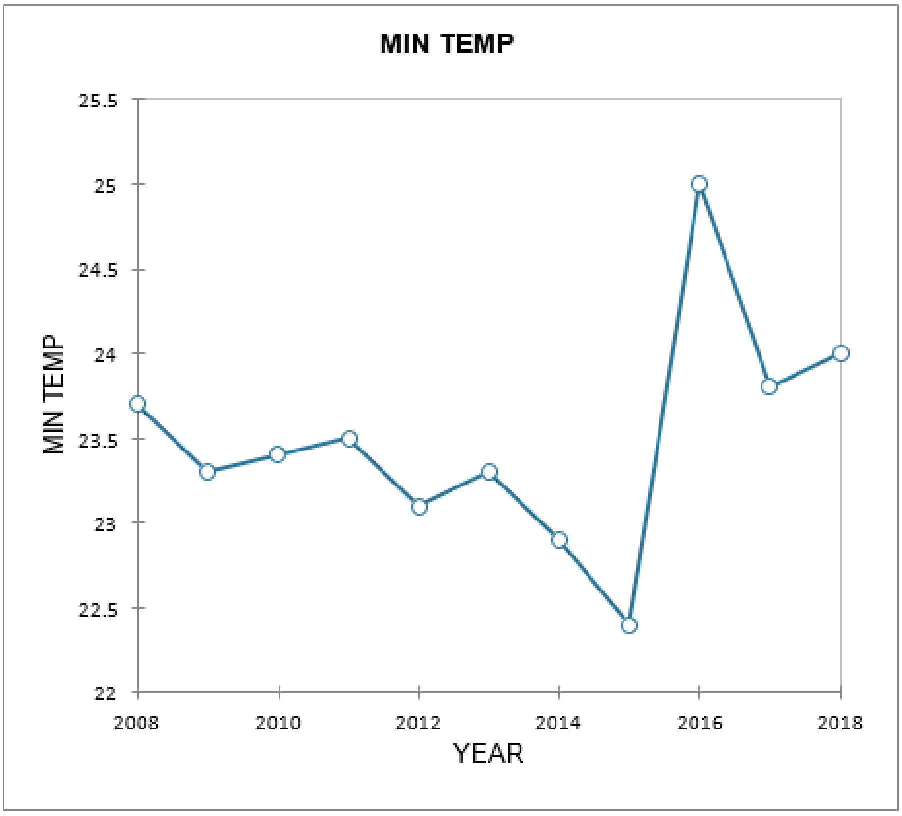

Fig. 3. Graphical illustration of minimum temperature variation

3.3 Analysis of Rainfall

Table 5. Monthly Values of Rainfall (mm) between 2008 and 2018

Months	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Jan	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
Feb	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
Mar	00.0	00.0	00.0	00.0	00.0	17.1	2.7	00.0	00.0	00.0	TR
Apr	26.8	43.9	34.9	2.5	12.0	TR	57.2	19.5	46.2	71.2	3.6
May	32.3	63.9	50.7	58.8	108	61.0	66.5	28.2	226.3	170.2	104.5
Jun	84.0	148.8	193.7	29.9	213.4	142.4	134.3	50.9	256.1	145.5	178.4
Jul	41.1	122.2	176.0	75.7	157.1	93.8	148.1	115.6	113.8	215.6	233.8
Aug	89.2	183.3	135.6	134.1	162.8	120.0	162.4	203.2	208.6	161.3	144.8
Sep	148.5	122.3	162.4	210.0	189.5	178.7	156.9	216.4	198.7	145.9	236.1
Oct	46.6	33.7	104	55.9	67.2	40.9	75.9	57.4	30.2	00.0	38.5
Nov	00.0	00.0	00.0	00.0	TR	00.0	00.0	00.0	00.0	00.0	00.0
Dec	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
Total	**468.5**	**718.1**	**857.3**	**566.9**	**910**	**653.9**	**804**	**691.2**	**1079.9**	**909.7**	**939.7**

TR = Traceable Rainfall Not Measurable

3.3.1 Summary statictics of rainfall

The following is the summary statistics of Rainfall.

The rainfall increased in the area because the computed P value of 0.043 is less than the confidence level of 0.05.

Table 6. Summary statictics of rainfall

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Rainfall	11	0	11	468.500	1079.900	781.745	180.484

Mann-Kendall trend test / Two-tailed test (Rainfall)

Kendall's tau	0.491
S	27
Var(S)	165.000
p-value (Two-tailed)	0.043
alpha	0.05

An approximation has been used to compute the p-value.

Table 7. Annual Value of Rainfall, Mean Maximum Temperature and Mean Minimum Temperature

Year	Annual Rainfall (mm)	Mean Annual Maximum Temp (^{O}C)	Mean Annual Minimum Temp (^{O}C)
2008	468.5	35.4	23.7
2009	718.1	35.3	23.3
2010	857.3	35.7	23.4
2011	566.9	35.3	23.5
2012	910.0	35.0	23.1
2013	653.9	36.0	23.3
2014	804.0	35.1	22.9
2015	691.2	35.7	22.4
2016	1079.9	35.2	25.0
2017	909.7	35.7	23.8
2018	939.7	34.6	24.0

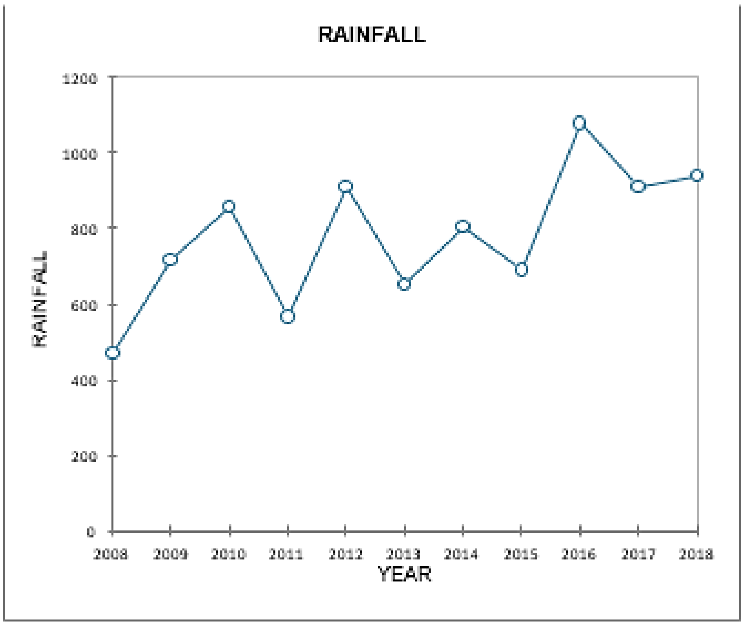

Fig. 4. Graphical illustration of Rainfall Variation

4. DISCUSSION

Minimum and maximum temperature variation did not show any significant increase or decrease but maintained the high level that is prevalent in the area. High temperature was observed from January to April which is the period of dry season. The highest maximum temperature occurred during the month of April (2010) with 42.3°C as in Table 1, also the highest minimum temperature occurred in the same month of April (2008) with 30.5°C as in Table 2. This is because since April is a transition month (change from dry season to wet season), the high temperature give room to high evaporation leading to the beginning of rainy season and at the onset of rainy season, temperature begins to drop till it reaches the least degree.

Low temperature was observed from May to September which is the period of rainy season and there is an increase in temperature between October and November, as raining season begins to give way to dry season. However, temperature drops between December and January of the following year due to onset of harmattan. The least maximum temperature occurs in the months of August. This is due to high rainfall and thick cloud covering the sun thereby reducing the amount of radiation heating the ground and this leaves high moisture in the atmosphere therefore low temperature is observed in this period. The least minimum temperature observed in the month of December and January of the following year is quite different from the least maximum temperature observed during the raining season. This is due to the cold hammattan that prevails between December and January.

In establishing the relationship between rainfall and temperature variation from the data above, it is observed that there is no significant relationship between rainfall and maximum temperatures, but between rainfall and minimum temperature, this is a relationship because in 2016 when the highest amount of rainfall of 1079.9mm was recorded and that also was when highest minimum temperature of 25.0°C was recorded, this means that the warmest year has the highest amount of rainfall; The same scenario happened in 2018 when the second highest amount of rainfall amount of 939.7mm occurred, that year also the second highest minimum temperature of 24.0°C occurred within the period of research (2008 to 2018). This can be seen in Table 7.

5. CONCLUSION

The temporal trend, characteristics and variability of rainfall and temperature over Yola metropolis has been investigated in this research using eleven years period data. Significant variations, trends in rainfall and temperature for every year during the eleven-year period were found. It was concluded that both maximum and minimum temperature did not continue to increase non remain constant or decrease but varied with time but however, there is a net increase in the amount of annual rainfall within the period despite the variation in the amount of annual rainfall. There is also no significant change in the period of onset and cessation of rainfall within the period of the study, in this regard famers in this region are advised to maintain their normal period of farming activities i.e., their planting, and harvesting period.

6. RECOMMENDATIONS

In light of the above results, the following recommendations are proposed:

1. Due to the high temperature prevalent in Yola, the government should continue to encourage people to build houses that allow good ventilation.

2. The government has to educate the inhabitants of Yola about the importance of maintaining clean water drainage systems and avoiding constructing structures near waterways in order to prevent flooding.

3. Farmers should avoid farming on water ways to avoid destruction of farm produce during rainy season.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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