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Rising Temperature: Evidence of Global Warming in Northern Nigeria

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Abstract
Climate change phenomenon is recognized worldwide as serious environmental problem; the risk it poses to all sectors of the economy justifies the considerable attention given to the issue. Trend detection although is not a new exercise is gaining more prominence as tool for analyzing evidence of climate change. The current study used temperature record from 1970-2012 for 11 States of northern Nigeria to detect trend and quantify the magnitude of temperature change in the region, using the Mann-Kendall test and Sen Slope estimator. Findings of the study showed that over the period of forty two years significant ($p< 0.01$) and positive increase in temperature was recorded in the region. Findings of the study led to the conclusion that there was evidence of global warming in the area and the implication for the study was the need for an urgent mitigation and adaptation measures to reduce the negative impact of global warming.
Keywords: Temperature; increase; evidence; global warming; northern Nigeria

Introduction

Climate change is recognized by today's world as the most important environmental problem that affects humanity. It refers to a serious and continuous change in weather pattern, largely attributed to the emission of greenhouse gases such as carbon dioxide, methane, nitrous oxide and water vapor by humans, mainly produced from the transport, agriculture, manufacturing and energy sectors of the economy. Recent changes in climate leads to warmer temperatures, heavy rainfall, drought, floods and cyclones. The impacts of climate change together with rising world population constituted a serious threat to all vital sectors of the world economy. A change in temperature is an important indicator of global warming that directly determines the impact of climate change. Recent concern about rising global temperature was justified by its negative impact in all sectors of the economy most especially water supply, ecosystems, coastal habitats, industries, health and agriculture sectors.

Findings from several studies (Anuforom, 2010; BNRCC, 2011; Farauta et al., 2011; Odjugo, 2010; UNDP 2010) predicted a temperature rise of 1.5 ^{0} to 2.5 ^{0}C for Nigeria in the 21st century. The threat has serious negative consequences for all sectors of the economy. Temperature trend detection is an important exercise in climatology that will provide an indication of the magnitude of global warming this will provide a clear picture of the negative impact of climate change a prerequisite for developing a framework for mitigation and adaptation policies. Among the statistical tools for detecting trend in time series data such as climate, Mann-Kendall is one of the most powerful test that is used in detecting increasing or decreasing trend, it is the strength of this test that makes it suitable for this study.

Despite forecast for rising temperature and its negative consequences for all sectors of the Nigerian economy few studies considered the analysis of temperature trend in the country (Akinsanola & Ogunjobi 2014; Babatolu & Akinnubi, 2013; Ekpoh & Nsa, 2011; Emaziye, et al., 2012; Obasi & Ikubuwaje, 2012; Oyamakin et al., 2010). These studies mainly focused on the southern part of the country. However, among the few studies conducted in some part of northern Nigeria is that of Bose et al., (2014) who reported an increase of 0.76 C° in annual temperature of northeastern part of the country. Despite effort by the previously mentioned studies to analyse the trend of temperature in Nigeria, an extensive analysis over long period of time which covered a significant part of the country is lacking. It could therefore be concluded that little is known about the trend of temperature with regards to northern Nigeria and as such the impact of climate change on the economy is uncertain. Dearth of knowledge on the trend of temperature in northern Nigeria justified the need to conduct temperature trend analysis in the region which was forecasted to be more vulnerable to the impact of climate change among all the regions of Nigeria. This study which is one of the first regional scale study in northern Nigeria, is an attempt to bridge these gaps. Findings of the research are expected to improve the knowledge of temperature trends in the area and provide more insight on the impact to the economy. What makes this study unique is the scope of its analysis where it considered the entire northern Nigeria.

The broad objective of this study is to evaluate temperature trend in northern Nigeria. The specific objectives are:

1. To detect the direction of temperature trend for northern Nigeria
2. To detect the significance of the trend
3. To determine the magnitude of the trend

The rest of the article was structured as follows; under the methodology a brief description of the study area was given, followed by a brief outline on data and statistical trend analysis; results of the study were presented and main findings were analyzed. Finally conclusions were drawn based on the findings of the study.

Materials and Methods

Study area

Northern Nigeria administratively is made up of 19 States out of the 36 States of Nigeria. It covered an estimated 692,826 km^2 almost two third of the total area of Nigeria. The area is located between latitudes 7^0 and 14^0 North and longitudes 3^0 and 15^0 East. The climatic setting of the area supported the production of large varieties of agricultural products. The observed changes in temperature and rainfall trends in the area and dearth of literature on the nature of trend provide the motivation for the study. The short to medium growing grasses are the predominant vegetation found in the area 4 agro ecological zones, namely the southern guinea savanna; the northern guinea savanna, Sudan savanna and a small strip of the Sahel savanna intersected the area. Northern Nigeria is the most populous of all the regions of Nigeria with an estimated population of over 73 million people (NBS 2011). The area is an open grassland savanna; agriculture is the predominant economic activity that provides means of sustenance for most of the population including Women who makes a significant percentage of the agricultural labor force. The area accounts for wide varieties of important food and cash crops produce in Nigeria; this is in addition to providing almost all the livestock animals in the country. The climate of area has two marked seasons wet and dry season the wet season is short usually occurring from May to September. High temperature all year round with wide diurnal variation is one of the main features of the climate. Northern Nigeria generally has a mean annual rainfall of about 500mm.

Data and Statistics

Series of climatic data for 11 stations in northern Nigeria were used for the analysis. Average annual values of temperature and rainfall from 1970-2012 were used to observe the trend of climate change in the study area. Sample statistics such as mean, standard deviation, variance and data normality for the variables were computed to observe the characteristics of the data. The data was obtained from the Nigeria Meteorological Agency (NIMET).

Statistical Trend Analysis

Trend analysis is a widely used statistical method for analyzing climatic and hydrological data. One of the tests for detecting a monotonic increase or decrease trend in the time series of climate such as temperature and rainfall is the Mann-Kendall test. The test is a non-parametric statistical technique that is based on sign differences and not directly on the values of the random variables and as such the test is less susceptible to the effect of outliers. Mann-Kendall test is useful in analyzing data trends over a period of time. It is applicable for dataset with uneven sampling and missing values. The test does not require the assumption of normality for the random variables and is used to show the direction of the significant trends. Due to its superiority Mann-Kendall test has been widely applied to detect trends in climatic studies.

To detect trend using the Mann-Kendall test the null hypothesis H_0 that there is no trend and data are independently and randomly ordered is tested against the alternative hypothesis H_1 that there exist a trend in the time series. Mann-Kendall test statistics S is given by the equation:

$$S = \sum_{k-1}^{n-1} \sum_{j=k=1}^{n} sgn\,(\mathrm{Xj} - \mathrm{Xk}) \qquad (1)$$

Where x_j and x_k are the annual data values in years j, k and n is the length of the data. S is assumed to be 0 if no trend. An S statistic with a high positive value shows an increasing trend whereas low negative value represents a decreasing trend in the time series as in equation below:

$$sgn(xj - xk) = \begin{cases} 1\ if\ xj - xk > 0 \\ 0\ if\ xj - xk = 0 \\ -1\ if\ xj - xk < 0 \end{cases} \qquad (2)$$

To indicate the statistical significance of the trend the probability of S and the sample size n needs to be determined. The variance of S is calculated as VAR(S)

$$\mathrm{Var}\,(S) = \lfloor n\,(n-1)(2n+5) - \textstyle\sum_t (t-1)(2t+5) \rfloor / 18 \qquad (3)$$

The calculated values of S and VAR(S) are obtained to calculate the Z test statistic which is given as:

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & if\ S > 0 \\ 0 \quad if \quad S = 0 \\ \frac{S+1}{\sqrt{Var\,(S)}} & if\ S < 0 \end{cases} \qquad (4)$$

To test the statistical significance of Z value at 95% and 99% levels of significance where the critical value of Z at 95% level is $Z_{0.005} = 1.96$ and the critical value of Z at 99% level is $Z_{0.001} = 2.58$. If Z is negative and the absolute value of Z calculated is greater than the critical value the trend is said to be significantly decreasing but if the value of Z calculated is positive and greater than the critical value the trend is said to be significantly increasing. If the absolute value of Z is less than the critical value it implied that there is no trend and the alternative hypothesis that there is trend is rejected. If the trend is significant it implied that the trend is as a result of a definite cause and not

due to chance alone. A significant trend at 99% level showed that the trend is highly significant.

Theil-Sen method of linear regression

After estimating the Mann-Kendall statistic which only shows the direction of the trend, a Sen Slope estimator called the Kendall robust line fit is applied to calculate the degree of the trend. Sen slope in time series data where the trend is assumed to be linear. The technique was named after Theil Sen who developed the estimator. It is a non-parametric test that is employed to provide an estimate of true slope of the Mann-Kendall trend. It showed the measure of the change in the trend per unit time; it is less vulnerable to single data and outlier effect. One of its strength is that it provides a more accurate estimate than linear regression for skewed and heteroscedastic data. Sen Slope estimation is given by:

$$Q = \frac{Xj}{j} - \frac{Xk}{k} \quad (5)$$

Where Q = Sen Slope estimator X_j and X_k are data values at time j and k

Results and Discussion

Values of the parameters for the statistical analysis conducted in the study were presented in this section. Descriptive statistics of the figures for the States considered in the study were presented in Table 1. Result of the Mann-Kendall test and Sen Slope analysis followed in Table 2. The results showed that among the States Nassarawa had the lowest minimum temperature with a record of 25.7 ^{0}C while Borno States had the highest maximum temperature of 36.3 ^{0}C.

Table 1: Descriptive statistics of the variables used in the study

State	Observation	Minimum	Maximum	Mean	Std. deviation
Adamawa	43	33.042	36.367	34.778	0.585
Bauchi	-	31.867	34.375	33.064	0.583
Borno	-	34.300	36.378	35.281	0.507
Kaduna	-	29.800	34.500	31.756	0.806
Katsina	-	31.900	35.033	33.773	0.625
Kebbi	-	32.200	35.500	34.388	0.625
Kwara	-	29.700	36.400	32.471	0.911
Nassarawa	-	25.700	38.300	28.353	2.419
Niger	-	28.700	38.300	33.218	1.207
Sokoto	-	32.300	36.800	35.259	0.777
Zamfara	-	31.600	35.025	33.703	0.618
Northern Nig.	-	31.418	35.528	33.277	0.647

Furthermore, the result showed that at the regional level northern Nigeria had a minimum temperature of 31 ^{0}C and a maximum temperature of 35^{0}C with a mean temperature of 33.27^{0}C Figure one showed the annual time trend of temperature variable for northern Nigeria. The temperature values considered in the analysis were for a period of 1970 - 2012. The Mann-Kendall test was employed in the study to detect increasing or decreasing trend of annual temperature in northern Nigeria. Statistic for S, Q and Z test for all the 11 States of northern Nigeria detected a positive in the mean temperature of the area over the period of 42 years as shown in Table 2.

Table 2: Result of Mann-Kendall Test and Sen Slope Estimator from 1970 to 2012

State	Unit	S	Q	Z	Trends	p-value	Trend significance
Adamawa	^{0}C	148	0.008	1.53	↑	0.124	NS
Bauchi	-	285	0.021	2.98	↑	0.003	***
Borno	-	95	0.008	0.98	↑	0.325	NS
Kaduna	-	369	0.035	3.85	↑	0.000	***
Katsina	-	239	0.022	2.49	↑	0.013	**
Kebbi	-	127	0.01	1.32	↑	0.187	NS
Kwara	-	53	0.005	0.54	↑	0.58	NS
Nassarawa	-	289	0.025	3.02	↑	0.003	***
Niger	-	104	0.01	1.07	↑	0.281	NS
Sokoto	-	249	0.025	2.59	↑	0.009	***
Zamfara	-	75	0.008	0.77	↑	0.439	NS
N. Nigeria	-	305	0.023	3.18	↑	0.001	***

Note: *** significant at 1%; **sig. at 5% level; NS; not significant

The significance of the trend was tested at 95% and 99% levels of significance. Results of the study for the States revealed varying levels of significance for the positive trend. The statistic for Z test values of Bauchi, Kaduna, Nassarawa and Sokoto showed that the trend of rising temperature was significant at 99% level whereas the level of significance of the trend for Katsina State was significant at 95% level. The Z statistic for Adamawa, Borno, Kebbi, Kwara and Zamfara showed that the trend for temperature increase was not significant. The result implied that for most of the States there was a significant rise in temperature over the period of 42 years. This finding has an important implication for the socio economic development of the States as most the people are farmers whose agricultural activities solely depend on climate.

Analysis of data for the whole region of northern Nigeria revealed that the value of Mann- Kendall S obtained was 305 with a Sen Slope estimate of 0.023 and a Z statistic of 3.181. These values indicated that over the period of 42 years from (1970-2012) mean temperature for northern Nigeria increased with about 0.023 ^{0}C and the increase was statistically significant (p> 0.01). This shows that although the magnitude of the rise in temperature was small: there was a significant rise in temperature for northern Nigeria in recent times (Figure 1).

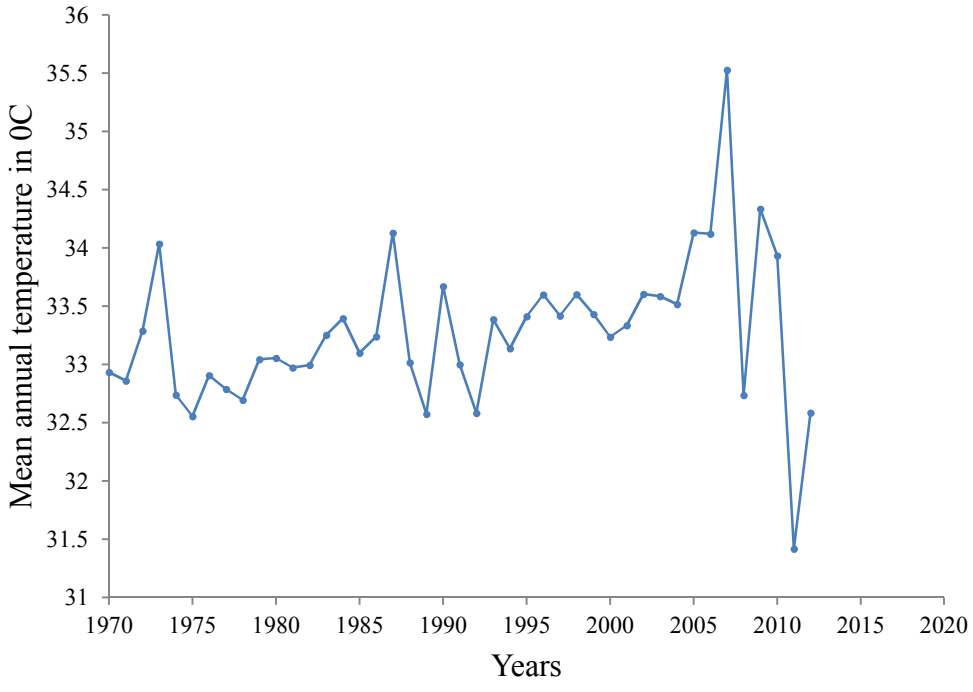

Figure 1: Temperature Trend in Northern Nigeria from 1970-2012

The spatial distribution of annual temperature trends (mm per decade) is shown in Figure 2. Positive slopes represent an increase in temperature over the period and negative slopes represent a decrease in temperature. The temperature trend contour map illustrates the spatial distribution of temperature trends in the study period using ordinary kriging as interpolation technique. The result could be a strong evidence of global warming in northern Nigeria. Similarly, the result of the study at the regional level could be important in so many ways.

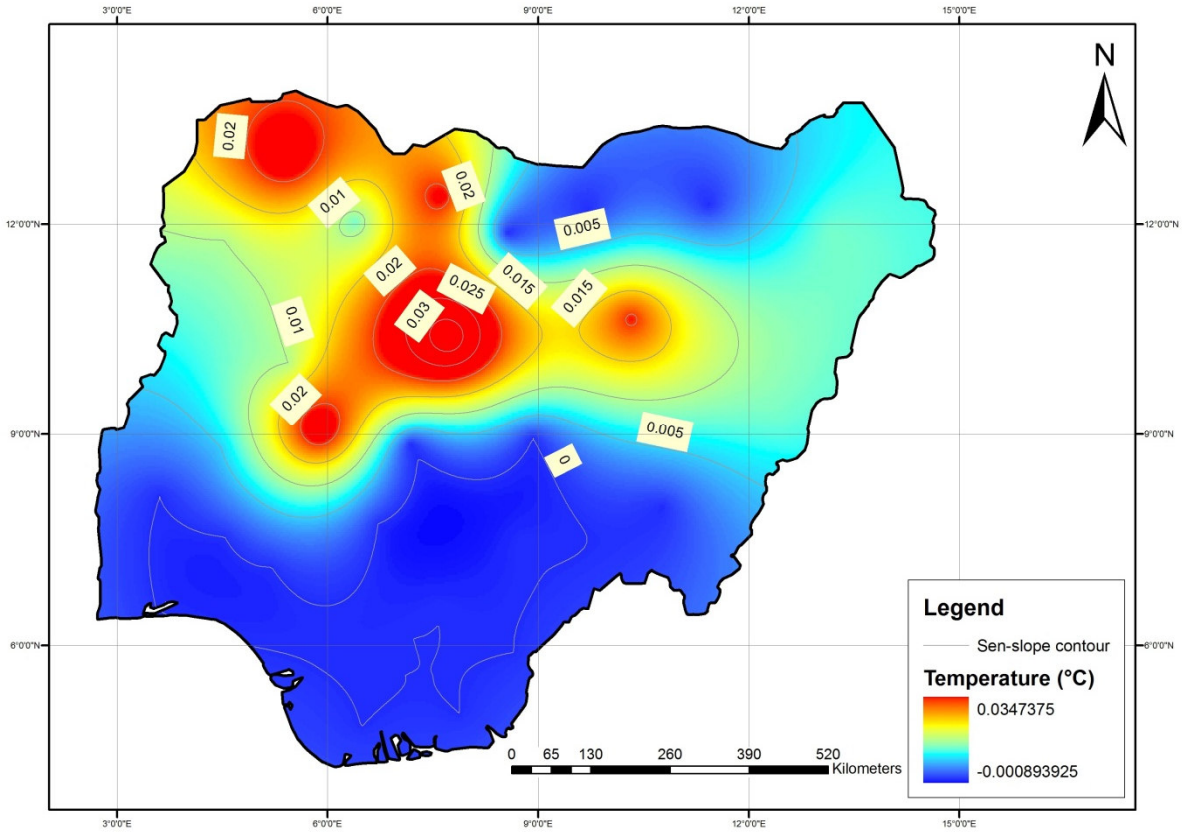

Figure 2: Spatial distribution of mean temperature trends for northern Nigeria ^{0}C from 1970-2012

Although the magnitude of change seems small, little change in temperature may translate to an enormous change in the environment. A large percentage of the people in the area depend on natural resources for their livelihood and indirectly they relied on climate for survival. Proliferation of many pest and diseases is linked to climate. Rise in temperature could be harmful to the hydrological balance of the already dry northern Nigeria. In general increase in temperature will have serious negative impact on the social and natural systems which people depends on for survival. This finding was consistent with similar studies that observed an increase in temperature for the area in recent years (Anuforom 2010; Farauta et al 2010; Odjogu 2011).

Conclusion and managerial implications

Presenting a trend of temperature changes over time will clearly show how climate manifested itself; this will provide an insight on the behavior of future climate scenario. Emerging scientific facts showed evidence of rising world average temperature due to global warming. The same observations were made with regards to the climate of northern Nigeria. Evaluating the direction and magnitude of temperature increase in northern Nigeria is an important step towards developing mitigation and adaptation options with the aim of reducing vulnerability of climate change impact. This study using a time series data for a period of 42 years attempted to determine the trend and magnitude of rise in temperature in northern Nigeria. Findings of the study showed that the average temperature of the area has witnessed a significant positive trend in recent times. The result provided enough evidence of global warming in the region. This study differed from other studies in Nigeria in that it considered the entire northern region. The current analysis was limited to one element of climate; future researches should include other climatic elements and strive to cover more geographical area.

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