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Research Paper

Trends and Variations of Some Meteorological Parameters in Uyo, Nigeria

S.O. Amadi[1,*] and T.O. Chigbu[2]

[1] Dept of Physics, Geology and Geophysics, Federal University, Ndufu-Alike Ikwo, P.M.B 1010, Abakaliki, Ebonyi State, Nigeria

[2] Dept of Science Laboratory Technology, (Physics /Electronics Unit), Abia State Polytechnic Aba, Abia State, Nigeria

* Corresponding author, e-mail: (solomonokeamadi@gmail.com)

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Abstract: *The trends and variations of four meteorological elements in Uyo were analyzed in this paper. The aim is to identify possible trends and variations, and examine the statistical characteristics of these elements. The data used for the research were extracted from the archives of the Uyo Station of the Nigerian Meteorological Agency for the period 2005 to 2011, covering a period of 84 months. Basic data consist of monthly rainy days, monthly rainfall totals, monthly mean values of minimum and maximum temperature and relative humidity. Statistical techniques such as scatter plots with trend lines, measures of variability and non-parametric Kendall's rank correlations were carried out on the data using EXCEL and SPSS computer packages. The results are presented in graphs, tables and charts. Relative humidity and minimum temperature show downward trends that are significant at the 5% level while rainfall and maximum temperature show upward trends that are not statistically significant. Rainfall has the highest coefficient of variation while maximum temperature has the least.*

Keywords: Trends, variations, meteorological parameters, statistical techniques, Uyo.

1.0 Introduction

The weather condition of any given place is often described in terms of meteorological elements such as the state of the sky, temperature, winds, pressure, sunshine, rainfall, humidity, evaporation etc. These factors influence the atmosphere and also respond to other phenomena like *El Nino, La-Nina*, direct and indirect release of energy to the atmosphere by humans, including effects of atmospheric pollution. According to Ogolo (2002), all these result in the spatio – temporal variation of weather.

Climate and weather information are important in agriculture, aviation, water resources management, health, electric power generation, road and marine transport etc. The profound influence of weather and climate over human activities can be regulated to a reasonable extent by how we live and nurture our environment. The classical approach to weather and climate studies focuses on those surface variables that affect our daily lives such as terrestrial solar radiation, minimum and maximum air temperature, wind speed and direction, rainfall, humidity, sunshine, aerosol concentrations and evapo transpiration, etc. These are the variables mostly measured by a large number of weather stations around the world on daily basis. They represent an important step in understanding and predicting weather and climate changes.

A study of the trends under local climate is indispensable given the highly variable nature of climate in space and time. Different approaches abound in the literature on trend detection. Several researchers have used linear regression method to search for trends in many climatic time series (Hutchinson 1995; Subbaramaya and Bhanu-Kumar, 1987). However, the non-parametric test has been proved to be superior to the parametric tests in trend studies (Turkes *et a*l 2009; Zhihua *et al*., 2013; Brunetti *et al*., 2001; Eris and Agiralioglu, 2012, Karaburun *et al.,*2011; Ustaoglu, 2012, Karabulut *et al.,* 2008).

In this paper, non-parametric Mann-Kendall's rank correlation is used to detect and test the significance of trends in the climatic elements and for the period under review. Several researchers have determined variations and trends of some meteorological parameters in many countries (Turkes *et al.*, 1995; Turkes 1996; Turkes, 1999; Batisani and Yarnal, 2008; Cislaghi *et al*, 2005, Bocheva *et al*, 2009; Frich*et al*, 2002; Ratnayake and Herath, 2005; Jacobiet, 1995; Goswami *et al*, 2006; Tuller, 2004).

In Nigeria, similar studies have been carried out (Odjugo, 2010; Ati *et al*, 2008; Adebayo, 1997; Thompson and Amos, 2010; Omotosha, 2002; Ojonigu *et al*, 2009; Umar, 2010; Ogolo and Adeyemi 2009; Obot *et al*, 2010; Enete and Ebenebe, 2009; Ewona and Udo, 2008).

On the whole, recent studies on climate change have focused mainly on long-term variability of temperature and rainfall which are, however, the most important climate change indicators. Other important climate factors controlling energy and mass exchange between terrestrial ecosystem and atmosphere such as relative humidity has received less attention. Relative humidity is incorporated in this work to study its potential trends or otherwise vis-à-vis the two most widely studied weather elements.

The objectives of the present study include the following:

I. To evaluate the seasonal and annual variations in the meteorological elements under study.
II. To identify trends and trend significance in those elements for the period under study using the Kendall's*tau b* rank correlation coefficient.
III. To give essential information on the descriptive statistical features of the parameters under analysis.

2.0 Study Area

Uyo coordinates on the latitude $04^{o}56^{1}$N and longitude $07^{o}56^{1}$E. The altitude is 80m above mean sea level. Uyo climate is tropical and it belongs to the swamp forest agro-ecological zone of Nigeria. As in other West African towns, the climate is dominated by the Inter Tropical Discontinuity, (ITD). The seasonal north – south migration of the ITD dictates the city's weather pattern.

3.0 Data and Methodology

3.1 The Data

The monthly rainfall totals (in millimeters), monthly rainy days, mean values of minimum temperature, maximum temperature and relative humidity were obtained from the archives of the Uyo Station of the Nigerian Meteorological Agency, located at the AkwaIbom International Airport, Uyo. The period of data coverage is 2005 to 2011, a period of seven years (eighty-four months).

The data were subjected to checks for missing observations and in homogeneites. There were no missing entries. The statistical test for homogeneity using Kruskal – Wallis (K-W) statistical homogeneity test indicates that the data is homogeneous.

3.2 Methodology

The Kendall rank correlation coefficient (Kendall's *tau* (τ) coefficient) is a statistic used to measure the association between two measured quantities. A *tau* test is a non – parametric hypothesis test for statistical dependence based on the *tau* coefficient. It is a measure of rank correlation, i.e, the similarity of the orderings of the data when ranked by each of the quantities. Under the null hypothesis of independence of the two measured quantities, the sampling distribution of *tau*(τ) has a value of zero. The *tau b* statistic makes adjustments for ties (Agresti, 2010). Values of *tau b* range from -1 to +1, representing perfect inversion and perfect agreement respectively. A zero value indicates the absence of association. The Kendall *tau b* coefficient is defined as (Agresti, 2010; Prokhorov, 2001).

$$\tau_b = \frac{n_c - n_d}{\sqrt{(n_0 - n_1)(n_0 - n_2)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$n_0 = n(n-1)/2$

$n_1 = \sum_i t_i(t_i - 1)/2$

$n_2 = \sum_j u_j(u_j - 1)/2$

n_c = number of concordant pairs

n_d = number of discordant pairs

t_i= number of tied values in the i^{th} group of ties for the first quantity

u_j= number of tied values in the j^{th} group of ties for the second quantity.

For *tau b*, the following statistic, Z_b, is approximately equal to a standard normal distribution when the two variables are statistically independent:

$$Zb = \frac{n_c - n_d}{\sqrt{V}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where $V = (v_0 - v_t - v_u)/18 + v_1 + v_2$

$$V_0 = n(n-1)(2n+5)$$

$$V_t = \sum_i t_i(t_i - 1)(2t_i + 5)$$

$$V_u = \sum_j u_j (u_j - 1)(2u_j + 5)$$
$$V_1 = \sum_i t_i (t_i - 1) \sum_j u_j (u_j - 1) / (2n(n-1))$$
$$V_2 = \sum_i t_1 (t_i - 1)(t_i - 2) \sum_j u_j (u_j - 1)(u_j - 2) / (9n(n-1)(n-2))$$

To test whether two quantities are statistically dependent, one computes Zb, and finds the cumulative probability for a standard normal distribution at /Zb/. For a two – tailed test, the value of the cumulative probability is multiplied by 2 to obtain the *p* – value. If the *p* – value is below a given level of significance, the null hypothesis that the quantities are statistically independent is rejected (at that level of significance). In this paper, the chosen significance level is 0.05(5%).

4.0 Results and Discussion

4.1 Results

Table 1 shows the result of the non-parametric test. The Kendall's *tau b* (Kendall rank correlation coefficients) are shown alongside the *p* – values. Statistical significance are also indicated with asterisks. Table 2 gives the descriptive statistics of the parameters. The mean, the standard deviation, σ, the coefficient of variation C.V and the mean deviation MD, are shown in the table. The ratio of the absolute mean deviation to the standard deviation, /MD//σ, has been include as a measure of the normality of the distribution. Table 3 showsthe distribution of annual rainfall intensities within the period of study. Rainfall intensity is the ratio of cumulative rainfall totals to the total number of rainy days. Figs 1a – d show the scatter plots with the trend lines for the four parameters studied for Uyo. Figs 2a – e are graphical displays of the annual variations of the parameters, including that of the monthly mean rainy days. Figs 3a – e are the Bar charts depicting the seasonal variations of the parameters, together with that of the rainy days.

Table 1: Kendall's test result

Parameters	Data length (months)	Kendall's *tau b*	*p* – value
Rainfall	84	0.027	0.817
Minimum Temperature	84	-0.149*	0.049
Maximum Temperature	84	0.019	0.796
Rel. Humidity	84	-0.152*	0.046

* Correlation (*tau b*) is significant at the 0.05 level (2 - tailed).

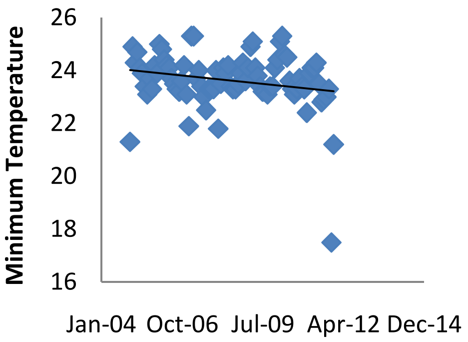
Table 2: Descriptive statistics of the meteorological parameters for the period 2005 – 2011

Parameters	Mean	σ	C.V (%)	MD	$\frac{/MD/}{\sigma}$
Rainfall	221.62mm	35.40mm	15.97	29.42mm	0.83
Minimum Temperature	23.44°C	0.88°C	3.76	0.72°C	0.82
Maximum Temperature	31.70°C	0.45°C	1.42	0.41°C	0.91
Rel. Humidity	81.53%	1.86%	2.28%	1.58%	0.85

Table 3: Annual distribution of rainfall intensities from 2005 – 2011

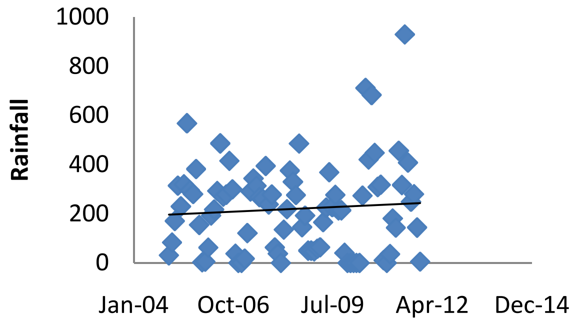
Years	Rainfall Intensity (mm/day)
2005	17.46
2006	16.69
2007	16.13

2008	14.16
2009	13.25
2010	21.73
2011	18.84



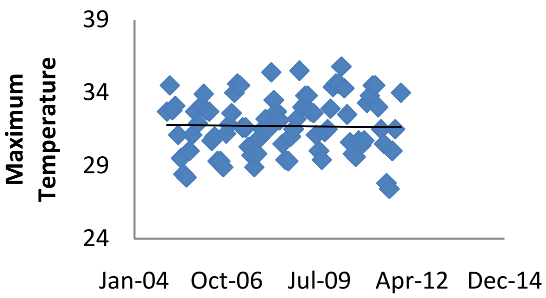
Months

Fig 1a – Scatter plots for Min Temp.



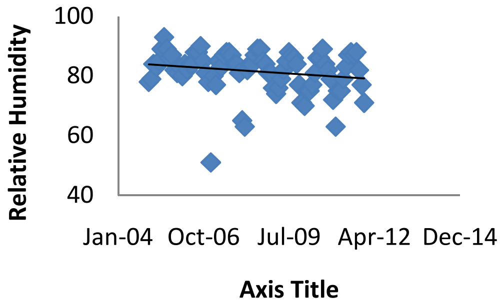
Months

Fig 1c – Scatter plots for Rainfall.



Months

Fig 1b – Scatter plots for Max. Temp.



Months

Fig 1d – Scatter plots for Relative Humidity

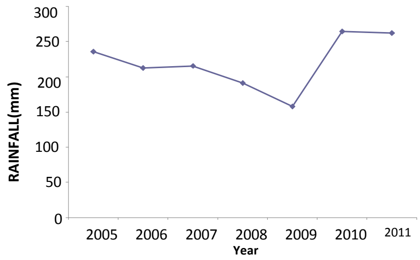


Fig 2a: Mean Annual Rainfall 2005-2011

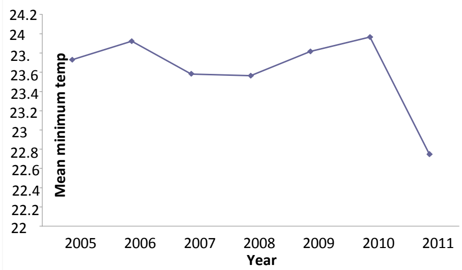


Fig 2d: Average minimum Monthly temperature 205-2011

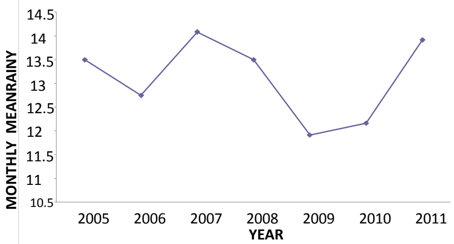


Fig 2b: Monthly rainy days 2005-2011

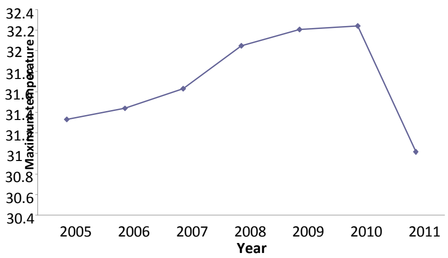


Fig 2e: Average maximum temperature 2005-2911

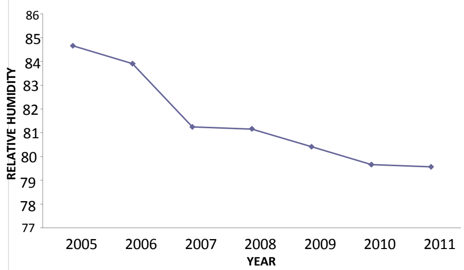


Fig 2c: Average relative humidity 2005-2011

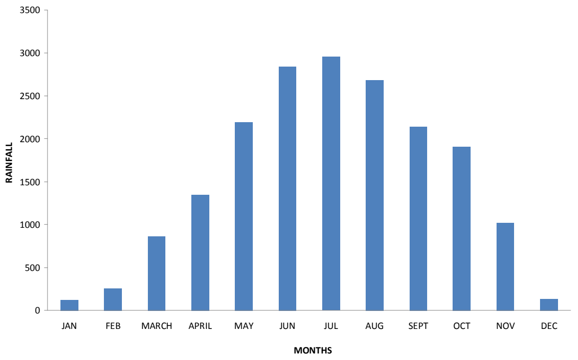


Fig 3a :Seasonal variation of the rainfall for each of the months averaged over seven years.

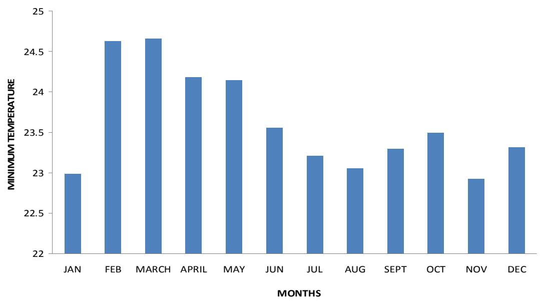


Fig 3d :Seasonal variation of the minimum temperature for each of the months averaged over seven years.

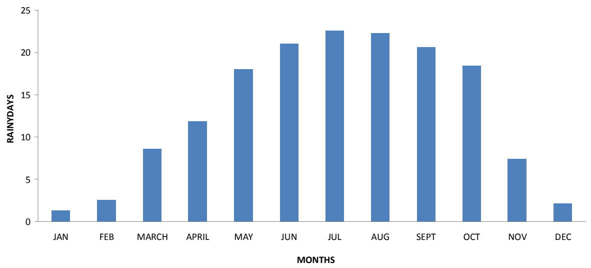


Fig 3b :Seasonal variation of the rainy days for each of the months averaged over seven years.

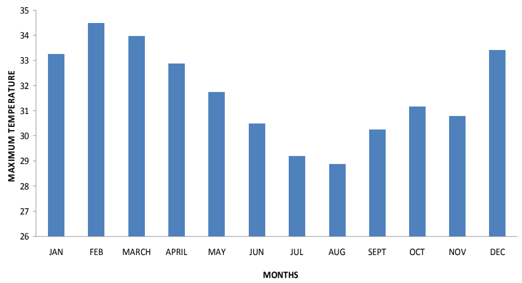


Fig 3e :Seasonal variation of the maximum temperature for each of the months averaged over seven years.

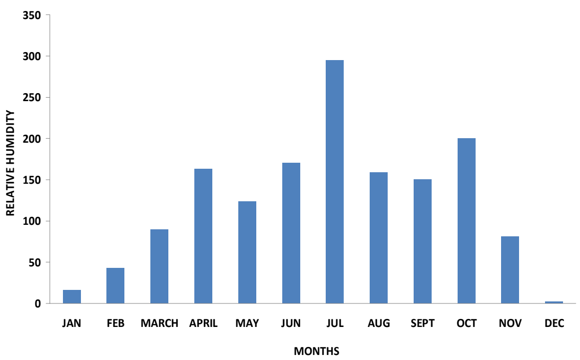


Fig 3c :Seasonal variation of the relative humidity for each of the months averaged over seven years.

4.2 Discussion

The Kendall's test result (table 1) indicates that both minimum temperature and relative humidity show downward trends that are significant at the 0.05 level (*p* – values equal to 0.049 and 0.046 respectively). On the other hand, rainfall and maximum temperature show upward trends that are not statistically significant. These observations are corroborated by the trend lines (figs 1a – d). The values of coefficient of variation (table 2) show that rainfall suffers greatest variability (C.V of 15.97%) whereas maximum temperature has least value of coefficient of variation. This means that maximum temperature is stable. The values of /MD/ indicate that the meteorological observations are not normally distributed for all the parameters. This further justifies the use of non-parametric test in this research which makes no assumption of the normality of the data distribution, and is more robust to outlier's effect. This could also affirm the credibility (reliability) of the test results. Table 3 shows that the year 2010 followed by 2011 recorded the highest rainfall intensities. Thus the year 2010 followed by 2011 are the most probable years to record extreme rainfall events (high incidence of flooding). This result is consistent with the high incidence of flooding that prevailed in 2010 in many parts of Nigeria. The trendlines of figs 1a – d follow similar trends with the trend test result using Kendall's rank correlation test.

Fig 2a shows that the year 2009 recorded the least amount of rainfall while 2010 have the highest amount of annual mean rainfall. Fig 2b indicates that the year 2009 followed by the year 2010 recorded the least monthly mean rainy days. Comparing figs 2a and 2b reveals that the years 2009 and 2010 were years of extreme events. The year 2009 having the least annual mean rainfall (fig. 2a), and the least monthly mean rainy days (fig 2b) reveals incidence of drought in 2009. On the other hand, the year 2010 having the highest annual mean rainfall (fig 2a) and relatively very low (least but one) value of the monthly mean rainy days (fig 2b) reveals flooding event in 2010. The year 2011 recorded the highest value of monthly mean rainy days (fig 2b) and almost tied with the year 2010 as having the highest annual mean rainfall. The annual mean relative humidity generally indicates a decreasing trend (fig 2c). A cursory look at figs 2d and 2e shows that the year 2010 recorded the highest values of annual mean minimum and maximum temperatures. Thus, the year 2010 appears to be associated with extreme weather events in Uyo. The year 2011 recorded the least values of both minimum and maximum temperatures.

The seasonal distribution of the meteorological parameters indicates that the month of July recorded the highest mean values of rainfall and rainy days averaged over the seven years (figs 3a and 3b). Similarly, the month of July recorded the highest mean value of R.H. averaged over the seven years (fig 3c). December, January and February (winter months) recorded the least mean values of rainfall, rainy days, and relative humidity averaged over the seven year period while June, July and August (summer months) recorded the highest values. The seasonal variations of rainfall, rainy days and relative humidity follow analogous pattern. Figs 3d and 3e clearly show that the seasonal distribution of minimum and maximum temperature share the same features. While the highest mean values of minimum and maximum temperatures averaged over the seven years were recorded in February and March, their least values were observed in August. The sudden drop in annual mean maximum temperature from over 32^{o}C in 2010 to about 31^{o}C in 2011 could be worrisome. The same sharp drop is observed in annual mean minimum temperature from about 24^{o}C in 2010 to less than 23^{o}C. The result further reveals that the parameters under analysis show considerable seasonal variations. Rainfall peaked in summer with a minimum in winter. Temperatures peaked in winter while the least values are recorded in summer. The results presented here agree with similar studies conducted in nearby locations (e.g. Ewona and Udo, 2008).

5.0 Conclusion

The evaluations of annual and seasonal mean values of the meteorological parameters at Uyo, using seven years experiences show marked seasonal and annual variations. There is evidence of significant downward trends in minimum temperature and relative humidity and non-significant increasing trends in rainfall and maximum temperature. The results further reveals incidences of extreme weather events judging from the annual variations in the meteorological elements under analysis. The implication of the results is that the study area requires continuous monitoring as it has potentials for occurrence of some extremeweather events such as drought, flooding and rapid temperature fluctuations. In this way, any possible unfavourable event could be detected early enough, so that potential problems would be addressed before they become critical, thus preventing incidences of catastrophic events. Such catastrophic events include tremendous crop failure or flooding of farmlands whenever there is significant changes in the rainfall pattern, outbreak and spread of some diseases as a result of changing temperature regime, etc.

References

[1] A.A. Adebayo, The application of agro – climatology to agricultural planning in Adamawa state, Nigeria, *Journal of Applied Science and Management*, 1(1) (1997), 69.

[2] A. Agresti, Analysis of Ordinal Categorical Data (2nd edn.), New York, John Wiley and Sons, 2010.

[3] O.F. Ati, S.Q. Muhammed and M.H. Ati, Variations and trends in annual rainfall amounts and the onset of the rainy season for Kano for 87 years (1916 – 2006), *J. Appl. Sci Res*, 4(12) (2008), 1959-1962.

[4] N. Batisani and B. Yarnal, Rainfall variability and trends in semi – arid Bostwana: Implication for climate change adaptation policy, *Applied Geography*, 30(2008), 1-7.

[5] L. Bocheva, T. Marinova, P. Simeonov and V.I. Gospodina, Variability and trends of extreme precipitation events over Bulgaria (1961–2000), *Atmos. Res*., 93(2009), 490-497.

[6] M. Brunetti, M. Maugeri and T. Nanni, Change in total precipitation, rainy days and extreme events in North – Eastern Italy, *International Journal of Climatology*, 21(2001), 861-871.

[7] M.D. Cislaghi, T.C. Michele, A. Ghezz and M.R. Ross, Statistical assessment of trends and oscillations in rainfall dynamics: Analysis of long daily Italian Series, *Atmos. Res*, 77(2005), 188-202.

[8] I.C. Enete and I.N. Ebenebe, Analysis of rainfall distribution over Enugu during the little dry season (1990–2005), *Journal of Geography and Regional Planning*, 2(7) (2009), 182-189.

[9] E. Eris and N. Agiralioglu, Homogeneity and trend analysis of hydrometeorological data of the Eastern Black Region, Turkey, *Journal of Water Resources and Protection*, 4(2012), 99-105.

[10] I.O. Ewona and S.O. Udo, Trend studies of some meteorological parameters in Calabar, Nigeria, *Nigerian Journal of Physics*, 20(2) (2008), 283-289.

[11] P. Frich, L.V. Alexander, P. Della–Marta, B. Gleason, M. Haylock, M.G. Klein–Tank and T. Peterson, Observed coherent changes in climate extremes during second half of twentieth century, *Clim.Res*., 19(2002), 193-212.

[12] B.N. Goswani, V. Venugopal, D. Sengupa, M.S. Madhusoodanan and P.K. Xavier, Increasing trends of extreme rain events over India in a warming environment, *Science*, 314(2006), 1442-1445.

[13] P. Hutschinson, Rainfall analysis of the Sahellian drought in Gambia, *J.Clim*, 5(1985), 665-672.

[14] J. Jacobeit, Atmospheric circulation changes due to increased greenhouse warming and its impact in seasonal rainfall in the Mediterranean area, *Papers of the Regional Workshop on Climate Variability and Climate Change (In draft)*, (1995).

[15] M. Karabulut, M. Gurbuz and H. Korkmaz, Precipitation and temperature trend analyses in Samsun, *Int. J. Environmental Application and Science*, 3(5) (2008), 399-408.

[16] A. Karaburun, A. Demirci and F. Kora, Analysis of spatially distributed annual, seasonal and monthly temperatures in Istanbul from 1975 to 2006, *World Applied Sciences Journa*l, 12(10) (2011), 1662-1675.

[17] N.I. Obot, M.A.C. Chendo, S.O. Udo and I.O. Ewona, Evaluation of rainfall trend for Nigeria for 30 years (1978–2007), *International Journal of Physical Sciences*, 5(14) (2010), 2217-2222.

[18] P.A.O. Odjugo, General overview of climate change impacts in Nigeria, *Journal of Human Ecology*, 29(1) (2010), 47-55.

[19] E.O. Ogolo, Characterization of weather parameters for Ibadan using Bowen ratio as an index of seasonal variation, *Unpublished Ph.D Thesis*, (2002), Dept of Physics, University of Ibadan, Ibadan, Nigeria.

[20] E.O. Ogolo and B. Adeyemi, Variations and trends of some meteorological parameters at Ibadan, Nigeria, *Pacific Journal of Science and Technology*, 10(2) (2009), 980-987.

[21] F. Ojonigu, I.O. Edwin and O.M. Seidu, Temporal variation of annual rainfall season in Kastina State of Nigeria, *International Journal of Environment and Policy Issues*, 4(2) (2009), 2.

[22] J.B. Omotosho, Synoptic meteorology: Pathway to seasonal rainfall prediction for sustainable agriculture and effective water resource management in West–Africa but Nigeria in particular, *Journal of the Nigerian Meteorological Society*, 3(2) (2002), 82-88.

[23] A.A. Prokhorov, Kendall coefficient of rank correlation, In: M. Hazewinkel, Encyclopedia of Mathematics, Springer, 2001.

[24] U. Ratnayake and S. Herath, Changing rainfall and its impacts on landslides in Sri Lanka, *J. Mon. Sci*., 2(3) (2005), 218-224.

[25] I. Subbaramaya and O.S.R. Bhanu–Kumar, Variation of the onset of the summer monsoon over India, *Meteorolo. Mag.*, 116(1987), 309-317.

[26] O.A. Thompson and T.T. Amos, Climate change and food security in Nigeria, *Journal of Meteorological and Climate Science*, 8(2) (2010), 91.

[27] S.E. Tuller, Measured wind speed trends on the West Coast of Canada, *Int. J. Climatol*, 24(2004), 1359-1374.

[28] M. Turkes, Spatial and temporal analysis of rainfall variation in Turkey, *Int. J. Climatol*, 16(1996), 1657-1676.

[29] M. Turkes, Vulnerability of Turkey to desertification with respect to precipitation and aridity conditions, *Tr. J. Engineering and Environmental Science*, 23(1999), 363-380.

[30] M. Turkes, T. Koc and F. Saris, Spatio–temporal variability of precipitation total series over Turkey, *Int. J. Climatol.*, 29(8) (2009), 1056-1074.

[31] M. Turkes, U.M. Summer and G. Kilic, Variations and trends in annual mean air temperature in Turkey with respect to climate variability, *Int. J. Climatol.*, 15(1995), 557-564.

[32] A.T. Umar, Recent trends and variability in the length of growing season in Northern Nigeria, *Journal of Meteorology and Climate Science*, 8(1) (2010), 41-46.

[33] B. Ustaoglu, Trend analysis of annual mean temperature data using Mann – Kendall rank correlation test in Catalca –Kocaeli Peninsula, North West of Turkey for the period 1970 – 2011, *IBAC*, 2(2012), 276-287.

[34] Z. Zhihua, L. Rui, Q. Hui, C. Jie and Z. Xuedi, Analysis of rainfall variation over the past 55 years in Guyuan City, China, *Journal of Environmental Science, Computer Science and Engineering Technology*, 2(3) (2013), 640-649.