International Journal of Weather, Climate Change and Conservation Research, 10(1),42-53, 2024
Print ISSN: ISSN 2059-2396 (Print)
Online ISSN: ISSN 2059-240X (Online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

Recent Changes in Rainfall and Diurnal Temperatures in Selected Cities in Tropical Monsoon and Tropical Savanna Climatic Zones of Southern Nigeria

Ernest Benjamin Ikechukwu Ugwu
Natural Science Unit/Department of Physics and Astronomy, University of Nigeria, Nsukka, Nigeria

doi: https://doi.org/10.37745/ijwcccr.15/vol10n14253 Published June 20, 2024

Citation: Ugwu E.B.I (2024) Recent Changes in Rainfall and Diurnal Temperatures in Selected Cities in Tropical Monsoon and Tropical Savanna Climatic Zones of Southern Nigeria, *International Journal of Weather, Climate Change and Conservation Research*, 10(1),42-53

ABSTRACT: *Statistical approach has been used to analyze trends of rainfall and diurnal temperatures in Southern Nigeria. Daily data from Nigerian Meteorological Agency from 2000 to 2019 in five stations are used for the analysis. XLSTAT software is employed in generating the Mann-Kendall (MK) trends for rainfall, DTR and, in plotting graphs. The results show that annual rainfall amount is on increasing trend in all the stations with the lowest increase of 1.2 mm/year in Owerri to 11.46 mm per year in Ibadan. The increasing annual trends, even though insignificant in all the stations except in Ikeja, is enough to cause negative impacts on the environment. Also, diurnal temperatures are in anti-correspondence with rainfall amount*.

KEYWORDS: rainfall, diurnal temperatures, cities, tropical monsoon, tropical savanna climatic zones, Southern Nigeria

INTRODUCTION

Floods and droughts are one of the serious environmental threats to humanity, particularly in Nigeria, causing loss of life and property. Floods are mainly caused by excess rainfall beyond the soil's storage capacity (Nwachukwu et al., 2018). Drought is due to insufficient rainfall. In Nigeria, hundreds of deaths have been recorded in recent years, and more than 2.5 million people are at risk of loss of livelihoods by 2022 (Echendu 2020; Njoku 2022; Khalid and Mashman 2022).
Umar and Gray (2023) believe that appropriate mapping methods should be used to address environmental threats such as flooding. Nigeria as a whole has high variability in amount, intensity and frequency of rainfall (Ogunrinde et al., 2019; Animashaun et al., 2020; Ugwu et al., 2023). Most of these events are relatively recent in Nigeria and provide evidence of climate change in Nigeria. The southern part of Nigeria records the highest annual rainfall in Nigeria and, in recent years, there seems to be a steady increase in rainfall indexes in this part of the country.

Temperature is another climate element that affects human activity. Surface warming is being experienced all over the world. The Intergovernmental Panel on Climate Change (IPCC, 2018) Reports indicates a rise of between 0.85 -1.2^{0}C preindustrial time. Recent IPCC Reports of 2021 indicates that the 1.5^{0}C global warming limit may soon be exceeded due to anthropological activities. Porter and Brown (1991) predicts that it may reach 4.5^{0}C in the near future. In Nigeria, there are signs of increase in surface temperature (Kehinde, 2022). Global warming, if unchecked, will adversely affect the economy of Nigeria. Southern Nigeria, due to its proximity to the Atlantic Ocean, is most vulnerable to climate change. Activities of oil exploration in this region and global warming has reduced crop and animal production, increased post-harvest losses, increase in pests and diseases and low health status of the inhabitants of the area (Adedoyin. 2011). Several mitigation methods have been suggested (Olaniyi et al., 2013) like afforestation and reforestation, reduction in burning of fossil fuels and emission of greenhouse gases, change in atricultural practices etc.

There are several studies in climate change in Nigeria most of which dwells on rainfall trends and variability (Ogunrinde et al., 2019, Animashuan et al., 2020, Ugwu et al., 20,23) variations in temperatures, emission of greenhouse gases (GHG), impact of climate change on various aspects of human endeavor and health (Echendu, 2020; Umar and Gray, 2023;), agriculture and economy (Abubakar, 2022) etc.

Considering the enormous losses associated with climate change, it is necessary that more efforts be put in the understanding of its effects, trend and variability, mitigation and possible future scenarios. This article is centered on the trends of rainfall and surface temperatures in Southern Nigeria. Hopefully, the findings will be of help to farmers especially fishermen, policy makers and environmentalists.

MATERIALS AND METHOD

Study Area

The selected cities are found in the coastal region of Nigeria and are located within latitude 4-7^{0}N and longitude 3-7^{0}E. Two of the towns (Owerri and Port Harcourt) are in the tropical monsoon climate (Am) while the rest (Benin City, Ikeja and Ibadan) are in the tropical Savanna (Aw). Rainfall amount is usually high in these areas with long duration and its amount decreases with latitude towards the North. Tropical monsoon climate zone records an average annual rainfall amount of 2,000mm and sometimes even up to 4,00mm and a mean temperature of 25-28^{0}C. It is located close to the equator and is intermediate between the very wet tropical wet climate (Af) and the drier tropical Savanna (Aw). The tropical Savanna occupies a very large area of Nigeria and is above the tropical monsoon but below the hot and semi-arid tropical Sahel. The average annual rainfall is 1,200mm and mean temperature is 29-35^{0}C.

Port Harcourt is the capital of Rivers State. It is the fifth most populous city in Nigeria. It lies along the Bonny River, a tributary of River Niger. It is a few kilometers from the Gulf of Guinea and the headquarters of most Petroleum Companies.

Owerri is the capital City of Imo State and home to many tertiary institutions like Imo State University, Federal University of Technology etc. Ikeja is the capital City of Lagos State and the most populous city in Lagos State.

Benin City is the capital of Edo State and the fourth largest City in Nigeria. It is famous for bronze casting. Ibadan is the third populous city in Nigeria behind Lagos and Kano. It is the capital city of Oyo State, Nigeria and home to many tertiary schools. Their locations are shown in **Table 1.**

Table 1: Geographical locations of the Towns

Town	Latitude (^{0}N)	Longitude (^{0}E)	Köppen Climate Zone
Owerri	5.476	7.026	Am
Port Harcourt	4.824	7.034	Am
Benin City	6.339	5.617	Aw
Ikeja	6.606	3.349	Aw
Ibadan	7.377	3.940	Aw

Sources of Data

Daily data for rainfall, maximum, temperatures and minimum temperatures from 2000 to 2019 are collected from the headquarters of the Nigerian Meteorological Agency (NIMET), Abuja, Nigeria. The Shapiro-Wilk tests is used to test for data distribution at 5% level of significance. It is observed that the data is approximately normally distributed. Standard normal homogeneity test (SNHT) showed that variation in the data is due to climatic factors only (Aguilar et al., 2003)

Data Analysis

In-built XLSTAT software was employed in data analysis. Monthly and annual averages of rainfall and standard deviation (SD) are calculated for the period of study. Equations 1 and 2 respectively are the formula for mean and SD. Diurnal temperature range is calculated using Equation 3. Clustered column plots seasonal and annual rainfall to identify trends in rainfall while and line plots are used compare diurnal temperatures and rainfall.

$$Mean, X_{mn} = \frac{\Sigma X}{N} \quad 1$$

where X_{mn} = mean rainfall, X = daily or average monthly values and N = number of data points.

$$SD = \frac{\Sigma(X-X_{mn})^2}{N} \quad 2$$

$$DT = T_{max} - T_{min} \quad 3$$

where DT = diurnal temperature, T_{max} =maximum temperature, T_{min} = minimum temperature

Mann-Kendall Trend Test

The Mann-Kendall (MK) is a non-parametric test widely used in meteorological and hydrological analysis of data. It requires a significant amount of data. The MK trend tests are based on two hypotheses: (1) The null hypothesis: there is no trend in the series or trend is insignificant (H_0) and (2) The alternative hypothesis: there is trend in the series or trend is significant (H_a). If P-value < the level of significance (α =0.05), accept H_a but if P-value > α, accept H_0. In this analysis, the level of significance is 5% or 0.05. In this article, annual and seasonal trends are analyzed and results are presented in Tables 2, 3 and 4. The Mann-Kendall test is given by Equation 4 below.

$$S = \Sigma_{k=1}^{n-1}\Sigma_{j=k+1}^{n} sign\ (X_j - X_i) \quad 4$$

where Xj and Xi are annual rainfall values in years j and i, j > i, respectively

$$\text{where } Sign\big((X_j - X_i)\big) = \begin{cases} +1, > (X_j - X_i) \\ 0 = (X_j - X_i) \\ -1, < (X_j - X_i) \end{cases} \quad 5$$

Sen's Slope Estimator (Q1)

The magnitude of trend can be estimated using Sen's slope estimator. Equation 6 below is the slope (d_k).

$$d_k = \frac{y_j - y_i}{j-i}, for\ (1 \le i \le j \le m) \quad 6$$

where $y_i\ and\ y_j$= values at time $i\ and\ j$ respectively, m is the number of data points.

International Journal of Weather, Climate Change and Conservation Research, 10(1),42-53, 2024
Print ISSN: ISSN 2059-2396 (Print)
Online ISSN: ISSN 2059-240X (Online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

The Sen's slope estimator, Q_1 is the median of d_k given by Equation 7

$$Q_1 = \begin{cases} \frac{d_{m+1}}{2}, m\ is\ odd \\ \frac{1}{2}\left(\frac{d_m}{2d} + \frac{d_{m+2}}{2}\right), m\ is\ even \end{cases} \quad 7$$

Positive/negative value of Q_1 means increasing/decreasing trend.

RESULTS AND DISCUSSION

Trend Analysis

a) Clustered Column charts

Figure 1 is the clustered column chart of annual rainfall variation for the period (2000-2019). It shows that Port Harcourt recorded the highest amount of rainfall for all the years except in the year 2000 that Owerri has the highest amount. Port Harcourt and Owerri have a higher significant amount of rainfall than the three towns in tropical savanna. This supports the conclusion that rainfall amount in Nigeria is latitudinal dependent; it increases with latitude (Atuma et al., 2023, Ibebuchi and Abu, 2023). The two stations are in the tropical monsoon climate zone where it rains throughout the year and are closest to the Atlantic Ocean. Harmattan and "August Break" are rarely observed in these two places. In 2000 and 2007, the amount of rainfall is highest for most stations.

There is a decline in rainfall amount in 2014 and 2015. A gradual increase in amount of rainfall is seen between 2016 and 2019.This shows that southern Nigeria has been receiving more rainfall in recent years. It is an evidence of climate change.

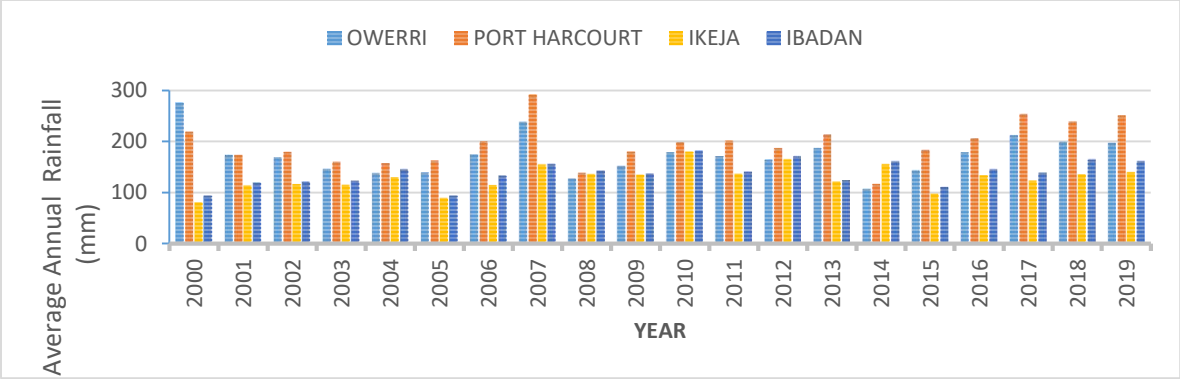


Figure 1: Annual variation of average rainfall

Figure 2 shows that monthly rainfall increases from very low values in January to maximum values from June to September and falls again to low values in December. This

means that most of the rainfall in all stations occurs between June and September. In the tropical Savanna cities of Benin City, Ikeja and Ibadan, rainfall decreased slightly in August. This is the result of a short dry season called August Break or Little Dry Season that is observed in late July and early August for two to three weeks (Chineke et al., 2010). However, the August break is not clearly observed in Port Harcourt and Owerri.

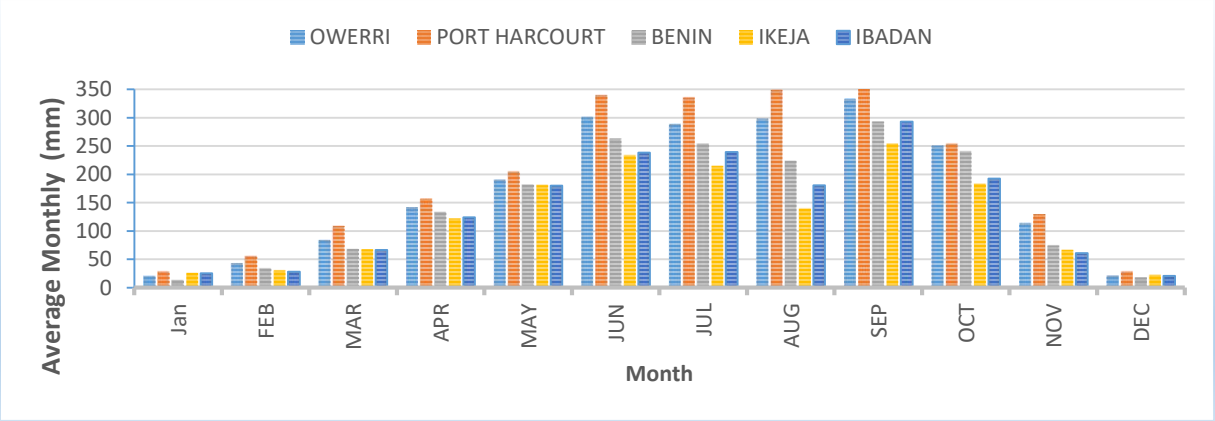
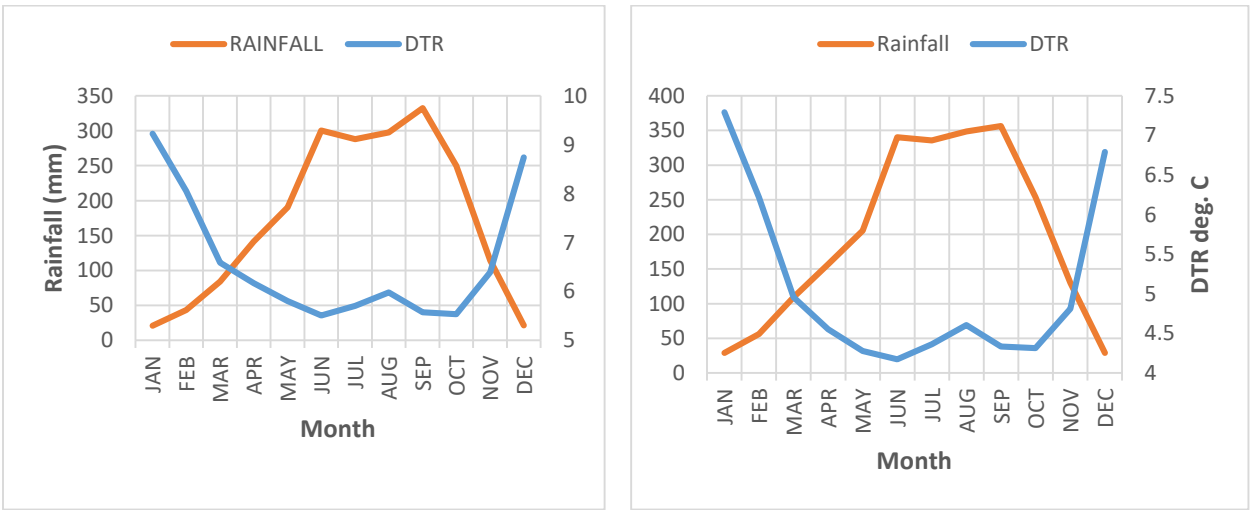


Figure 2: Monthly variation of average rainfall

b) Line plots

Plots of charts of monthly rainfall are used to compare the variations of diurnal temperature and monthly rainfall. The charts are presented in below:

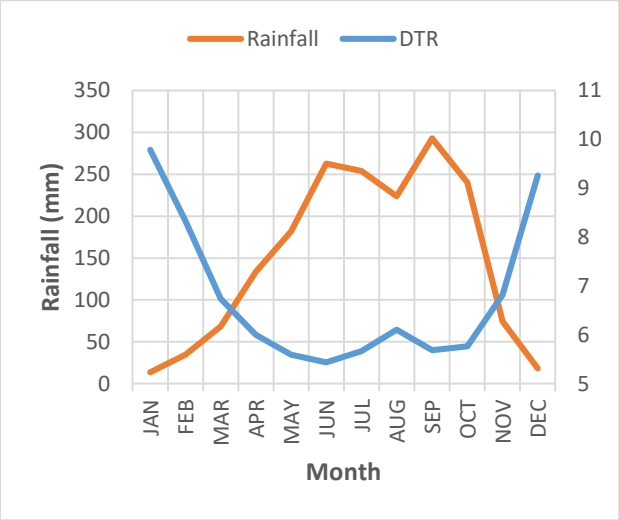


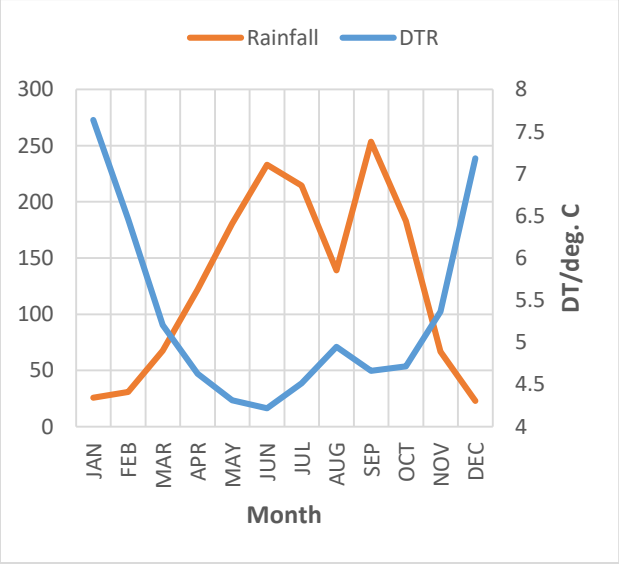
a b

Figure 3: Line charts for Owerri (a) and Port Harcourt (b)

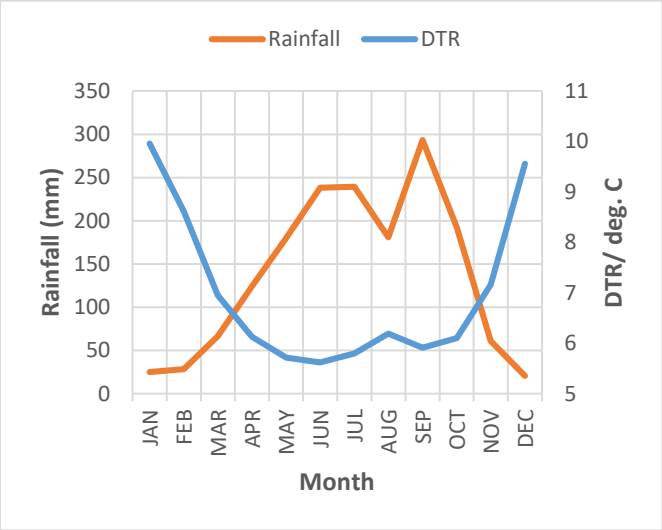
Figure 3 shows an anti-correspondence between monthly rainfall variations and monthly diurnal temperature range (DTR). Diurnal temperatures are least within the period of very heavy rainfall

(May to September) and maximum during the dry season (December, January, February and March). There is a small rise in diurnal temperature for both towns in August. This is the period of "Little Dry season" or 'August Break".





a b



c

Figure 4: Line charts for Benin City (a), Ikeja (b) and Ibadan (c) respectively.

Figure 4 shows that diurnal temperatures increase with decrease in the amount of rainfall. Again, maximum values are got when the amount of rainfall is the least (dry season). Also, there is a small rise in diurnal temperature during "August Break" in all the tropical savanna towns. The reason for this anti-correspondence between rainfall and DTR may be because of high humidity prevalent during the rainy season months. Water has a very high latent heat capacity. It absorbs heat during the day and at night loses little amount of heat at night. This accounts for the little variations in between maximum and minimum temperatures. During dry season, the amount of water vapour in the atmosphere is very low resulting to high diurnal temperature range.

c) Mann-Kendall Trend Test Results

From Table 2 below, it is clear that in Owerri, $P < \alpha$ in the months of March, April and August, implying significant trend in rainfall amount but insignificant trend in rainfall ($P > 0.05$) in the remaining nine (9) months. In April, there is significant decrease in rainfall amount (Sen's slope = -7.1mm/month) while there is significant increase in trend in March and August (Sen's slope = 3.5 mm/month and 6.9 mm/month respectively). Within the period studied, monthly rainfall increased between 0.1mm/month and 6.9mm/month for nine (9) months of the year but the decrease is between 0.3mm/month and7.1mm/month for three (3) months. On annual basis, there is an increase in the amount of rainfall by 1.2mm/year. This means that annual rainfall amount in Owerri is on the increase but the increase is significant.

Rainfall amount in Port Harcourt has increased from 0.1mm/month in February to 13.3mm/month in July. There is decrease in April and December by 0.42mm/month and 5.1mm/month

respectively. On annual basis, there is an increase by 3.3mm/year within the period studied. However, these changes are not significant in Port Harcourt as P > 0.05. The implication is that in the tropical monsoon towns in Nigeria, there is no significant trend in the annual amount of rainfall, however it is an evidence of gradual change in climate in Port Harcourt.

Table 2: The results of the (MK) analysis for Tropical Monsoon Towns

Duration	**Owerri**		**Port Harcourt**	
	P-value	Sen's slope (mm/month)	P-value	Sen's slope (mm/month)
Annual	0.46	1.2*	0.06	3.3*
January	0.97	0.1	0.82	0.2
February	0.92	0.1	0.82	0.1
March	**0.03**	3.5	0.11	3.8
April	**0.04**	-7.1	0.21	-5.1
May	0.38	-1.9	0.77	1.1
June	0.32	6.3	0.11	13.3
July	0.42	4.1	0.26	4.9
August	**0.04**	6.9	0.11	8.0
September	0.97	0.4	0.46	4.4
October	0.35	4.7	0.13	6.2
November	0.16	2.3	0.09	4.1
December	0.27	-0.34	0.26	-0.4

*mm/yea

Table 3: The results of the (MK) analysis for Tropical Savanna Towns

Duration	**Benin City**		**Ikeja**		**Ibadan**	
	P-value	Sen's slope (mm/month)	P-value	Sen's slope (mm/month)	P-value	Sen's slope (mm/month)
Annual	0.32	2.1*	**0.04**	1.4*	0.07	11.46*
January	0.38	0.26	0.77	0.16	0.75	0.07
February	0.18	1.36	**0.02**	2.34	**0.02**	0.38
March	**0.01**	4.20	0.11	2.13	0.09	1.95
April	0.23	-4.49	0.21	-2.66	0.46	-1.92
May	0.58	-1.36	0.23	3.33	0.32	3.71
June	0.26	7.44	0.82	1.01	0.28	3.24
July	0.32	4.14	0.92	-2.52	0.82	0.72
August	**0.02**	10.63	0.42	2.12	0.26	2.02
September	0.38	4.71	0.13	4.96	0.11	6.46
October	0.92	0.57	0.16	2.73	0.13	3.46
November	0.23	2.08	**0.04**	2.12	0.07	2.00
December	0.58	0.08	0.23	0.42	0.16	0.30

*mm/year

Table 3 shows that the tropical savanna towns, annual rainfall increased between 1.4 mm/year in Ikeja and 11.46/mm/year in Ibadan. However, the increment in yearly rainfall amount is significant only in Ikeja ($P < 0.05$). This may be as a result of significant increases ($P < 0.05$) in rainfall in February and November in Ikeja. There are significant increasing trends in rainfall amount in the months of March and August in Benin City, February and November in Ikeja and February in Ibadan. Monthly increasing trends range between 0.08 mm/year and 10.63 mm/month in Benin City, 0.16 mm/month and 6.49 mm/month in Ikeja and 0.07 mm/month and 6.47 mm/month in Ibadan within the period studied. There are few months of decrease in rainfall amount, particularly in April where the Sen's slope is negative for all the stations. The implication of all the trend scenarios is that the increasing trends are can lead to significant impacts on the environment. Extreme weather events have been reported in so many parts of Nigeria in the recent past.

CONCLUSION

Statistical approach has been used to analyze trends of rainfall and diurnal temperatures in Southern Nigeria. Daily data from NIMET from 2000 to 2019 (20 years) in five stations are used for analysis. XLSTAT software is employed in generating the MK trends for rainfall, DTR and graphs. Results show that annual rainfall amount is on increasing trend in all the stations with the lowest increase of 1.2 mm/year in Owerri to 11.46 mm/year in Ibadan. However, the increment is no significant but can still cause noticeable impacts on the environment. It is seen that diurnal temperatures are highest during the dry season months and least during the rainy season. This is attributed to the prevalence of moisture (water) in the atmosphere during the rainy season. Water has high capacity and can retain the heat gained during the day for a long time. Hence, nighttime temperatures and daytime temperatures are very close in magnitude.

During the preparation of this work the author(s) used [**WRITEFULL]** in order to [**improve on the grammar and structure of the article**]. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication

REFERENCES

1. Chineke, T.C., Nwafor, O. and Jagtap, S.S. (2010), West African monsoon: Is the August break "breaking" in the eastern humid zone of Southern Nigeria?, Climatic Change 103(3), Pp 555-570, DOI:10.1007/s10584-009-9780-2
2. Aguilar, E., Auer, I., Brunet, M., Peterson, T.C. and Wieringa, J. (2003) "Guidelines on climate metadata and homogenization, WMO/TD No. 1186, World Meteorological Organization, Geneva, Switzerland.
3. Njoku, G. (2022), More than 1.5 million children at risk as devastating floods hit Nigeria, UNICEF, https://www.unicef.org/press-releases/more-15-million-children-risk-devastating-floods-hit-nigeria

4. Khalid, I and Maishman, E. (2022), Nigeria floods: 'Overwhelming' disaster leaves more than 600 people dead, BBC News, Abuja & London
5. Umar, N., and Gray, A. (2023). Flooding in Nigeria: a review of its occurrence and impacts and approaches to modelling flood data. *International Journal of Environmental Studies*, *80*(3), 540–561. https://doi.org/10.1080/00207233.2022.2081471
6. Nwachukwu, M.A., Alozie, C.P., and Alozie, G.A. (2018), Environmental and rainfall intensity analysis to solve the problem of flooding in Owerri urban. *Journal of Environmental Hazards* 1, 107.
7. Ugwu, E.B.I., Ugbor, D.O., Agbo J.U. and Alfa, A. (2023) "Analyzing rainfall trend and drought occurrences in Sudan Savanna of Nigeria", *Scientific African*, https://doi.org/10.1016/j.sciaf.2023.e01670.
8. Animashaun, M., Oguntunde, P.G., Akinwumiju, A.S., Olubanjo, O.O. (2020) Rainfall Analysis over the Niger Central Hydrological Area, Nigeria: Variability, Trend, and Change point detection, Scientific African,8, e00419, https://doi.org/10.1016/j.sciaf.2020.e00419.
9. Ogunrinde, A. T., Oguntunde, P.G., Akinwumiju, A.s. and Fasinmirin, J.T. (2019) Analysis of recent changes in rainfall and drought indices in Nigeria, 1981–2015}, Hydrological Sciences Journal, 64, Pp 1755-1768.
10. IPCC, 2013: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.
11. Echendu, A.J. (2020) The impact of flooding on Nigeria's sustainable development goals (SDGs), Ecosystem health and sustainability, 6(1), DOI: 10.1080/20964129.2020.1791735
12. Kehinde, A.O. (2022), The effect of global warming in Nigeria: Flood in perspective, Studia Prewno-Ekonomiczne, Pp 39–58, https://doi.org/10.26485/SPE/2022/124/3
13. Porter, G. and Brown, J.W. (1991), Global Environmental politics: Dilemmas in World politics, Colorado Washington Press.
14. Adedoyin, I.A., Ayoola, S.O. and Ikenweiwe, B. (2011), Impact of Climate Change in Nigeria, Iranian Journal of Energy and Environment 2(2):145-152, 2(2):145-152.
15. Olaniyi O.A., Ojekunle Z.O. and Amujo, B.T.(2013), Review of climate change and its effect on Nigeria ecosystem, International Journal of African and Asian Studies, Vol.1, 57.
16. Abubakar, A. (2022), Flooding in Nigeria: A review, African Journal of sustainable development, 10(1).
17. Atuma, M.I., Ndakara, E.O. and Efe, S.I. (2023), Analysis of rainfall distributions and variations in Nigeria, Hmlyn J. Agr (4), Pp72-80, DOI:10.47310/hja.2023.v04i04.012
18. Ibebuchi, C. Abu, I-O, (2023), Rainfall variability patterns in Nigeria during the rainy season, Scientific Reports 13(1), DOI:10.1038/s41598-023-34970-7

Author Contributions:

EBIU was involved in conceptualization, designing study, data acquisition, analysis, writing the original manuscript, interpretation of results, prepared all the figures and tables and interpreting them.

OJU was involved in data acquisition, conceptualization, designing and manuscript review.

JUA took active part in reviewing the manuscript and proofreading it.

Competing Interests

The authors declare no competing interests.

Data Availability

`The datasets generated and/or analyzed during the current study are available on demand from Nigerian Meteorological Agency (NIMET), Abuja, Nigeria

Funding

No funding was received by the authors

HIGHLIGHTS

- Work is on trends of rainfall in Southern Nigerian Cities and diurnal temperature
- Area of coverage is tropical Monsoon and tropical Savanna area of Nigeria and period is 2000-2019 (20 years).
- Observed rainfall data are used.
- Shapiro-Wilk test and SHNT were used in data validation.
- XLSTAT software was used in the analysis
- Results show insignificant trends in rainfall and anti-correspondence between rainfall and diurnal temperatures,