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Climate Change, Trend Analysis of Temperature in Yola, North East Nigeria

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ABSTRACT

Climate change is causing temperature and rainfall patterns to change in most parts of the globe. Consequently, a trend analysis of temperature in Yola, North East Nigeria, between 1975 and 2018 was carried out using the Mann-Kendall trend test to determine the trend of temperature in the region and hence determine the impact of climate change in the region. The data on temperature was obtained from the archive of the Nigerian Meteorological Agency (NiMet). The Mann Kendall's statistics of maximum temperature showed that the highest maximum temperature recorded within the period is 38.7˚C while the lowest maximum temperature is 33.3˚C, the test also showed a Kendall's tau value of -0.392 with a P value of 0.000 indicating that maximum temperature is decreasing while the Mann Kendall's statistics on minimum temperature showed that the highest minimum temperature recorded within the period was 24.0˚C while the lowest minimum temperature recorded is 21.4˚C. The results revealed that climate change is not very pronounced in the region as the maximum temperature is decreasing while the minimum temperature is increasing in the region. This result implies that the region is becoming warmer and is likely to experience an increase in rainfall. It is therefore recommended that residences build houses that allow for good ventilation to minimise heat stress, and residences should not build or farm on waterways to avoid flooding and destruction of houses and farm produce during the rainy season.

Keywords:
Climate Change,
Temperature,
Yola,
Flooding,
Rainfall.

INTRODUCTION

Climate is commonly defined as the synthesis of weather averaged over a long period. It is the statistically appreciable variations of weather parameters that stay for a long period, which could be decades or longer. Although the normal averaging time for climate data is 30 years, the purposes for which it is used vary (World Meteorological Organisation (WMO), 2017). One of the biggest challenges to the environment, society, and economy that our world is currently experiencing is climate change, which is the result of the abnormality of climate parameters (Chomitz et al., 2006). Changes in Earth's environment, such as adjustments to its orbit around the sun or human-caused atmospheric modification, are the cause of climate change. This is the frequency and magnitude shift of sporadic weather events as well as the slow constant increase in the mean surface temperature worldwide. Climate change has nothing intrinsically wrong with it. It will happen once more as it has in the past. The present source of concern is the rate of change, or how quickly things are changing faster than humans can adjust. The Intergovernmental Panel on Climate Change (IPCC, 2001) defines climate change as any alteration in the global temperature over time, whether as a result of human activity or natural variability. The main cause of concern for the world today is human activity-induced climate change, particularly the atmospheric production of greenhouse gases like carbon dioxide. The two main causes of greenhouse gas emissions are the combustion of fossil fuels and the deforestation of forests. There is no denying that the climate system is warming, and the rate of change is quickening, according to scientific data. Researchers have discovered that the present pace of temperature increase is higher than any previously seen in the last 800,000 years (Medori et al., 2012). The most meteorological variables used in climatic trend studies are rainfall and temperature. A trend is a long-term change (increase or decrease) in a time series. A trend analysis is ordinarily used in climatology to know how the temperature for example, changes with time. It is also useful in predicting the future behaviour of climate parameters. In Africa temperature and precipitation are the two most studied parameters in terms of past, present and future trend because of the economy that is

based mainly on agriculture (O'Loughlin et al., 2014). Knowing and controlling the two parameters is very important to maximise the agricultural production. Regional temperature and rainfall over the West Africa region have changed with the time and this has caused damages to the ecosystems and the interrelationships between them (IPCC, 2014)

The trend of the climate variable has always fluctuated throughout time and space, never being constant. Variations in the climate variable's frequency and pattern have a major effect on both human and natural system. Certain extreme weather occurrences, such floods, droughts, and increases in heat stress, as well as dry and wet spells, plant pests, and diseases, may be brought on by these changes. The IPCC (2007) reports that between 1906 and 2005, global temperatures near the earth's surface rose by 0.74°C, and over the 21st century, those temperatures are expected to rise by an average of 6.4°C. Over the course of the 20th century, the average temperature on the African continent increased by 0.7ºC, with a rising rate of 0.05^0C every decade (IPCC, 2007). Similar to this, many parts of Nigeria are now warmer than they were thirty years ago. In Adamawa State, for instance, there is evidence of climate change in the form of a delayed start date for rainy season rains, an increase in the number of dry days, and a rise in maximum temperature (Adebayo, 2010). Increased surface air temperatures, more heat waves that fuel disease vectors and infectious disease epidemics, rising sea levels and related coastal erosion, flooding, salt water intrusion, and mangrove degradation, increased evaporation that causes streams and rivers to dry up, a decline in forest vegetation that encourages soil degradation and desertification, and variations in seasonal patterns of climatic variables that result in decreased agricultural productivity are all signs of climate variability and change in the nation. Worldwide, meteorological time series patterns can be identified using the Mann–Kendall test (MK). The objectives of the study are to detect the presence of significant monotonic increasing and decreasing trends in temperature, and determine the magnitude of trends and variability in temperature series.

MATERIALS AND METHODS

Materials

The Study Area

Yola is a city in Adamawa state, in north eastern Nigeria, in latitude 09°14'North and longitude 12°28'East. Taraba State, Gombe State, Borno State, and an international border with the Cameroon Republic border Adamawa State to the south and west, the north and northwest, and the eastern side (Fig. 1). Tropical dry and wet weather prevails there. Yola has two distinct seasons, the wet season (April to October), and the dry season (November-March). This happens as a result of two main air masses that affect the region's weather and environment. The rain bearing south western wind that originates from the Atlantic Ocean and dry north eastern air masses (Harmattan) from the Sahara Desert.

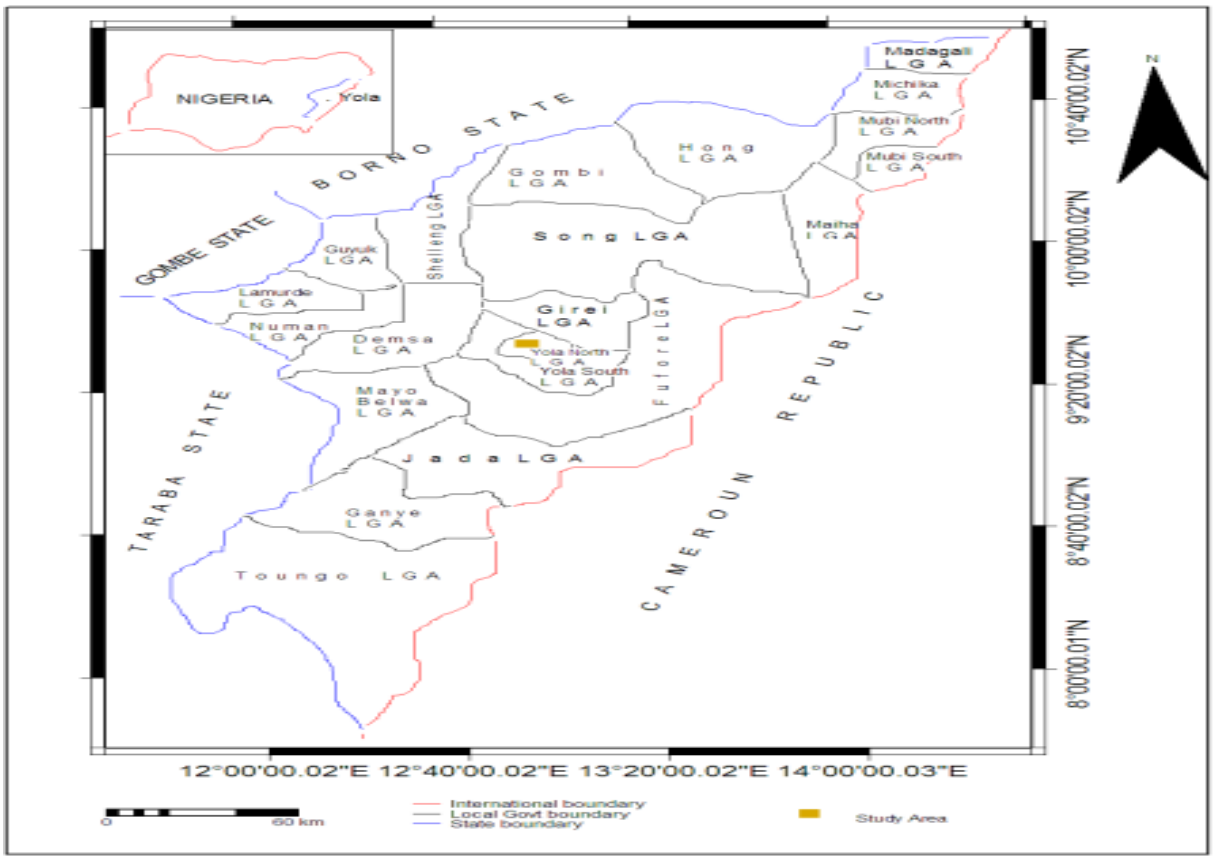

Figure 1: The Map of the Study area

Data Collection

Monthly mean maximum and minimum temperature data for a period of 44 years were collected from the Nigerian Meteorological Agency (NiMet), Yola, Adamawa State. The data used spans between the periods of 1975 to 2018.

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 itself. 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 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 or hydrological data. Mann Kendall test is a statistical test widely used for the analysis of trend in climatology and in hydrologic time series. In this work, annual mean maximum and minimum temperature time series data during the 44-years study period were subjected to the Mann-Kendal test and Theil-Sen estimator for trend analysis.

$$S = \sum_{i=1}^{n-1} \sum_{j=1+i}^{n} sign(x_j - x_i) \quad (1)$$

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. Mathematically,

$$sign(x_j - x_i) = \begin{cases} +1 \; for \; x_i - x_j > 0 \\ 0 \; for \; x_i - x_j = 0 \\ -1 \; for \; x_i - x_j < 0 \end{cases}$$

The variance is calculated by;

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

$$Zs = \{\frac{s-1}{\sqrt{var(S)}}, for \; S > 0 \; 0, for \; S = 0 \; \frac{s+1}{\sqrt{Var(S)}}, for \; S < 0 \quad (3)$$

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. (Yue & Wang, 2002 Mondal, Kundu & Mukhopadhyay, 2012; Yadav *et al.*, 2014)

RESULTS AND DISCUSSION

Maximum Temperature

Table1: Monthly mean maximum temperature (ºC) between 1975 and 2018

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	AVER
1975	37.3	41.0	41.9	34.6	39.5	32.4	34.7	32.6	40.2	38.5	34.0	31.7	36.5
1976	34.6	37.4	38.6	41.5	37.0	34.7	33.5	31.3	37.3	34.6	32.6	36.8	35.8
1977	38.5	38.0	41.2	38.7	39.2	34.9	35.6	33.2	35.8	37.8	36.5	35.8	37.1
1978	40.3	37.5	37.4	39.5	37.6	37.2	37.7	35.6	34.6	35.5	39.4	37.3	37.5
1979	36.6	38.4	40.7	37.8	34.8	32.9	33.6	31.8	36.8	33.7	36.7	36.2	35.8
1980	33.8	33.5	42.7	42.3	33.0	33.7	36.8	31.5	32.7	36.2	36.6	34.1	35.6
1981	34.2	35.2	30.0	41.0	38.7	31.4	34.3	34.8	37.4	37.6	33.9	38.4	33.3
1982	36.0	38.7	37.0	35.2	36.5	34.6	37.5	38.1	32.3	34.5	37.0	35.4	36.1
1983	38.0	40.3	36.8	35.9	41.7	37.2	32.4	32.7	34.6	36.4	38.0	32.6	36.4
1984	36.8	36.6	38.1	39.2	39.3	35.0	33.8	33.3	41.6	38.2	36.8	36.9	37.1
1985	32.7	36.4	41.1	40.4	36.6	32.8	37.4	34.5	37.9	34.8	38.4	39.5	36.9
1986	34.2	39.3	39.9	40.1	41.0	33.5	33.6	30.7	31.0	37.3	39.8	35.0	36.3
1987	35.1	38.2	37.9	40.5	42.1	38.8	35.4	34.0	32.7	33.9	36.9	37.7	36.9
1988	38.2	38.0	42.0	39.1	37.7	36.8	33.7	34.2	33.0	35.7	38.5	37.1	37.0
1989	41.5	40.7	41.3	39.9	39.0	38.1	39.4	40.2	36.8	32.1	38.0	37.2	38.7
1990	36.6	37.1	39.9	40.2	41.7	38.0	34.7	33.9	31.0	35.7	37.8	31.5	36.5
1991	34.2	38.6	39.0	41.7	38.0	32.8	32.1	31.5	35.1	35.0	37.9	30.0	35.5
1992	37.3	36.4	39.3	41.0	37.2	37.2	33.9	30.9	31.4	32.6	35.1	38.0	35.9
1993	31.9	37.6	37.8	40.2	35.7	32.0	32.9	30.7	30.5	35.0	36.9	31.8	34.4
1994	36.6	35.3	37.9	38.7	39.4	40.5	34.6	31.0	31.0	37.6	39.1	37.0	36.6
1995	38.4	41.7	39.0	39.2	38.9	40.0	37.1	31.3	33.7	36.5	30.5	35.9	36.9
1996	34.7	38.0	41.3	37.0	34.2	31.7	30.5	36.0	32.9	31.4	38.7	33.6	35.0
1997	35.0	38.2	41.9	41.9	37.2	36.6	33.6	31.4	31.2	32.1	36.4	35.5	35.9
1998	33.5	37.8	39.7	41.5	36.5	33.4	34.1	30.4	31.7	33.7	37.0	36.2	35.5
1999	33.9	38.0	41.2	40.9	37.0	34.9	32.5	30.8	30.6	34.1	37.8	36.1	35.7
2000	36.1	36.2	39.0	39.5	35.1	34.2	31.7	30.0	31.5	34.0	38.2	35.0	35.0
2001	33.6	39.0	39.9	40.2	38.7	36.7	34.7	31.8	30.9	34.5	36.4	34.5	35.9
2002	33.5	37.5	40.7	41.7	37.4	33.7	32.1	31.5	32.0	35.0	38.1	35.8	35.8
2003	36.2	36.8	37.8	41.0	37.2	35.3	30.4	29.8	34.1	36.0	37.7	34.6	35.6
2004	35.5	38.0	37.0	40.7	36.0	36.7	32.9	29.2	30.5	34.5	36.9	33.9	35.2
2005	38.0	39.4	36.8	39.2	35.6	35.9	31.2	30.7	31.0	35.2	38.0	34.1	35.4
2006	34.6	37.6	38.1	39.2	35.1	35.0	35.3	30.0	31.2	33.7	37.4	34.7	35.2
2007	35.9	36.4	41.1	39.6	35.9	33.1	35.5	31.2	31.9	35.1	37.3	35.8	35.7
2008	35.2	38.0	38.9	39.8	36.8	34.0	32.4	31.1	31.5	33.2	37.3	36.2	35.4
2009	36.8	38.8	40.0	38.5	35.7	33.6	32.6	31.5	31.7	33.0	35.3	36.0	35.3
2010	36.5	39.7	40.7	42.3	37.3	33.5	31.4	30.9	31.1	32.6	36.3	35.5	35.7
2011	33.5	38.7	41.2	40.9	36.9	34.8	32.4	31.4	30.6	33.5	35.2	34.5	35.3
2012	33.5	38.4	39.9	40.6	35.8	32.8	30.8	30.4	31.3	33.2	37.0	35.8	35.0
2013	36.2	39.0	41.9	40.2	37.9	34.7	31.5	30.8	31.5	34.1	37.8	36.1	36.0
2014	36.1	37.6	39.8	39.2	35.6	33.4	31.7	30.0	31.5	34.0	36.8	35.4	35.1
2015	33.6	39.0	39.9	40.2	39.4	35.1	33.3	31.8	30.9	33.7	36.4	34.8	35.7
2016	33.5	31.5	40.7	41.7	36.6	33.7	32.1	31.5	32.0	35.0	38.1	35.8	35.2
2017	35.9	36.4	41.1	39.6	35.9	33.1	35.5	31.2	31.9	35.1	37.3	35.8	35.7
2018	33.4	31.2	40.2	40.1	35.4	33.6	32.5	31.8	31.5	35.1	36.9	33.9	34.6

The summary statistics of the test show that maximum temperature is decreasing within the area because Kendall's tau value is - 0.392 while the computed P- value of 0.000 is less than the confidence level of 0.05.

Table 2: Summary statistics of Maximum Temperature

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Max Temp	44	0	44	33.300	38.700	35.85	0.918

Mann-Kendall trend test / Two-tailed test (Max Temp)

Kendall's tau	-0.392
S	-365
Var(S)	9734.333
p-value (Two-tailed)	**0.000**
alpha	0.05

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

Sen's slope

	Value	Lower bound (95%)	Upper bound (95%)
Slope	-0.033	-0.050	-0.017
Intercept	102.350	85.733	119.058

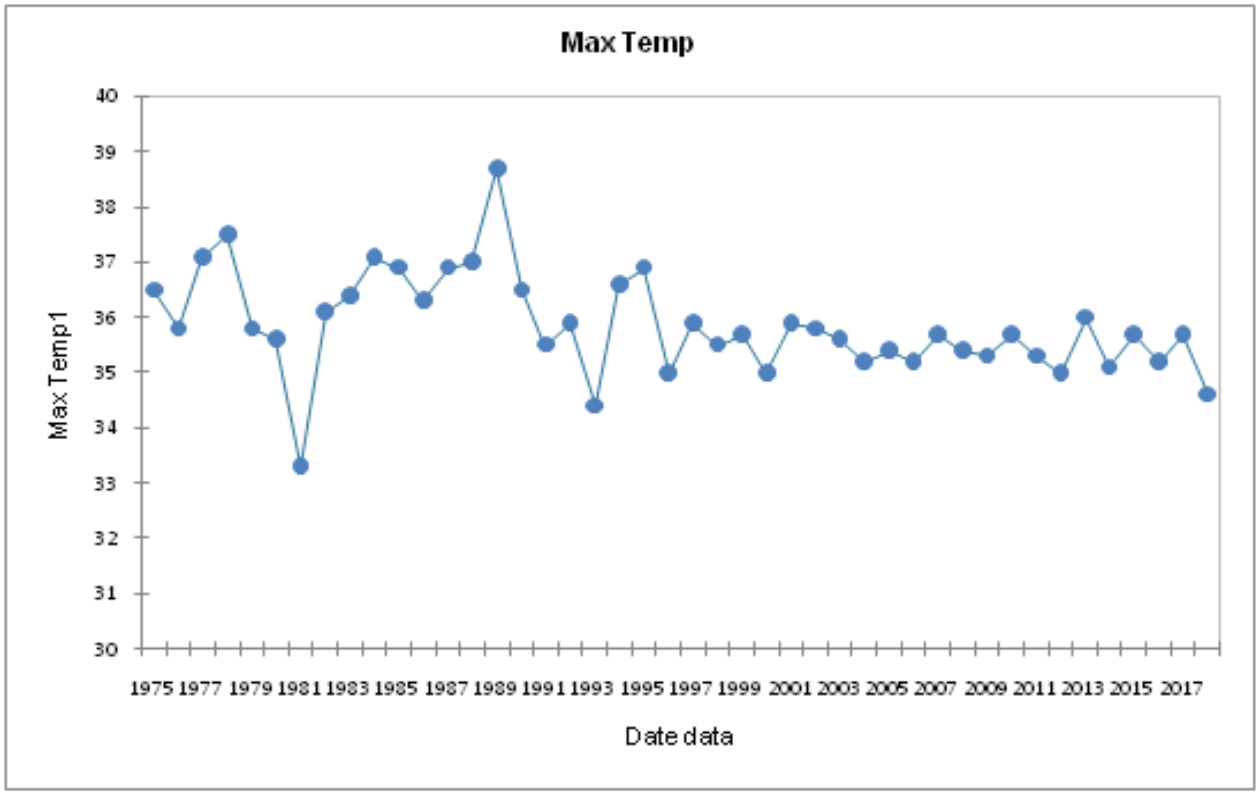

Figure 2: Time plot of monthly maximum temperature series of Yola

Minimum Temperature

Table 3: Monthly mean minimum temperature (°C) between 1975 and 2018

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV.	DEC.	AVE.
1975	19.6	19.0	24.7	22.5	28.4	27.6	24.6	23.0	26.7	28.5	24.4	18.6	24.0
1976	18.7	20.4	22.4	27.8	26.8	24.5	22,5	24.5	21.3	26.2	21.9	17.4	22.9
1977	20.5	21.6	24.6	25.4	22.1	26.4	26.7	25.6	20.4	27.3	26.4	18.5	23.9
1978	17.0	17.8	24.2	26.2	27.4	19.6	27.4	23.2	18.9	28.7	22.5	10.7	22.0
1979	21.8	18.5	26.3	28.7	27.9	21.3	25,8	20.4	18.4	24.6	21.1	19.4	22.6
1980	18,8	22.1	19.0	24.6	26.6	26.6	19.9	22.7	23.8	25.3	19.6	22.9	23.0
1981	17.5	19.4	22.5	26.4	23.4	25.4	18.3	24.6	24.7	21.6	21.7	21.7	22.3
1982	21.6	21.4	24.6	27.8	26.5	27.7	20.5	21.5	22.2	23.8	19.5	20.4	23.1
1983	18.4	20.6	24.9	23.5	28.2	20.4	18.4	26.8	25.4	20.0	24.3	18.3	22.4
1984	19.8	23.8	26.0	25.7	30.4	18.0	17.8	24.4	27.0	24.7	28.4	21.5	24.0
1985	16.7	24.4	24.7	24.0	28.0	27.3	18.0	22.8	24.4	22.6	24.7	22.9	23.4
1986	21.3	21.0	24.7	21.6	23.0	24.6	24.5	19.7	18.4	20.0	20.9	18.7	21.4
1987	21.4	23.8	24.6	26.8	25.6	24.0	21.6	23.2	23.0	25.8	21.4	17.0	23.2
1988	16.5	19.9	21.6	26.1	26.6	23.8	19.0	20.7	22.9	21.8	20.9	19.2	21.6
1989	18.7	23.8	22.4	23.7	22.5	23.7	23.6	24.1	26.0	24.3	18.0	18.4	22.4
1990	20.4	17.2	18.7	23.8	24.6	24.5	26.2	22.7	21.5	25.4	20.1	16.8	21.8
1991	19.3	18.6	21.8	26.2	27.5	24.7	26.3	27.5	25.1	21.7	20.8	18.3	23.2
1992	16.5	22.7	23.7	27.1	28.0	24.6	26.7	22.8	23.8	25.2	23.5	21.7	23.9
1993	19.4	19.9	24.2	28.2	27.1	26.7	26.5	22.4	23.9	17.0	20.1	18.5	22.8
1994	17.0	21.0	21.5	27.5	28.2	24.6	27.8	24.7	23.8	16.9	24.6	21.3	23.2
1995	21.4	20.6	24.5	22.0	22.8	21.8	19.6	21.3	20.4	20.7	19.8	21.5	21.4
1996	17.6	19.0	23.9	28.6	29.1	26.7	25.8	23.8	21.9	20.4	20.2	17.8	22.9
1997	16,9	21.2	26	25.0	26.0	24.0	23.4	22.9	22.6	22.9	17.0	16.2	22.0
1998	18.2	21.0	25.3	24.8	26.7	25.0	23.6	23.0	23.5	24.0	20.9	16.9	22.7
1999	18.0	22.3	24.6	28.1	27.1	25.0	23.9	23.2	23.5	24.0	20.1	18.0	23.2
2000	18.3	22.7	26.0	28.0	26.6	24.9	24.0	23.5	22.9	23.8	20.4	17.0	22.3
2001	19.1	21.0	24.2	28.0	26.2	23.7	24.0	23.1	23.6	23.6	19.0	16.5	22.7
2002	18.1	21.7	25.0	27.4	26.1	24.5	23.9	23.4	23.8	24.0	21.9	17.0	23.1
2003	18.5	21.0	26.4	28.4	27.5	25.4	24.2	23.7	23.7	23.9	20.1	17.6	23.4
2004	17.5	22.0	25.3	28.4	28.0	24.4	24.2	23.8	23.8	24.5	21.7	17.4	21.4
2005	18.8	21.4	25.3	29.0	26.5	24.0	24.1	23.4	23.9	19.0	22.6	18.5	23.0
2006	19.6	23.5	24.4	30.5	29.1	23.3	25.1	24.7	23.9	18.0	23.8	19.5	23.8
2007	19.3	22.8	25.2	28.6	28.4	25.0	24.5	23.8	23.2	19.6	20.2	19.4	23.3
2008	19.6	23.5	24.4	30.5	29.1	23.3	25.1	24.7	22.9	18.0	23.8	19.5	23.7
2009	19.3	22.8	25.2	28.6	28.4	25.0	24.5	23.8	23.2	19.6	20.2	19.4	23.3
2010	19.5	23.2	25.3	29.0	28.2	23.8	24.2	24.0	23.8	20.0	20	19.2	21.5
2011	19.6	23.3	25.0	29.5	29.0	24.4	24.0	23.8	23.6	21.6	19.4	19.2	23.5
2012	18.2	21.7	25.0	27.4	26.1	24.5	23.9	23.4	23.8	24.0	21.9	17.0	23.1
2013	18.0	22.7	26.1	28.0	27.0	24.6	23.9	23.6	23.1	24.0	21.9	17.1	23.3
2014	17.3	23.4	24.5	27.6	25.7	25.1	24.2	23.9	23.4	24.2	17.7	17.3	22.9
2015	17.7	23.1	24.8	20.5	25.7	23.7	23.0	23.3	23.1	23.9	21.8	18.1	22.4
2016	19.8	21.9	26.9	28.7	26.8	25.7	24.1	24.2	23.7	24.4	21.7	20.6	24.0
2017	18.9	21.8	26.4	27.8	26.2	25.1	24.5	23.8	23.7	23.9	22.5	21.5	23.8
2018	18.5	24.2	26.9	28.8	25.7	24.3	24.0	24.1	23.9	24.8	21.6	21.5	24.0

The summary statistics show that minimum temperature within the region is increasing because Kendall's tau value is 0.255 while the computed P- value is 0.017 which is less than the confidence level value 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	44	0	44	21.400	24.000	23.023	0.688

Mann-Kendall trend test / Two-tailed test (Min Temp)

Kendall's tau	0.255
S	236
Var(S)	9720.000
p-value (Two-tailed)	**0.017**
alpha	0.05

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

Sen's slope

	Value	Lower bound (95%)	Upper bound (95%)
Slope	0.018	0.003	0.036
Intercept	-13.177	-30.771	1.871

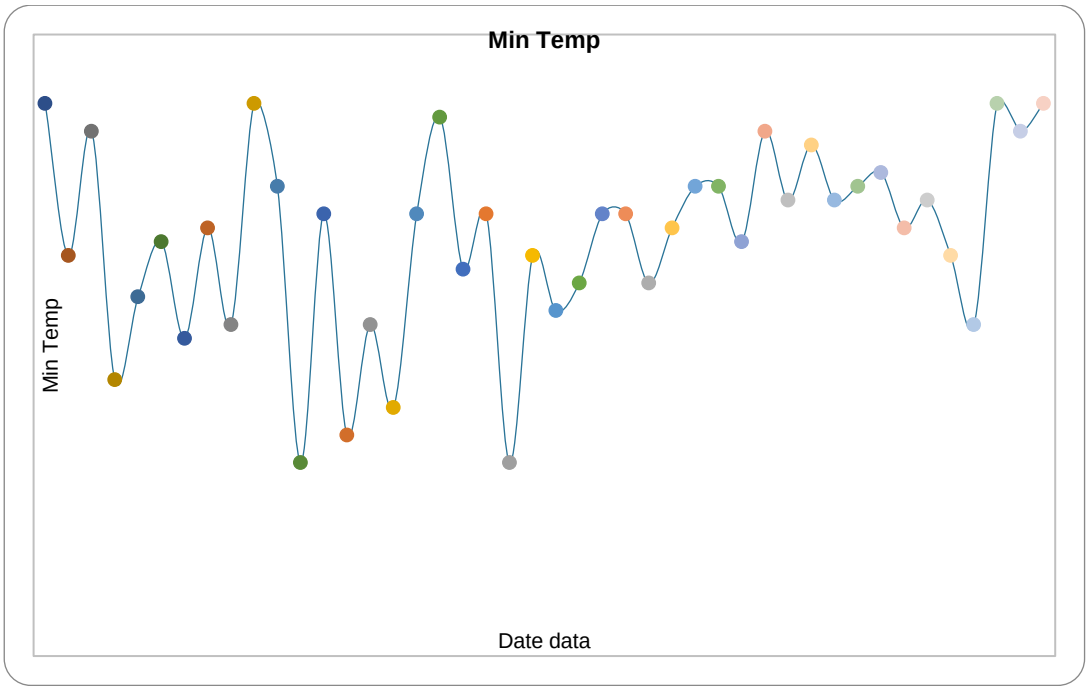

Figure 3: Time plot for monthly minimum temperature series for Yola

Discussion

This study showed that there were variations in temperature between 1975 and 2018. It has been noted that there is temperature variability in the region. Maximum temperature has a decreasing trend while minimum temperature has an increasing trend (Jacob and Iyen, 2024)

Mann Kendall's statistics of maximum temperature showed that the highest maximum temperature recorded within the period is 38.7 ºC while the lowest maximum temperature is 33.3 ºC and the mean maximum temperature of 35.9 ºC with a standard deviation of 0.918 implying that the data on maximum temperature are close to the mean value of 35.9 ºC. The test also showed a Kendall's tau value of -0.392 with a P value of 0.000 indicating that maximum temperature is decreasing, and a Sen's slope value of -0.033, ascertaining the decline. The study showed a different scenario with the minimum temperature. Mann Kendall's statistics on minimum temperature showed that the highest minimum temperature recorded within the period is 24.0 ºC while the lowest minimum temperature recorded is 21.4 ºC with a mean of 23.02 ºC and a standard deviation of 0.688, indicating that the values of minimum temperature are clustered around the minimum temperature of 23.02 ºC. The test showed that Kendall's tau value is 0.255 with a P value of 0.017, which is greater than the confidence level value of 0.05.

This result indicates that there is a significant increase in minimum temperature in the region during the period. The Sen's Slope value of 0.018 also confirms the result. This result indicates that the region is becoming warmer, and it is therefore likely to experience an increase in rainfall.

CONCLUSION

This study examined the temperature trends as an indication of climate change in Yola, Adamawa State, Nigeria. The results showed that the region is becoming warmer as average minimum temperature is on the increase in the region. Therefore, it is recommended that residents should build houses that allow for good ventilation to reduce heat stress while measures should be in place to mitigate likely increase in rainfall in the region.

REFERENCES

Adebayo, A.A. (2010) Climate: Resource and Resistance to Agriculture. Eight inaugural lecture, Federal University of Technology, Yola.

Chomitz, K.M. Buys, P DeLuca, G., Thomas,T. S Wertz-Kanounnikoff, S(2006). ″At Loggerheads? Agricultural expansion, poverty reduction, and theenvironment in the tropics″. (TheWorld Bank, Washington 2006),Book p. 308. ISBN: 9780821367353

Intergovernmental Panel on Climate Change (2014) Climate Change 2014 Mitigation of Climate Change. Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

IPCC (Intergovernmental Panel on Climate Change) (2007) Climate Change Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Assessment Report, Summary for Policymakers.

IPCC TAR (2001). IPCC Third Assessment Report. Climate Change 2001. Working group II: Impacts, Adaptation and Vulnerability. Chapter 1

IPCC, (2014) Summary for policy makers Climate change 2014: Mitigation of climate change. Contribution of working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, NY, USA.

Jacob, A., & Iyen, C. (2024). Evaluation of Temperature and Rainfall Variation in Yola, Adamawa State, Nigeria. *BIONATURE, 44(2), 1–10.* https://doi.org/10.56557/bn/2024/v44i22037

Medori, M, Michlini, L, Nogues, I, Loreto, F, Calfapietra, C, (2012). The impact of root temperature in photosynthsis and isoprene emission in three plants species, Science World Journal. 2012.

Mondal, A., Kundu, S., & Mukhopadhyay, A. (2012). Rainfall trend analysis by Mann-Kendall test: A case study of north-eastern part of Cuttack district, Orissa. *International Journal of Geology, Earth and Environmental Sciences*, *2*(1), 70-78.

O'Loughlin, J., Linke, A.M. and Witmer, F.D.W. (2014) Effects of Temperature and Precipitation Variability on the Risk of Violence in Sub-Saharan Africa, 1980-2012. Proceedings of the National Academy of Sciences of the United States of America, 111, 16712-16717. https://doi.org/10.1073/pnas.1411899111

World Meteorological Organization (WMO) (2017). Guidelines on the calculation of climate normal 2017 edition. WMO -No. 1203.

Yadav, R., Tripathi, S. K., Pranuthi, G., & Dubey, S. K. (2014). Trend analysis by Mann-Kendall test for precipitation and temperature for thirteen districts of Uttarakhand. *Journal of Agrometeorology*, *16*(2), 164-171.

Yue, S., & Wang, C. Y. (2002). Applicability of prewhitening to eliminate the influence of serial correlation on the Mann-Kendall test. *Water resources research*, *38*(6), 4-1.