Journal of Applied Sciences, Information, and Computing
Vol. 2, No. 2 (December 2021)
School of Mathematics and Computing, Kampala International University

ISSN: 1813-3509 https://jasic.kiu.ac.ug

Evidence of Climate variability by the Spatio-Temporal Analysis of Temperature in the City of Sokoto

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Abstract

Temperature is crucial in observing changes occurring in the environment, such as climate change. Climate change is caused by the emission of excessive greenhouse gas and has been acknowledged as the main cause of various environmental impacts such as an increase in the flood scenario, frequent droughts, increasing wildfires, and heatwaves in various parts of the world. Temperature behaviour which has been studied in the city of Sokoto was used as a yardstick to check for the presence of variance in climate. Temperature data were gotten from the Nigerian Meteorological Agency (NIMET) that spanned thirty-one years (1980–2010) was used for this study. ANOVA and the Mann Kendall trend test were used to analyze the data used. The ANOVA findings revealed that the maximum and minimum temperatures differed significantly between the months. The Mann-Kendall trend test results suggest an increasing trend in maximum temperature and a declining trend in minimum temperature in the annual statistics. The monthly trend was made up of both increasing and decreasing trends. The city of Sokoto being located in the region of the Sahel savannah has very sensitive to minor changes in climate variance, hence this result will help in the planning of agriculture-related activities such as planting time, type of crops to plant, type of animals to be reared, types of animal diseases to provide vaccines for, etc.

Keywords: Climate variability; Sokoto; Temperature; Climate Change; Sahel Savannah; Nigeria.

1. Introduction

Air temperature close to the Earth's topography is a very important parameter for a lot of research areas, and also applications in various fields of engineering. To calculate evapotranspiration, the daily mean air temperature is combined with humidity, wind speed, and solar radiation. Temperature is also very important in monitoring the changes in the environment, crop production, climate prediction, and change. In weather stations, the temperature is usually measured using temperature sensors that are put in shelters and are placed 2 m above ground level. Generally, air temperature is known to change across time and space (Emamifar *et al*., 2013). Air temperature is a very important variable in a wide range of environmental applications, including vector-borne disease bionomics, terrestrial hydrology, biosphere processes, and climate change (Chow *et al*., 1988; Prince & Goward, 1995; Kuhn *et al*., 2002; IPCC, 2007). As a result of the multiplicity of the environmental elements which affect the land-atmosphere energy balance, spatiotemporal patterns of temperature can be highly diverse and complex depending on the scale. Latitude which determines the sun's relative position which in turn influences the length of the day, and distribution of total incoming solar radiation throughout the year, cloud cover, and Particulate matter in the atmosphere, are factors that affect the total amount of solar radiation reaching the Earth's surface. The absorption of incoming solar radiation is crucial for maintaining energy balance in the earth-atmosphere system, as well as in the shortwave part of the light spectrum, infrared longwave radiation emission, and sensible and latent heat loss fluxes. These mechanisms assist the surface heating and cooling processes, which are the primary determinants of the daily air temperature cycle (Prihodko &Goward; Jacobson, 2000; Jin & Dickinson, 2010; Ahrens, 2003; Benali *et al*., 2012).

Researches in climate change and variability has been carried out and reported in various parts of the world, even now more researches are still being carried out and reported. Climate change and variability occur on all spatial scales (Umar *et al*., 2012). Climate change which is majorly caused by excessive greenhouse gas emissions has been widely acknowledged as the main cause of increased flooding, severe and more frequent droughts, increasing wildfires, and heatwaves in various parts of the world. Global annual mean surface air temperature has increased by about 1.8°F (1.0°C) over the last 115 years (1901–2016). This period is now the warmest in the history of modern civilization. Climate-related weather extremes have also broken records in recent years, with the last three years being the warmest on record across the planet. Over climate timescales, these tendencies are projected to continue. Due to rising temperatures and a shift in precipitation, droughts have become more frequent and severe. In many regions of the world, this has resulted in greater poverty, loss of life, property damage, and ecosystem degradation (Umar *et al*., 2012). Understanding the impact of climate variables like temperature in various climatic zones is very important for climate change adaptation and mitigation for long-term development. Anthropogenic activities are the major causes of change in the features of global climate, in addition to global warming. A lot of studies carried out by experts all around the world have indicated an increase in surface, atmospheric, and oceanic temperatures, as well as melting ice caps, depreciating snow cover, vanishing sea ice, rise in sea levels, acidification of the ocean, and growing atmospheric water vapor. For example, since the 1900s, the worldwide average sea level has risen by around 7–8 inches, with over half of that gain (about 3 inches) occurring since 1993. The anthropogenic activity caused by climate change has made a great contribution to this rise since 1900, contributing to a rate of rise that is greater than during any preceding century in at least 2,800 years (Umar *et al*., 2012). This study is aimed at finding evidence for climate variability in the city of Sokoto by analyzing temperature for the period 1980-2010 using various analysis methods.

2. Materials and methods

2.1 Study location

Sokoto State is located in Nigeria's far north-western corner. It is located between latitude 13° 0' 21.1428" N and longitude 5° 14' 51.1872" E. The population of the state is expected to be 3,696,999 people. The Hausa/Fulani, a predominantly Muslim tribe, is the most populous. Other tribes in the state include the Zabarmawa, Igbo, Yoruba, and Nufawa. The Sokoto metropolis includes Wamakko, Kware, Sokoto north, and Sokoto south. The Sudan Savannah ecozone encompasses Sokoto. The yearly average rainfall is 647mm, and the annual mean temperature is 34.5°C, with temperatures frequently reaching 40°C during the dry season (1981 - 2010) (Ekpo & Nsa, 2011; WMO, 2016; Falaiye *et al*., 2021).

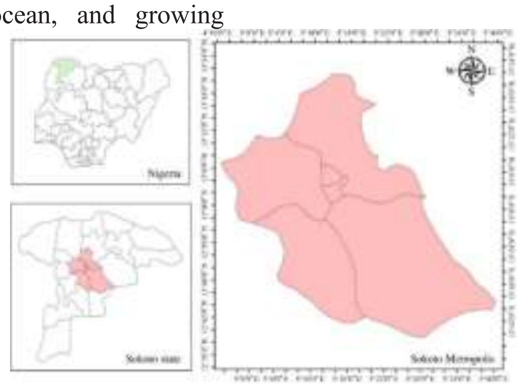

Figure 1: Sokoto city map; source: google

2.2 Seasons in Sokoto

The cold-dry season (CDS; harmattan), which runs from November to February, the hot-dry season (HDS), which runs from March to May, and the wet (WS) season, which runs from June to October, are the 3 seasons of the northern-guinea zone of Nigeria (Igono & Aliu, 1982; Dzenda *et al*., 2011). These seasons have a unique set of meteorological characteristics. Since the city of Sokoto is located in Sokoto State, which is located in the northern guinea zone of Nigeria, these seasons apply to it too.

2.3. Data Collection

The temperature (Tmax and Tmin) dataset used in this study was for a total of 31 (1980-2010) years and was collected from the Nigerian Meteorological Agency (NIMET). Table 1 shows a summary of the information gathered. The monthly values for both Maximum and Minimum Temperature are included in the collected data. The monthly data were subjected to quality assurance and quality control (QA/QC) analysis, this was done before applying the needed statistics (Duhan &

Pandey, 2013). Missing data, outliers, are examples of anomalies that were considered in these monthly data sets (Chatterjee & Hadi,2015).

Table 1: Summary of the mean seasonal temperature for the period 1980-2010

	Wet (mean)		Dry (Hot) mean		Dry (Cold)		Annual Mean	
YEAR	**Tmin**	**Tmax**	**Tmin**	**Tmax**	**Tmin**	**Tmax**	**Tmin**	**Tmax**
1980	23.2	33.5	24.1	39.7	20.2	33.7	22.4	35.1
1981	23.2	34.0	24.8	38.6	17.0	32.9	21.5	34.8
1982	23.1	34.2	25.9	39.2	18.0	32.8	22.1	35.0
1983	24.8	34.1	25.0	40.0	17.9	33.6	22.5	35.4
1984	24.5	34.7	25.9	39.8	18.4	33.9	22.8	35.7
1985	24.0	34.0	26.4	39.3	19.0	33.0	22.9	35.0
1986	23.9	34.0	27.4	39.8	19.1	33.3	23.1	35.2
1987	23.1	35.3	25.0	39.6	18.9	34.3	22.2	36.1
1988	23.5	33.0	27.5	39.7	18.8	32.8	22.9	34.6
1989	23.4	33.6	25.0	39.0	17.8	31.8	22.0	34.3
1990	24.1	34.5	25.1	38.4	19.9	34.5	22.9	35.5
1991	23.6	33.3	26.0	37.6	19.4	34.0	22.8	34.6
1992	23.5	33.8	25.8	37.1	18.2	32.2	22.3	34.1
1993	23.8	34.4	26.0	39.6	18.5	33.4	22.6	35.4
1994	24.3	33.8	26.5	40.1	18.0	33.0	22.7	35.1
1995	24.0	34.7	26.4	40.0	17.7	33.5	22.5	35.6
1996	23.3	33.9	23.9	39.8	18.5	35.5	21.8	35.9
1997	23.8	34.5	24.8	37.9	18.2	34.7	22.2	35.4
1998	24.2	33.8	26.4	39.7	19.4	35.1	23.1	35.7
1999	23.4	33.3	26.0	40.5	18.5	34.6	22.4	35.5
2000	23.6	33.7	25.3	40.0	18.0	33.4	22.1	35.2
2001	24.7	33.9	25.6	39.5	17.8	34.4	22.6	35.5
2002	22.4	33.7	27.4	39.6	19.6	35.7	22.7	35.8
2003	23.0	34.0	26.4	39.1	20.0	35.5	22.8	35.8
2004	22.8	35.0	26.0	38.0	19.5	36.9	22.5	36.4
2005	23.6	33.8	26.9	40.7	19.8	35.1	23.2	36.0
2006	24.0	34.0	25.4	40.5	19.3	34.8	22.8	35.9
2007	23.5	33.5	25.9	40.0	21.0	36.0	23.3	36.0
2008	21.9	32.8	24.1	38.4	16.7	33.9	20.7	34.6
2009	21.7	32.8	23.5	38.2	15.2	32.2	20.0	33.9
2010	22.5	32.7	24.3	39.8	16.5	34.6	20.9	35.1

2.4. Data Analysis

The descriptive analysis, Man-Kendall and Sen's slope test, and the Analysis of Variance (ANOVA) were used to analyze the variance in maximum and minimum temperatures for the city of Sokoto. Mann-and Kendall's Sen's slopes were used in the trend analysis. ANOVA was used to examine the variation of the selected parameters.

2.4.1. Descriptive Analysis

Descriptive statistics are used to describe the major components of a data set. They are a set of brief information that gives a summary of a data set, which may either be the whole data or just a fraction. Descriptive statistics show the metrics of central tendency and variation/spread in data (Bluman, 2008). They serve as the foundation for analyzing quantitative data (Umar *et al.,* 2012).

2.4.2. Analysis of Variance (ANOVA)

ANOVA is a well-known statistical approach for detecting whether or not there is variation between two or more sets of observations. It's used to determine if the averages of two or more groups that are independent are the same (Chatterjee & Hadi, 2015).

2.4.3. Mann-Kendall Trend Test and Sen Slope Estimator.

Nonparametric tests have been the most widely utilized tests for identifying the temporal fluctuations in hydro-meteorological variables (Zhang *et al*., 2014; Li *et al*., 2016). The Mann–Kendal (MK) trend test is the most extensively used non-parametric statistical family (Yurekli, 2018). Its broad adoption was owing to several benefits, including the capacity to manage missing values, outliers, and data with skewed distributions (Ab Razak *et al*., 2018). The hypothesis (Ho) of the MK test is that time series values do not show a trend, whereas the alternative hypothesis (H1) is that the data set does. The test indicates a significant trend in this study when the P-value is less than 0.05. This test is based on the statistic

$$S = \sum_{k=1}^{n=1} \sum_{j=k+1}^{n} sgn(xj - xk) \qquad (1)$$

where S is the Man-Kendall test values, and are the sequential data values, j, k, and n are the length of the data. Sign (xj - xk) is a pointer function that assumes any of the values 1, 0, and − 1, subject to the sign of. (xj - xk) (see equations 2 – 4)

$$sgn(xj - xk) = 1 \; if \; xj - xk > 0 \qquad (2)$$

$$sgn(xj - xk) = 0 \; if \; xj - xk = 0 \qquad (3)$$

$$sgn(xj - xk) = -1 \; if \; xj - xk < 0 \qquad (4)$$

The Sen Slope estimator is used to estimate the trueness of the Man-trend Kendall's analysis slope (Zhang *et al*., 2014). This test is applied to check the size of any visible trend observed in the Mann-Kendall test (Gocic & Trajkovic, 2013). The Sen Slope estimator can be calculated using equation 5.

$$h = \frac{xj}{j} - \frac{xk}{k} \qquad (5)$$

where h is the value of Sen Slope estimator, and are data values at time j and k

3. Results and discussion

3.1. Descriptive analysis

Figures 2 a and b show the descriptive analysis of both the Annual maximum and minimum temperatures respectively. From Figure 2a, it is seen that the lowest annual maximum temperature mean was recorded in the year 2009, while the highest was recorded in the year 2004. The trend line also indicated an upward trend for the mean annual maximum temperature. From figure 2b, the highest mean annual temperature was recorded in the year 2007, while the lowest was recorded in the year 2009. The trend line shows a downward trend in the mean annual minimum temperature.

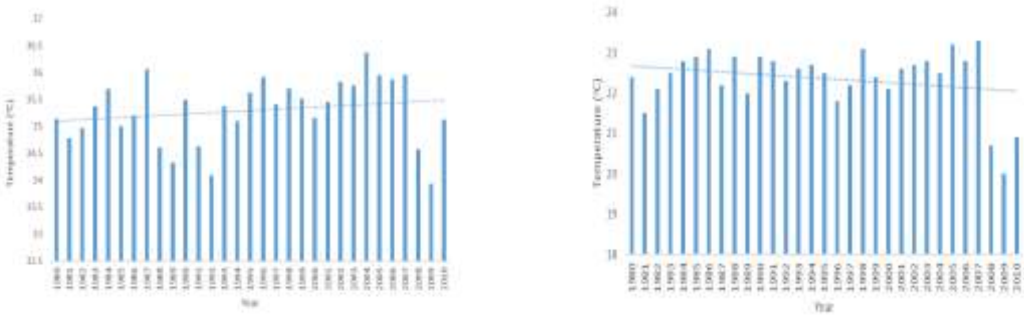

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Figure 2: Descriptive analysis of annual T_{max} and T_{min} respectively

The charts in Figures 3 to 5 demonstrate the seasonal temperature variance (minimum temperature and maximum temperature). Figure 6 depicts the average yearly temperature variation across the research period (1980-2010). The seasonal and annual mean maximum and lowest temperatures are summarized in Table 1.

Figures 3 a and b show the plot of the variance in T_{max} and T_{min} for the dry (hot) season, respectively. T_{max} recorded few extreme events, the most notable of which occurred in 1992 when the temperature dropped to 37.1oC, but T_{min} recorded more extreme cases e.g. steep peaks in the year 1996, 1998, and 2002 with temperatures of 39.8°C, 39.7°C, and 39.6°C respectively, and steep dips in the year 1980, 1996, and 2009 with temperatures 24.1°C, 23.9°C, and 23.5°C.

Figures 4 a and b depict a plot depiction of the variation in maximum and minimum temperatures for the dry(cold) season for the years 1980 to 2010Tmax and Tmin didn't have many extreme examples, but they did have a few. For example, there was an increase in minimum temperatures from 2001 and 2009, followed by a decrease. As shown in Table 1, the lowest reported values for Tmax and Tmin were 31.8°C and 15.2°C in 1989 and 2009, respectively, while the highest values, 36.9°C and 21.0°C, were recorded in 2004 and 2007.

T_{max} and T_{min} variations for the wet season from 1980 to 2010 are shown in Figures 5 a and b. Figure 5 shows an abrupt shift from a sharp rise to a severe decrease between 1997 and 1998, i.e., from table 1, the temperature in 1996 was 33.9°C, rose to 34.5°C in 1997, and then dropped to 33.8°C in 1998. The trendlines demonstrate that both maximum and minimum temperatures are on the decline, implying that we can expect lower T_{max} and T_{min} values in the following years.

The variance in the annual T_{max} and T_{min} mean is plotted in Figures 6 a and b. There were also extreme occurrences, such as for the T_{max}, where there was a dip that surpassed the typical range of variation between 1992 and 2009. Similarly, the most notable extreme occurrence for T_{min} occurred in 2009, when the plot showed a dip that was so far outside the range of variation. The lowest and highest T_{min} and T_{max} temperatures were recorded in 2009, at 20.0°C and 33.9°C, respectively, whereas the highest temperatures were 23.3°C in 2007 and 36.4°C in 2004.

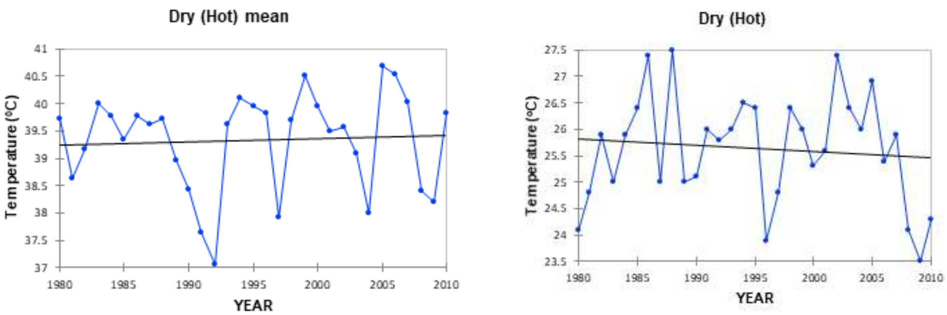

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Figure 3: Dry (hot) Seasonal variation of T_{max} and T_{min} for the period 1980-2010

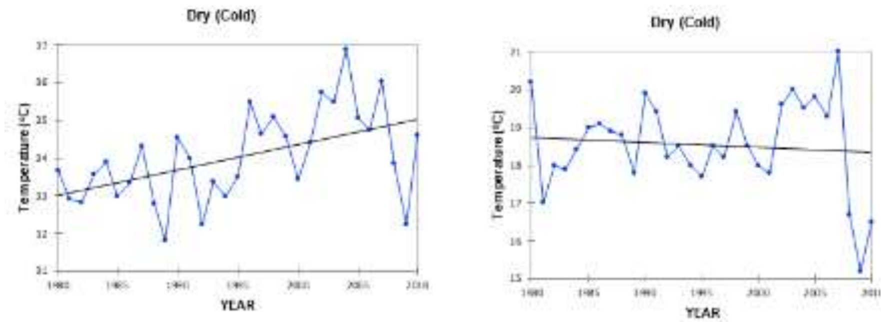

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Figure 4: Dry (cold) Seasonal variation of T_{max} and T_{min} for the period 1980-2010

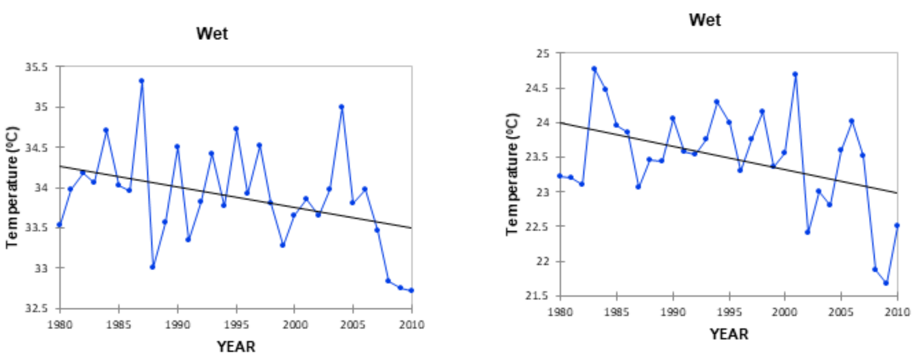

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Figure 5: variation in T_{max} and T_{min} for the wet season over the period 1980-2010

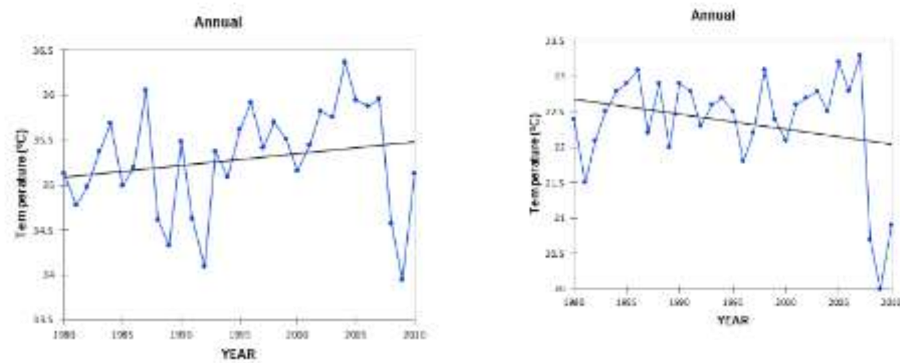

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Figure 6: mean annual variation in T_{max} and T_{min} for the period 1980-2010

Figures 7 to 18 show the monthly variation in temperature (Tmax and Tmin) across the 31-year study period for both Tmax and Tmin, i.e. the variation in temperature (Tmax and Tmin) for each month (e.g. January).

The plots showing the variance in T_{min} and T_{max} for January for the observation period (1980-2010) are shown in Figures 7a and b. T_{min} reached its peak point of 26.4°C in 1980, while it reached its lowest point of 12.8°C in 2010. T_{max} reached its highest point of 37.3°C in the year 2003, while its lowest point was 28.5°C in the year 1983, as shown in Figure 7b. There was a succession of spikes and dips in the T_{max} values reported for January over the 31 years of observation, such as between 1991 and 1993, 2004 and 2006, and so on, indicating a significant variability in the T_{max} values recorded for January throughout the 31 years of observation.

T_{min} and T_{max} variations for February from 1980 to 2010 are shown in Figures 8a and 8b. The highest minimum temperature ever recorded was 24.3°C in the year 2002, while the lowest was 15.4°C in 2009. The highest maximum temperature, 39.5°C, was recorded in the year 2002, while the lowest, 31.2°C, was recorded in the year 2000, according to figure 8b. In Figure 8b, there were several steep rises followed by severe drops, for example, a steep rise in 1984 followed by a steep fall in 1985, a steep rise in 1996 followed by a strong dip in 1997, and a steep rise in 1998.

Figures 9a and 9b illustrate the variance in T_{min} and T_{max} for March over the 31 years of observation. According to Figure 9a, the lowest recorded minimum temperature was 19.1°C in 2009, and the highest value was 27.8°C in 2002. Between 2003 and 2009, the mean T_{min} values recorded decreased steadily. The lowest recorded maximum temperature was 32.9°C degrees Celsius in 1992, while the highest was 41.3°C in 2005.

Figure 10a shows the variance in T_{min} from 1980 to 2010 for April. The lowest temperature ever recorded was 20.8°C in 1996, while the highest was 28.9°C in 1986. There were a series of ups and downs, but in 1996, there was a particularly steep drop. Figure 10b shows a graph of T_{max} fluctuation from 1980 to 2010 for April. In 2004, the lowest temperature ever recorded was 38°C, while the highest temperature was 42.2°C in 2000.

Figure 11a depicts the change in T_{min} for May from 1980 to 2010. The lowest temperature ever recorded was 24.5°C in 1981, and the highest temperature ever recorded was 29°C in 1998. The variance in T_{max} for May from 1980 to 2010 is depicted in Figure 11b. The lowest temperature of 35°C was recorded in 2004, while the maximum temperature was recorded in 1987.

Figures 12a and b show the change in T_{min} and T_{max} for June from 1980 to 2010. In the case of T_{min}, the lowest temperature recorded was 23°C in 2004, while the highest was 26.9°C in 1995. The lowest recorded maximum temperature was 33 °C in 2004, while the highest was 37.8 °C in 1995. In the plots, there was no discernible dramatic climb or dip.

Figures 13a and b show the change in T_{min} and T_{max} for July from 1980 to 2010. The lowest minimum temperature, 21.3°C, was recorded in 2008, while the highest, 28.2°C, was recorded in 1983. The highest recorded maximum temperature was 35.5 °C in 1987, and the lowest was 30.7°C in 2003.

Figures 14a and b show the change in T_{min} and T_{max} for August from 1980 to 2010. The lowest minimum temperature, 21.4°C, was recorded in 2009, while the highest, 25.9°C, was recorded in 1994. The highest recorded temperature was 34°C in 2004, and the lowest was 28.9°C in 1988.

Figures 15a and b show the change in Tmin and Tmax for September from 1980 to 2010. The lowest minimum temperature, 21.3°C, was recorded in 2010, while the maximum, 28 degrees Celsius, was recorded in 2001. The highest recorded maximum temperature was 39°C in 2004, and the lowest was 31.2°C in 2007.

Figures 16a and b show the change in Tmin and Tmax for October from 1980 to 2010. The lowest value for the minimum temperature, 19.4°C, was recorded in 2009, while the highest, 24.8 °C, was recorded in 1984. The highest recorded maximum temperature was 37.6°C in 1997, and the lowest was 34.8°C in 1999.

Figures 17a and b show the change in Tmin and Tmax for November from 1980 to 2010. The lowest minimum temperature, 16.1°C, was recorded in 2009, while the hottest, 28.4°C, was recorded in 2007. The highest recorded temperature was 40°C in 2004, and the lowest was 32°C in 2006.

Figures 18a and b depict the fluctuation in Tmin and Tmax for December between 1980 and 2010. The lowest minimum temperature, 13.1°C, was recorded in 2009, while the highest, 20.3°C, was recorded in 2003. The maximum temperature was 35.5°C in 2004 and 30°C in 1985 and 1986.

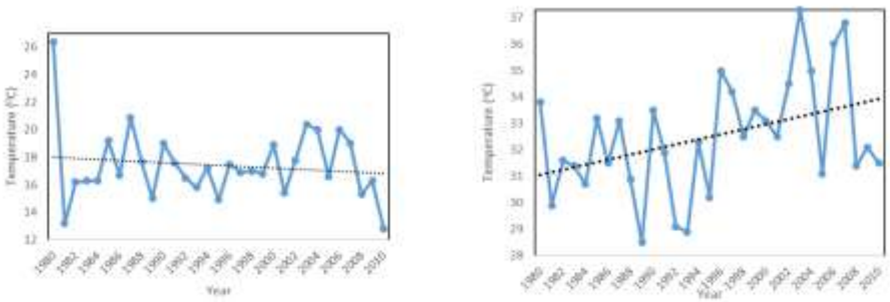

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Figure 7: Variation of T_{min} and T_{max} for January for the period 1980-2010

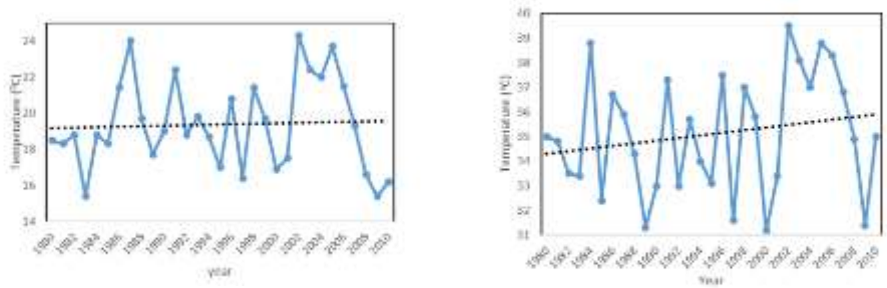

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Figure 8: Variation of T_{min} and T_{max} for February for the period 1980-2010

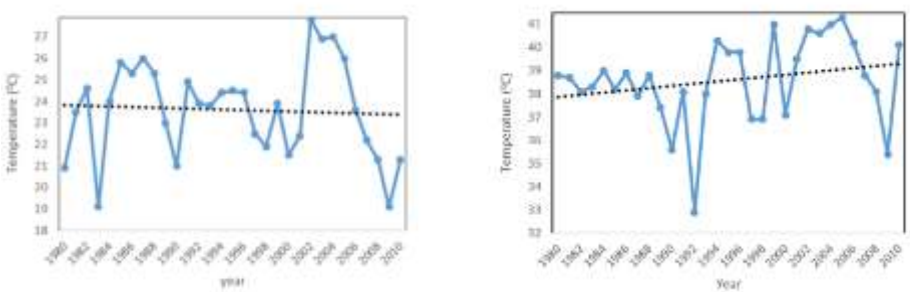

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Figure 9: Variation in T_{min} and T_{max} for March for the period 1980-2010

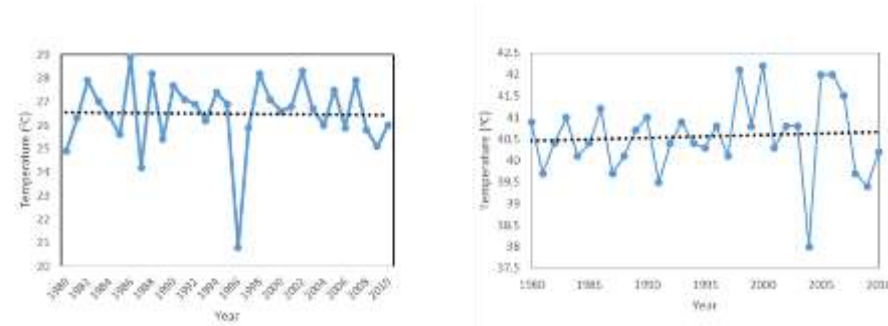

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Figure 10: Variation of T_{min} and T_{max} for April for the period 1980-2010

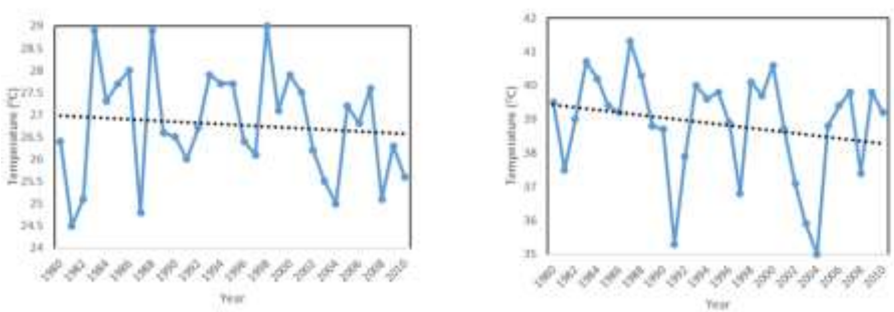

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Figure 11: Variation in T_{min} and T_{max} for May for the period 1980-2010

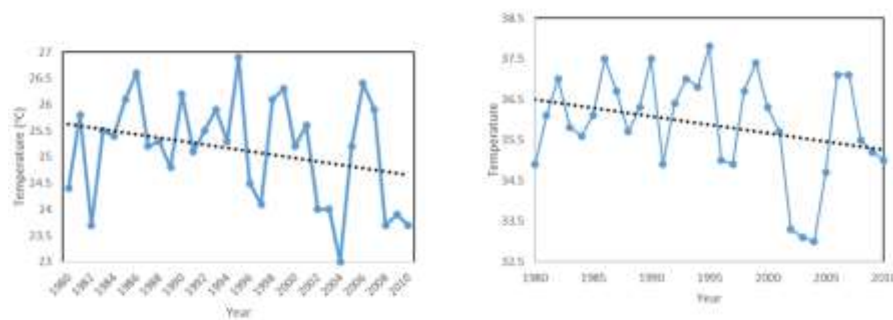

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Figure 12: Variation in T_{min} and T_{max} for June for the period 1980-2010

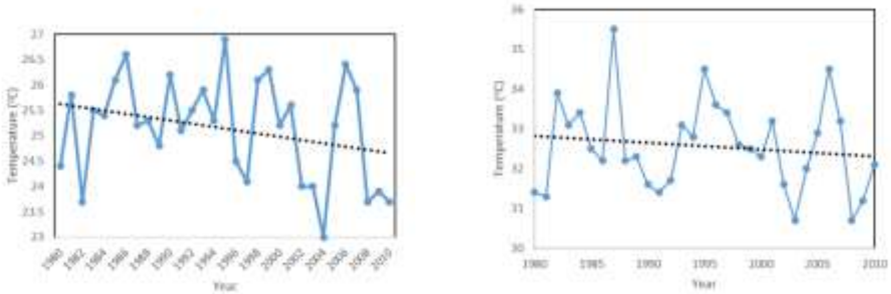

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Figure 13: Variation of T_{min} and T_{max} for July for the period 1980-2010

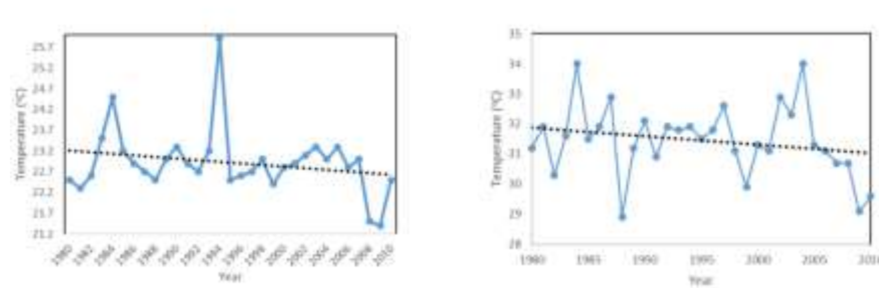

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Figure 14: Variation in T_{min} and T_{max} for August for the period 1980-2010

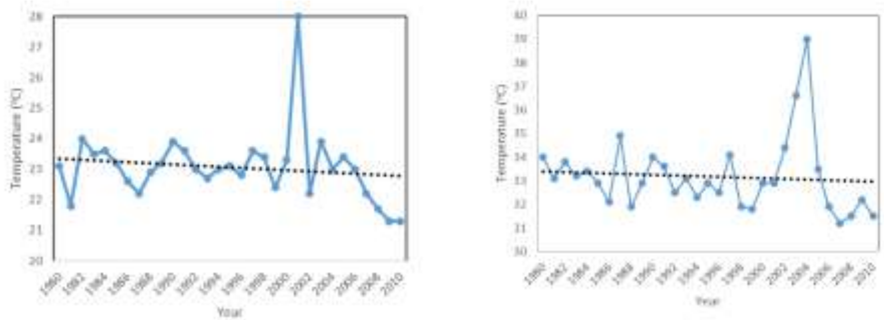

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Figure 15: Variation in T_{min} and T_{max} for September for the period 1980-2010

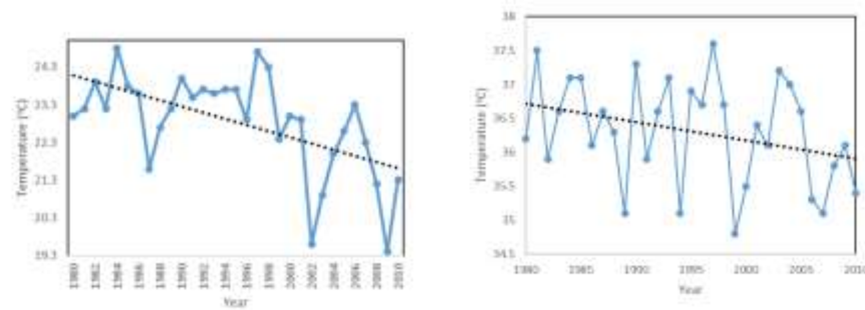

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Figure 16: Variation of T_{min} and T_{max} for October for the period 1980-2010

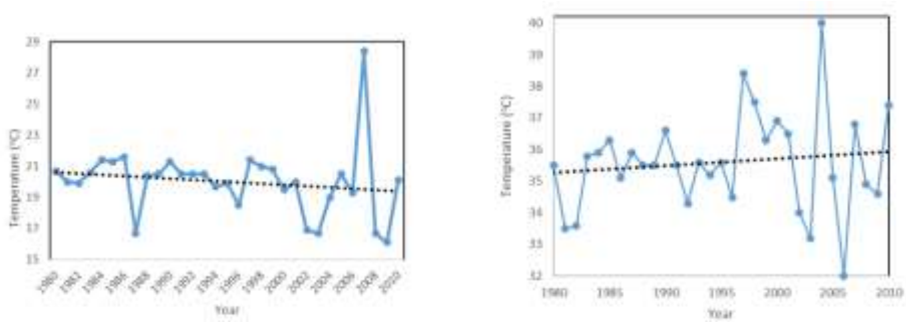

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Figure 17: Variation of T_{min} and T_{max} in November for the period 1980-2010

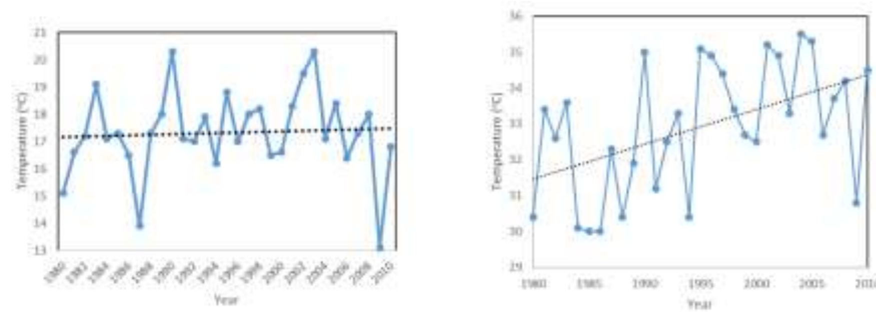

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Figure 18: Variation of T_{min} and T_{max} in December for the period 1980-2010

3.2. One Way Analysis of Variance

A one-way Analysis of Variance (ANOVA) was carried out to compare the difference between the months on the mean temperature for the period of observation (1980-2010). Table 2 shows the ANOVA summary for T_{max}, while Table 3 shows that of T_{min}. The result shows significant difference in the maximum temperature based on the computed months [F (11, 360) = 103.5261, *P* < .05], and also for the minimum temperature based on the computed months [F (11, 360) = 109.8519, *P* < .05],

Table 2: ANOVA tests for various months on minimum temperature for the period 1980-2010

Groups	*N*	Mean ± S. D.	*Df*	*F*	*P-value*
Maximum Temperature			11	103.5261	2.7E-104
JANUARY	31	32.484 ± 2.192			
FEBRUARY	31	35.113 ± 2.427			
MARCH	31	38.590 ± 1.848			
APRIL	31	40.561 ± 0.887			
MAY	31	38.852 ± 1.558	360		
JUNE	31	35.874 ± 1.277			
JULY	31	32.561 ± 1.134			
AUGUST	31	31.452 ± 1.182			
SEPTEMBER	31	33.177 ± 1.566			
OCTOBER	31	36.313 ± 0.777			
NOVEMBER	31	35.597 ± 1.581			
DECEMBER	31	32.910 ± 1.789			

Table 3: ANOVA tests for various months on minimum temperature for the period 1980-2010

Group	N	Mean ± SD	df	F	P-value
Minimum Temperature			11	109.8519	8.1E-108
JANUARY	31	17.406 ± 2.558			
FEBRUARY	31	19.377 ± 2.488			
MARCH	31	23.606 ± 2.197			
APRIL	31	26.503 ± 1.523			
MAY	31	26.774 ± 1.227			
JUNE	31	25.139 ± 1.007			
JULY	31	23.468 ± 1.139			
AUGUST	31	22.919 ± 0.784	360		
SEPTEMBER	31	23.061 ± 1.167			
OCTOBER	31	22.839 ± 1.307			
NOVEMBER	31	20.013 ± 2.205			
DECEMBER	31	17.319 ± 1.550			

3.3. Trend analysis

The temporal behavior of both maximum and minimum temperature of the city of Sokoto was analyzed using the Man-Kendall's trend test. The Mann-Kendall and Sen's slope analysis of the maximum temperature trend of the various seasons in Sokoto is shown in table 4a. This seasonal maximum temperature trend analysis showed an upward but not significant trend for the Dry (Hot) season, an upward significant trend for the Cold (dry) season, a significant downward trend was recorded for the wet season, and a significant upward trend for the annual mean of maximum temperature. Table 4b shows the summary of the Mann-Kendall and Sen's slope analysis of the minimum temperature trend of the seasons in Sokoto. From the Mann-Kendall and Sen's slope trend analysis, there was a very insignificant downward trend in the occurring minimum temperature in the Dry (Hot) season. Also, there was recorded a not-so-significant upward trend for the dry (cold) season. Similarly, there was a significant downward trend recorded for the wet season. Finally, a significant downward trend was recorded for the annual mean of the minimum temperature.

Table 5a shows the Mann-Kendall and Sen's Slope trend analysis of the monthly maximum temperature (T_{max}) for the period 1980-2010, i.e. all January that occurred during the observation period (1980-2010). The trend analysis showed a significant upward trend for the months; January, February, March, September, November, and December, while April recorded an insignificant upward trend. The analysis done showed a significant downward trend for the months' May, June, July, August, and October. The summary of the Mann-Kendall and Sen's Slope trend analysis of the minimum temperature (T_{min}) of each month measured over the period 1980-2010is shown in Table 5b. The Mann-Kendall and Sen's Slope trend analysis shows that there is an upward trend in the temperature occurrence in January, February, August, and December, while there is a downward trend in the minimum temperature occurs in the months' March, April, May, June, July, September, October, November.

Table 4: Mann-Kendall and Sen's Slope Seasonal temperature trend

Variable	Mean ± S.D.	Z	Sen's slope	Trend
A				
Maximum Temperature				
Hot Dry (mean)	39.3 ± 0.9	0.4591	0.006	↑
Cold Dry (mean)	34.02± 1.2	2.9242	0.073	↑
Wet (mean)	33.9 ± 0.6	-2.1082	-0.024	↓
Annual (Mean)	35.3 ± 0.6	1.8189	0.024	↑
B				
Minimum Temperature				
Hot Dry (mean)	25.6 ± 1.0	-0.0171	0	↓
Cold Dry(mean)	18.5 ± 1.2	0.0170	0	↑
Wet (mean)	23.5 ± 0.8	-1.6489	-0.027	↓

Annual (Mean)	22.4 ± 0.7	-0.1023	0	↓

The alpha value is 0.05

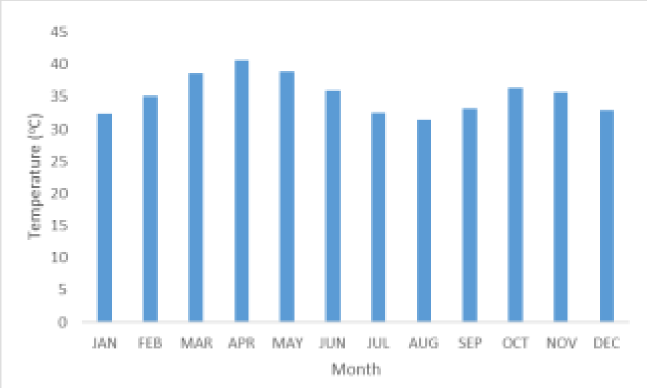
Table 5: Mann-Kendall and Sen's Slope monthly temperature trend

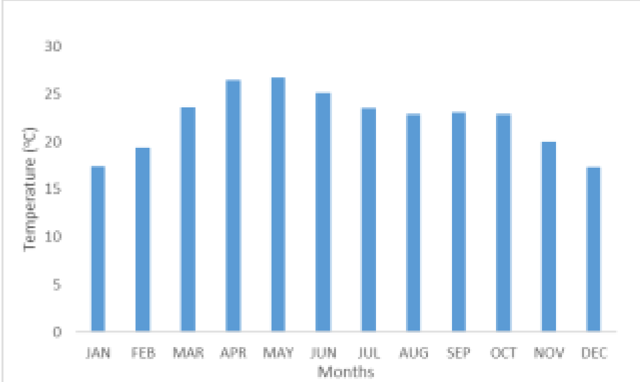
Variable	Mean ± S. D.	Sen's Slope	Z	Trend
A				
Maximum Temperature				
JANUARY	32.484 ± 2.192	0.100	1.973	↑
FEBRUARY	35.113 ± 2.427	0.054	0.867	↑
MARCH	38.590 ± 1.848	0.054	1.207	↑
APRIL	40.561 ± 0.887	0.000	0.273	↑
MAY	38.852 ± 1.558	-0.032	-1.209	↓
JUNE	35.874 ± 1.277	-0.017	-0.681	↓
JULY	32.561 ± 1.134	-0.017	-0.681	↓
AUGUST	31.452 ± 1.182	-0.032	-1.568	↓
SEPTEMBER	33.177 ± 1.566	-0.048	1.927	↑
OCTOBER	36.313 ± 0.777	-0.029	-1.586	↓
NOVEMBER	35.597 ± 1.581	0.024	0.579	↑
DECEMBER	32.910 ± 1.789	0.100	2.706	↑
B				
Minimum Temperature				
JANUARY	17.406 ± 2.558	0.000	0.017	↑
FEBRUARY	19.377 ± 2.488	0.013	0.170	↑
MARCH	23.606 ± 2.197	-0.055	-0.817	↓
APRIL	26.503 ± 1.523	-0.015	-0.442	↓
MAY	26.774 ± 1.227	-0.023	-0.766	↓
JUNE	25.139 ± 1.007	-0.023	-0.766	↓
JULY	23.468 ± 1.139	-0.032	-1.447	↓
AUGUST	22.919 ± 0.784	0.000	0.187	↑
SEPTEMBER	23.061 ± 1.167	-0.030	-1.722	↓
OCTOBER	22.839 ± 1.307	-0.070	-2.979	↓
NOVEMBER	20.013 ± 2.205	-0.056	-2.269	↓
DECEMBER	17.319 ± 1.550	0.020	0.630	↑

4. Discussion

We analyzed the trend in the temperature-time series to determine if there is a climate change or variability present in the city of Sokoto using the period 1980-2010. It was found out that for both monthly, and seasonal observation, there was a series of up-and-down movements, which showed that the climate varied. The fluctuations in the monthly temperature were evaluated using the Analysis of Variance, ANOVA, and the results were statistically different between the various months from 1980 to 2010. Based on the computed months, the result shows a considerable variance in maximum temperature [F (11, 360) = 103.5261, $P < .05$], and also for the minimum temperature based on the computed months [F (11, 360) = 109.8519, $P < .05$].

The mean annual temperature data showed that 2004 was the hottest, while the year 2009 was the coldest. The dry (hot) season was discovered to be the busiest, as there were numerous extreme temperature cases documented for both maximum and minimum temperatures (figure 3). April (figure 19a) was the hottest month throughout the observation period (1980-2010), with a mean temperature of 40.56ºC. (Table 6). Similarly, December (figure 19b) was the coldest month during the observation period (1980-2010), with a mean temperature of 17.32ºC. (Table 6). This further goes confirm that the savannah region has the warmest temperature before the rainy season begins in earnest, and the harmattan (cold-dry) season peaks in December (personal interview). This analysis will help us to understand the climate in the City of Sokoto and turn can be used as a yardstick for the determination of various climatic behaviours in the region.





a b

Figure 19: Plot of the variation in the monthly mean of T_{max} and T_{min} for the period (1980-2010) respectively

Figure 6: Monthly temperature mean for the period 1980-2010

Month	T_{max}	T_{min}
JANUARY	32.48	17.41
FEBRUARY	35.11	19.38
MARCH	38.59	23.61
APRIL	40.56	26.50
MAY	38.85	26.77
JUNE	35.87	25.14
JULY	32.56	23.47
AUGUST	31.45	22.92
SEPTEMBER	33.18	23.06
OCTOBER	36.31	22.84
NOVEMBER	35.60	20.01
DECEMBER	32.91	17.32

This study's temperature trend data revealed nothing but increased climate variability, not a change. In recent times, the semi-arid regions have been found to have a great climate variability according to Byakatonda *et al*., 2018. According to Salih *et al*., 2018, the Sudano-Sahelian region of Africa is very prone to climate variability, which is typically manifested in terms of temperature abnormalities. Variables such as uncontrolled human and animal population expansion can bring about several issues relating to warming in the area (Salih *et al.,* 2018). The cumulative effects of these elements have the potential to increase the region's vulnerability to minor climatic changes, as was the case in the upper Chad Basin, Iraq, Argentina, Greece (Antonio *et al*., 2018; Duka & Karacostas,2018; Salman *et al*., 2018).

5. Conclusions

In the city of Sokoto, temperature series was used to find out about the presence of an increase in the variability in climate. There was found out to be an increase in the seasonal and monthly trend for the observational period (1980-2010). For the maximum temperature series, there was an upward discovered trend for the cold-dry season, dry-hot season, the months January, February, March, April, September, November, December. The minimum temperature also showed the presence of an upward trend in the cold-dry season, months of January, February, August, and December. As a result of the city being prone to every slight change in climate, these results come in handy in the planning and management of various agricultural activities and programs, such as the kind of crops to plant, the time to plant, time to prepare for the harvest, when irrigation is needed and the likes.

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Acknowledgment

Immense gratitude to Nigerian Meteorological Agency (NIMET) for making available Data used for this study.