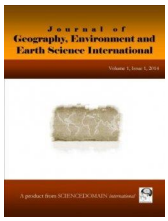

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Trend and Change Analysis of Monthly and Seasonal Temperature Series over North-Eastern Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author MND designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author MND managed the literature searches, analyses of the study performed. Authors BSUIA and AYS managed the experimental process. All authors read and approved the final manuscript.

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ABSTRACT

Temperature is one of the indicative factors of climate change which is one of the very important issues discussed in the recent two decades. The present research aimed at studying temporal and seasonal variation in temperature over North-eastern Nigeria, during the period 1981–2010. Trends in annual and seasonal temperature series were analyzed using Mann-Kendall test. The analysis revealed that temperature ranged between 20.2 - 31.8°C among all the locations, and over months and years. Temperature was significantly higher (P<0.01) in April compare to all the other months. The trends, both annual and seasonal, showed increasing tendency in temperature during the period 1981-2010. There was significant increase (positive trend) in temperature in all studied

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locations (less Taraba where trend was negative), indicating Nigeria is experiencing a rise in air surface temperature too. Since most of the Nigerian population is dependent on economic activities that are temperature sensitive, findings here implicate Nigeria is also one of the susceptible to the attendant consequences of global warming. Thus, the models developed in this study could assist the prediction of temperatures over the locations it covered.

Keywords: Trend; temperature; Mann-Kendall test; climate change; North-Eastern Nigeria.

1. INTRODUCTION

Global climate has changed significantly in the last hundred years. Global mean surface air temperature has increased by 0.74°C during the last century [1]. Increasing temperature and changing patterns of precipitation, are among the many consequences, which are attributed to climate change. Regional variations can be much wider, and considerable spatial and temporal variations may exist between climatically different regions [2]. Temperature differences from day to night and from season to season are the consequences of the intensity of sunlight falling to the surface and into the earth's atmosphere [3]. Rapid industrialization, extensive use of fossil fuels and exploding population growth is the principal cause of the pronounced late twentieth-century warming. [4] reported, the effects and evidences of climate change vary over space and across latitudes. Similarly, there has been report of significant global change in climate mean temperatures over time in the last century indicating increase in temperature [5-10,4,11]. [12] are of the opinion that the global increase in temperature and changes of other climatic variables such as rainfall and evaporation are as a result of greenhouse gas emission. Many researchers [13-17] analyzed temperature-time series from various climate change perspectives across a wide range of temporal and spatial scales. The analysis indicates significant increase of temperature in different parts of the world. [18] noted that, increase in temperature could result in dryness in some areas, while in others areas it may increase rainfall. [19] reported separately that diurnal temperature range (DTR) has been on the decrease in most region of the world.

However, increasing flood risk is now being recognized as the most important threat from climate change in most parts of the region; and this has prompted public debate on the apparent increased, frequency of extreme, and in particular, on perceived increase in temperature intensities [20]. This knowledge of climate variability over the period on different temporal and spatial scale is important to understand the nature of different climate systems and their impact on the environment and society [21]. The present study focuses on the trend and changes of monthly and seasonal temperature series over North-eastern Nigeria. The objectives of the study were to

i. To determine variations in temperature patterns in the study area by using the mean monthly and mean annual temperature values for 30 years.
ii. To determine the effects of temperature variation in the study area.

2. METHODOLOGY

The study site cover an area of approximately 157,000 sq km located between latitude 10°03′ 00′′ – 13°50′ 00′′E and longitude 7°43′ 00′′ – 12°45′ 00′′ N (Fig. 1)

Data were collected on temperature for a period of 30 years, 1981 – 2010. These data were supplemented by Nigeria Meteorological Agency (NIMET) at Abuja and Maiduguri. The data collected were processed into monthly and annual mean values for all the locations based on the formulae:

$$X = \Sigma(xi)/n \quad (1)$$

The integrity of the data was determined by collecting the data from each of the data source and checking for inconsistencies and missing gaps using linear regression to estimate the missing values using the available values [22]. It may be written as:

$$y = a + bx \quad (2)$$

Where:

$$b = n\,\Sigma xy - (\Sigma x)(\Sigma y)/\mathrm{n}\,\Sigma x^2 - (\Sigma x)^2 \quad (3)$$

$$a = \Sigma y/n - \mathrm{b}\Sigma \mathrm{x}/\mathrm{n} = \bar{y} - \mathrm{b}\,\mathrm{x} \quad (4)$$

a is the intercept; b, the regression coefficient or slope; y, the temperature values; x, the time in years; x, the mean time, and $\bar{y}$ is the mean temperature value.

The data collected were subjected to statistical analysis using the analytical software, Statistix Version 8.0 (Microsoft, 2003) to determine the mean annual and monthly values of temperature across locations, using analysis of variance, based on the formulae:

$$S^2 = 1/n \sum (X_t - X)^2 \quad (5)$$

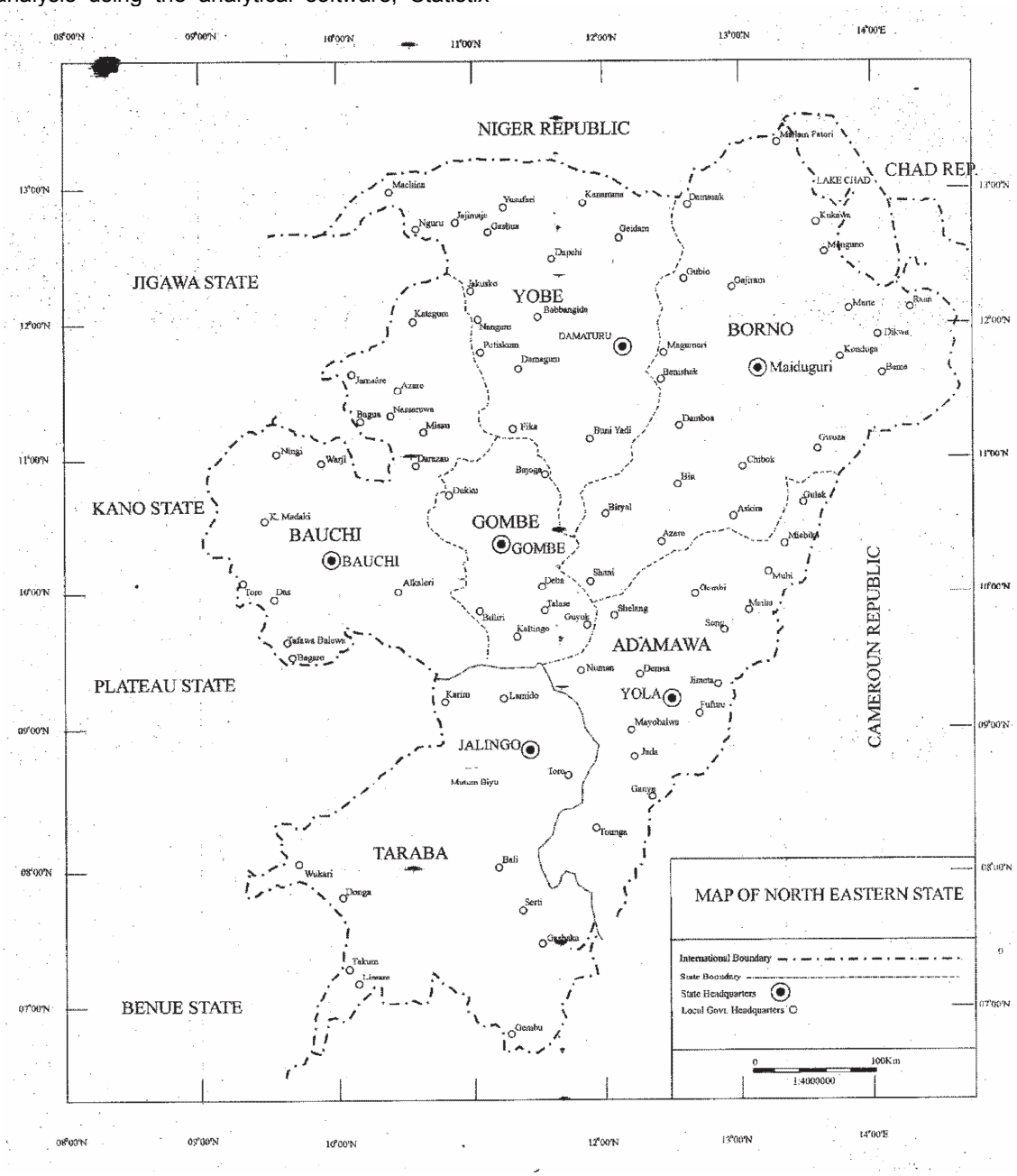

Fig. 1. Map of North – Eastern, Nigeria
Source: Ministry of Lands and Survey Maiduguri, Nigeria

Analysis of variance were carried out to test whether the mean monthly temperature received in the region are the same for the year 1981-2010 or vary significantly and means were compared using least significant difference (LSD) at 5% probability level among locations, years and months base on the formulae:

$$LSD = t\alpha \times \sqrt{MSE/r} \quad (6)$$

Where:

$$t_\alpha = 0.05 \quad (7)$$

Regression and correlation analysis were also carried out using the same analytical software. Trend in temperature was evaluated using Mann-Kendall rank correlation described below:

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

$$sign(x_j - x_k) = 1 \text{ if } x_j - x_k > 0$$
$$= 0 \text{ if } x_j - x_k = 0$$
$$= -1 \text{ if } x_j - x_k < 0 \quad (8)$$

where:

X_j represents the data point at time j
X_k represents the data point at time k

3. RESULTS AND DISCUSSION

Mean temperature varied significantly ($p<0.05$) from 20.2 - 31.8°C among locations, and over months (Table 1).

These variations observed could result from the land resources degradation, sand dune, flood plain and basement nature of the locations- *Are these variations not mostly a result of the natural variations of influential factors from one location to the other?* Yobe recorded the highest mean temperature, followed by Bauchi, Gombe, Borno, Adamawa and Taraba (Fig. 2). The high temperature observed in Yobe is influenced by climatic fluctuation that is reflected by superficial deposit of quaternary Chad formation being a common feature of desertification and the prevailing wind that runs northeast to southwest direction. Thus, the low temperature observed in Taraba could result from high rising hills that have undulating lowlands in between. Table 2 *showed* increased and variability in temperature, in which it increased over all locations (less Taraba where it decreased) over the last decade.

These increase and variability observed could be an evidence of climate change resulting from population increase and excessive emission of CO_2 and greenhouse gases into the atmosphere and the geographical nature of the locations. The observation is in line with the observations of [8,10,4] which indicate increase of mean temperatures over time in the last century. Temperature was significantly higher in April followed by March, May, June and October compared to all the other months successively in Yobe, Bauchi, Gombe, Borno, Adamawa and Taraba (Fig. 3).

However, temperature changes in February, July, September and November did not differ significantly, but were higher than the remaining months of January, August and December.

Table 1. Mean monthly/average annual temperatures of three decades (1981 – 1990, 1991 – 2000 and 2001 – 2010) across the 6 locations in North-eastern Nigeria

Location	Gombe	Adamawa	Taraba	Yobe	Borno	Bauchi
Mean	28.1	26.8	20.2	31.8	27.9	29.9

Table 2. Mean average annual temperature for 3 decades in 6 locations in N/E Nigeria (°C)

Location	Average Temperature (°C)			
	1981 – 1990	1991 – 2000	2001 – 2010 MEAN?	
Gombe	27.66	27.96	28.70	28.1
Adamawa	26.76	25.75	25.87	26.8
Taraba	20.71	20.81	18.76	20.2
Yobe	31.73	31.68	32.06	31.8
Borno	29.29	27.78	28.31	27.9
Bauchi	29.57	29.71	30.4	29.9
Range	20.71 – 31.73	20.81 – 31.68	18.76 – 32.06	

Interactions of location vs year, as well as location vs month were significant (P<0.05). These demonstrated peak temperature in 2007, 2004, 1996, 2009 and 1982 over locations respectively (Fig. 4). For monthly pattern, the month of April appears to be the hottest month at Yobe, Bauchi, Gombe and Adamawa states, while the month of March was the hottest month in Borno and Taraba (Fig. 2). The desertification, flood plain and basement nature of the locations could be the reason for changes in monthly rise in temperature. In addition, temperature values are generally lower in wet (May, June, July, August September and October) season than in dry (January, February, March, April, November and December) season in all the locations. The trend is of 4th order polynomial (Fig. 5), with a monthly rise in temperature at the rate of 11.267 - 17.902°C from the month of (January to April), and subsequently decreased to 0.0036 - 4.2903°C showing rise, fall and rise pattern in the studied period.

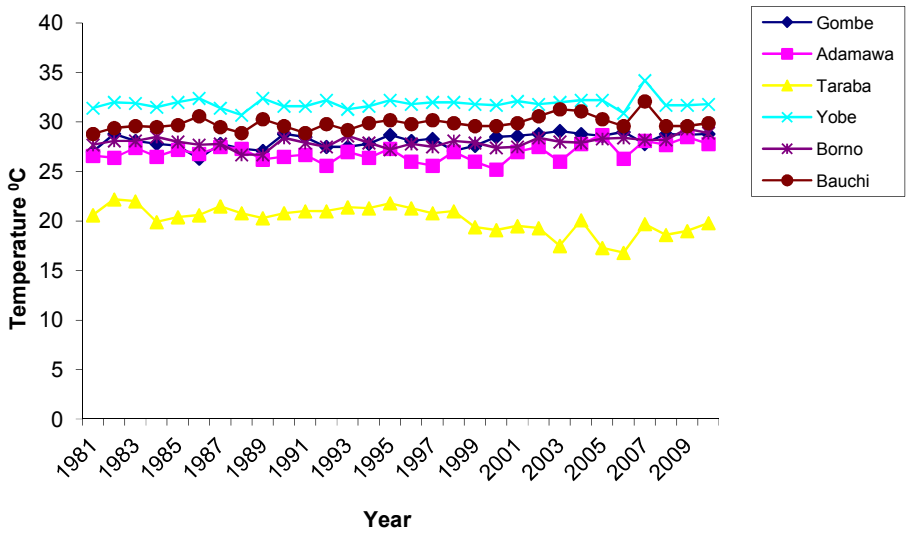

Fig. 2. Pattern of changes in temperature over 30 years in 6 locations in N/E Nigeria

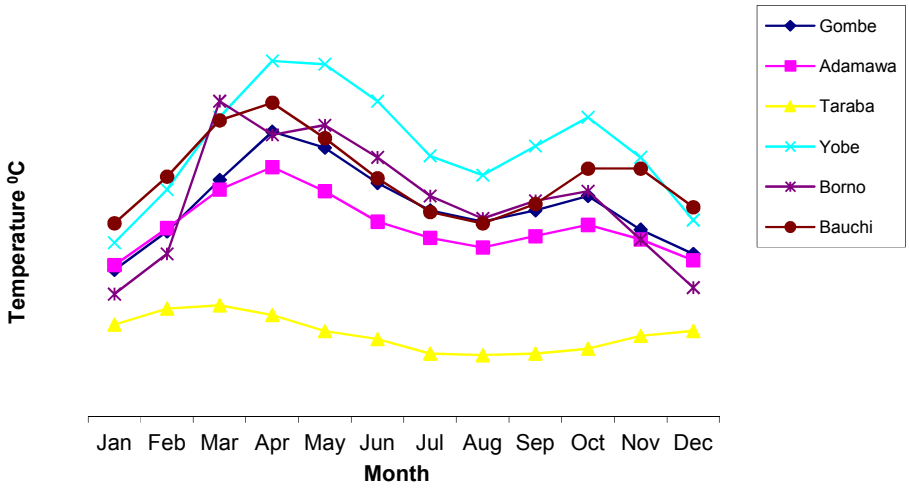

Fig. 3. Pattern of changes in monthly temperature in 6 locations in N/E Nigeria

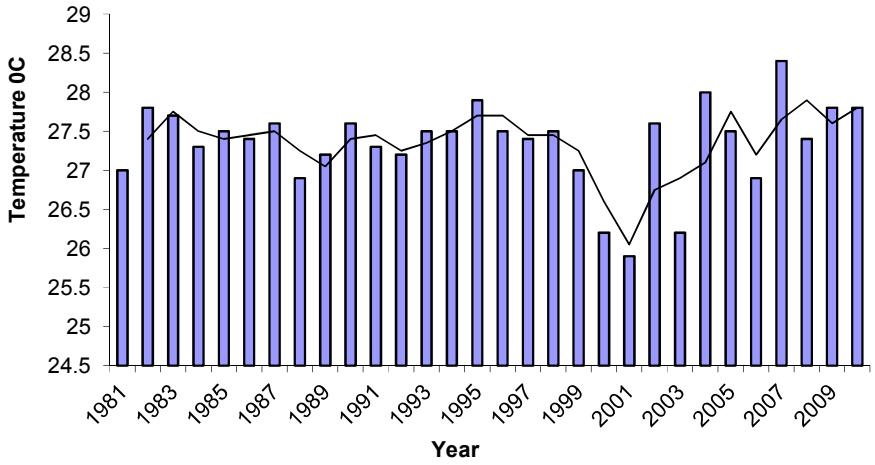

Fig. 4. Relative mean temperature over 30 years period in 6 location in N/E Nigeria

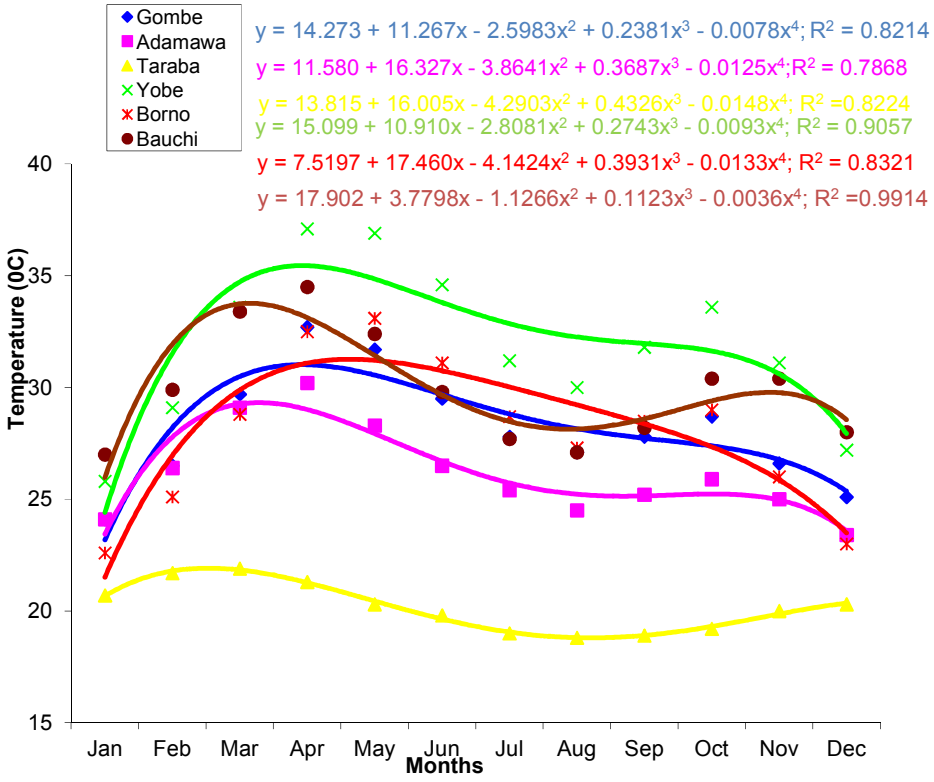

Fig. 5. Mean monthly trend of temperature across 6 locations in N/E Nigeria
Where: y = Temperature (°C); x = water level (m);x^1 = Rainfall (mm); x^2 = Evaporation (mm/day) x^3 = Relative humidity (%); R^2 = Coefficient of determination

4. CONCLUSION

Results expressed highly significant ($p<0.01$) variability in mean temperature across locations. There was significant increase (positive trend) in temperature in the studied area with the exception of Taraba, indicating Nigeria is experiencing a rise in air surface temperature.

Since most of the Nigerian population is dependent on economic activities that are temperature sensitive, findings here implicate Nigeria is also susceptible to the attendant consequences of global warming. Thus, the models developed in this study could assist the prediction of temperatures over the locations covered in this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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