International Research Journal of Agricultural Science and Soil Science (ISSN: 2251-0044) Vol. 6(2)
pp. 025-031, May, 2016
Available online http://www.interesjournals.org/IRJAS
DOI: http:/dx.doi.org/10.14303/irjas.2016.013

Full Length Research Paper

Analysis of trend and variability of atmospheric temperature in Ijebu-Ode, Southwest Nigeria

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Abstract

Heat waves have become more frequent as global warming continues to raise the average temperature of the earth. This study investigated the annual average trend and variability of atmospheric temperature in Ijebu-Ode, Southwest Nigeria. Secondary data of atmospheric air temperature was obtained from the Nigeria Meteorological agency (NIMET) Ijebu-Ode, Ogun state station, which covers thirty-one (31) years. Both parametric (Least Square Regression) and non parametric (Mann Kendall) test was performed on the data to investigate the trends, while variability was investigated using the t-test statistics and standardized index. The analysis of result revealed that temporal air temperature trend has remained generally on the increase since 1983. The increase was gradual between 1991 and 2013. A slight drop in temperature was experienced between the late 1984 and 1985. Thereafter, the gradual increase continued until date. Both least square regression and Mann Kendall test showed that the increasing trend was significant. Stakeholders ranging from government, individuals and cooperate bodies have been encouraged to take the issue of climate variability serious in the study area and Southwest Nigeria in general.

Keywords: Global Warming, Temperature, Variability, Parametric, Trend

INTRODUCTION

Global and regional climate features such as temperature has change as a result of persistent increase in carbon dioxide in the atmosphere since the 1950s, (Yu et al., 2002 and Wang, 2006). Greenhouse gases that occurs naturally in the troposphere is quickly getting thicker as a result of increase emissions of green house gases causing rapid warming of the world's climate. The Fourth Assessment Report Working Group I (WG1) of the Intergovernmental Panel on Climate Change (IPCC, 2007a) has concluded that 'Warming of the climate system is unequivocal', and that 'discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes and wind patterns'. The Report also assesses the likely range of future climate. For example, by 2100, the best estimate of global surface temperature across the IPCC SRES scenarios is a rise of 1.8 to 4° C with a likely range of 1.1 – 6.4 °C in relation to 1990 levels, and a global mean sea level rise of between 18 to 59 cm. The WGII report (IPCC, 2007b) documents that the impacts of climate change are already being observed.

As global warming continues to raise the average temperature of the earth, heat waves have become more frequent and thermometers have hit record highs (CENR, 2008). These high temperatures and the increasing number of heat-related deaths worldwide over the last few decades have portrayed an alarming picture of the extreme weather conditions and devastating impacts on human health to come if this warming continues unmitigated (CENR, 2008). A major problem faced in developing countries is the absence of information to tackle inherent climate change induced challenges. Some of the tackling force which includes climate change mitigation, adaptation and vulnerability assessment may not yield adequate results if the extent of variability of climatic elements is not known. This study endeavors to investigate the annual average trend and variability of atmospheric temperature in Ijebu-Ode, Southwest Nigeria.

Description of study area

Ijebu-Ode is located approximately around latitude 6° 47° and longitude 3° 58°E in South Western Nigeria (figure 1). It has an area of 192 km^2 and a population of 154, 032 at 2006 census, it is bounded in the North by Ijebu North, bounded in the East by Ijebu East Local Government, bounded in the West by Odogbolu Local Government and in the South by Epe Local Government Council of Lagos State. The study area experiences humid tropical climate which is characterized by alternate wet and dry season seasons like the rest of Nigeria. Ijebu-Ode region on annual basis is under the influence of hot-wet tropical maritime airmass during the rainy season (April-October) and hot-dry tropical continental airmass during the dry season (November-March) the following year. Rainfall is generally heavy with peaks occurring in July and September (double maxima) coupled with high temperature, high evapotranspiration and high relative humidity. The mean annual rainfall is between 1575 mm and 2340 mm. The rains may be unduely prolonged in some years while their onset may be delayed as “AUGUST BREAK” is usually experienced between late July and Mid-August.

MATERIALS AND METHODS

Data

Secondary air temperature data was obtained from the Nigeria Meteorological agency (NIMET) Ijebu-Ode, Ogun state station. The time series of meteorological data covering 31 calendar years i.e. 1983-2013 was obtained.

Descriptive Statistics

Several descriptive statistics comprising the mean, standard deviation, range were used for descriptions for used for the study Period. The descriptive statistics was chosen in order to provide concise information and make analysis easier.

Least Square Regression and One-Sample T-Test

Trend analysis was accomplished with the line graphs for modeling. One-Sample T-Test procedure which tests whether the mean of a single variable differs from a specified constant or normal, this test was used for ascertaining the anomalies in the meteorological parameters. Though time series data are not bivariate data, a linear trend line can be obtained by using the simple regression analysis technique (Udofia, 2004, Okoko, 2001). Therefore, in this study, time in years is one independent variable (x) while annual temperatures (1983-2013) were considered as dependent variable (y). The least square model is presented as;

$$Y = a + bx + e \qquad \text{I}$$

where;

Y = Dependent variable (annual rainfall in mm)

X = Independent variable (time in years).

a = A constant and y – intercept

b = Regression coefficient

c = Error random term

Standardized Index

An index number is a device which measures the relative change in the magnitude of a group of related variables in two or more situations. The standardize index was chosen for the study because it has the ability to reflect movement of the parameter as well as indicating rise and fall of the variable. To analyze annual temperature and rainfall variability, the standardize rainfall anomaly index was used.

The standardize index is represented as (Uduak et al., 2012):

$$Z = \frac{(\times i - \mu)}{\sigma} \qquad \text{II}$$

Where, $\times i$ is the annual mean air temperature, μ is the 10-year mean and σ is the standard deviation of the data set.

Mann Kendall’s Test

The results obtained from the trend analysis were further verified by using a powerful and nonparametric Mann□Kendall Statistics (S) (Gilbert, 1987) developed by Mann (1945) and Kendall (1976). The test uses the ranking of all the values to determine if there are more increasing or decreasing values in historical records. In the Mann-Kendall each test value x1 ... xn, are compared with all available values. For a positive difference between the data points the so-called S-statistics increases with +1 while it decreases with -1 for a negative difference.

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn\ (xj - xi) \qquad \text{III}$$

$$\text{Sgn (xj – xi)} \begin{cases} +1, > (xj - xi) \\ 0, = (xj - xi) \\ -1, < (xj - xi) \end{cases} \qquad \text{IV}$$

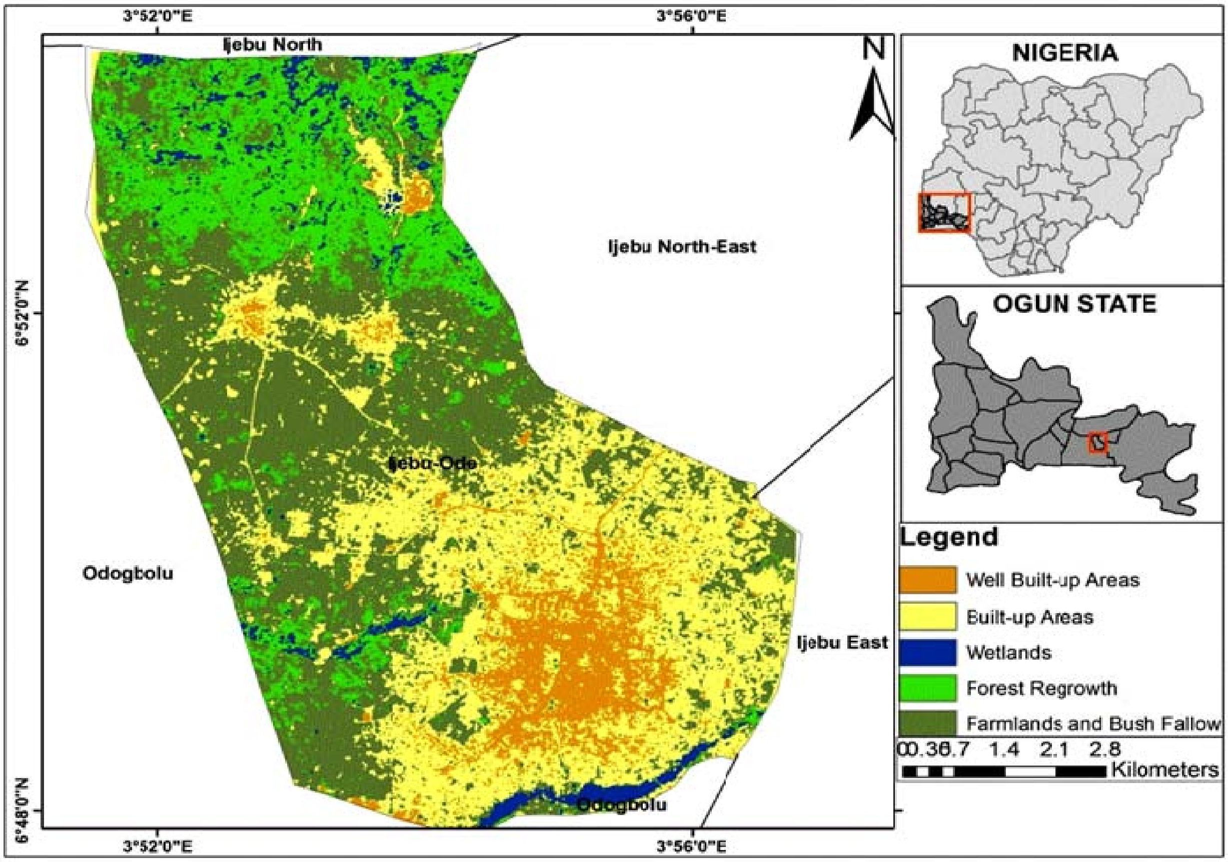

Figure 1: Map of the Study Area

$$\text{Var (s)} = \frac{n(n-1)\,()\,\sum_{1=1}^{m} t1\,(i)(i-1)(1+5)}{18} \qquad \text{V}$$

Thus a large positive value of S indicates a strong positive (increasing) trend while a large negative value of S implies a negative (decreasing) trend. The nonparametric assumption of Mann-Kendall's test when used for a time series with a large number of values is documented which allow the use of a regular z-test to determine whether a trend is significant or not:

$$Z = \begin{cases} \dfrac{s-1}{\sqrt{\dfrac{n(n-1)(2n+5)-\sum_{j=1}^{9})tj\,(tj-1)(2t+5)}{18}}}, if\ s > 0 \\ \dfrac{s+1}{\sqrt{\dfrac{n(n-1)(2n+5)-\sum_{j=1}^{9})tj\,(tj-1)(2t+5)}{18}}}, if\ s < 0 \end{cases} \qquad \text{VI}$$

where n = sample size; q= number of tied groups in the data set; and t_j = number of data points in the j^{th} tied group.

RESULTS

The results obtained for the study as well as its discussion are presented under this section.

Descriptive statistics and Seasonal Variation of Temperature

The monthly air temperature for the study period was high in the dry season, that is between 28.7°C in January to 30.11°C in March; and dropped sharply from April to August (26.06°C), before it rises in December (28.57°C) (Figure 2). This implies that average air temperature was generally high in the dry season and low in the wet season in Ijebu-Ode. More so, average temperature was generally low during August break when rainfall seizes. The air atmospheric temperature recorded in January, March, September, October, November, and December departed largely from their means (Sd = 1.5- 2.0 °C); while the remaining months had little deviation from their means (Table 1). The months of May and August had the lowest standard deviation (0.8 and 0.9°C respectively), this implies that the lowest air temperature experienced during these months did not vary significantly during the study period.

Trend Analysis of Annual Atmospheric Temperature

The temporal air temperature trend had remained

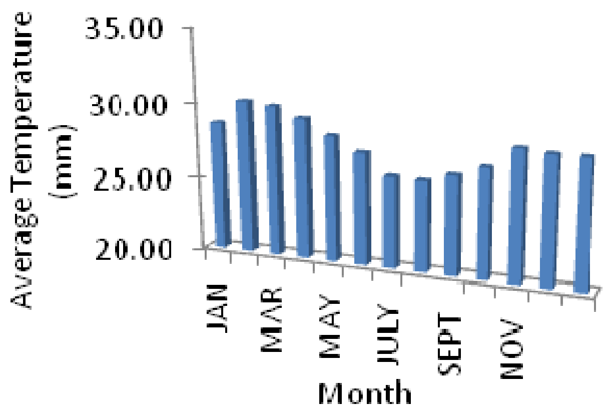

Figure 2: Trend in average monthly Temperature

Table 1: Summary of Monthly Temperature

	Minimum (mm)	Maximum (mm)	Mean (mm)	Std. Deviation (mm)
January	23.50	36.00	32.9	1.9
February	31.30	36.60	34.6	1.1
March	30.50	37.10	34.1	1.5
April	29.50	34.60	33.1	1.1
May	28.60	33.20	31.7	0.8
June	28.30	39.00	30.4	1.8
July	23.30	31.20	28.5	1.4
August	27.20	32.80	28.4	0.9
September	22.00	35.80	29.1	1.9
October	22.40	36.50	30.5	1.9
November	23.30	36.70	32.2	1.9
December	21.80	34.00	32.4	2.0

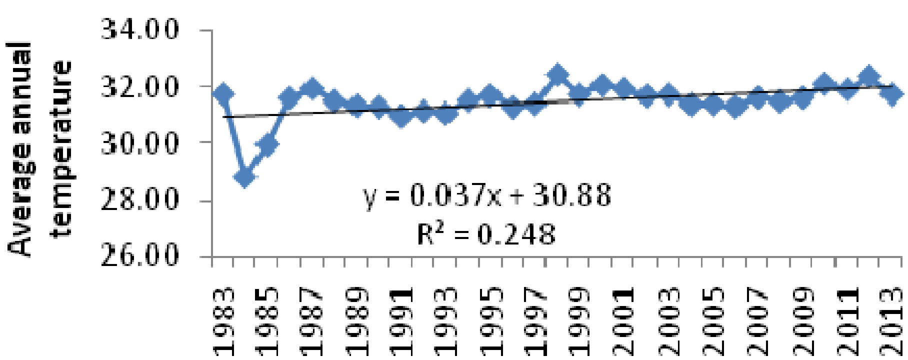

Figure 3: Trend of Variation in Annual Atmospheric Temperature

generally on the increase since 1983 (figure 3). The increase was gradual between 1991 and 2013. A slight drop in temperature was experienced between the late 1984 and 1985. Thereafter, the gradual increase continued until the end of the study period.

The line and least square composite graphs of the average air temperature regimes for Ijebu-Ode is shown in figure 3. While the y-axes represent the average air temperature in°C, the x-axes show time in years. Initial processing of the 31 year series utilizing the basic filtering technique indicates that, Ijebu-Ode temperature is on the increase. This fluctuating and increasing temperature series for Ijebu-Ode is statistically defined by the function.

Table 3 Summary of Result of Mann Kendall Test

Mann Kendall Statistics	Kendall's Tau	Var (s)	P-Value (Two Tailed Test)	Alpha	Remark
143	0.308	3459.7	0.016	0.05	This is positive significant trend

Table 4: Temperature Variability Summary

Year	Mean Temperature	Standard Deviation
1983-1992	31.03	0.96
1993-2002	31.68	0.40
2003-2013	31.70	0.33

Table 5: One-Sample T-test Summary of Temperature Variability

	Test Value = 31.7°C					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Temperature	-1.8	30	0.029	-0.22	-.4695	.0275

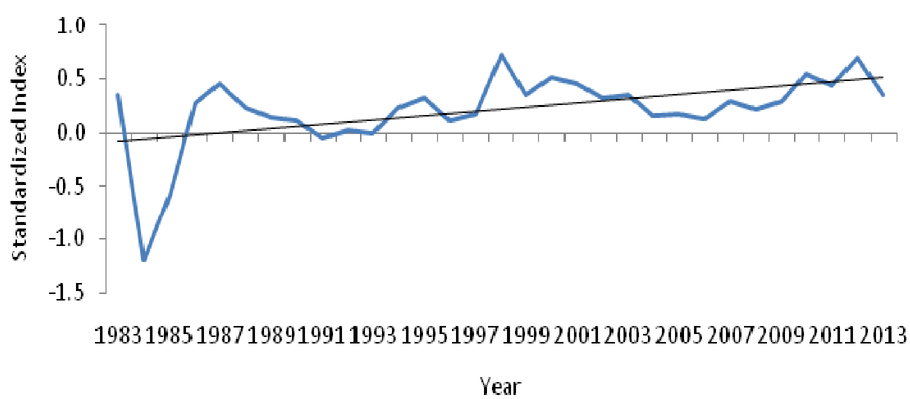

Figure 4. Temperature Anomalies in Ijebu-Ode Using the 2003-2013 Normal

Y = 0.037x + 30.88 + e. VII

It is significant at 99% confidence level with a coefficient of determination figure of 0.248 or 24.8%. The Mann Kendall test further confirms that there is a significant rise in the pattern of atmospheric air temperature in Ijebu-Ode; this is confirmed by the Kendall's tau value of 0.308($p<0.05$) as could be seen in table 3.

Analysis of decadal variability of atmospheric temperature

In order to investigate climate change in Ijebu-ode using air temperature, the 31 years of study was divided into three study periods as shown in table 4, it can be seen that there was a significant increase between 1983-1992 and 1993-2002; while there was a slight increase between the second period and the third. The lowest standard deviation of 0.33 experienced in the last 11 years (0.33° C) suggests that the increase in the warming of Ijebu-Ode did not vary significantly in this category.

As observed in table 5, there was an increase in the temperature of Ijebu-Ode with a value of 0.22°C between 1983 to 2013; **furthermore, since the significance value of 0.029 (df = 30) is less than 0.05, the null hypothesis which says that there was no significant difference in the mean air temperature of Ijbeu-Ode between the last decade and the former two decades was rejected, while the alternate hypothesis was accepted.** Hence, it can be concluded that this increase in temperature experienced in Ijebu-ode was significant and did not occur by chance.

Figure 4 represents the anomalies of air temperature experienced in Ijebu-Ode using the 2003-2013 mean. The anomalies show that climate change is apparent in

Ijebu-Ode as the air temperature experienced in the later decade was higher than the previous two. This shows that temperature is on the increase in Ijebu-Ode. The anomalies in temperature between 1993 to 2013 were above 0.0 indicating an increase in the last two decades.

DISCUSSION

Trend is the general pattern of fluctuation of data over time (Okoko, 2001). Many methods are available for calculating trend but the most common ones are the least square regression techniques (Box and Jenkins, 1976). For reasons of hypothesis testing, generalization and projection, the study adopted the one sample t-test, least square regression method Mann Kendall trend test and standardized index.

Thirty one years (1983-2013) temperature data for Ijebu-Ode South western Nigeria has been studied for pattern and trend to show evidence of climate change. For the period under study the temperature regimes for Ijebu-Ode appear to be varying and changing statistically. Results revealed that the temporal air temperature trend has remained generally on the increase since 1983 (Figure 2). The increase was gradual between 1991 and 2013. A slight drop in temperature was experienced between the late 1984 and 1985. Thereafter, the gradual increase continued until date. Both least square regression and Mann Kendall test showed that the increasing trend was significant.

A sharp rise in air temperature became evident as from the early 1980s, which continued till 2013 (Figure 3).The sharp rise in temperature observed in Ijbeu-Ode since the early 1980s is in agreement with the global trend (IPCC, 2007a) as well as Nigeria trend (Odjugo 2010). The mean air temperature for the study period for the first decade (1983 - 1992) is 31.03 °C. In the 1993 - 2002 periods, the mean air temperature rose to 31.68 °C. By 2003 – 2013, the air temperature increased to 31.70 °C. The decadal variation as shown in Table 4 supports Figure 4 that reveals a gradual temperature rise from 1983-2013. A sharp increase in temperature between 1983 and 2013 could be linked to the effect of climate change and its associated global warming earlier reported (Mabo, 2006).

The air temperature anomalies relative to 1993-2013 normal also support the increasing temperature trend, which was more from the early 1980s (Figure 4). Between 1983 -1992 and 1993 - 2002 periods temperatures were below the 2003-2013 normal. The temperature anomalies actually confirm the facts that global warming is unequivocal (IPCC, 2007a) and climate change signal is stronger as from the 1970s. NEST (2003) provided indicators that one could use to assess the evidence of climate change in a region. These include increasing temperature, increasing evapotranspiration, decreasing rainfall amount in the continental interiors, increasing rainfall in the coastal areas, increasing disruption in climate patterns and increasing frequency and intensity of unusual or extreme weather related events such as; thunderstorms, lightning, landslides, floods, droughts, bush fires, unpredictable rainfall patterns, sea level rise, increase desertification and land degradation, drying up of rivers and lakes and constant loss of forest cover and biodiversity. While this study reveals that an indicator (increasing temperature) is already present in Ijebu-Ode, recent studies show evidence of those indicators (Chindo and Nyelong, 2005; Nwafor, 2007; Umoh, 2007).

The human body responds to thermal stress by forcing blood into peripheral areas to promote heat loss through the skin, therefore health disorders are expected at higher temperature. The inhabitants of the study area may be vulnerable to medical disorder such as heart failure, bronchitis, peptic ulcer, adrenal ulcer, glaucoma, goiter, eczema, and herpes zoster are. Plant and animal also respond to temperature variability which as economic consequences on agricultural yield.

CONCLUSION

Little attention has been given to primary and secondary impact of changing temperature in Ijebu-Ode, Southwest Nigeria. Having analyzed major negative impact of variability of temperature, it is important that all stakeholders ranging from government, individuals and cooperate take the issue of climate variability serious in the study area and Southwest Nigeria in general.

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