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ASSESSING EFFECTS OF CLIMATE CHANGE ON TEMPERATURE TRENDS DETECTION ON WATER RESOURCES IN NIGERIA USING MANN KENDALL

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Abstract: Assessing of trends of temperature is imperative and fundamental to the success of many sectors of the economy in which water resources is principal ones. The effects of temperature trends on water resources were assessed. Temperature data for 57 years (1960–2016) were collected from Nigerian Meteorological Agency Oshodi. Data were and analyzed using Mann–Kendall non parametric test and Auto Correlation analyses respectively. The results indicated that annual temperature increased in trends in 15 out of 20 stations with return period ranged between 1–2 years to 13–15 years. Stations like Abeokuta, Akure, Enugu, and Maiduguri decreased in trends of annual temperature at rate of 0.080°C/mo/yr, 0.040°C/mo/yr, 0.030°C/mo/yr, and 0.120°C/mo/yr with return period between 1–2 years and 7–19 years. Benin station recorded the highest peak in trends of temperature in the month of September at the rate of 3.390°C/mo/yr with return period of 1–2 years. Some of the effects of these trends on water resources vary from one station to another, depending on the trends and magnitude of return period of temperature. Bauchi and Minna cities were observed to experience high rate of evaporation due to the continuous monotonic increase in trend of annual temperature.
Keywords: Trends, Mann–Kendall, Auto–correlation Analysis, Dominant peak and return period, Nigeria

1. INTRODUCTION

Scientific evidence shows that climate change has begun to manifest itself, globally, in the form of Changing in temperature and precipitation as the fundamental components of climate changes that had effect on human health, ecosystems, plants, and animals [1]. There is a scientific consensus that the average temperature of earth has risen between 0.4 and 0.8°C in the last 100 years [2]. Several researchers such as [1–5] reported that global warming is caused by human (anthropogenic) activities include increase in the emission of GHGs through the burning of fossil fuels (oils, natural gas and coal), burning of wood, wood products and solid wastes, raising of livestock and the decomposition of organic wastes in solid wastes landfills; combustion of solid wastes and fossil fuels in industrial and agricultural activities; bush burning; and deforestation. An increase in temperature can result in heat wave incidents and cause illness and death in susceptible populations. In addition, temperature changes can cause a shift in animal and plant species [6]. Agricultural production in arid and semi–arid regions were affected by variability of environmental factors principally the temperature and precipitation [4]. Climate variability and periods of variable lengths of relatively dry and wet years which mainly affect rainfall are also endemic in semi-Arid and Arid regions [4]. Considerable effort has been expended in large scale studies of general circulation modeling to assess climatic risk. However, there have been few attempts to account for inter–annual climate variability [5], and to downscale data to the local level in order to assess climatic risk for agricultural areas and crops has proven difficult [7].

Sustainable management and future development of water resources entail accurate knowledge and understanding of trends and variability study of hydro–climatic variables [8]. To meet the demand for water due to population and economic growth within the context of global warming, information regarding hydro climatology and water and energy cycles becomes veritable. The scientific consensus that global climatic change is a real problem to contend with as it alters the hydrological cycle was reported by World Resources Institute in year 2000. However the impacts of future climatic changes on water resources and wetlands will depend on many non–climatic factors such as regional demographic factors, water policies and hydraulic structures [9]. To achieve long–term water resources planning and management, trends, cycle and variability in hydrological variables such as precipitation and temperature must be quantified. [10] reported that future decades will pose a challenge of meeting food security for vastly growing world population particularly in countries with limited water and land resources. The dependency on water for agriculture has become a critical constraint for development in Arid and Semi–Arid countries where water is expected to be scarce in the coming decades [11].

In the recent years, several extreme events due to advent of climate change have caused large losses of life and tremendous increase in economic losses from weather hazards which justify the need for the analysis of trends and cycles of temperature.

In climate change studies, trend detection is the demonstration that a change has occurred in a defined statistical sense [12]. This has been widely used to assess the potential implications of climate change and variability on climatic variables in various parts of the world. Different types of trends on each variable interpret different implications on water resources. For instance, increasing trend in temperature will enhance the evaporation, which will reduce in water storage; decreasing trend in precipitation will result in drought and catchment drying. Furthermore, agriculture that is the mainstay of Nigerian economy depends largely on spatial and temporal distribution of rainfall and temperature, and thus valuable historical record of hydrologic is imperative.

The rank–based Mann–Kendall test (MK) has been widely used throughout the world to detect trends in agro–meteorological as well as hydrological time series [13–15]. The specific objectives of the study are to detect the presence of significant monotonic increasing and decreasing trends in temperature, and determine the magnitude of trends and variability in temperature series.

2. DATA AND METHODS

— Location

Nigeria is located in West Africa between latitude 4^0–14^0N and longitudes 2^0–15^0E and has a total area of 925,796 km^2 with over 180 million in Population (2010 Census). The ecological zones of the country are broadly grouped into three, which are; Sahel, Savannah and the Guinea zones as shown in figure 1. The climate is semi–arid in the north and humid in the south and also humid strip along the coast with rainfall averages over 2000 mm with highest peak in the period of June to September.

Figure 1. Map of Nigeria showing ecological zones

— Data Sourcing and Processing

The data on temperature was obtained from fifteen selected states, across the six geopolitical zones of Country. It includes Ondo, Ogun, Oyo, Osun, Lagos, Niger, River, Sokoto, Delta, Maiduguri, Yola, Delta, Edo, Cross river and Bauchi. The temperature data were obtained from the Nigerian Meteorological service, Oshodi, Lagos. The length of the records is 57 years (1960–2016). These series do not have missing data, and for twenty (20) stations as summarized in the table 1. Data collected were processed into annual, monthly and seasonal for analytical convenience. The seasons are April, May and June (AMJ); July, August and September (JAS) and October, November and December (OND).

Table 1: Available Data on Temperature for various Stations

Stations	Temperature	Stations	Temperature
Abeokuta	1980–2016	Iseyin	1980–2016
Abuja	1980–2016	Lagos	1960–2016
Akure	1960–2016	Maid	1960–2016
Bauchi	1960–2016	Minna	1960–2016
Benin	1960–2016	Osogbo	1965–2016
Calabar	1960–2016	P/Harcourt	1960–2016
Enugu	1960–2016	Sokoto	1960–2016
Gusau	1960–2016	Warri	1960–2016
Ibadan	1960–2016	Yelwa	1980–2016
Ikeja	1965–2016	Yola	1960–2016

3. DESCRIPTIONS OF STATISTICAL TESTS USED

— Mann–Kendall test

Mann Kendall test is a statistical test widely used for the analysis of trend in climatologic [16] and in hydrologic time series [17]. There are two advantages of using this test. First, it is a non-parametric test and does not require the data to be normally distributed. Second, the test has low sensitivity to abrupt breaks due to inhomogeneous time series [18].

The Mann–Kendall test is applicable in cases when the data values xi of a time series can be assumed to obey the model

$$x = f(t) \tag{1}$$

where f (t) is a continuous monotonic increasing or decreasing function of time and the Residual Δt can be assumed to be from the same distribution with zero mean.

The Mann–Kendall test statistic S is calculated as it was in [8], using the formula. The Mann–Kendall S Statistic is computed as follows:

$$S = \sum_{i-1}^{n-1} \sum_{j=i+1}^{n} \mathrm{Sign}\ (T_j - T_i) \tag{2}$$

where x_j and x_k are the annual values in years j and k, $j > k$, respectively, and

The standardized test statistic Z is computed by

$$Z_S(MK) = \begin{cases} \frac{S-1}{\sigma}, \text{ for } S > 0 \\ 0, \text{ for } S = 0 \\ \frac{S+1}{\sigma}, \text{ for } S < 0 \end{cases} \tag{3}$$

The variance of S is computed by equation below to take care of ties that may be present.

$$E(S) = 0$$

The variance (σ^2) for the S – Statistic is defined by

$$\sigma^2 = \frac{n(n-1)(2n+5) - \sum t_i (i)(i-1)(2i+5)}{18} \tag{4}$$

where: t_i denotes the number of ties to extent i. The summation term in the numerator is used only if the data series contains tied values. The statistic S is then standardized (equation 3), resulting in the MK final value. The significance of the MK statistic can be estimated from the normal cumulative distribution function

To estimate the true slope of an existing trend (as change per year) the Sen's nonparametric method is used. The Sen's method can be used in cases where the trend can be assumed to be linear. This means that $f(t)$ in equation (1) is equal to

$$F(t) = Q_t + B \quad (5)$$

— The Fourier Transform

The Fourier transform was used to transform a continuous time signal into the frequency domain. It describes the continuous spectrum of a non–periodic time signal. The Fourier transform X (f) of a continuous time function x (t) can be expressed as:

$$X(f) = \int_{-\infty}^{\infty} X(t)\, e^{-i2\pi ft}\, dt \quad (6)$$

The inverse transform is

$$X(f) = \int_{-\infty}^{\infty} X(t)\, e^{i2\pi ft}\, df \quad (7)$$

— The Discrete Fourier Transform

This was used in the case where both the time and the frequency variables are discrete (which they are if digital computers are being used to perform the analysis). Let $X(nT)$ represent the discrete time signal, and let $X(mF)$ represent the discrete frequency transform function. The Discrete Fourier Transform (FT) is given by

$$X(m\,F) = \sum_n x(n\,T) e^{-inm2\pi FT} \quad (8)$$

where,

$$X(n\,F) = \frac{1}{N}\sum_n x(m\,F)\, e^{inm2\pi FT} \quad (9)$$

4. RESULTS AND DISCUSSIONS

— Spatial distribution and trends of temperature over Nigeria

The summary table shows that Benin recorded the highest annual temperature peak at the rate of 3.39°C/mo/yr in the month of September, with return period of 1–2 years, followed by Ibadan with the highest annual temperature peak of 1.82°C/mo/yr in the month of April and return period of 2–3 years. Meanwhile, the lowest annual temperature peak of –0.037°C/mo/yr was recorded for Akure in the month of March with cycles of 5 years.

Table 2: The Summary of the Result of Mann—Kendall and Auto—correction Spectral Analysis

Stations	Temperature Peak (°C/mo/yr)/ Month	Annual Temperature Cycles (years)
Abuja	0.031 / November	1 – 2 / 4 – 5 yrs
Akure	0.037 / March	5 / 20 – 25 yrs
Bauchi	0.033 / January	3 – 5 / 20 – 25 yrs
Benin	3.39 / September	1 – 2 / 15 – 20 yrs
Gusua	0.008 / April	6 – 7 / 20 – 25 yrs

– Positive and + negative signs show decreasing and increasing trends respectively

Table 2 shows the Mann–Kendall test statistics of mean monthly temperature for Abuja station. The month of January showed no change in mean monthly temperature trends while the months of November and December were increasing in temperature at the rate of 0.03°C/mo/yr and 0.029°C/mo/yr with significance level of 0.1. The months of February, march, April, May, June, July, August, September and October were decreasing in temperature trends at the rate of 0.009°C/mo/yr, 0.023°C/mo/yr, 0.038°C/mo/yr, 0.028°C/mo/yr, 0.025°C/mo/yr, 0.02°C/mo/yr, 0.021°C/mo/yr, 0.03°C/mo/yr, and 0.025°C/mo/yr respectively. The results show that the month of November experienced the highest temperature.

Table 2. Mann–Kendall test statistics for mean monthly temperature for Abuja station (SAVANNA)

Time Series	First Year	Last Year	Test Z Temp.	Slope Q Temp.	Time Series	First Year	Last Year	Test Z Temp.	Slope Q Temp.
Jan.	1960	2016	0.13	0.000	July	1960	2016	–3.07**	–0.020
Feb.	1960	2016	–0.58	–0.009	Aug.	1960	2016	3.24***	–0.021
March	1960	2016	–1.06	–0.023	Sept.	1960	2016	–2.95**	–0.030
April	1960	2016	–1.99*	–0.038	Oct.	1960	2016	–2.41*	–0.025
May	1960	2016	–1.94*	–0.028	Nov.	1960	2016	3.17**	0.031
June	1960	2016	3.55***	–0.025	Dec.	1960	2016	2.79**	0.029

*** if significance level (a) is 0.001, ** if (a) is 0.01, * if (a) is 0.1

Table 3. Mann–Kendall test statistics for mean monthly temperature for Akure station (GUINEA)

Time Series	First Year	Last Year	Test Z Temp.	Slope Q Temp.	Time Series	First Year	Last Year	Test Z Temp.	Slope Q Temp.
Jan.	1960	2016	–1.53	–0.018	July	1960	2016	–0.68	0.004
Feb.	1960	2016	–0.62	0.003	Aug.	1960	2016	–1.45	0.025
March	1960	2016	2.67**	0.037	Sept.	1960	2016	–1.78	0.017
April	1960	2016	0.84	0.010	Oct.	1960	2016	1.45	0.031
May	1960	2016	–0.15	0.000	Nov.	1960	2016	1.34	0.002
June	1960	2016	1.61	0.024	Dec.	1960	2016	0.41	0.023

*** if significance level (a) is 0.001, ** if (a) is 0.01, * if (a) is 0.05, + if (a) is 0.1

Table 3 shows the Mann–Kendall test statistics of mean monthly temperature of Akure station. The months of May and July showed no change in temperature trends while the months of March, April and June were increasing at the rate 0.037°C/mo/yr, 0.01°C/mo/yr and 0.024°C/mo/yr with various significance levels. Meanwhile, months of January, February, August, September, October, November and December were decreasing in temperature at the rate of 0.018°C/mo/yr, 0.003°C/mo/yr, 0.021°C/mo/yr, 0.073°C/mo/yr and 0.059°C/mo/yr respectively. The results show that the highest temperature was recorded in the month of March.

Table 4 shows Mann–Kendall test statistics for monthly temperature for Gusua station. The months of January, February, May and July showed no change in the trends of temperature. Months of March, June, August, September, October and November were decreased in temperature at the rate of 0.041°C/mo/yr, 0.018°C/mo/yr, 0.028°C/mo/yr, 0.023°C/mo/yr, 0.042°C/mo/yr and 0.013°C/mo/yr respectively. The month of April increased in temperature at the rate of 0.08°C/mo/yr. The results showed that month of April witnessed the highest temperature.

Table 4: Mann–Kendall test statistics for mean monthly temperature for Gusua (SAHEL

Time Series	First Year	Last Year	Test Z Temp.	Slope Q Temp.	Time Series	First Year	Last Year	Test Z Temp.	Slope Q Temp.
Jan.	1960	2016	0.24	0.000	July	1960	2016	−0.17	0.000
Feb.	1960	2016	0.13	0.000	Aug.	1960	2016	−2.20*	−0.028
March	1960	2016	−0.01	−0.041	Sept.	1960	2016	−1.52	−0.023
April	1960	2016	0.88	0.008	Oct.	1960	2016	3.20**	−0.042
May	1960	2016	−0.32	0.000	Nov.	1960	2016	−0.64	−0.013
June	1960	2016	−1.45	−0.018	Dec.	1960	2016	0.00	0.000

** if significance level is 0.01, * if significance level is 0.05.

Table 5 shows the annual temperature for twenty stations over Nigeria. The following stations; Abuja, Lagos, Minna, Port Harcourt, Sokoto, Warri, and Yola were increasing in temperature at the rate of 0.087°C/mo/yr, 0.157°C/mo/yr, 0.082°C/mo/yr, 0.032°C/mo/yr, 0.053°C/mo/yr, 0.026°C/mo/yr, and 0.046°C/mo/yr respectively, while Bauchi, Calabar, Gusua, Ibadan, Oshogbo, and Yelwa stations were also increasing in temperature at the following rate; 0.007°C/mo/yr, 0.014°C/mo/yr, 0.019°C/mo/yr, 0.02°C/mo/yr, 0.082°C/mo/yr, 0.012°C/mo/yr, and 0.004°C/mo/yr respectively. Meanwhile, Abeokuta, Akure, Benin, Enugu, Iseyin, and Maiduguri were decreasing in temperature at the rate of 0.021°C/mo/yr, 0.01°C/mo/yr, 0.002°C/mo/yr, 0.007°C/mo/yr, 0.029°C/mo/yr, 0.014°C/mo/yr and 0.01°C/mo/yr. The various significance levels at which they are increasing or decreasing are shown in table 5. Lagos has the highest annual temperature followed by Abuja, and Minna while Ikeja has the highest rainfall followed by Abeokuta and Gusau.

Table 5: Mann–Kendall test statistics for annual rainfall and annual temperature for twenty stations in Nigeria

Time Series	First Year	Last Year	Test Z Temp.	Slope Q Temp.	Time Series	First Year	Last Year	Test Z Temp.	Slope Q Temp.
Abeokuta	1960	2016	−1.21	0.021	Iseyin	1960	2016	−0.60	−0.014
Abuja	1960	2016	3.62***	0.089	Lagos	1960	2016	7.00***	0.157
Akure	1960	2016	−1.31	0.010	Maiduguri	1960	2016	−2.09*	−0.010
Bauchi	1960	2016	0.89	0.007	Minna	1960	2016	3.31***	0.082
Benin	1960	2016	−0.17	0.002	Osogbo	1960	2016	1.49	0.012
Calabar	1960	2016	−2.41*	0.014	P/Harcourt	1960	2016	4.98***	0.032
Enugu	1960	2016	−1.03	0.007	Sokoto	1960	2016	6.20***	0.053
Gusau	1960	2016	−2.04*	0.019	Warri	1960	2016	4.37***	0.026
Ibadan	1960	2016	1.92+	0.020	Yelwa	1960	2016	0.50	0.004
Ikeja	1960	2016	−2.00*	0.029					

*** if significance level (a) is 0.001, ** if (a) is 0.01, * if (a) is 0.05, + if (a) is 0.1

— Inter–annual trends of temperature

Figure 2 shows the residual mass curve of Abuja mean annual temperature. For annual, there was decrease in rainfall from 1960 to 1984 except 1972 and as from 1992 and thereafter the trend became positive. The highest rainfall occurred in 1965 and 2004, while the last two decades have experienced slight increase in temperature and 1972 experienced highest temperature.

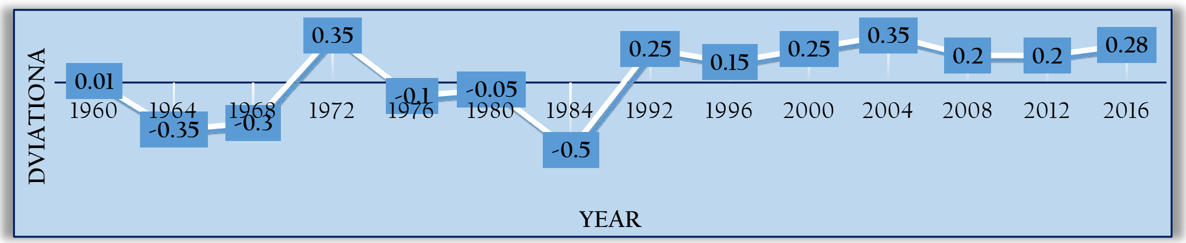

Figure 2: Residual mass curve of Abuja (SAVANNA) (i) mean Annual Temperature

Figure 3 shows residual mass curve of Akure mean annual temperature. There was slight decrease in annual temperature in the half decades and and 1960 experienced highest temperature. While the last two decades had experienced decrease in annual rainfall. There was a positive trend in temperature between 1996 and 2012 followed by slight decrease at the end. Figure 4 shows Residual mass curve of mean annual temperature for Gusua. The annual mean temperature for Gusua had experienced decrease in trend in the last two and half decades with peak temperature in year 1996. The year 1996 witnessed abnormal sunshine and recorded highest mean monthly temperature.

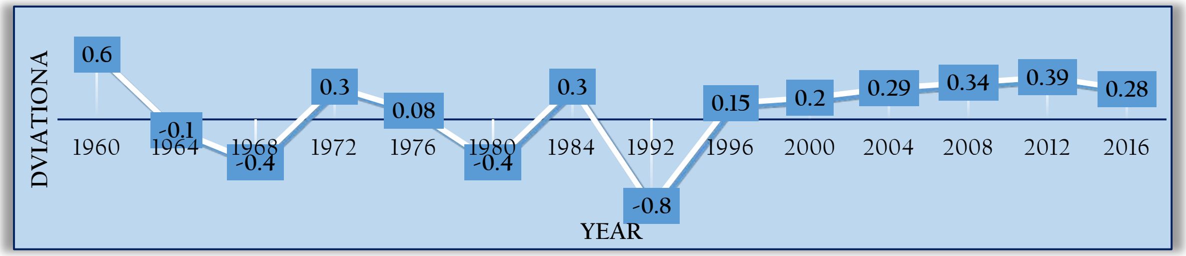

Figure 3: Residual mass curve of Akure (GUINEA) mean Annual Temperature

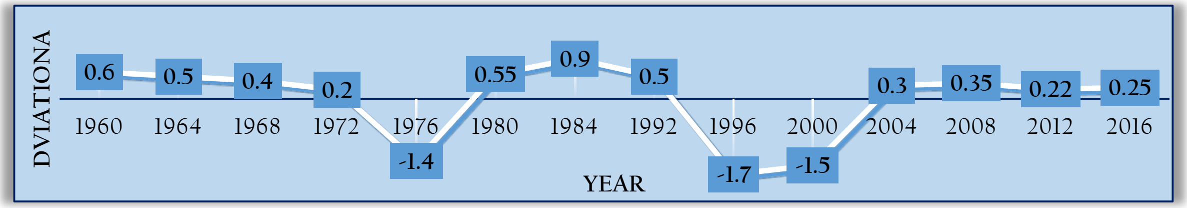

Figure 4: Residual mass curve of Gusua (SAHEL) mean Annual Temperature

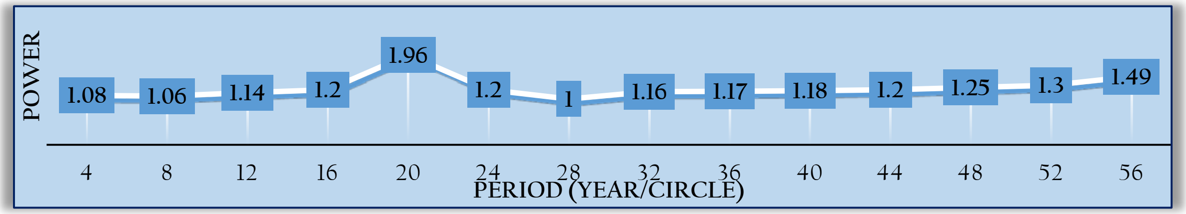

Figure 5: Auto correlation spectral analysis of Abuja (SAVANNA) Annual mean Temperature

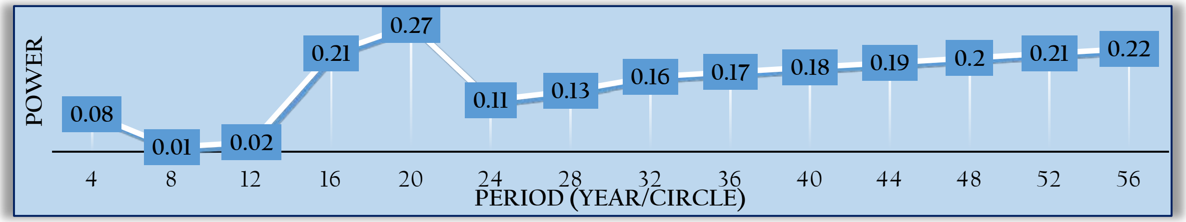

Figure 6: Autocorrelation spectral analysis of Akure (GUINEA) means Annual Temperature

Figure 5 shows the auto correlation spectral analysis (ASA) of Abuja (SAVANNA) mean annual temperature. The dominant peak in temperature has 1–2 years and 4–5 years as return period. The dominant peak in temperature has 4–5 years as return period. Figure 6 shows auto correlation spectral analysis (ASA) of Akure (GUINEA) mean annual temperature. The dominant peaks in temperature had 20 years and 20–25 years as return period.

The recent analysis on climate change [1] showed that the globally average surface temperatures have increased by $0.6 \pm 0.2^{0}C$ over the 20th century and likely to increase between 1.1–6.4°C by the end of 21st century [1]. In this study, covering twenty stations in Nigeria, it was observed that the trends in stations have changed drastically from what the patterns used to be in the past. Reversal of trends was observed in some of the locations.

Table 6. Summary of the Implications of the study on Agriculture and Water Resource

Trends Status	Stations under the category	Implications on Water Resource and Agriculture
Decrease in temperature trends	Akure, Maiduguri	Drought and shortage of moisture content are probable in the stations. Benin is inclusive.
Increase in temperature trends	Oshogbo, P/Harcourt, Sokoto, Warri, and Yelwa	Fair weather for Agriculture in the stations,
Increase in temperature and decrease in rainfall	Abuja, Benin, Calabar, Lagos and Yola	Desertification and water depletion are probable due to high evaporation rate.
Increase in temperature and decrease in rainfall	Abeokuta, Enugu, Ikeja, and iseyin	Flood is probable.
Increase in temperature and zero trend of rainfall	Minna and Bauchi	Desertification and water depletion are probable due to high evaporation rate

The results showed specifically that Akure and Maiduguri stations decreased in trends of both rainfall and temperature with magnitude of return period put at average of 2 years for rainfall and 5 years for temperature. On the other hand, Osogbo, Port Harcourt, Sokoto, Warri and Yelwa stations experienced upward trends in temperature and rainfall on annual basis. Stations that experienced upward trends in temperature and downward trends in rainfall are Abuja, Benin, Calabar, Lagos and Yola. The following stations; Abeokuta, Enugu, Ikeja and Iseyin experienced upward trends in rainfall and downward trends in temperature, while Minna and Bauchi stations experienced upward trends in annual temperature and rainfall showed no change in trend.

[19] confirmed and attributed the sharp increase in trends of temperature of Abuja to massive construction that followed relocation of the Federal Capital Territory from Lagos to Abuja. The magnitude of the return period at which the dominant peak of trend of Abuja temperature repeats itself was not stated in the paper. Precipitation was noticed to be decreasing in the last two decades as also confirmed by various studies [20]. Temperature and rainfall are principal controlling elements which determine the growing season and timing of agricultural activities most especially in Nigeria as well as other tropical regions [21].

The findings of this study have far reaching implications on both agriculture and water resources as summarized in table 6 above. The stations that experienced downward trends in temperature and rainfall are likely to face problems of drought and shortage of soil moisture content in no distant future expecially when the rate of decline in trends of rainfall is greater than the rate at which temperature declines. Other stations that experienced upward trends of temperature and downward trend of rainfall are prone to desertification and depletion of underground water. Stations that experienced upward in trends of both temperature and rainfall portend to have fair and clement weather conditions for agricultural activities.

4. CONCLUSION

In this study, there were variations in the rainfall and temperature distributions on annual and monthly basis over Nigeria. The rates at which dominant temperature and rainfall peaks return also vary, impacting different effects on climate and agriculture. For example areas experiencing positive trends and dominant rainfall of short return period will likely be prone to flood. Likewise areas experiencing positive trends and dominant temperature peak of short return period will likely be prone to drought and desertification.

References

[1] Inter–Governmental Panel on Climate Change (IPCC)., "Climate Change and Agriculture in Africa" Impact Assessment and Adaptation Strategies. www.earthprint.com.2007
[2] Inter–Governmental Panel on Climate Change (IPCC)., "Global Warming; Early Signs on Climate change" Retrieved online (http//www.climatehotmap.org.).2005
[3] Adefolalu D.O., "An Introduction to the Challenges of Climate Change and its Impact in Nigeria" Workshop on Climate Change and Natural Disasters in Nigeria. pp. 34 – 35, 2000
[4] Duce P., Spano D., Motroni A. and Canu S., "Rishchio climatico perl'agricoltura in ambiente mediterraneo" Proc. Workshop CLIMAGR Cagilari, Italy, where and when?. Climate Change. pp. 109 –142, 16 17th January, 2003
[5] Motroni A., Duce P., Spano D. and Canu S., "Estimation of climatic risk for Agriculture in a Mediterranean region" Proc.15 Conf. on Biometeorol. and Aerobiology, Kansas City, MO, USA. pp. 308 –309, 27 October– 1 November, 2002
[6] Enete I.C., "Potential Impacts of Climate Change on Coastal Settlements of Nigeria", at the 15th National Conference of the Environment and Behaviour Association of Nigeria held at Babcock University, Ogun State. International Institute of Tropical Agriculture, Annual Report. pp. 37– 43, 2008
[7] Parry M.L. and Carter T.R., "The assessment of effects of climatic variations on agriculture; aims, methods and summary of results" In: The impact of Climatic variations on agriculture, Vol, 1 reidel Publ. Co., Dordrecht, The Netherlands. pp. 11– 95, 1988
[8] Oguntunde P.G., Friese J.N., Van de Giesen H. and Savenije H.G.., "Hydroclimatology of the Volta River Basin in West Africa" Trends and Variability 1901–2002. Journal of Physics and Chemistry of the Earth. 2006
[9] Inter–Governmental Panel on Climate Change (IPCC)., "Climate change 2001" Mitigation Summary for Policy Makers and Technical Summary, Geneva, Switzerland. pp 72, 2001
[10] Smith M., "Application of climatic data for planning and management of sustainable rain–fed and irrigated crop production" Journal of Agricultural and technology. Pp. 231 – 239, 2000
[11] Crowley T.J., "Causes of Climate Change over the last 1000 years" Science (in press). 2000
[12] Houghton J.T., Ding, Y., Griggs D.J., Noguer M., Van der Linden P.J., Dai X., Maskell K. and Johnson C.A., "Climate Change 2001" The Scientific Basis: Contribution of working group I to the third assessment report of the Intergovernmental Panel on Climate Change, Cambridge University Press Cambridge, United Kingdom. pp. 110 – 126, 2001
[13] Yue S. and Hashiro M., "Temperature trends in Japan: 1900 –1996. Theoretical and Applied Climatology" Vol. 75, No. 1, pp. 15 – 27, 2003
[14] Yue S. and Pilon P A ., "Comparison of the power of the t test, Mann–Kendall and bootstrap tests for trend detection" Hydrological Sciences Journal, Vol. 49, No. 49, pp. 53 – 37, 2004
[15] Weng S.P., "Changes of diurnal temperature range in Taiwan and their large–scale associations: univariate and multivariate trend analyses" Journal of the Meteorological Society of Japan. World Resource Institute Report .2000. Fresh water systems–pilot analysis of global ecosystems, Washington D.C. Vol. 88, No. 2, pp. 203–226, 2010
[16] Mavromatis T. and Stathis D., "Response of the Water Balance in Greece to Temperature and Precipitation Trends" Theoretical and Applied Climatology. 104: pp.13–24, 2011
[17] Yue S. and Wang C., "The Mann–Kendall Test Modified by Effective Sample Size to Detect Trend in Serially Correlated Hydrological Series" Water Resources Management 18, pp. 201 –218, 2004
[18] Tabari H., Marofi S., Aeini A., Talaee P.H. and Mohammadi K. "Trend Analysis Reference Evapotranspiration in the Western half of Iran" Agricultural and Forest Meteorology 151, pp. 128–136, 2011
[19] Ogunjobi K.O., Ajayi V.O. and Oluleye A., "Influence of Urbanization on the Temperature of Abuja, Nigeria" Department of Meteorology, Federal University of Technology, Akure, Nigeria. 2004
[20] Unkasevic M. and Radinovic D., "Statistical analysis of daily maximum and monthly precipitation at Belgrade" Theor. Appl. Climatol. 66: 241–249. during 1982–1984. World climate data programme, 52 Pp. 2000
[21] Odekunle T.O., "Rainfall and Nigerian Growing Season" Intl. J. Climatol. 24: pp. 467– 479, 2004