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Trend Analysis of Temperature in Gombe State Using Mann Kendall Trend Test

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Authors' contributions

This work was carried out in collaboration between all authors. Authors UUA and COE designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ASY and COO managed the analyses of the study. Author EPA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This paper presents the trend analysis of temperature in Gombe State using Mann-Kendall trend test. The annual average of Maximum and Minimum Temperature data was obtained from the Nigerian Meteorological Agency (NIMET), Gombe State. In order to determine the nature of the trend and significance level, Mann-Kendall trend test and Sen's estimate were employed. From this study, it was found out that Maximum and Average temperature exhibit positive Kendall's Z value which indicates an upward trend and also imply increasing trend over time. The Test statistic (Z_S) for maximum and average temperatures are 4.38 and 4.43 respectively. This indicates that there is a significant increase in the trend at 5% level of significance since (p-values (0.0001) <0.05). However, the Z value for minimum temperature (1.59) shows a positive trend but not significant at 5% significant level since the p-value is greater than the significant level (p-value (0.107)>0.05). It can be inferred from both Mann- Kendall and Sen's Slope that there is the tendency of increment in

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temperature. This could be due to the impact of climate change and can lead to weather extremes in the study area. It is therefore recommended that the variability of temperature should be monitored in order to minimize its effects on human activities.

Keywords: Trend analysis; temperature; Mann- Kendall test; climate change.

1. INTRODUCTION

The global climate has been changing pursing advance and widespread threat [1]. While climate change is a global issue resulting from diverse anthropogenic activities, its trends are already affecting livelihoods and food security in the Sahel and West Africa region [2]. The year 2017 witnessed a series of climate related disasters in Nigeria ranging from the increased health risk, declining agricultural production, biodiversity loss, drying lakes, famine, conflicts, social unrest, poverty, worsening food insecurity situation, heat stress, declining Soil capacity for agricultural production, increased natural disaster, extreme weather events among others [3]. Another indirect effect of climate change is the prevailing clashes between herdsmen and farmers in the country in places like Benue, Taraba, Kaduna and Kebbi state in the northern part of the country as a result of inadequate availability of pasture and water which are consequence of climate change.

Change in climate alters temperature regimes in most parts of the world. Temperature is one of the basic climatic parameters and changes in its pattern can affect the living components of the earth [4]. An increase in temperature can result in heat wave incidents and cause illness and death in less resilient populations. In addition, temperature changes can cause a shift in animal and plant species [1]. An increase in Earth's temperature causes convectional current and increase the rate of evaporation thereby leading to cloud formation, which in turn, increases precipitation [5]. Increases in precipitation trends can also result in an increase in the frequency of floods and could thereby affect water quality.

Trend analysis can better be used to depict and predict the changing pattern and variability of climatic parameters (such as temperature and precipitation). This analysis gives knowledge about the changing condition of the climate. Various studies were done using Mann Kendall test. Salami *et al* used Mann Kendall trend test to study Variables such as rainfall, relative humidity, wind speed and sea level rise in Lagos, the result shown positive Kendall's (S) values indicate upward trend and imply an increase of the parameters over time [6]. However, temperature showed negative Kendall's (S) which indicates downward trend and implies decrease over time. Sea level rise, rainfall, relative humidity and wind speed has mean statistics of 3.99, 1.97, 3.09 and 2.26 respectively which are more than 1.96 (test statistics for a significant level of 5% that is ($Z_{0.025}$ =1.96), this implies that the upward trend is significance and there is tendency to continue. Temperature has statistic Z_s of 0.03 which is less than 1.96 and implies no significance, thus the reduction may not be noticed. Dammo, *et al* used same test to study Observed Trend of Changes in Relative Humidity across North-East Nigeria (1981-2010) [7]. Result indicates consistent increase in relative humidity over the years and across location with a stable increase in relative humidity at all locations. Mann–Kendall test was also applied for detecting monthly and annual trends in the relative humidity in Iraq for the Period 1951-2010 [8]. The monthly time series showed that relative humidity is decreasing during winter, spring and autumn months. The current study aimed at using Mann Kendall non-parametric test to analyse the trend in temperature from (1985-2016). Mann-Kendall non-parametric test was chosen for the analysis because of its applicability for a time series distribution, which does not follow a typical statistical distribution.

2. MATERIALS AND METHOD

2.1 Study Area

Gombe state is located between latitudes 09°30' to 12°30' north of the equator and longitudes 08°45' to 11°45' east of the Greenwich meridian and has a total land area of 20,265 km^2[9]. The state has a total population of 268,000 at 2006 census and over 80% are subsistence farmers growing cereals crops [10].

The climate of Gombe state is characterized by six months of dry season alternating with six months of rainy season. Rainy season starts by May and seize by October. This is as a result of seasonal shift of the Inter -Tropical Convergence Zone (ITCZ). The state has an average annual

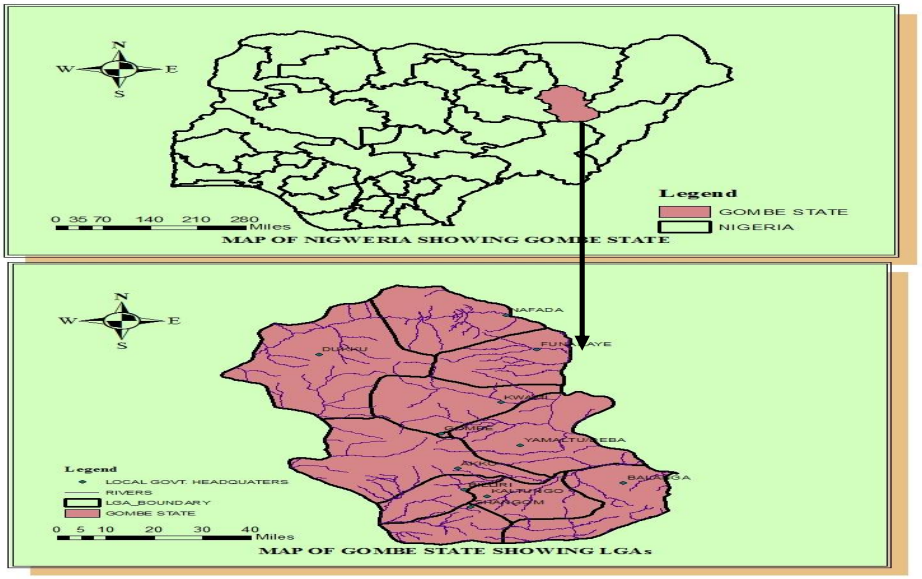

Fig. 1. Map of the study area

rainfall of 850 mm receiving its highest amount in the month of August [6,9]. The mean annual temperature is about 32°C but tends to get hotter around November to March. Around December to February hamattan wind tend to prevail making the weather cooler [11].

Gombe state falls within Sudan savannah type of vegetation characterized by short, thorny and narrow-leaves acacias, shrub and herb layers, and short grasses. Human activities through cultivation, grazing, bush burning and fuel wood exploitation have reduced the vegetation in many places to open farmlands. Some of the prominent species present include; *bulaniteagytica*, *TamarindusIndica*, *adasoniadegitata*, *Parkiabuglungosa, sodon* apple, camel spot, *cumbratum, etc.*

2.2 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 [12]. 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 or hydrological data.

Mann Kendall test is a statistical test widely used for the analysis of trend in climatology and in hydrologic time series. There are two advantages of using this test. First, it is a non-parametric 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 values. Let x_1 , x_2 , x_3 … x_n represent n data points where x_j represents the data point at time j. Then the Mann-Kendall statistic (S) is given by

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

Where:

$$sign(x_j - x_k) = 1 \text{ if } x_j - x_k > 0$$
$$sign(x_j - x_k) = 0 \text{ if } x_j - x_k = 0$$
$$sign(x_j - x_k) = -1 \text{ if } x_j - x_k < 0$$

A very high positive value of S is an indicator of an increasing trend, and a very low negative value indicates a decreasing trend. However, it is necessary to compute the probability associated with S and the sample size, n, to statistically quantify the significance of the trend. The

procedure to compute this probability will be described below.

2.3 Calculation of Probability Associated with the Mann-kendall Statistics

According to Kendall [13], a normal-approximation test that could be used for datasets with more than 10 values was described**,** provided there are not many tied values within the data set.

$$VAR(S) = \frac{1}{18}\left[\begin{matrix} n(n-1)(2n+5) - \\ \sum_{p=1}^{g} t_p(t_p-1)(2t_p+5) \end{matrix}\right] \quad (2)$$

where n is the number of data points, g is the number of tied groups (a tied group is a set of sample data having the same value), and t_p is the number of data points in the p^{th} group.

Compute a normalized test statistic Z as follows:

$$Z_s = \frac{S-1}{[VAR(S)]^{1/2}} \text{ If } S > 0 \quad (3)$$

$$Z_s = 0 \text{ If } S = 0$$

$$Z_s = \frac{S+1}{[VAR(S)]^{1/2}} \text{ If } S < 0$$

Compute the probability associated with this normalized test statistic. The probability density function for a normal distribution with a mean of 0 and a standard deviation of 1 is given by the following equation:

$$f(z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{z^2}{2}} \quad (4)$$

The trend is said to be decreasing if Z is negative and the computed probability is greater than the level of significance. The trend is said to be increasing if Z is positive and the computed probability is less than the level of significance. If the computed probability is less than the level of significance, there is *no trend*. This method, though approximate, is applicable to the datasets because the data to be obtained satisfies the various limitations, i.e., sample sizes greater than 10, and very few ties.

2.4 Sen´s Slope Estimator

If a linear trend is present in a time series, then the true slope (change per unit time) can be estimated by using a simple nonparametric procedure developed by Sen [14]. This means that linear model *f (t)* can be described as [15]

$$f(t) = Qt + B \quad (5)$$

where Q is the slope, *B* is a constant. To derive an estimate of the slope$Q$, the slopes of all data pairs are calculated

$$Q_i = \frac{x_i - x_j}{i-j} \qquad i = 1,2,3,4 \ldots N \; j > k \quad (6)$$

If there are *n* values x_j in the time series we get as many as $N = n(n-1)/2$ slope estimates Q_i. The Sen's estimator of slope is the median of these N values of Q_i. The N values of Q_i are ranked from the smallest to the largest and the Sen's estimator is

$$Q = \begin{Bmatrix} Q_{N+1/2} \; if \; N \; is \; odd \\ \frac{1}{2}\left(Q_{N/2} + Q_{N+1/2}\right) \end{Bmatrix} \quad (7)$$

A *100(1-α)* % two-sided confidence interval about the slope estimate is obtained by the nonparametric technique based on the normal distribution. The method is valid for *n* as small as 10 unless there are many ties [16].

Next $M_1 = (\mathrm{N} - \mathrm{C}\alpha)/2$ and $M_2 = (N + C\alpha)/2$ are computed. The lower and upper limits of the confidence interval, Q_{min} and Q_{max}, are the M_1th largest and the $(M_2 + 1)th$ largest of the N ordered slope estimates Qi. If M_1 and/or M_2 are not a whole numbers, the respective limits are interpolated. To obtain an estimate of B in equation (6) the *n* values of differences $x_i - Qt_i$ are calculated. The median of these values gives an estimate of B [17]. The estimates for the constant B of lines of the 99 % and 95 % confidence intervals are calculated by a similar procedure. Data were processed using an Excel macro named MAKESENS created by Salmi et al. [16].

2.5 Data Acquisition and Processing

To assess the recent trend patterns in Gombe, we collected the historic Temperature (Maximum and Minimum) data for Gombe. The utilized data in this study was kindly provided by the Nigerian Meteorological Agency (NIMET) in Gombe. The data was used to analyse trend in mean annual temperature from 1987 to 2016.

2.6 Method Used in Data processing

Mann Kendall Test was used to study the time series variation. Graphs were plotted using the Microsoft Excel sheet to study the variations of these parameters and Mann Kendall Test was conducted using "XLSTAT", which is an inbuilt functionality in Excel used for Statistical analysis.

The data was analysed to infer for any changes in climate. The data was logically interpreted along with simple tables, charts and graphs.

The temperature data were used to analyse the changes in trend happening in Gombe over the 30 years under study. XLSTAT 2018 was used for Mann-Kendall (MK) statistical test to detect if there is any statistically significant trends existing in the data. This test, MK, is a powerful non-parametric tool for analysing long time series data such as precipitation, temperature etc. Under the null hypothesis (H_0), the assumption is that there is no trend in the data and the alternative hypothesis (H_1) carries the assumption that there is an increasing or decreasing trend over time. The mathematical computational for the MK test statistics S, Var (S) and the standard test statistic Z_S were calculated using Equations (1), (2) and (3) respectively. Microsoft Excel function, **NORMSDIST()**, was used to calculate the probability.

The test statistic Z_S follows a normal distribution and was used as a measure of significance of trend. Positive and negative values of Z_S signify an increase and decreasing trend respectively. A significance level α is used to test the null hypothesis (increase or decreasing) trend exist. If Z_S is greater than $Z_{\alpha/2}$, the null hypothesis is rejected implying that the trend is statistically significant.

3. RESULTS AND DISCUSSION

Trend Analysis of Gombe state has been done with 30 years temperature data from 1987-2016. Mann-Kendall and Sen's Slope Estimator has been used to determine the trend. Fig 2a, 2b, 2c and 2d show the Maximum, Minimum, average temperatures and comparison of the temperatures of the study area for the study period respectively.

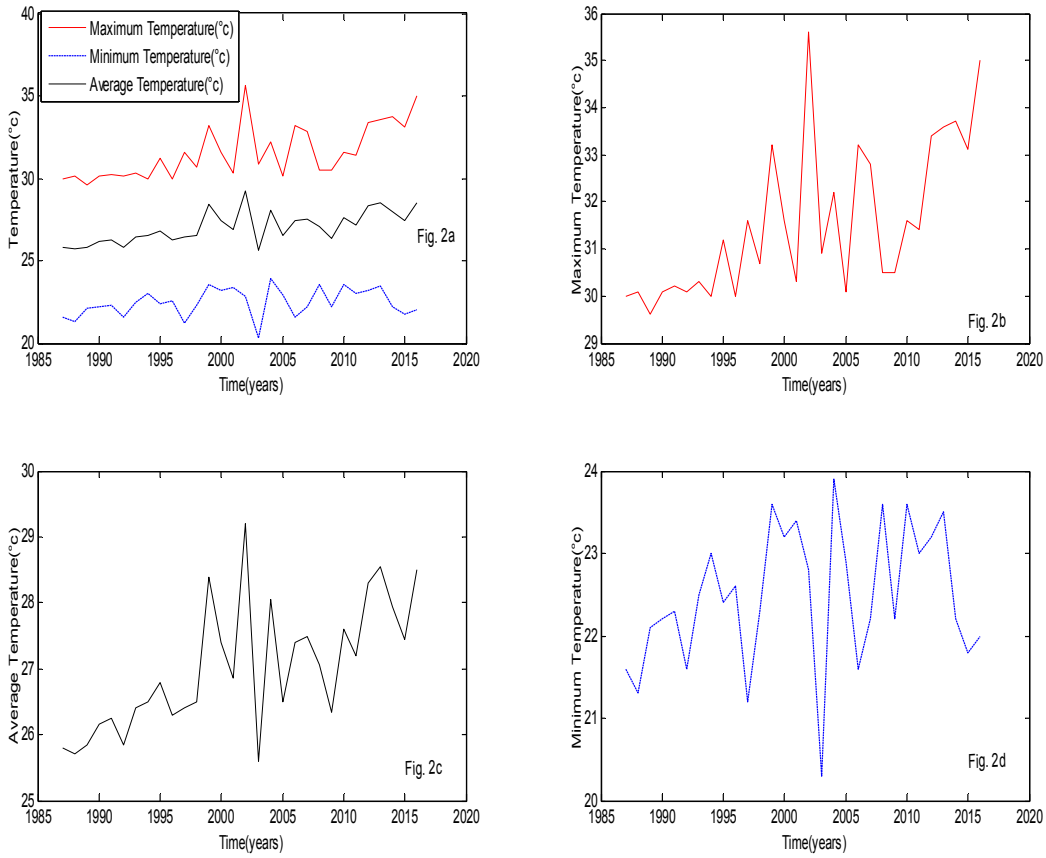

Fig. 2. (a) Plot of Minimum, maximum and average temperature against time. (b) Maximum temperature against time (years). (c) Maximum temperature against time (years) (d) Average temperature against time (years)

Table 1. Mann kendall result of temperature for Gombe state

Variables	Mann kendall statistic (S)	Kendall's Tau	Var (S)	Test statistic (Z)	p-value (two test)	Alpha	Sen's slope Q	Test interpretation
Max. Tempt (°c)	246.00	0.58	3122.67	4.38	<0.0001	0.05	1.29	Reject H_0
Min. Tempt (°c)	90.00	0.21	3122.67	1.59	0.107	0.05	3.50	Reject H_1
Average Temperature (°c)	250.00	0.58	3136.00	4.43	<0.0001	0.05	7.96	Reject H_0

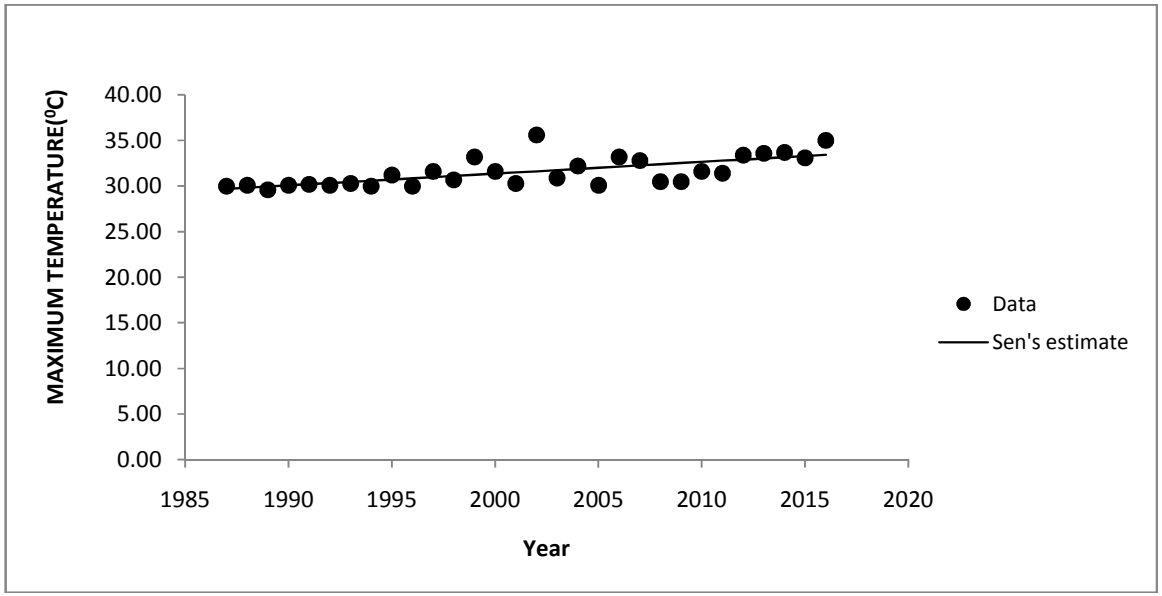

Fig. 3a. Sen's slope of maximum temperature for the period of 1987-2016

Fig 2(a-d) represents maximum, minimum and average temperatures for the study period. fig 2b revealed that the hottest year in the period is 2002 with a maximum temperature of 35.6°C follow by 2014 which recorded 33.7°C while the coldest year is 1989 with a temperature of 29.6°C. Fig 2d indicates that the year 2004 recorded the highest minimum temperature (23.6°C) while 2003 recorded the least minimum temperature. This shows that maximum and minimum temperatures do not exhibit direct relationship.

In the nonparametric Mann-Kendall test, trend of temperature from 1987-2016 has been calculated together with the Sen's magnitude of slope (Q). The result indicates that the Test statistics Z_s for maximum and average temperatures are 4.38 and 4.43 respectively. This means that there is significant increase in the trend at 5% level of significance since (p-values (0.0001) <0.05). However, the Z_s value for minimum temperature (1.59) shows positive trend but not significant at 5% significant level since the computed value (p-value (0.107)>0.05). The results obtained in this study agrees with the findings of an earlier study by Chong et al. [18], whose results showed that the annual and seasonal maximum temperatures are increasingly significant in the arid ecosystem in the Blue Nile-eastern Sudan. The annual minimum temperature and minimum temperature in dry seasons are decreasing respectively.

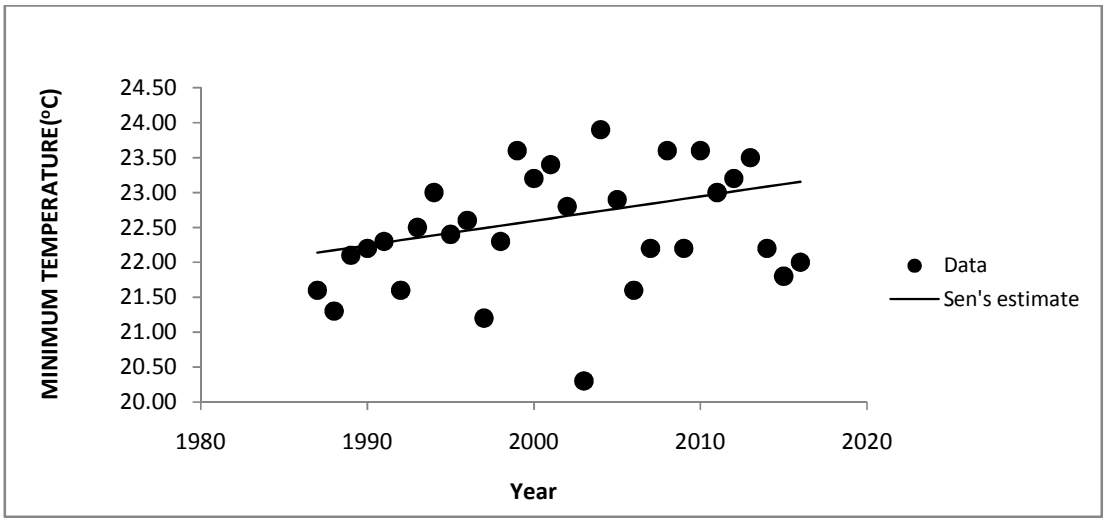

Fig. 3b. Sen's slope of maximum temperature for the period of 1987-2016

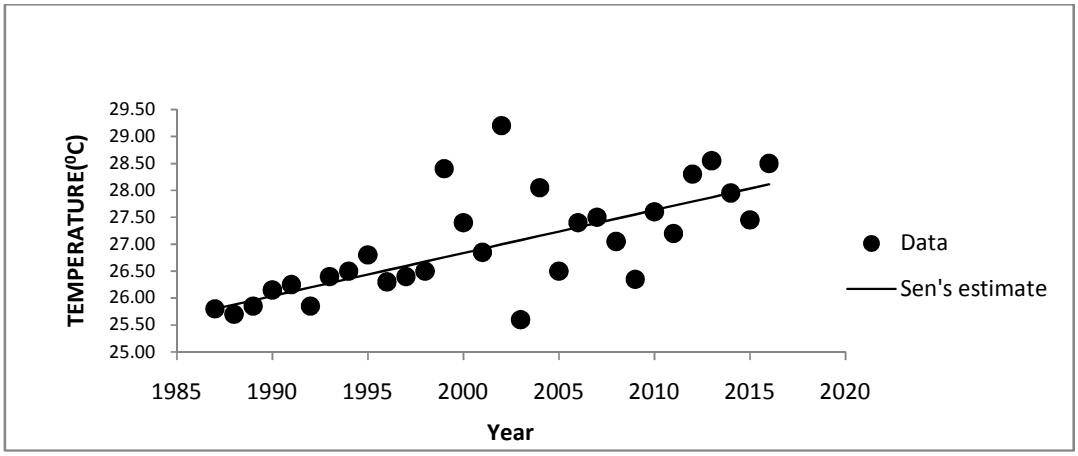

Fig. 3c. Sen's slope of average temperature for the period of 1987-2016

3.1 Sen´s Slopes of the Computed Data

A simple nonparametric procedure developed by Sen [14] was used to estimate the slopes (change per unit time) present in the trend. Positive and negative slope signifies increasing and decreasing slope respectively. Zero slope signifies no trend exist in the data for the study period.

The Sen's estimate as shown in Fig. 3a depicts increase in the trend of maximum temperature. The Sen's slope agrees with the Mann-Kendall Statistic result of positive value (4.38) as an indicator of increasing trend.

The Sen's estimate as shown in Fig. 3b depicts increase in the trend of minimum temperature. The Sen's slope agrees with the Mann-Kendall Statistic result of positive value (1.59) as an indicator of increasing trend. However, the increase is not significant because the computed value is greater than the significance level.

The Sen's estimate as shown (Fig. 3c) indicates an increase in the trend of average temperature. The Sen's slope agrees with the Mann-Kendall Statistic result of positive value (4.43) as an indicator of increasing trend.

4. CONCLUSION

It can be concluded from both Mann- Kendall and Sen's Slope that there is tendency of increment in temperature. This could be due to impact of climate change. However, if caution is not taken, it may lead to weather extremes in the study area. It is therefore recommended that the variability of temperature should be monitored in order to minimize its effects on human activities.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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