Journal of Forestry Research and Management. Vol.9, 61-72; 2012. ISSN: 0189-8418

ANALYSIS OF TEMPERATURE TRENDS OF IBADAN, NIGERIA OVER THE PERIOD OF 1965-2013

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ABSTRACT

Trends and variations in the annual mean, maximum and minimum temperatures of Ibadan, Nigeria were analyzed for 1965-2013 using data obtained from the meteorological station of Forestry Research Institute of Nigeria, Ibadan. Trend analysis using linear regression showed an increase in trends in the air temperatures over the period. These trends were statistically significant (at 5% confidence levels) with high coefficient of relationship (R^2 = 0.5 and 0.53 respectively) for annual mean and minimum temperatures. Meanwhile, there was no significant difference for maximum temperature (at 5% confidence levels) and the relationship was not strong (R^2 = 0.01). These increases in air temperatures have been attributed to urbanization and industrialization which was reflected by the population increase of Ibadan in the past years. The rising temperatures in Ibadan are not a healthy signature for crop production, water resources and hence human inhabitation in this region.

Keywords: annual mean temperature, maximum temperature, minimum temperature, trends, climate change.

INTRODUCTION

Climate change and global warming arising from anthropogenic-driven emissions of greenhouse gases and land-use and land-cover change have emerged as one of the most

important environmental issues in the past few decades (Singh *et al*., 2013). The continued build-up of greenhouse gases may force changes to the climatic system including increases in mean global temperatures. Changes in climate have significant implications for societies, future generations, the economy, ecosystems and agriculture (Capparelli *et al*., 2013). The global mean surface air temperature has been found to have risen by about 0.74°C from 1906 to 2005 and been attributed mostly to a rise in greenhouse gases (Intergovernmental Panel on Climate Change, 2007). The studies of urban climate are attracting significant attention in the present world. Several studies have attempted to assess the effect of urbanization and industrialization on temperature trends (Dhorde *et al*., 2009; Singh *et al*., 2013). Some studies have tried to establish a link between some of the intense man-made activities of urban industrial areas and temperature trends and found increased size and density of population, land use/land cover changes, reduction in the fraction of vegetative area, exclusive use of fossil fuel combination and emission of waste heat from industries, automobiles and building construction activities (roads, buildings etc), excessive use of air conditioning etc., responsible for the changing trends in temperature.

Studies have also been done on the global, regional and local basis on the trends in the monthly, seasonal and annual mean, maximum and minimum temperatures as well as diurnal temperature range (Dhorde *et al*., 2009, Jain and Kumar 2012, Ogolo and Adeyemi 2009, Rui and ZhiHua, 2013, Singh *et al*. 2013, Tshiala *et al*., 2011). Dhorde *et al*. (2009) observed a negative change in temperature with increase in population in India, indicating that the effect of urbanization is more pronounced during post-monsoon and winter seasons. Tshiala *et al*. (2011) also observed seasonal trends with variability in mean temperature increase, of about 0.18°C per decade in winter and 0.09°C per decade in summer.

Changes in temperature influence the hydrological cycle processes directly or indirectly. An increase in temperature causes the intensification of the hydrological cycle due to increase in evaporation and precipitation (Jain and Kumar, 2012; Tshiala *et al*., 2011). Temperature changes can therefore lead to changing patterns of precipitation, the spatial and temporal distribution of runoff, soil moisture, and groundwater reserves as well as increased frequency of drought and flood occurrences (Tshiala *et al*., 2011). Changing temperature patterns could also have effects on soil and plant growth characteristics since temperature and water content are important physical factors for plant growth. Non-optimum levels of water and temperature conditions can strongly perturb plant development, especially at the early stages

of growth such as seed germination and emergence (Tshiala *et al*., 2011). Due to the importance of atmospheric temperature and limited studies on the trends of temperature in Nigeria, it would be of interest to study the long-term variations of air temperature at Ibadan, South-West Nigeria which in the past few decades has noticed phenomenal rise in urbanization and industrialization. This is done using forty five years of mean, maximum and minimum temperature data obtained from Forestry Research Institute of Nigeria (FRIN) meteorological station.

METHODOLOGY

Study area

Ibadan is the capital of Oyo state in the South-West geo-political zone of Nigeria. Ibadan lies in the low latitude 7°3′N to 7°4′N and longitude 3°8′E to 3°9′E and is situated near the forest-grassland boundary of south-western Nigeria. The climate is tropical with wet and dry seasons. During the wet/rainy season (March – October), the city is under the influence of moist maritime south-west monsoon wind which blows inland from the Atlantic Ocean. The dry season occurs from November to February during which time, the dry dust laden winds blow from the Sahara desert (Ogolo and Adeyemi, 2009). This dry season is characterized with low humidity and high evaporation rate. The annual average temperature is between 24 and 32 °C with the average annual relative humidity of 80% and average annual precipitation between 1007 and 1703 mm.

Data collection and analysis

Monthly data of mean, maximum and minimum temperatures were obtained from the Forestry Research Institute of Nigeria (FRIN), Ibadan meteorological station for the period of 1965 to 2013 with the exception of 1975 due to missing data. Population data (Table 1) were collected from the National Population Commission (1991 and 2006) publication.

Table 1: Population of major Local Governments in Ibadan, Nigeria

Local Government	Population 1991	Population 2006	Percentage Increase	*Rate of Growth*

IBADAN LESS CITY				
Akinyele	140,118	211,359	50.84%	*2.78%*
Egbeda	129,461	281,573	117.50%	*5.32%*
Ido	53,582	103,261	92.72%	*4.47%*
Lagelu	68,901	147,957	114.74%	*5.23%*
Ona-Ara	123,048	202,725	121.49%	*5.44%*
Oluyole	91,527	265,059	115.41%	*5.25%*
Sub - Total	**606,637**	**1,211,934**	**99.78%**	***4.7.%***
IBADAN URBAN				
Ibadan North	302,271	306,795	1.5%	*0.10%*
Ibadan North East	275,627	330,399	19.87%	*1.22%*
Ibadan North West	147,918	152,834	3.32%	*0.22%*
Ibadan South East	225,800	266,046	17.82%	*1.10%*
Ibadan South West	227,047	282,585	2.00%	*0.13%*
Sub Total	**1,228,633**	**1,418,82**	**15.43%**	***0.57%***

Source: National Population Commission 1991 & 2006

Trend analysis of a time series consists of the magnitude of trend and its statistical significance (Jain and Kumar 2012). Linear regression method commonly used to find long-term trends (Dhorde *et al*., 2009; Jain and Kamar, 2012; Ogolo and Adeyemi, 2009; King'uyu *et al*., 2000; Rui and Zhihua, 2013; Singh *et al*., 2013; Tshiala *et al*., 2011; Ziv *et al*., 2013) was used in this study to derive trends in temperature. The regression analysis was conducted with time as the independent variable and temperature as the dependent variable as described by Jain and Kumar (2012). The magnitude of the temperature trends was derived from the slope *m*, of the regression line, as shown in equation (*i*). This slope represents the rate of change per unit time (Dhorde *et al*., 2009). The Analysis of Variance test was also used to test for statistical significance of temperature trends.

$$y = mx + c \qquad (i)$$

In this study, population of the city has been used as an index of urbanization. Several other parameters such as land cover, land use change, energy consumption and construction activities can also be used as indices of the extent of urbanization (Dhorde *et al*., 2009). Data of the population of Ibadan were presented in a tabular format to identify the extent of

industrialization and urbanization. This is in line with the method adopted by King'uyu *et al*. (2000).

RESULTS AND DISCUSSION

The annual mean, maximum and minimum temperature variations have been presented in figure 1. The residuals of data for annual mean, maximum and minimum temperatures have been presented in figure 2. During the study period, the warmest years with the annual maximum temperature of 34.1°C and 33.9°C were 1974 and 1998 respectively. The year with the lowest maximum temperature was 2005 with a value of 30.5°C. For the study period, 1976 had the least annual minimum temperature of 18.3°C (figure 1c) which was 3.9°C below the normal as shown in figure 2c. Observed annual mean temperature is affected by both maximum and minimum temperatures. The year with the highest mean temperature of 29°C was 1998 which was 1.2°C above the normal (Figure 2a). The coolest year with mean temperature of 24.8°C, 2.3°C below the normal was 1976.

Table 2: Summary of regression analysis of annual mean, maximum and minimum temperatures

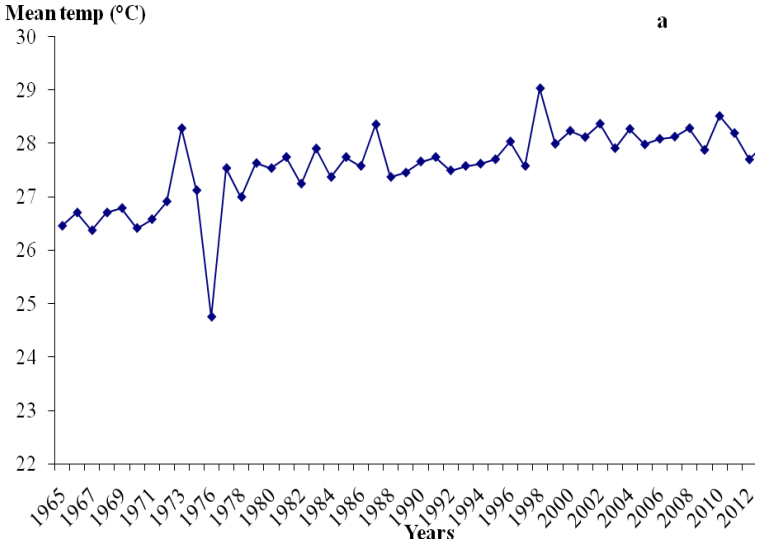
	F statistic value	Trend coefficient (°C/10y)	R^2 value
Mean Temperature	46.53	0.36*	0.50
Maximum Temperature	0.57	0.05	0.01
Minimum Temperature	51.41	0.67*	0.53

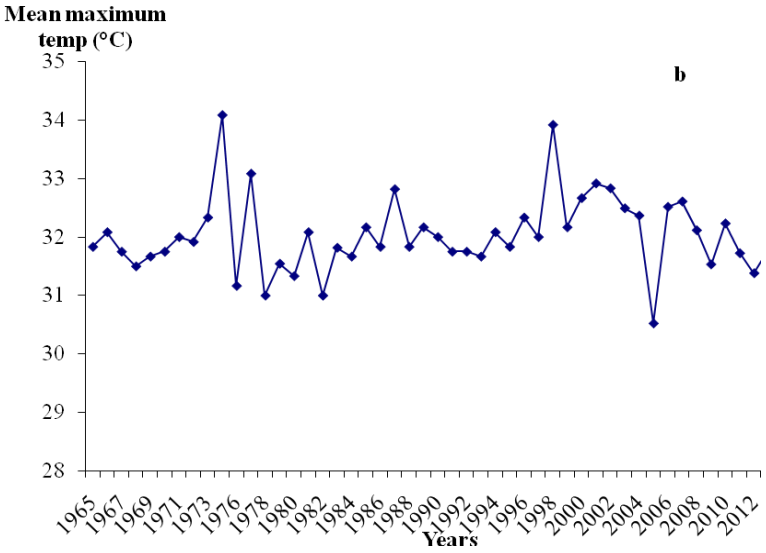
*significant at 95% confidence level

As shown in Figure 3 the annual mean temperature, maximum temperature and minimum temperatures all showed rising trends over the past 48 years. These changes were significant for annual mean and minimum temperatures with a temperature increase of 0.36°C and 0.67°C per decade respectively (Table 2). The increasing trend in the annual maximum temperature was however not statistically significant with a very weak R^2 value of 0.01. The annual mean temperature trend can be represented with the linear equation $y = 0.0362x - 44.453$. This result is in agreement with some studies that showed a rising trend in the annual mean, maximum and minimum temperatures. Ogolo and Adeyemi (2009) studied the variations and trends of six meteorological parameters in Ibadan for the period 1988 – 1997. They observed an annual increasing trend in air temperature that was statistically non-

significant. This could be attributed to the small number of study years (10 years). Jain and Kumar (2012) also found a rising trend in the mean maximum temperatures at most of the study stations in India with a decreasing trend at few of the stations. The study of linear trend by Singh *et al*., (2013) also found increasing trends in annual maximum, minimum and mean temperatures in Dehradun city, India during the period of 1967 to 2007. Rui and ZhiHua (2013) found increasing trends the annual average, highest and lowest temperatures over past 55 years in Guyuan city, China. The surface temperatures of a region vary seasonally and annually depending on the latitude, altitude and location with respect to geographical features such as water bodies (river, lake or sea), mountains etc (Jain and Kumar, 2012).

The rise in temperature exhibits a behaviour that is related to the global warming trend. The warming can be attributed to urbanization process as Ibadan has experienced industrialisation and urbanization which can be illustrated by the population increase (Table 1) over the past years. With the introduction of high-rise buildings in Ibadan in recent years, the city is able to absorb more solar radiation. The city also consumes huge resources, particularly the fossil fuels due to large vehicular population and power generation. Deforestation can also be a major contributor to the climate change being reflected in this study by the increases in air temperatures as most forest lands are increasingly been cleared for agricultural, residential and economic uses to be able to meet the increasing population demands.


Mean temp (°C)
a
30
29
28
27
26
25
24
23
22
1965 1967 1969 1971 1973 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Years


Mean maximum temp (°C)
b
35
34
33
32
31
30
29
28
1965 1967 1969 1971 1973 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Years

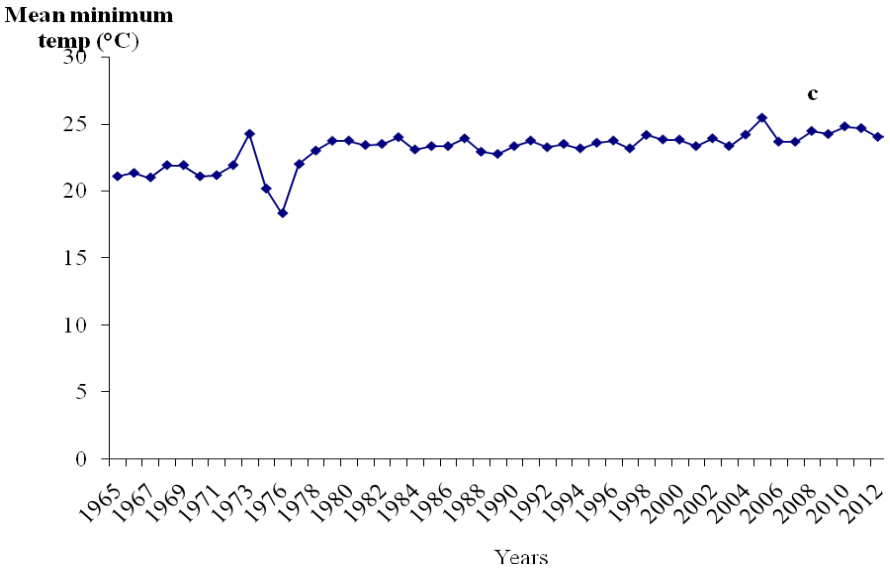
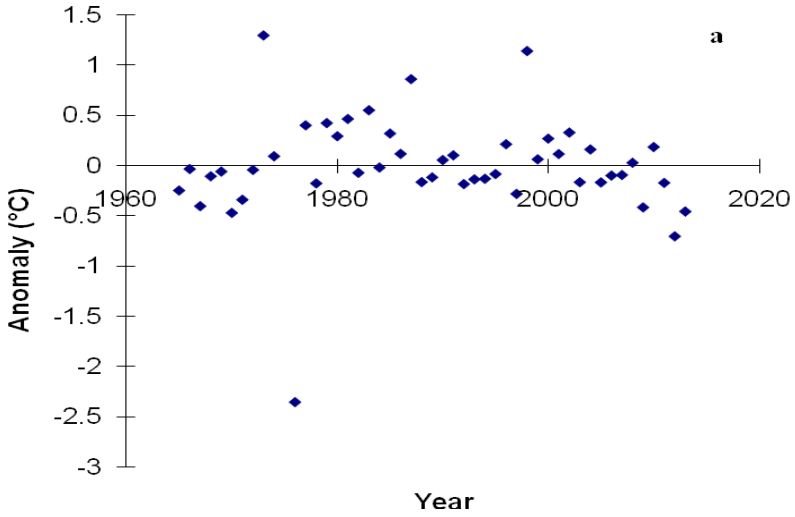
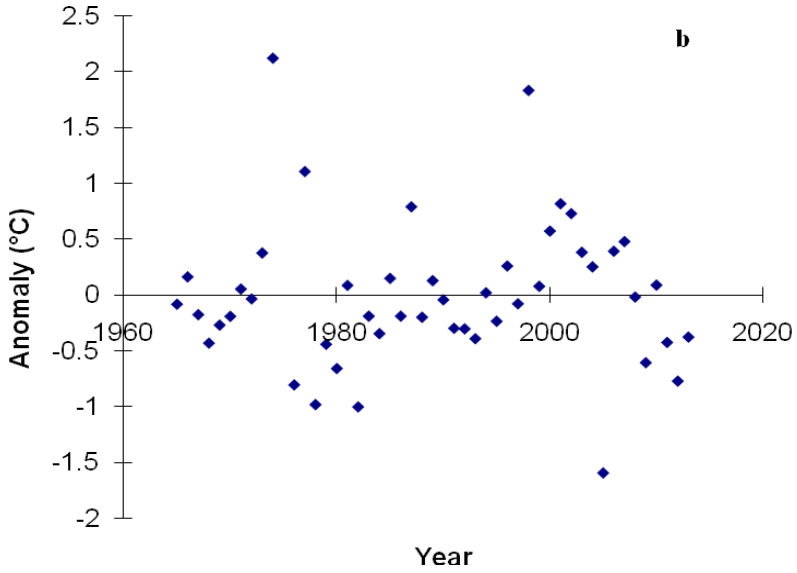


Figure 1: Annual mean (a), maximum (b) and minimum (c) temperatures of Ibadan for the period 1965-2013


a
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
1960
1980
2000
2020
Anomaly (°C)
Year


b
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
1960
1980
2000
2020
Anomaly (°C)
Year

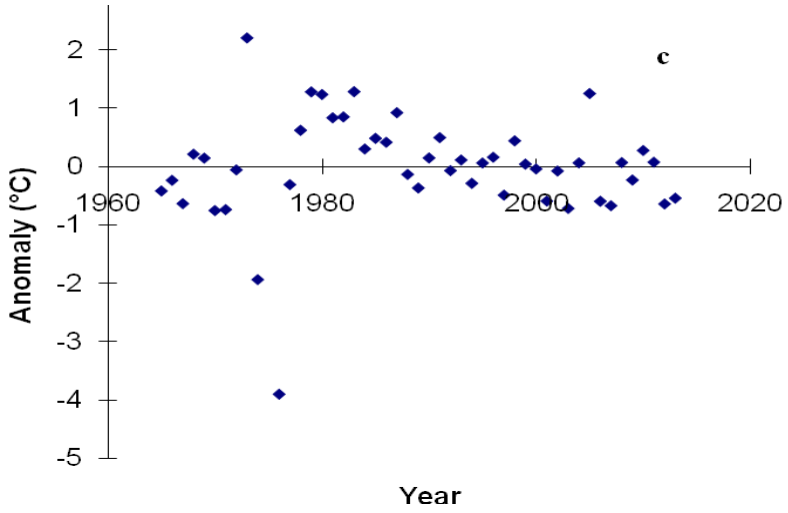
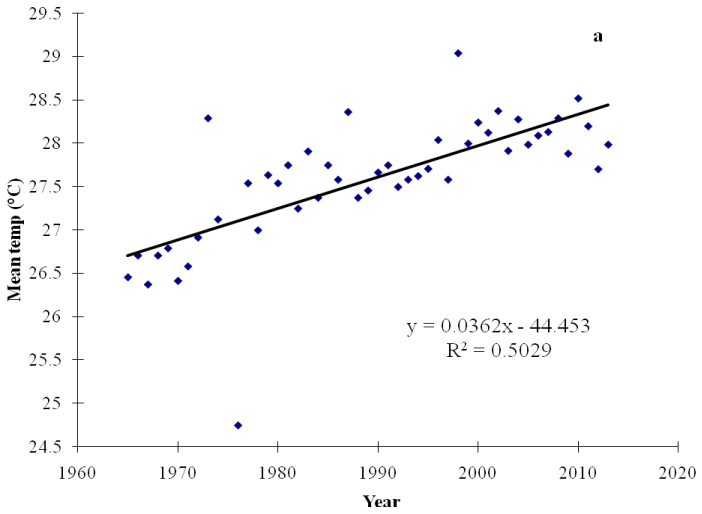
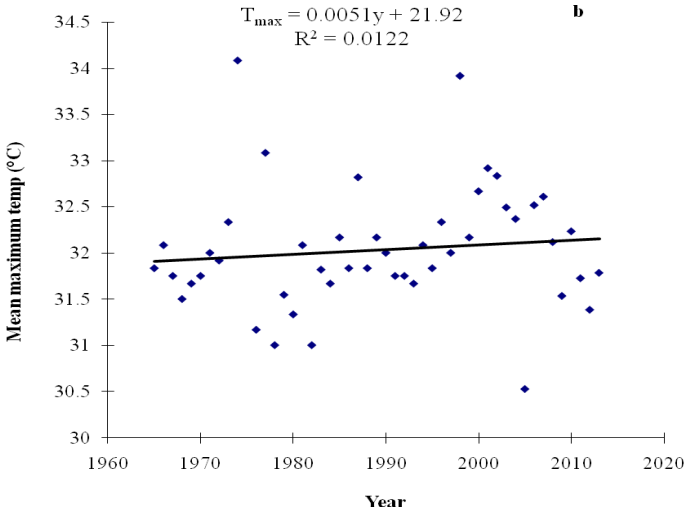


Figure 2: Residuals of annual mean (a) maximum (b) and minimum (c) temperatures of Ibadan for the period 1965-2013


a
Mean temp (°C)
Year
y = 0.0362x - 44.453
R² = 0.5029


b
Tmax = 0.0051y + 21.92
R² = 0.0122
Mean maximum temp (°C)
Year

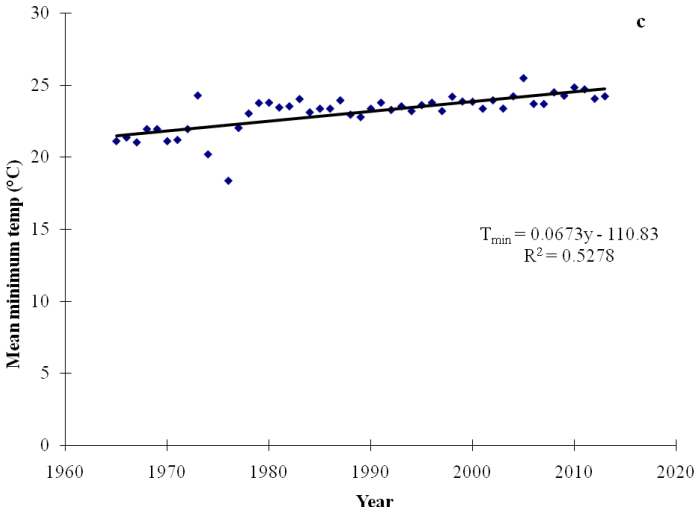

c
Mean minimum temp (°C)
Year
Tmin = 0.0673y - 110.83
R² = 0.5278

Figure 3: Regression analysis of annual mean (a), mean maximum (b) and mean minimum (c) temperatures.

CONCLUSION

The influence of weather and climate on the environment, forestry and human well being cannot be disregarded. All over the world, urban areas are being affected by urban climate change. If we know the status of the climate today and the differences between this and recent past, we can begin to plan for the future. Intergovernmental Panel on Climate Change (IPCC) in its January 2001 report concluded that most of the warming observed over the last 50 years is attributable to human activities (especially emissions of heat trapping gases from fossil fuels). Other anthropogenic activities include urbanization, industrialization, increase in automobiles, deforestation, etc. These changes are having a lot of influence on meteorological parameters.

The results from this study indicated increases in annual mean, maximum and minimum temperatures of Ibadan, Nigeria from the period of 1965 – 2013. Overall there was an increase of 0.4°C per decade in the annual mean temperature of Ibadan over the study period. This trend is undoubtedly real and warming is large enough to have significant impacts on the hydrology, agricultural productivity and natural ecosystems of the region.

The variability of temperature trends has been found to exhibit a spatial dependence therefore further work is required to investigate the temperature trends of other regions in the country which would be beneficial in making better decisions towards the mitigation and adaptation of climate change.

REFERENCES

Capparelli V., Franzke C., Vecchio M., Freeman M.P., Watkins N.W. and Carbone V. (2013): A spatiotemporal analysis of U.S. station temperature trends over the last century. *Journal of Geophysical Research: Atmosphere*, 118:1-8.

Dhorde A., Dhorde A. and Gadgil A.S. (2009): Long-term Temperature Trends at Four Largest Cities of India during the Twentieth Century. *J. Ind. Geophys. Union*, 13(2): 85-97.

Intergovernmental Panel on Climate Change (2007): Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge Univ. Press, Cambridge, U. K.

Jain, S.K. and Kumar, V. (2012): Trend analysis of rainfall and temperature data for India. *Current Science*, 102 (1): 37-49.

King'uyu S.M., Ogallo, L.A. and Anyamba, E.K. (1999): Recent Trends of Minimum and Maximum Surface Temperatures over Eastern Africa. *Journal of Climate*, 13: 2876-2886.

Ogolo, E.O. and Adeyemi, B. (2009): Variations and Trends of Some Meteorological Parameters at Ibadan, Nigeria. *The Pacific Journal of Science and Technology*, 10(2): 981-987.

Rui L. and Zhi Hua Z. (2013): Analysis of Temperature Variation over the Past 55 Years in Guyuan City, China. *International Journal of Science and Research*, 2(8): 1-5.

Singh O., Arya P. and Chaudhary, B.S. (2013): On rising temperature trends at Dehradun in Doon valley of Uttarakhand, India. *J. Earth Syst. Sci.* 122(3): 613-622.

Tshiala M.F., Olwoch J.M. and Engelbrecht F.A. (2011): Analysis of Temperature Trends over Limpopo Province, South Africa. *Journal of Geography and Geology*, 3(1): 13-21.

Ziv B., Saaroni H., Pargament R., Harpaz T. and Alpert P. (2013): Trends in rainfall regime over Isreal, 1975-2010, and their relationship to large-scale variability. *Regional Environmental Change*, 13(1): 14 pp.