PHYSICAL/CLIMATE SCIENCES

Trend Analysis of Temperature and Relative Humidity across the Climatic Zones of Nigeria

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Abstract
This paper presents the trend analysis of temperature and relative humidity in the climatic zones of Nigeria using Mann-Kendall trend test. The daily Temperature and relative humidity data were obtained from Nigerian Meteorological Agency (NIMET) via the data bank of the West African Science Service Center on Climate Change and Adaptive Land Use (WASCAL) of the Federal University of Technology Minna for the period of Thirty-three years (1981-2014). In order to determine the nature of the trend and significance level, Mann-Kendall trend test and Sen's estimate were employed. From this study, it was observed that temperature shows a positive Kendall's Z value which indicates an upward trend and also, implies increasing trend over time. The result also indicates that there is a significant increase in the trend at 5% level of significance since (p-values (0.0001) <0.05). The results of the relative humidity also indicate that there is an increase in the trend at 5% level of significance since (p-values (0.0001) <0.05). It can also be seen from both the Mann-Kendall and Sen's Slope that there is a possibility of an increment in temperature and relative humidity. This could be due to the impacts of climate change and this leads to devastating unfavorable changing in conditions in the study area. It is therefore recommended that the variability of temperature and relative humidity should be monitored in order to reduce its effects on human activities

Keywords: Variation, trend, temperature, relative humidity

1. INTRODUCTION

Temperature and relative humidity are very important elements that determine the weather condition of a particular area as asserted by National Centre for Environmental Information. These elements are not constant and as such they keep on changing from time to time due to human interference and this uncertainty can cause havoc to the environment (Abraham *et. al*., 2002). To forestall these devastating effects of unfavourable changing in weather conditions due to changing temperature and relative humidity, there is need for scientific prediction (Kumar *et al*., 2012). Temperature and relative humidity play an important role in the forming of natural life. It is not just significant to humans alone but also to animals, plants and all living things. It also plays a unique role in agriculture.

Climate change has been confirmed following the release of the 4th Intergovernmental Panel on Climate Change (IPPC) assessment report. Africa, of which Nigeria is a part, will be worst hit by the effect of climate change. The change in climatic conditions due to the increasing greenhouse emission has made human beings and the planet earth to experience negative impact such as persistent drought flooding, off season's rains and dry spells therefore having great impact on the growth seasons of a country dependent on agriculture (Olaniyi, 2014). According to the World Meteorological Organization (WMO), 30 years is the classical period for performing the statistics used to define climate (Goosse *et. al*., 2010).

Change in climate alters temperature regimes in most parts of the world. Temperature is one of the basic climatic parameters and changes in its pattern can affect the living components of the earth (Onoz and Bayazit, 2003). An increase in temperature can result in heat wave incidents and cause illness and death in less resilient populations. In addition, temperature changes can cause a shift in animal and plant species (Mishra and Herath, 2012). An increase in Earth's temperature causes convectional current and increase the rate of evaporation thereby leading to cloud formation, which in turn, increases precipitation (Salami *et. al*., 2016). Increase in precipitation trend can also result to increase in the frequency of floods and could thereby affect water quality.

Trend analysis can better be used to depict and predict the changing pattern and variability of climatic parameters (such as temperature and precipitation). This analysis gives knowledge about the changing condition of the climate. Various studies were done using Mann Kendall test. Olaniran and Sumner (2001) used Mann Kendall trend test to study variables such as rainfall, relative humidity, wind speed and sea level rise in Lagos, the result showed positive Kendall's (S) values, indicating upward trend and implying increase in the parameters over time. However, temperature showed negative Kendall's (S), which indicates downward trend and implies decrease over time. Sea level rise, rainfall, relative humidity and wind speed had mean statistics of 3.99, 1.97, 3.09 and 2.26 respectively which are more than 1.96 (test statistics for a significant level of 5% (Z =1.96), this implies that the upward trend is significance and there is tendency for continuity. Temperature had statistic of 0.03 which is less than 1.96 and implies no significance, thus the reduction may not be noticed.

Dammo *et. al.* (2016) used same test to study observed trend of changes in relative humidity across North-East Nigeria (1981-2010). Results indicated consistent increase in relative humidity over the years and across location with a stable increase in relative humidity at all locations. Mann–Kendall test was also applied for detecting monthly and annual trends in the relative humidity in Iraq for the Period 1951-2010 (Abdulwahab and Alobaidi, 2015). The monthly time series showed that relative humidity decreases during winter, spring and autumn months.

This study is aimed at using Mann Kendall non-parametric test to analyse the trend in temperature and relative humidity for a 33-years period (1981-2014). Mann-Kendall non-parametric test was used for the analysis because of its applicability for a time series distribution, which does not follow a typical statistical distribution.

2. 0 MATERIALS AND METHOD

2.1 Data Acquisition

The study area is Nigeria located at the extreme inner corner of the Gulf of Guinea on the west coast of Africa. She occupies an area of 923,768 km². 910,768 km² of the area is land, while water takes up the remaining 13,000 km². Nigeria can be divided into five climatic zones namely Sahel, tropical rainforest, Guinea savannah, Sudan savannah and Coastal zones (Olaniran and Sumner, 2001). Two weather stations were selected for each of the 5 climatic zones as shown in figure 1. Table 1 shows the coordinates and elevation of the selected weather stations.

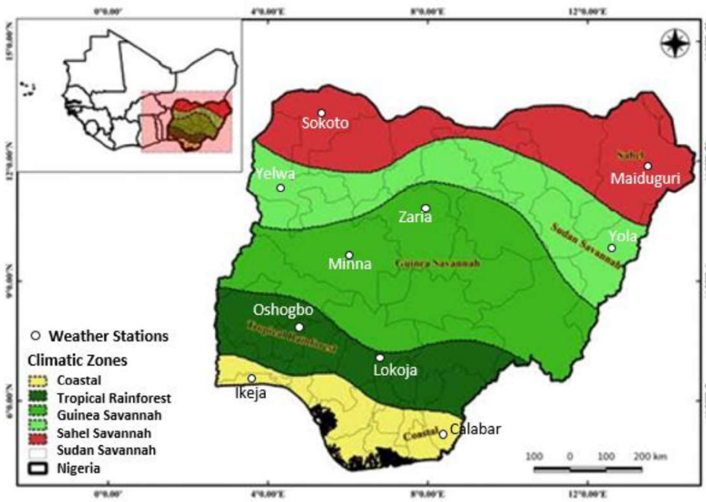

Figure 1: The selected weather stations within the climatic zones of Nigeria

Table 1: The geographical coordinates of selected weather stations.

Climatic Zone	Station	Latitude (°N)	Longitude (°E)	Elevation (m)
Coastal	Calabar	4.97	8.35	63
	Ikeja	6.59	3.34	36
Tropical Rainforest	Lokoja	7.81	6.74	44
	Oshogbo	7.78	4.54	304
Guinea savannah	Minna	9.60	6.55	260
	Zaria	11.09	7.72	640
Sudan savannah	Sokoto	13.02	5.25	302
	Maiduguri	11.83	13.15	354
Sahel savannah	Yelwa	10.88	4.75	243
	Yola	9.23	12.47	174

Thirty-three (33)-year period (1981-2014) data were obtained from the Nigerian Meteorological Agency (NIMET) via the data bank of the West African Science Service Centre on Climate Change and Adaptive Land Use (WASCAL) of the Federal University of Technology Minna.

2.2 Data Analysis

The mean monthly values of relative humidity and temperature were respectively computed and shown in plots and tables. Trend Analysis of the climatic zones in Nigeria was carried out using Mann-Kendall and Sen's Slope Estimator. The statistical significance of trends is indicated by p value. The significance level (the alpha value) was taken to be 0.05 for a significant trend to occur the p-value must be less than the alpha value. Mann– Kendall trend test was used to see whether there is a decreasing or increasing trend. Mann–Kendall statistics (S) is one of the nonparametric statistical tests used for detecting trends of climatic elements. Mann–Kendall trend test is also the most widely used methods since it is less sensitive to outliers (extraordinary high values within time series data) and it is the most robust as well as suitable for detecting trends (Allan *et. al.,*2013).

4.0Results and Discussion

4.1 Mean Monthly Variation of Relative Humidity and Temperature

Plot of the mean monthly relative humidity for each station in the climatic zone is shown in the plot in figure 2.

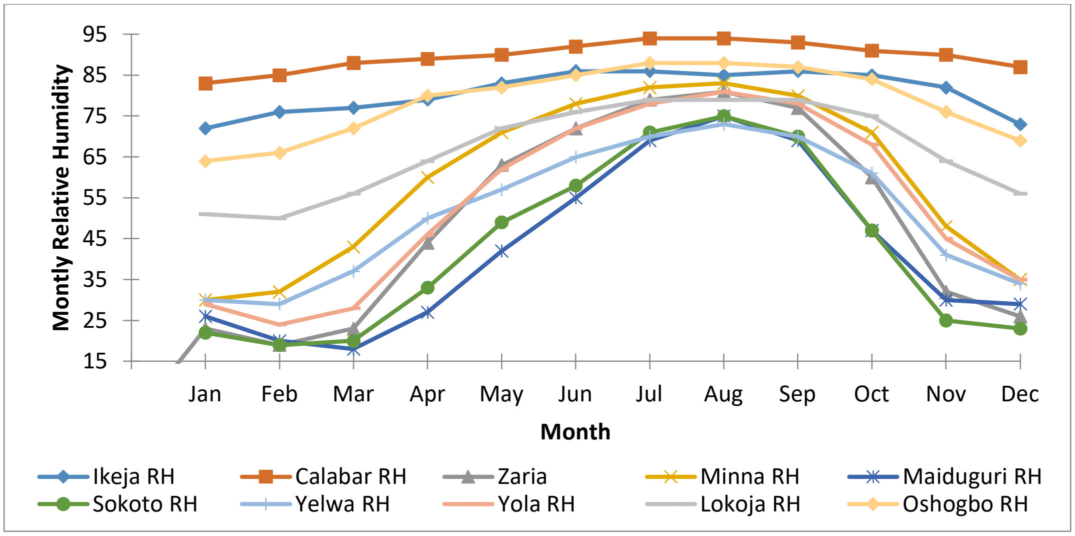

Figure 2: Mean monthly relative humidity for each station in the climatic zone

The coastal climatic zone had higher relative humidity with Calabar the highest in the zone. Calabar experiences more rainfall than Ikeja, and this makes Calabar to be cool all through the year than Ikeja, in the tropical climatic zone, Oshogbo had a higher relative humidity than Lokoja, In the Guinea savannah climatic zone the trend of Zaria is a little superimposed with that of Yola that is, they tend to have the same mean monthly variation in relative humidity this is because relative humidity increases with altitude. Zaria, though located in the guinea savannah climatic zone, tends to have the same relative humidity with the Sudan savannah climatic zone. Minna had a higher relative humidity than Zaria.

In the Sudan savannah climatic zone, Yola had a higher relative humidity than Yelwa this is because Yola is located in a mountainous area and experiences extreme seasonal variation in monthly rainfall. In the Sahel savannah climatic zone, which is the least climatic zone in the plot, Sokoto from January had higher trend than Maiduguri but in the month of August Maiduguri and Sokoto had the same peak relative humidity while in the month of October they tend to have the same mean monthly variation.

The mean monthly temperature for each station in the climatic zone is shown in figure 3.

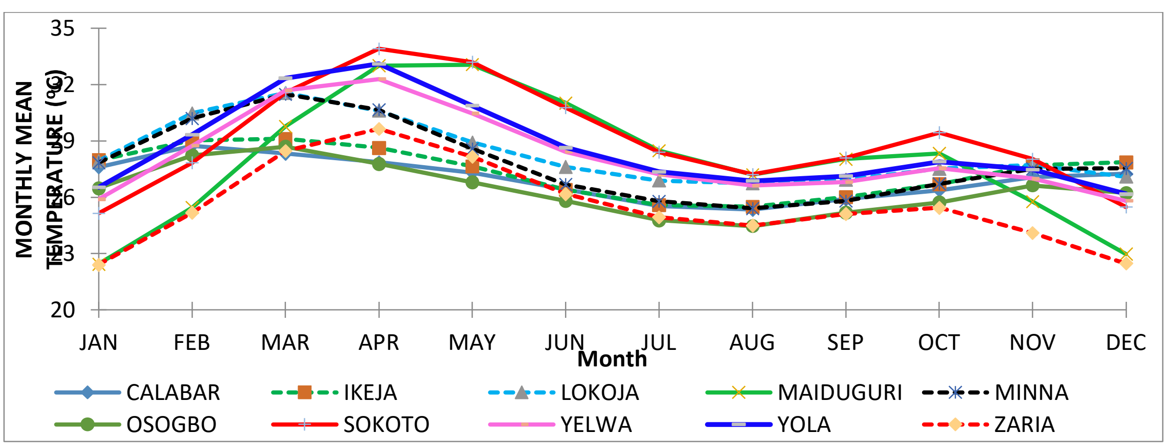

Figure 3: Mean monthly plot of temperature for each station in the climatic zone

As shown in figure 3, the coastal climatic zone had low temperature and Calabar had the lowest in the zone and Calabar experiences more rainfall than Ikeja due to high relative humidity, and these makes Calabar to be cool all through the year than Ikeja, in the Tropical climatic zone, Oshogbo had a low temperature than Lokoja, In the Guinea savannah climatic zone Minna had a higher temperature than Zaria.

In the Sudan savannah climatic zone, Yola had a low temperature than Yelwa this is because Yola is located in a mountainous land and Yola experiences extreme seasonal variation in monthly rainfall. The Sahel savannah climatic zone, which is the least climatic zone and which has the highest temperature and lowest humidity and they tend to have the lowest rainfall throughout the year.

4.2 Mann Kendall Trend (M-K) Test

The M-K test results for relative humidity and temperature, comparing with significant level of 5% (0.05), shows that the p-value of all the regions is less than the alpha value which implies that there is trend. Tables 3 and 4 show the Mann Kendall non-parametric test on relative humidity and temperature data set respectively.

Results of the Mann-Kendall test for relative humidity shown in table 3 shows four stations (Calabar, Yelwa, Lokoja and Oshogbo) having negative Z-values and Q values, which signifies a decreasing trend (downward trend) in relative humidity. The Kendall Tau (τ) values for these 3 stations indicate negative correlation and statistical dependence of the variables (time series data). The other 7 stations (Ikeja, Minna, Zaria, Sokoto, Yola and Maiduguri) had positive Z-values and Q values, which signifies an increasing trend (upward trend). The Kendall Tau (τ) values for these 7 stations indicate positive correlation. In a similar study, Ogolo (2011) showed a decreasing trend for relative humidity in the tropical rainforest region of Nigeria. According to Amadi *et. al.* (2015), trend and variation of relative humidity in Nigeria is usually affected by latitudinal variation therefore the general trend of humidity in Nigeria must be considered over various ecological zones of the country, varying from the Savannah in the North to the tropical/coastal regions of the South.

The Mann-Kendall test for temperature shown in table 4, shows all the stations (Calabar, Ikeja, Yelwa, Yola, Lokoja, Oshogbo, Minna, Zaria, Sokoto, and Maiduguri) having positive Z and Q values, which signifies an increasing trend (upward trend) in temperature. The Kendall Tau (τ) values for these 10 stations indicate positive correlation. A rise in temperature is among the indicators of climate change (Asfaw *et. al.,* 2018). Onyeneke *et. al*. (2020) reported that temperature increased substantially over time across all main agro-ecological regions in Nigeria. The rise in temperature can cause scorching of crops as well as reduced crop yield. Research conducted by Freduah *et. al.*, (2019) shows an increase in temperatures of the Savannah areas of Guinea and Sudan. These agro meteorological areas equally showed evidence of decreasing precipitation, which, along with rising temperatures. This implies that there has been a steady increase on local scale for the period 1981 – 2014 which conforms to the 3rd Assessment Report of the IPCC that showed an increase in global temperature during the twentieth century Freduah *et. al.*, (2019). The positive trends observed are in agreement with the results obtained by Freduah *et. al.*, (2019). Based on the above results, it is of great importance to consider the future effect of increasing temperatures on the environment, agriculture and health if the present trend is continuous.

5.0 CONCLUSION

It can be concluded from both Mann- Kendall and Sen's Slope that there is a possibility of increment in temperature and relative humidity. This could be due to impact of climate change. However, if caution is not taken, it may lead to devastating unfavourable changing in weather conditions in the study area. It is therefore recommended that the variability of temperature should be monitored in order to minimize its effects on human activities.

Table 3: Results of the Mann-Kendall test for Relative Humidity Data.

Climatic Zones	Stations	Kendall's Tau	Var(S)	Test Statistic (S)	Test Statistic (Z)	p-Value (two test)	Alpha	Sen's Slope (Q)	Test Interpretation
Costal	Calabar	-0.052	212143545556.667	-394757	-8.57	< 0.0001	0.05	-9.355E-5	H_1
	Ikeja	0.073	212322348090	5600220	12.15	< 0.0001	0.05	1.904E-4	H_1
Guinea	Minna	0.026	212378068391	1967333	4.26	< 0.0001	0.05	1.9384E-4	H_1
	Zaria	0.031	212380131400.667	2352806	5.1	< 0.0001	0.05	2.569E-4	H_1
Sahel	Sokoto	0.014	212380391760	1093532	2.37	0.018	0.05	2.037E-4	H_1
	Maiduguri	0.041	212380356852.667	3185102	6.91	< 0.0001	0.05	4.468E-4	H_1
Sudan	Yelwa	-0.018	212371883680.333	-1344283	-2.91	0.004	0.05	-5.570E-4	H_1
	Yola	0.016	212380996305.333	1192426	2.58	0.010	0.05	3.070E-4	H_1
Tropic	Lokoja	-0.017	212369241260	-1304752	-2.83	0.005	0.05	-1.109E-5	H_1
	Oshogbo	-0.028	212357092601	-2151759	-4.66	< 0.0001	0.05	-2.137E-4	H_1

Table 4; Results of the Mann-Kendall test for temperature data

Climatic Zones	Stations	Kendall's Tau	Var (S)	Test Statistic (S)	Test Statistic (Z)	p-Value (two test)	Alpha	Sen's Slope (Q)	Test Interpretation
Costal	Calabar	0.030	211369377937.333	2253098.000	4.9	< 0.0001	0.05	1.848E-5	H_1
	Ikeja	0.077	211845015112.667	5826080.000	12.65	< 0.0001	0.05	5.746E-5	H_1
Guinea	Minna	0.023	211920296153.667	1710687.000	3.71	0.000	0.05	0	H_1
	Zaria	0.048	212031132017.667	3634425.000	7.89	< 0.0001	0.05	3.650E-5	H_1
Sahel	Sokoto	0.024	212184607918.000	1804642.000	3.91	< 0.0001	0.05	0	H_1
	Maiduguri	0.025	212238783014.000	1866650.000	4.05	< 0.0001	0.05	1.291E-5	H_1
Sudan	Yelwa	0.047	212121336802.667	3578186.000	7.76	< 0.0001	0.05	7.493E-5	H_1
	Yola	0.033	212136144025.667	2537257.000	5.50	< 0.0001	0.05	1.754E-5	H_1
Tropic	Lokoja	0.057	212002870315.667	4313925.000	9.36	< 0.0001	0.05	5.502E-5	H_1
	Oshogbo	0.062	211662388664.333	4675299.000	10.16	< 0.0001	0.05	2.479E-4	H_1

Reference

Abraham, A, Ninan, S. P., Baikunth, N. and Saratchandran, P. (2002): Second Internaltional Workshop on intelligent Systems Design and applications computational intelligence and applications, pp. 181-186.

Kumar, A., Yang, F., Goddard, L. and Schubert, S. (2012): Differing trends in the tropical surface temperatures and precipitation over land and oceans. *Journal of Climate*, 17(3), pp. 653-664.

Olaniyi, O. A., Fumilayo, O. A. and Olutimehin, I, O. (2014): Review of Climate Change and its Effect on Nigeria Ecosystem. *International Journal of Environment and Pollution Research* 2(3), pp.70-81.

Goosse, H., Barriat, P. Y., Loutre, M.F. and Zunz, V. (2010): Introduction to climate dynamics and climate modeling.

Onoz, B. and Bayazit, M. (2003): The power of statistical tests for trend detection. *Turkish Journal of Engineering & Environmental Sciences* 2012(27) pp. 247–251.

Mishra, B. K. and Herath, S. (2012). An investigation on climate change risk for run-of-river hydropower schemes: A case study of Sunkoshi river basin. Nepal;

Salami, W., Ikpee, D., Ibitoye, B. and Oritola, F. (2016): Trend analysis of hydro-meteorological variables in the coastal area of Lagos using Mann-Kendall trend and standard anomaly index methods. *J. Appl. Sci. Environ.* Manage; 20(3): pp.797-808.

Olaniran, O. J. and Sumner, G. N. (2001): A study of climatic variability in Nigeria based on the onset, retreat, and length of the rainy season. *International Journal of Climatology*, 9(3), pp. 253-269.

Dammo, N., Yadima, G. and Sangodoyin, Y. (2016): Observed trend of changes in relative humidity across north-east Nigeria. Civil and Environmental Research; 8(3). (ISSN 2224-5790) (ISSN 2225-0514)

Abdulwahab, H. and Alobaidi (2015): Analysis of relative humidity in Iraq for the period 1951-2010. *International Journal of Scientific and Research Publications*; 5

Allan, C., Xia, J. and Pahl-Wostl, C. (2013): Climate change and water security: challenges for adaptive water management. Current Opinion in Environmental Sustainability 5(6): pp. 625–632.http://dx.doi.org/10.1016/j.cosust.2013 .09.004.

Ogolo, E. O. (2011): Regional trend analysis of pan evaporation in Nigeria (1970 to 2000). *J. of Geog and Reg Plan* 4(10) pp. 556 – 577

Amadi, S.O., Udo, S. O and Udoimuk, A. B. (2015): An examination of trends and variation of monthly mean relative humidity data in Nigeria from 1950 – 2012. *Int. J. Pure Appl. Sci. Technol.*, 28(2) pp. 63-76

Asfaw, A., Simane, B., Hassen, A., and Bantider, A. (2018): Variability and time series trend analysis of rainfall and temperature in northcentral Ethiopia: A case study in Woleka sub-basin. Weather and climate extremes, 19, 29-41.

Onyeneke, R. U., Emenekwe, C. C., Munonye, J. O., Nwajiuba, C. A., Uwazie, U. I., Amadi, M. U., and Onyeneke, L. U. (2020): Progress in Climate–Agricultural Vulnerability Assessment in Nigeria. Atmosphere, 11(2), 190.

Freduah, B. S., MacCarthy, D. S., Adam, M., Ly, M., Ruane, A. C., Timpong-Jones, E. C. and Adiku, S. G. (2019): Sensitivity of maize yield in smallholder systems to climate