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DECADAL ANALYSIS AND ESTIMATION OF TEMPERATURE CHANGES IN NORTHERN SENATORIAL ZONE OF KADUNA STATE-NIGERIA

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ABSTRACT
This study examined the decadal analysis and estimation of temperature changes in northern senatorial zone of Kaduna state-Nigeria. Temperature data (minimum and maximum) covering 1967 to 2016 was obtained from the archives of Nigeria Meteorological Agency (NiMet) station Zaria. These data were used to determine the decadal trends and estimate changes in minimum, maximum and average temperatures using trend analysis in Microsoft excel tool (2013) and SPSS 23.0 version. Findings indicate a total increase in average temperature of 1.72°C at the rate of 0.034°C year^{-1}. For the maximum temperature, a total increase of 1.68°C at the rate of 0.033°C year^{-1} and for minimum temperature an increase of 1.72°C the rate of 0.034^{0}C year^{-1}, indicating increased warming in recent years. The result of Cramer's test for the monthly average temperature analysis indicated that the tk values for the last two decades shows an increase in temperature as indicated by their positive with the months of March, April, may, June, July, August, September and October being significantly warmer at 95% confidence level than the long-term condition. The paper concludes that the study area is getting warmer in recent years. The paper recommends that government should come up with policies that will help in managing socio- economic consequences of rising temperature and /or planned interventions to avoid surprises and take right decision in case of unexpected periods of intense heat. Additional functioning synoptic weather stations should be provided to complement the existing one since the study area is becoming hotter in recent years.

Keywords: Decadal, Analysis, Estimation, Temperature changes, Northern Kaduna

INTRODUCTION

Intergovernmental Panel on Climate change [IPCC], (2007) effectively put to rest many of the debates surrounding the science of climate change, rendering evidence solid enough to impel action that the warming of the climate system was "unequivocal" and that a number of attendant effects were already observable. Scientists have high confidence that global temperatures and sea level are rising and will continue to rise throughout 21st century. Instrumental observation over 157 shows that temperatures at the surface have risen globally, with regional variations (Trenberth *et al.,* 2007 and Abaje, 2016). Scientists have also noted that the average temperature of the earth has increased by 0.74 degrees Celsius over the past 100 years. Global average warming in the last century has occurred in two phases, from the 1910s to the 1940s (0.35 ^{0}C), followed by a slight cooling (0.1 ^{0}C), and more strongly from the 1970s up to the end of 2006 (0.55 ^{0}C) (Trenberth *et al.,* 2007). The warmest year in the instrumental record of global surface temperatures are 1998 and 2005. Surface temperatures in 1998 were enhanced by the major 1997- 1998 Elnino but no such strong anomaly was present in 2005 (IPCC, 2007; Trenberth *et al.*, 2007). Evidence shows that global mean temperature increased by 0.6 ^{0}C during the 20th century, with the 6 hottest years occurring between 1997 and 2007 (IPCC, 2007). Global average temperature is predicted to rise by 1.5- 4.5 ^{0}C by the year 2050 if carbon dioxide reaches the predicted level of 600 parts per million (Trenberth *et al.*, 2007; IPCC, 2014). Consequently, the vulnerable populations are already feeling the impacts, irrespective of their level of economic development.

The global increase in temperature is as a result of increase in greenhouse gases (GHGs) due to human activities. These activities result in the emission of four long-lived GHGs. These Carbon dioxide (CO_2,) Methane (CH_4), Nitrous Oxide (N_20) and Halocarbons (IPCC, 2007). The rapid increase in these anthropogenic GHGs, since the great industrial revolution, has resulted in global warming. As a result of global warming, the world is experiencing greater weather extremes changes in rainfall patterns, heat and cold waves and increase in drought and floods. These phenomena have a negative consequence on the environment and on the people's live and livelihood (Abaje, 2016). Thus, if nothing is done, there is going to be more rise in the earth's temperature to the extent that it will be difficult to cope with it as such, there are likely to be more instance and frequent extreme weather events, like floods, hurricanes, and sea levels could rise further followed by extended droughts and powerful tropical storms (Yelwa and Dangulla, 2013).

Several studies on temperature trends have been carried out at different temporal scales and in different parts of the globe. For example, in Nigeria, many studies conducted such as (Obot *et al*. 2010; Odjugo and Ikhuoria, 2003 and Adefolalu, 2007; Ishaya and Abaje 2009; Abaje, 2016; Hazo, 2018; Atiku, 2019) indicated that the temperature increase of about 0.2-0.3 ^{0}C per decade has been observed as a result of global warming which adversely affects the environment and the livelihood assets. The above reviews have pointed the importance of temperature and the need for continuing monitoring of its characteristics from time to time. It is in view of the above that this research aimed at estimating temperature changes in northern senatorial zone of Kaduna state-Nigeria. As a result, the following objectives were set out to: estimate the rate of changes in temperature per year over the study period (1967-2016) and determine the decadal changes in monthly temperature for the area over the study period (1967-2016).

The Study Area

Northern senatorial zone of Kaduna state is located between Latitude 9º 58' N - 11º 30' N of the equator and Longitude 7º 29' E- 8° 35'E of GMT. It is approximately 650km from the Atlantic Ocean. The study area is bounded by Katsina to the north, Kaduna central senatorial zone to the West, southern senatorial zone to the South and Kano State to the East. The study area experiences a typical tropical continental climate classified by Koppen as Aw. It has two distinct wet and dry seasons. The wet seasons begins in May and extend to October with peak in August. The dry season extends from mid- October one calendar to April next year (Abaje, 2010). The spatial distribution of the rain varies, decreasing from an average of about 1733mm in Kafanchan-Kagoro areas in the Southeast to about 1032mm in Ikara, Makarfi districts in the northeast. The highest average air temperature occurs in April (28.9 ^{0}C) and the lowest in December (22.9 ^{0}C) through January (23.1 ^{0}C). The mean atmospheric relative humidity ranges between 70-90% and 25-30% for the rainy and dry seasons respectively. The highest amount of evaporation occurs during the dry season (Abaje, *et al*., 2016). The relief of area is dominated by high plains, popularly known as the high plains of Hausa land which is between 500 – 600 metres above sea level (Udo, 1970). The drainage of the area is dominated by three important rivers. River Saye and Kubanni are major tributaries to river Galma which is a major tributary to river Kaduna (Adamu, 2004). The study area is covered by the tropical grassland vegetation with the density of trees and other plants decreasing as one move northwards (Abaje, 2007). The whole area is covered by the tropical grassland vegetation with the density of trees and other plants decreasing as one move northwards (Abaje, 2007). The dominant species are trees are *Acacia nilotica* (Bagaruwa), *Acacia albida* (Gawo), *Tamarinda indica* (Tsamiya), *Adansonia digitata*/Baobab (Kuka), *Azadirachta indica* /Neem (Tsamiya) and *Eucalyptus spp*.(Turare*), Isoberlina spp*. (Doka) and *Parkia biglobosa (Dorawa).* The study area is covered by the red-brown to red-yellow ferruginous tropical soils which are heavily weathered and markedly laterized. soils within the "fadama" areas are richer in kaolinitic clay and organic matter, very heavy and poorly drained, characteristics of hydromorphic/ vertisols soil (Adamu, 2008).

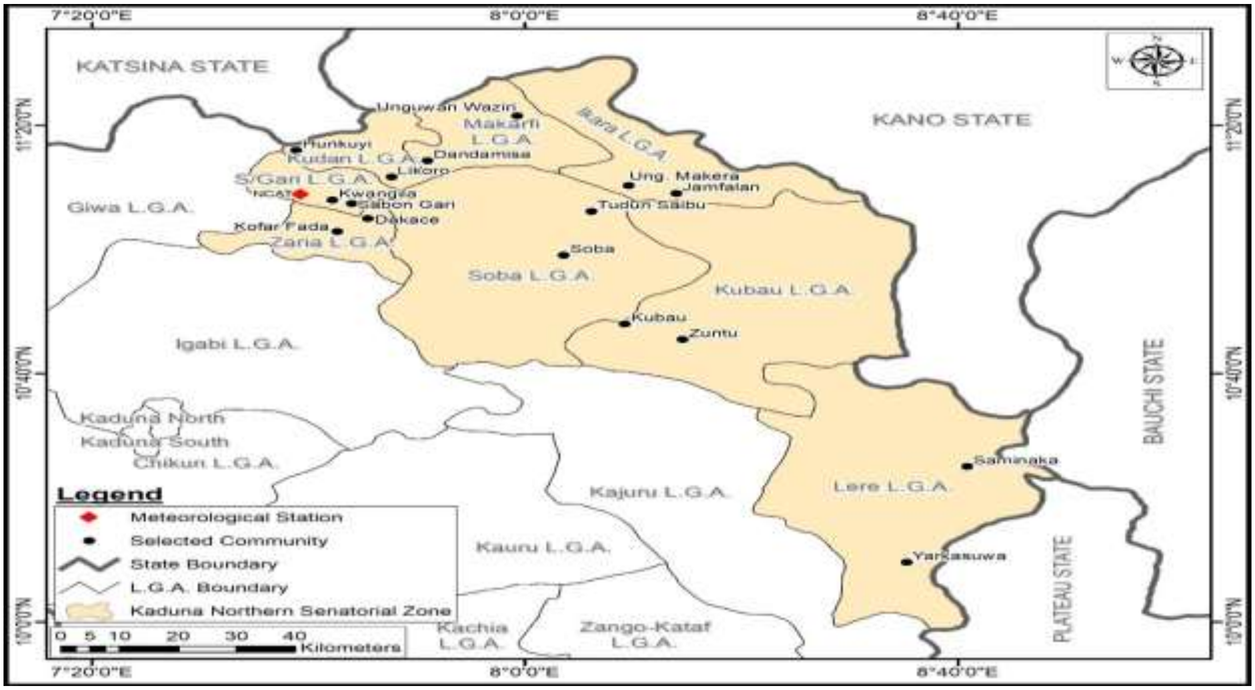

Fig. 1: Kaduna Northern Senatorial Zone (Study Area) Showing the Meteorological Station
Source: Extracted from Google Map 2018

MATERIALS AND METHODS

The temperature data covering 1967 to 2016 was obtained from the archives of Nigeria Meteorological Agency (NiMet) Zaria station (Nigeria College of Aviation and Technology) (NCAT). The use of this source to represent the entire study area is because: (1) it is the only synoptic station in the area (2) it has no significant missing records during the period of study (3) recent records of climate data not available in other LGAs.

The data was analyzed using trend analysis. These data were used to characterize the temperature trends and estimate changes in temperature. Linear trend lines and trend line equations of the minimum, maximum and average temperature for the area were plotted graphically against the years of records for easy identification of the rate of increases or decreases in the average values between the beginning and the end of the series using Microsoft excel tool (2013) and SPSS 23.0 version.

To further specify the trends, linear regression was used to determine the linear trends of the temperature for the station and amount/ rate of increase or decrease in temperature were estimated using Linear regression is represented with a formula:

$y = a + bx$ ………………………..(1)

Where: a is the intercept of the regression is a line on the y-axis, b is the slope of the regression line. The value of a and b can be obtained from the following equations:

$$a = \frac{\sum y - b(\sum x)}{n} \quad \text{……………2)}$$

$$b = \frac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2} \quad \text{……………………(3)}$$

To determine the nature of trends and measurement of variability of the average temperature, the standard deviation, which provides the deviation from normal (average) was equally determined and plotted using Microsoft excel (2013). From the plotted graphs, extreme conditions were then detected. The standard deviation given by the formula:

$$\delta = \frac{\sqrt{\sum(x-\bar{x})^2}}{n} \quad \text{…………………………………(4)}$$

where: x = value of temperature observations

$\bar{x}$ = mean value of the temperature observations

n = number of temperature observations

δ= standard deviation

The Cramer's test (Lawson, Balling, Peters and Rundquist 1981) was adopted to compare the means of the sub- periods (n-years) with the mean of the entre record period (N-years).

The t-statistics is computed as:

$$t_k = \left(\frac{n(N-2)}{N - n(1+\tau_k^2)}\right)^{1/2} \tau_k \quad \text{……………………………(5)}$$

Where: t_k is a standardized measure of deference between means given as:

$$\tau_k = \frac{\bar{x}k - \bar{x}}{S} \quad \text{...(6)}$$

The standardized coefficients of Skewness (Z_1) and Kurtosis (Z_2) statistics as defined by Brazel and Balling (1986) were used to test for the normality in the temperature series for the area.

The standardized coefficients of Skewness (Z_1) was computed as

$$Z_1 = \left[\left(\sum_{i=1}^{N}(xi-\bar{x})^{3}/N\right) \Big/ \left(\sum_{i=1}^{N}(x_i-\bar{x})^{2}/N\right)^{3/2}\right] \Big/ (6/N)^{1/2} \qquad \ldots\ldots(7)$$

and the standardized coefficient of kurtosis (Z_2) was calculated as:

$$Z_2 = \left[\left(\sum_{i=1}^{N}(xi-\bar{x})^{4}/N\right) \Big/ \left(\sum_{i=1}^{N}(x_i-\bar{x})^{2}/N\right)^{2}\right] - 3 \Big/ (24/N)^{1/2} \qquad \ldots\ldots(8)$$

RESULTS AND DISCUSSIONS

Trend Analysis of Temperature in Northern Senatorial Zone of Kaduna State

The result **o**f analysis of temperature data from NiMet Zaria station is presented in Table 1, while Figures 2(a-c) showed the graphical presentation of the minimum, maximum and average temperature trends.

Table 1: Statistical Characteristics of Temperature for Northern Senatorial Zone of Kaduna State from 1967 – 2016

Descriptive statistics	Minimum Temp. (^{0}C)	Maximum Temp.(^{0}C)	Average Temp.(^{0}C)
Mean	19.05	31.91	25.48
Standard Deviation	0.65	0.90	0.66
Skewness (Z_1)	-0.32	1.42	0.66
Kurtosis (Z_2)	-0.57	2.36*	0.40
Range	2.80	4.43	2.97
Minimum value	17.52	30.16	24.28
Maximum value	20.325	34.59	27.24
Trend (^{0}C /year)	0.034	0.033	0.034
Total change (^{0}C/ 50Yrs)	1.72	1.68	1.72

Source: Author's, Analysis, 2018

*Significant at 95% confidence level

For the minimum annual temperature, the result also indicated a long-term mean of 19.05 ^{0}C; the standard deviation of 0.65 ^{0}C; the minimum value of 17.52 ^{0}C; the maximum value of 20.33 ^{0}C with a long-term range of 2.80 ^{0}C over the 50-years period. Estimation of total changes of the minimum temperature (Figure a) expressed in ^{0}C for the 50-years period of the study indicates an increase of 1.72 °C for the period of study at the rate of 0.034 ^{0}C year^{-1} .

For the maximum annual temperature, the result also indicated a long-term mean of 31.91 ^{0}C; the standard deviation of 0.90 ^{0}C; the minimum value of 30.16 ^{0}C; the maximum value of 34.59 ^{0}C with a long-term range of 4.43 ^{0}C over the 50-years period. The linear trend line for the maximum temperature (Figure b) indicates a total increase of 1.68 °C at the rate of 0.033 °C year^{-1} .

For the average temperature the result also indicated a long-term mean of 25.48 ^{0}C; the standard deviation of 0.66 ^{0}C; the minimum value of 24.28 ^{0}C; the maximum value of 27.24 ^{0}C with a long-term range of 2.97 ^{0}C over the 50-years period. The average temperature (Figure c) indicates a total increase of 1.72 °C at the rate of 0.034 °C year^{-1}.

Comparing results for the estimated total changes in minimum and maximum temperatures showed that the value for the minimum temperature is greater than the maximum temperature value, indicating increase in temperature in cold season in recent years. This result is supported by the findings of IPCC, (2014) that increase in minimum temperature more than the maximum temperature is a clear evidence of global warming in recent years. Result further indicates that the estimated average total change value (1.72 °C) falls within the prediction range of IPCC, (2007) using computer models that the global mean surface temperature will rise by 1.5 ^{0} to 4.5 ^{0}C by the year 2050 if carbon dioxide reaches the predicted level of 600 parts per million.

The plotted standard deviation for minimum temperature anomaly (Figure a) showed 13 years of temperature above mean standard deviation, out of the 13 years, 1years (1994), found in the third decade, five years (1998-1999, 2000, 2004 and 2005) in the fourth decade, and seven years (2008, 2010, 2013-2016) found in the last decade, fourth and fifth decades indicated a significant increase in temperature above mean standard deviation, with peak in 1993. This is followed by 10years of temperature below mean standard deviation, out of the 10 years 4 years (1967, 1968, 1971, and 1973) found in the first decade. 4 years (1979, 1982, 1983, and1991) were found in the second and third decades. 2 years (2010- 2011) occurred in the last decade. This result is in agreement with the findings of Ikenna, Okey, Clement and Ugochukwu (2017) that Abuja also witnesses an upward trend in the average minimum temperature and Olarenwaju (2009) that Ilorin experiences fluctuations and significant rise in minimum temperature.

For the maximum temperature anomalies (Figure b) showed 6 years of temperature above mean standard deviation, out of the 6years, 1year (1975) occurred in the first decade and 5 years (2007-2011) in the last decade, with peak in 2009. There was also 6 years of abysmal temperature below mean standard deviation, out of the 6 years, 1 year (1967) occurred in the first decade. 3 years (1977, 1979 and 1980) occurred in the second decade and 2 years (1991 and 1994) occurred in the third decade. This is a clear evidence of increase warming of the earth in recent years. This result corresponds with the findings of Opeyemi (2016) which revealed increase in maximum temperature in Lagos. This is a clear evidence of increase warming of the earth in recent years.

The average temperature (Figure c.) has 7 years of temperature above mean standard deviation. Out of these years, 1year (1975) occurred in the first decade, 1 year also in the fourth decade and 5 years (2007-2011) in the last decade. On the other hand, 7 years were below mean standard deviation, out of these years, 2 years (1967-1968) occurred in the first decade, 4 years (1977, 1979-1980, 1983) in the second decade, and 1year (1991) in the third decade. This result is in line with the findings of Olarenwaju (2009) in Ilorin, but disagrees with the findings of Opeyemi (2016) which indicates fluctuation and decrease in average annual temperature in Lagos. The basis for the disagreement is not unconnected to periodic changes in cloud cover in the area. This is another scientific evidence of rising temperature (global warming) in the study area from meteorological parameters with peak in 2008. Figure 2 (a-c) illustrate the trends for minimum, maximum and average temperature in the study area

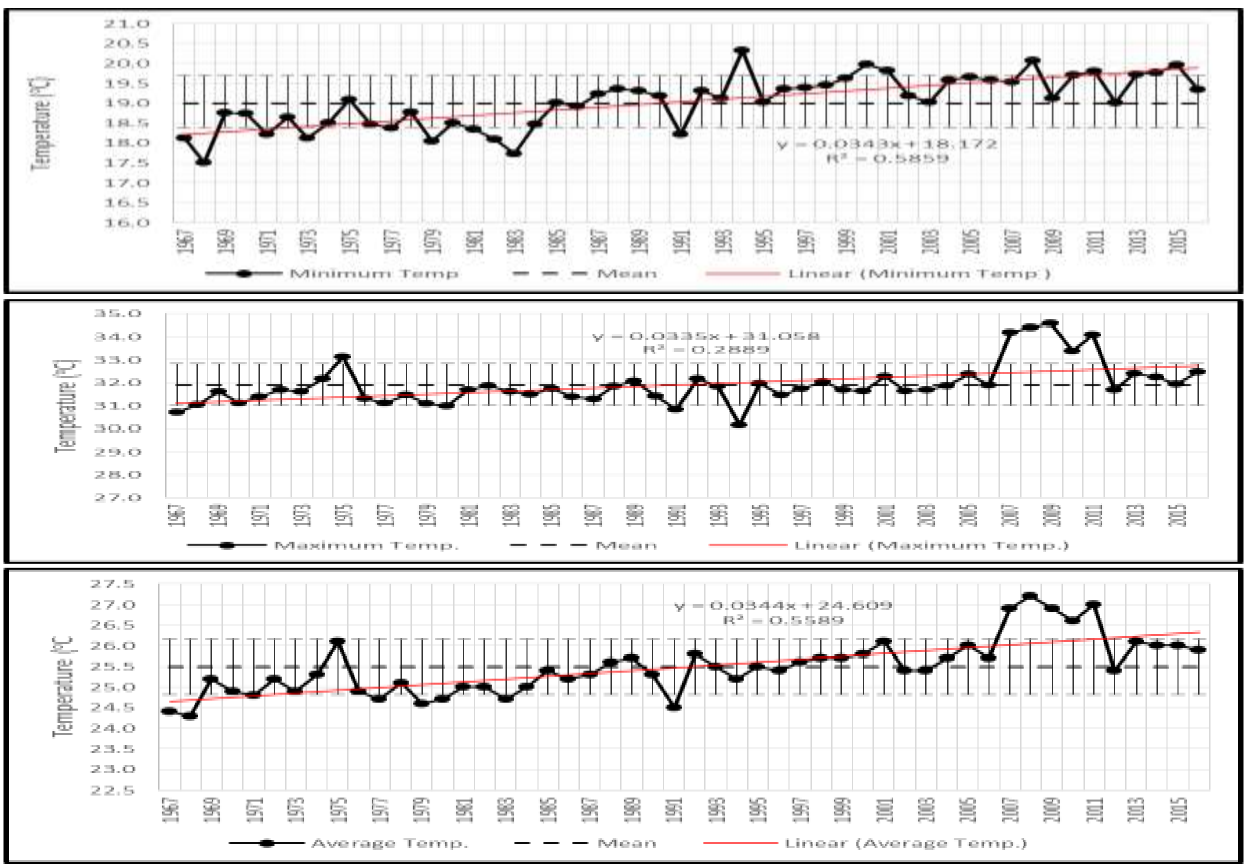

Fig. 2(a-c)**:** Temperature Trends of Northern Senatorial Zone of Kaduna State for: (a) Minimum Temp. (b) Maximum, (c) Average Temp.

Decadal Temperature Trend (Cramer's Test) of Northern Senatorial Zone

Table 2: 10-year (Decadal) Non- Overlapping Sub-Periods Analysis of Minimum, Maximum and Average Temperature of Northern Senatorial Zone

Sub-periods	Minimum Temp.	Maximum Temp.	Average Temp.
1967-1976	-2.54*	-1.08	-2.09*
1967-1976	-2.54*	-1.67	-2.33*
1987-1996	0.53	-1.39	-0.52
1997-2006	1.82	0.00	1.00
2007-2016	2.11*	-2.29*	2.79*

Source: Author's, Analysis, 2018

NB: * Significantly warmer/ colder for ***tk*** values ± ≥ 1.96

The result of 10-year (decadal) non- overlapping sub-periods analysis (Cramer's test) for the minimum, maximum and average temperature series of northern senatorial zone presented in Table 2 indicated the first three decades (1967-1976, 1967-1976 and 1987-1996) were significantly colder as indicated by their negative values (except for values of minimum temperature in the third decade). However, from there after ward there was an increase in temperature in the last two decades (1997-2006 and 2007-2016) with a significant increase in the last decade.

Table 3: 10-year Non- Overlapping Sub-Periods Analysis of Monthly Minimum Temperature of the Study Area from 1967 – 2016

Months	1967-1976	1977-1986	1987-1996	1997-2006	2007-2016
January	-0.23	-1.92	0.46	1.92	0.00
February	-0.46	-1.10	-0.46	1.10	1.46
March	-1.88	-1.32	0.79	1.88	2.32*
April	-1.29	-1.99*	1.00	1.55	2.57*
May	-1.66	-2.04*	0.91	1.18	2.45*
June	-1.68	-2.13*	0.38	1.10	2.57*
July	-2.08*	-1.84	0.43	1.84	1.82 *
August	-1.78	-0.34	-1.00	0.34	2.32*
September	-2.13*	-1.41	-0.38	1.10	1.29
October	-2.32*	0.00	-0.34	0.68	1.78
November	-2.16*	-1.78	0.34	1.00	0.98
December	-1.06	-1.40	1.78	0.28	0.14

Source: Author's, Analysis, 2018

NB: * Significantly warmer/ colder for ***tk*** values ± ≥ 1.96

The result of 10-year (decadal) non- overlapping sub-periods analysis (Cramer's test) for the minimum temperature revealed that the ***tk*** values for the first two decades (1967-1976 and 1977-1986) were colder as indicated by their negative ***tk*** values with months of April, May, June, September, October and November being significantly colder. There was also a clear evidence of insignificant increase in temperature in the months of the third decade (1987-1996) as indicated by their positive ***tk*** values. However, from there after ward there was a significant increase in temperature in the last two decades (1997-2006 and 2007-2016) with the months of March April, May, June, July and August being significantly warmer at 95% confidence level than the long- term condition. This is a clear evidence of increased warming in the study area from meteorological parameter.

Table 4: 10-year Non- Overlapping Sub-Periods Analysis of Monthly Maximum Temperature of the Study Area from 1967 – 2016

Months	1967-1976	1977-1986	1987-1996	1997-2006	2007-2016
January	-0.74	-1.38	-1.01	0.00	1.70
February	0.57	-0.19	-1.41	-0.93	0.31
March	0.00	-1.92	-0.57	0.29	2.71*
April	-0.89	-0.89	-1.10	-0.23	2.71*
May	-0.93	-1.81	0.19	-0.38	2.51*
June	-0.64	-1.39	-0.84	-1.22	2.16*
July	-1.45	-1.64	-0.53	-0.78	2.34*
August	-1.78	-0.34	-1.00	0.34	2.32*
September	-2.04*	-0.62	-0.62	0.62	1.41*
October	-0.84	-0.84	-1.10	-1.10	1.92
November	-1.92	-0.57	0.29	-0.57	1.41
December	0.84	-0.34	-2.16*	1.29	0.68

Source: Author's, Analysis, 2018

NB: * Significantly warmer/ colder for ***tk*** values ± ≥ 1.96

The result of 10-year (decadal) non- overlapping sub-periods analysis (Cramer's test) for the maximum temperature decadal analysis also revealed that only the ***tk*** values for the first four decades (1967-1976, 1977-1986, 1987-1996 and 1997-2006) were colder as indicated by their negative ***tk*** values(except for the months of February, March, of the first decade, May of the third decade and January, March, August, and September of the fourth decades) with months of September and December being significantly colder. On the contrary, the ***tk*** values for the last decade were all positive with the months of March, April May, June, July, August and September being significantly warmer at 95% confidence level than the long-term condition. Findings also gives a clear indication that the study area (northern senatorial zone) is getting warmer in recent years.

Table 5: 10-year Non- Overlapping Sub-Periods Analysis of Monthly Average Temperature of the Study Area from 1967 – 2016

Months	1967-1976	1977-1986	1987-1996	1997-2006	2007-2016
January	-0.40	-1.62	-0.98	1.62	1.32
February	0.00	-0.64	-1.22	0.00	0.84
March	-1.45	-1.64	0.27	1.45	2.45*
April	-1.18	-1.43	-0.31	0.62	2.79*
May	-1.45	-2.11*	0.27	0.00	2.77*
June	-1.18	-1.86	-0.31	-0.62	2.45*
July	-1.92	-1.92	-0.38	0.38	2.04*
August	-2.45*	-1.10	-0.57	1.55	2.45*
September	-2.30*	-1.41	-0.75	0.75	2.57*
October	-2.08*	-0.84	-1.22	-0.43	2.71*
November	-2.16*	-1.29	0.34	0.00	1.55
December	-0.29	-1.55	0.00	1.75	1.45

Source: Author's, Analysis, 2018

NB: * Significantly warmer/ colder for ***tk*** values ± ≥ 1.96

The result of 10 year (decadal) non- overlapping sub-periods analysis (Cramer's test) for the average temperature analysis indicated that all the *tk* values for the indicated the first three decades (1967-1976, 1967-1976 and 1987-1996) were colder as indicated by their negative values (except for the months of March and May of the third decade) with the months of May, August, September, October and November being significantly colder. However, the *tk* values for the last two decades (1997-2006 and 2007-2016) shows an increase in temperature as indicated by their positive values (except for the months of June and October) with the months of March, April, May, June, July, August, September and October being significantly warmer at 95% confidence level than the long-term condition. This therefore, gives a clear indication that the study area is getting warmer in recent years. This finding further showed that the intensity of temperature is higher during the hot dry season and wet seasons compered to harmattan. These results are in line with the findings of Sawa and Abdulhamid (2009) and Usman, (2016) in their researches on Urban Canopy Heat Island in Zaria and Kaduna. The study revealed that the intensity of temperature is higher during the hot dry season compered to harmattan and wet season.

CONCLUSION AND RECOMMENDATIONS

Based on the result of the linear trend analysis of the temperature it's possible to generalized that there has been a significant rise in temperature in the study area over the recent decades/years. Its worthy of note that good understanding of changes in temperature is indeed very important in enhancing appropriate measures to mitigate the scourge of global warming and climate change in general. The possible implication of the rise in temperature could be drying/ wilting of crops, shortage of pasture and frequent incidences of heat-related human and animals' diseases. The increase in temperature could also exacerbate excessive evaporation, leading to drying up of rivers, streams and wells consequently water scarcity for both domestic and commercial purposes.

Based on the aforementioned findings the following recommendations are made:

i. There is the need to improve information delivery and foster the use of climate information to inform people to avoid surprises, and take right decisions in case of unexpected periods of intense heat, known as heat waves. As such, additional functioning synoptic weather stations should be provided to complement the existing ones in the study area with distance from each other not more than 100km so as to conform to WMO standard. This will enhance network of data collection and accurate daily temperature prediction.

ii. There is the need for clear understanding decadal increase in temperature of the last two decades in the study area especially minimum, maximum and average trends in order to assist government to come up with policies that will help in managing socio-economic consequences of rising temperature and /or planned interventions.

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