International Journal of Environment and Climate Change

Volume 13, Issue 5, Page 202-212, 2023; Article no.IJECC.97603
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Establishing Climatic Change on Rainfall Trend, Variation and Change Point Pattern in Benin City, Nigeria

Masi G. Sam [a], Ify L. Nwaogazie [a*] and Chiedozie Ikebude [a]

[a] Department of Civil and Environmental Engineering, University of Port Harcourt, Choba, Rivers State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2023/v13i51761

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/97603

Original Research Article

Received: 15/01/2023
Accepted: 21/03/2023
Published: 27/03/2023

ABSTRACT

This study examined the effect of changing climate for thirty-six years (1982-2017) on 24-hourly annual maximum time series (AMS) rainfall data for Benin City. The results show the existence of a trend, variation in magnitude, and change point dates. Trend analysis was performed using Mann-Kendall (MK) test and Sen's slope estimator (SSE) applied to obtain the trend magnitude. A statistically significant trend was found for Benin City at a 5% level of significance. The MK |Z| statistic varied from 2.0710 to 2.1550 for IMD and 2.0844 to 2.0995 for MCIMD downscaling models, which were both greater than the critical Z-value of 1.96. The SSE gave the magnitude of the trend variation rate due to climate change at 24-hour duration as 1.008 mm/year (10.08 mm/decade) and 1.1376 mm/year (11.376 mm/decade) for the IMD and MCIMD models, respectively. Also, the trend change point analysis was conducted using the distribution-free cumulative sum test (CUSUM) and the sequential Mann-Kendall test (SQMK) which has rainfall pattern definite change point date for Benin City as 2005 from where continued a positive trend which intensified through the year 2015. Thus, proving the existence of increasing changing climatic condition for the study area.

**Corresponding author: E-mail: ifynwaogazie@yahoo.com;*

Keywords: Rainfall data; 24-hourly AMS; statistical tests; trend analysis; change point; changing climate.

1. INTRODUCTION

The earth's climate is moderated by a balance between rays coming from the Sun, and returning infrared rays from the earth. The infrared rays are absorbed by the greenhouse gases (GHG) and the cloud on its way back which eventually converts them to heat energy. Also, the heat engine of the earth is the solar radiation which contributes immensely in phenomena like rainfall, flooding, sea level rise and relative humidity because of differences in temperature. Thus, temperature and trends in climate data such as rainfall has been used as indicators of climate change by researchers to study the subject of climate change [1-5].

"Rainfall is an indicator for climate change which could be an increasing or decreasing process. The rainfall measurements constitutes series of data that can be analyzed as a time series. The characteristic of given set of time series observations could possess a gradual process in pattern termed as trend or possess abrupt changes that are described as trend change point. Recent studies on climate change have mostly focused on long-term variability of temperature and rainfall which are, as it were, considered the most important climate change indicators. However, evidence of climate change elsewhere and in Nigeria's meteorological system indicates an increasing rainfall trend in the coastal region and a decreasing rainfall inland" [5-10]. "Time-series analysis is an applied tool for the detection and quantitative description of the generating process characteristic of a given set of observations. The generative process of the time series possesses both gradual and abrupt changes that are described as either a trend or a trend change point. Therefore, trend analysis deal with evaluating gradual future events from past measured data, while change point detection deal with determining the unexpected, structural, changes in the time series data properties like mean or variance of the data" [11,12]. "There are different approaches in the literature used in calculating both the trend and change point. A parametric test is applied as a powerful tool, wherein the condition for its application required in trend analysis for a given data set are normal distribution and independence. Whereas, the non-parametric test data should be independent and tolerant of outliers. The non-parametric test for trend analysis in time series data that are most commonly applied adopted for this study is the Mann-Kendall test [11,13-16] and the Sen Slope estimator for evaluating the trend magnitude and its intercept" [17].

"Different techniques in the literature for the analysis of trend change points available are Wild binary segmentation, the Bayesian analysis of change points, the E-Agglomerative algorithm, and Iterative robust detection methods" [18-20]. "However, other methods of trend change-point analysis applied in this study is the Distribution-free cumulative sum (CUSUM) and the Sequential Mann-Kendall (SQMN) tests" [21-23].

The purpose of this study is to determine the effect of changing climate in Benin City, Nigeria using measured time series rainfall data recorded for 36 years (1982-2017) in terms of trend, its variation and magnitude, and the trend change point dates. Trend analysis was performed using the Mann-Kendall (MK) test, and the Sen's slope estimator (SSE) was applied to obtain the trend magnitude. The trend change point analysis was conducted using the distribution-free cumulative sum test (CUSUM) and the sequential Mann-Kendall test (SQMK). The 'python statsmodel library-pymannkendall' [24] and 'trendchange' [25,26] were the two different open-source software packages adopted.

2. METHODOLOGY

2.1 Study Area

The study station Benin City is located in Edo State in the South-South region of Nigeria. It lies between latitudes 6^o $52^'$ N – 6^o $21^'$ N and longitudes 5^o $34^'$ E – 5^o $44^'$ E, as shown in Fig. 1, sourced and enhanced from [27]. The area is located at an altitude/elevation of Nonem above sea level. Benin City has a tropical Savanna climate which is dry and wet. The driest month takes place in December period with 22.44 mm rainfall and the wettest month occurs in July with 332.95 mm of rainfall. The study area receives about 189.68 mm of rainfall with about 274.89 rainy days annually which is 75.31 % of the period. The annual highest and lowest temperature of 33.89 ^{0}C and 24.5 ^{0}C are recorded, respectively.

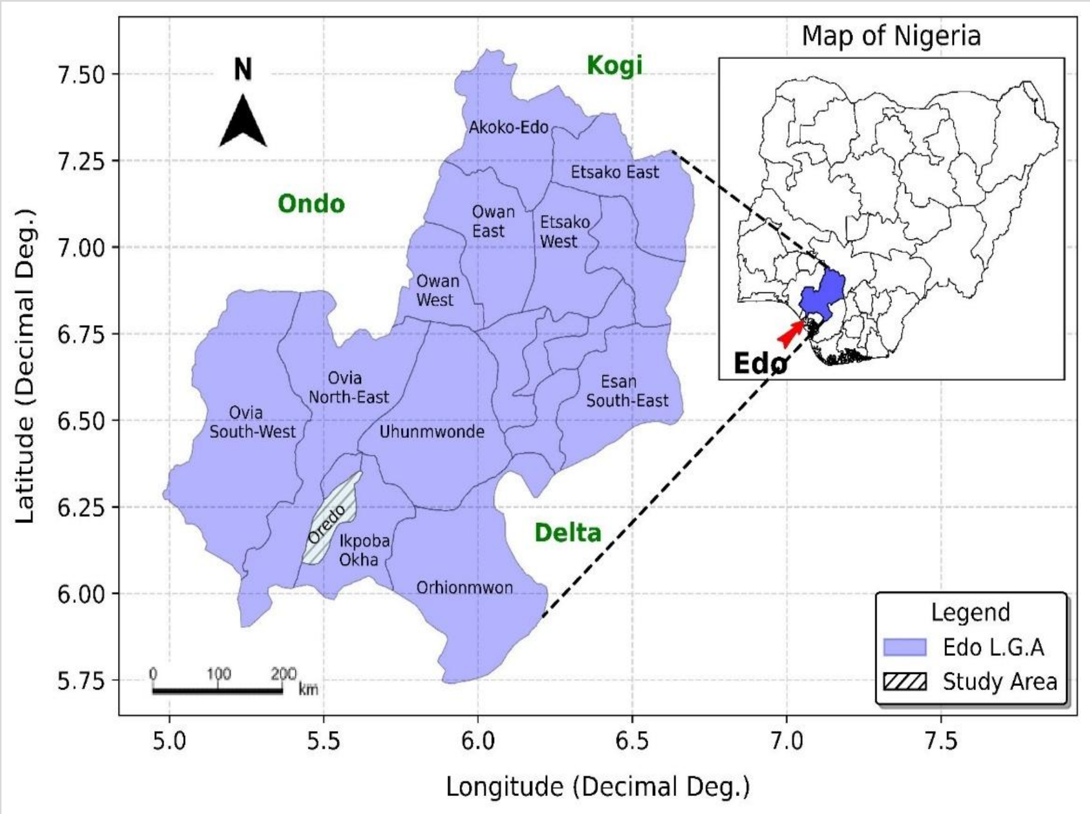

Fig. 1. Map of Edo State showing the study area - Benin City

2.2 Data Collection

The measured rainfall data for this study was collected for 36 years (1982-2017) from the Nigeria Meteorological Agency (NIMET) meteorological gauge station at Benin City. The collected data on rainfall amount was recorded in mm against corresponding durations recorded in minutes. Thereafter, the data was sorted out by extraction of the maximum daily (24-hourly) rainfall amount for each month with the maximum for each year extracted to obtain the 24-hourly annual maximum series (AMS) for the rest of the 36 years interval.

2.3 Downscaling of 24-hourly Rainfall Time Series Data into Shorter Durations

“Maximum daily rainfall data were collated for each month for the 36 years for various analysis of the time series data. The maximum 24-hourly annual maximum series (AMS) rainfall data extracted was further downscaled into shorter duration rainfall as detailed in [28] for the trend study”. “The formula applied was the proposed Indian meteorological department (IMD) initially proposed by [29] and the modified Chowdhury Indian meteorological department (MCIMD) [30] given in Equations (1) and (2), respectively”. Equation (3) was used for conversion of rainfall amount to its intensity equivalent;

$$R_t = R_{24}\left(\frac{t}{24}\right)^n \quad (1)$$

$$R_t = R_{24}\left(\frac{t}{24}\right)^n + C \quad (2)$$

$$I = R_t \,/\, t \quad (3)$$

Where: R_t is the required rainfall depth in mm for durations less than 24 hours, R_{24} is the daily rainfall depth (mm), t is the required duration (hours), n is an exponential constant = 1/3; while for the MCIMD model the n and C are determined constants, where I denotes the rainfall intensity (mm/hr).

2.4 Mann-Kendall Trend & Sen’ Slope Estimation Test

“Mann Kendall test [11,13,31] is a rank-based statistical test that helps to check if there is a monotonous upward or downward trend existing in a time series data". "Mann Kendall (MK) test is a non-parametric test in which the distribution of the data set must not be auto-correlated (no serial correlated). The conditions required to achieve a relatively error-free MK test result are well treated in the literature" [32-35]. Trend Free Pre-Whitening (TFPW) is used to remove serial correlation where it exists in the rainfall data. [24] documented "the procedure used in performing the Mann-Kendall test to find if a monotonous positive or negative trend exist in the time series data. Where serial correlation exist in the data set the TFPW is applied to remove the serial correlation. And where the ACF is not significant, the MK test is applied directly to the original data set". "The python statsmodel library-pymannkendall [24] was used to compute both the ACF at lag 1 and in applying TFPW to the time series data set before MK test was carried out on the pre-whitened data set if applicable. The trend magnitude was computed using the Sen Slope estimator analyzed with microsoft Excel stat 2016 and python pymannkendall library".

2.5 Trend Change-Point Test

"Identifying trends and time of trend change, play a significant part in precipitation parameters and time-series studies. To determine the trend change-point, two non-parametric testing methods, the Distribution-free cumulative sum (CUSUM) test [21] and the Sequential Mann-Kendall test [22,23] were applied". The distribution free CUSUM test utilizes a cumulative sum chart, while the sequential Mann-Kendall (SQMK) test uses each sample point sequence that are sequentially treated in both pro-grade and retrograde manner. [36] also demonstrated "in detail the application of both non-parametric approaches. The "trendchange" package was used for the change-point analysis". "The software package is an open-source library freely available via the CRAN repository as version 1.2" [25,26].

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Data sets used for the time series analysis

Detecting trend in the time series data was carried out for three different data sets. The first set of data was rainfall measurements obtained from downscaling 24-hourly rainfall data for Benin City (see Table 1) using the IMD formula in Equations (1) and (3), while the second set of data was the rainfall intensities obtained from downscaling the same 24-hourly rainfall data using the MCIMD model in Equations (2) and (3). The third data set is the initial sorted 24-hourly monthly maximum series (MMS) for the 36 years (1982-2017) study period.

3.1.2 Trend change analysis using Mann-Kendall (MK) statistic

The performance of the MK test require the computation of the autocorrelation function (ACF) at lag 1 at 95% Confidence interval (see Fig. 2 plot), which produced an insignificant result. Therefore, no trend free pre-whitening (TFPW) was applied, hence, the MK test was conducted directly on the original time series data. The results of the MK test are presented in Table 2. The $|Z|$ value for MCIMD model data varied for the various downscaled durations and ranges from 2.0844 to 2.0986 with slight variations for the IMD model data with range from 2.0710 to 2.1550. All the MK statistic $|Z|$ values were greater than the Critical Z-value of 1.96. Similarly, the p-value for the MCIMD modeel data produced a range of value varying from 0.0359 to 0.0371 for the different durations, while the IMD model data p-value were 0.0312 to 0.0384. These p-values obtained were all also below alpha, $\propto$ = 0.05 level of significance. These results reinforces the existence of statistically significant trend in the various downscaled short duration data.

3.1.3 Evaluation of trend magnitude & variation

Evaluation of the magnitude of the trend was carried out using Sen's slope estimator (SSE). The trend line intercept and slope, Q_i obtained are indicated in Figs. 3 to 5 and the values presented in Table 2. The result of the slope shows decreasing positive values of 0.9574 at 0.25 hour to 0.0420 at 24 hour, and 1.3893 at 0.25 hour to 0.0474 at 24 hour for IMD and MCIMD models, respectively. The intercept for the IMD method also decreased from 79.3963 to 3.8647 at 0.25 and 24 hours, respectively. The MCIMD data produced higher intercept values which similarly decreased from 139.0875 to 4.0197 at 0.25 to 24 hours, respectively. From Fig. 3 graph, the result obtained for the 24-hourly MMS data confirmed the trend variation magnitude results by giving a slope value of 0.020 mm/hr/year and intercept of 1.5168. The p-value of 0.00118 which is far less than alpha value at 5% significant level was obtained.

Table 1. 24-hourly annual maximum series (AMS) rainfall data for Benin City

Year	Rainfall Amount (mm)	Year	Rainfall Amount(mm)	Year	Rainfall Amount(mm)
1982	164.3	1994	156.1	2006	109.8
1983	93.7	1995	93.3	2007	122.6
1984	54.7	1996	121.1	2008	125.3
1985	61.6	1997	122.6	2009	84.1
1986	59.6	1998	87.8	2010	183.6
1987	112.4	1999	78.9	2011	169.6
1988	88.5	2000	99.1	2012	83.8
1989	133.4	2001	96.9	2013	131.6
1990	114.4	2002	95.8	2014	119.2
1991	110.4	2003	102.5	2015	106.6
1992	120.8	2004	101.7	2016	111.0
1993	79.9	2005	114.6	2017	266.6

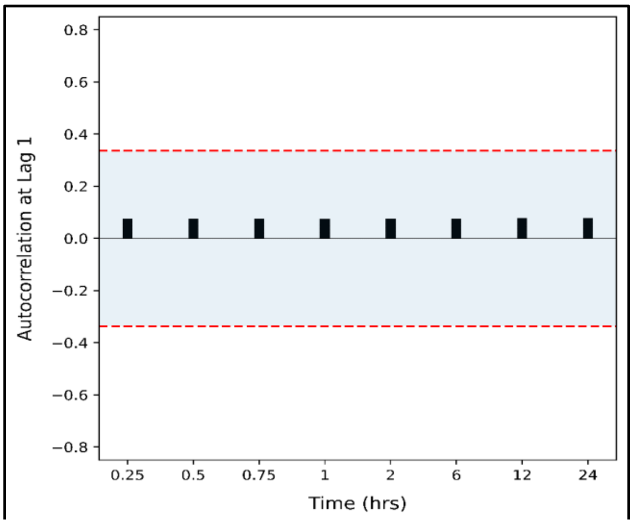

Fig. 2. Correlogram of ACF at lag-1 for various 24-hourly AMS downscaled durations using MCIMD model for Benin City

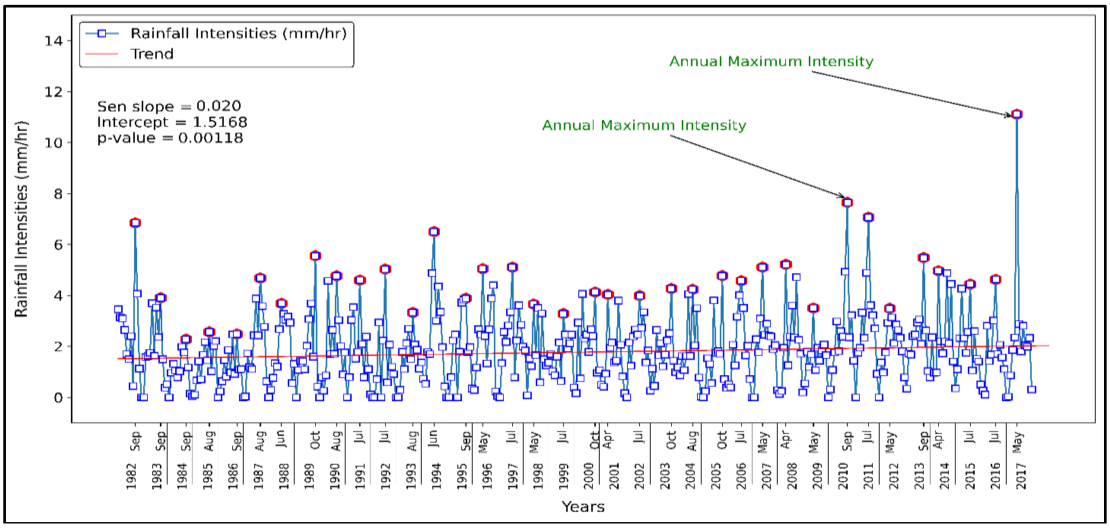

Fig. 3. 24-hourly MMS rainfall intensities trend pattern for Benin City (1982-2017)

Table 2. Mann-Kendall test and Sen Slope estimates result for Benin City

Time (hrs)	Statistic	IMD Value	MCIMD Value
0.25	Z	2.0978	2.0978
	p-value	0.0359	0.0359
	Q_i	0.9574	1.3893
	Intercept	79.3963	139.0875
0.5	Z	2.0978	2.0978
	p-value	0.0359	0.0359
	Q_i	0.5999	0.8274
	Intercept	50.1000	80.5208
0.75	Z	2.0978	2.0978
	p-value	0.0359	0.0359
	Q_i	0.4609	0.6095
	Intercept	38.1838	58.6346
1	Z	2.0844	2.0844
	p-value	0.0371	0.0371
	Q_i	0.3741	0.4929
	Intercept	31.6538	46.825
2	Z	2.0710	2.0844
	p-value	0.0384	0.0371
	Q_i	0.2352	0.2935
	Intercept	19.93	27.314
6	Z	2.0986	2.0986
	p-value	0.0359	0.0359
	Q_i	0.1155	0.1232
	Intercept	9.5292	11.7938
12	Z	2.0718	2.0986
	p-value	0.0383	0.0359
	Q_i	0.0707	0.0768
	Intercept	6.0625	6.8562
24	Z	2.1550	2.0995
	p-value	0.0312	0.0359
	Q_i	0.0420	0.0474
	Intercept	3.8647	4.0197

Level of significant ∝ = 0.05, where Z = standardized Mann Kendall statistic,
Q_i = Sen Slope (mm/hr/year), Critical Z-value = 1.96.

Table 3. Distribution free CUSUM result for Benin

Parameters	Values
Maximum CUMSUM value	5
Critical value at 90% CI	7.32
Critical value at 95% CI	8.16
Critical value at 99% CI	9.78
Date of Change	2004 and 2006

3.1.4 Evaluation of time series data for trend change-point

The result for the trend plots of the 24-hourly AMS rainfall intensities against duration (year) for Benin City for both long (24 hours) and short (0.25 hours) downscaled durations are presented in Figs. 4 and 5, respectively. Also carried out was trend change-point analysis for all the downscaled durations. The results of the distribution-free CUSUM and the Sequential Mann-Kendall tests are presented in Tables 3 & 4. Figs. 6 and 7 show distribution-free CUSUM plot and Sequential Mann-Kendall plot for 24-hourly AMS rainfall intensities, respectively, which were obtained via the "trendchange" software package [25,26].

Table 4. Trend change point for different downscaled duration rainfall intensities for various stations

Rainfall durations (mins)	CUSUM	SQMK
15	2004 and 2006	2005
30	2004 and 2006	2005
45	2004 and 2006	2005
60	2004 and 2006	2005
120	2004 and 2006	2005
360	2004 and 2006	2005
720	2004 and 2006	2005
1440	2004 and 2006	2005

3.2 Discussion

3.2.1 Analysis of 24-hourly AMS non-stationary rainfall trend

This investigation established the existence of hydrological trends and variation in 24-hourly AMS extracted data from the 24-hourly Monthly Maximum Series (MMS) historical precipitation (rainfall) data (HPD). Three sets of meteorological time-series data were applied. The IMD model data and the MCIMD model data downscaled from Table 1 using Equations (1) and (2), respectively, with those of the initially extracted MMS recorded rainfall intensities. The data produced identical or consistent results as can observed as we progress.

3.2.2 Analysis of 24-hourly AMS rainfall trend change-point

Change point analysis identifies the most probable date for occurrence of significant change in the time series. Analysis of trend change points was for all the 24-hourly AMS time series downscaled durations. Results of the distribution-free cumulative sum (CUSUM) and sequential Mann-Kendall (SQMK) tests are presented in Table 4. Figs. 6 and 7 provide the graphical plots of the distribution-free CUSUM and SQMK tests carried out, respectively, for different durations of the 24-hourly AMS rainfall intensity. Interpreting the result for Benin, the distribution-free CUSUM plot showed two change dates of 2004 and 2006 at the maximum CUSUM value of 5.00 which is less than the critical value of 8.16 at 95% confidence interval (CI) shown in Table 3. Contrastingly, the SQMK plot produced a definite intersection point between the pro-grade and retrograde in the year 2005 at 95% CI. Therefore, it can be considered as the trend change point date being the intersection point between the pro-grade and retrograde at 95% confidence interval as indicated in Fig. 7. The positive trend continued and intensified through the year 2015, another point of intersection for the SQMK plot.

3.2.3 Autocorrelation and trend-free pre-whitening of 24-Hourly AMS rainfall

The statistical tool adopted for non-stationarity check to confirm if trend exists in the time-series data was the Mann-Kendall (MK) test after autocorrelation analysis at 95% Confidence interval (CI). The Correlogram in Fig. 2 showed that the ACF at lag 1 was statistically insignificant for all downscaled rainfall durations. The 24-hourly MMS data subjected to autocorrelation also exhibited the same features. Therefore, ACF values for the time-series data at a 95% Confidence interval were insignificant. This result does not require any trend-free pre-whitening (TFPW) because the time series data had no significant serial autocorrelation. Hence, the MK test was applied directly to the time series data.

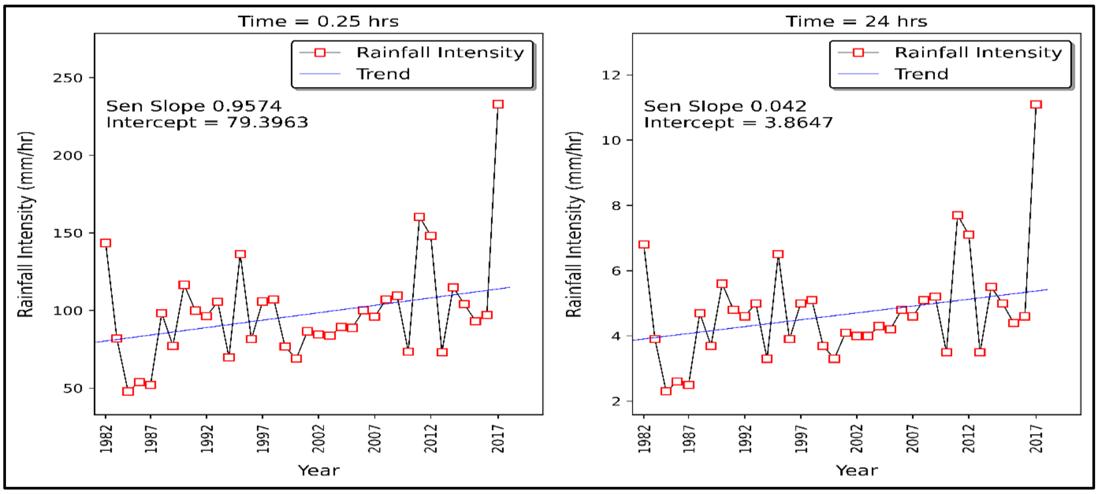

Fig. 4. 24-hourly AMS rainfall intensities trend pattern for IMD model downscaled durations for Benin City (1982-2017)

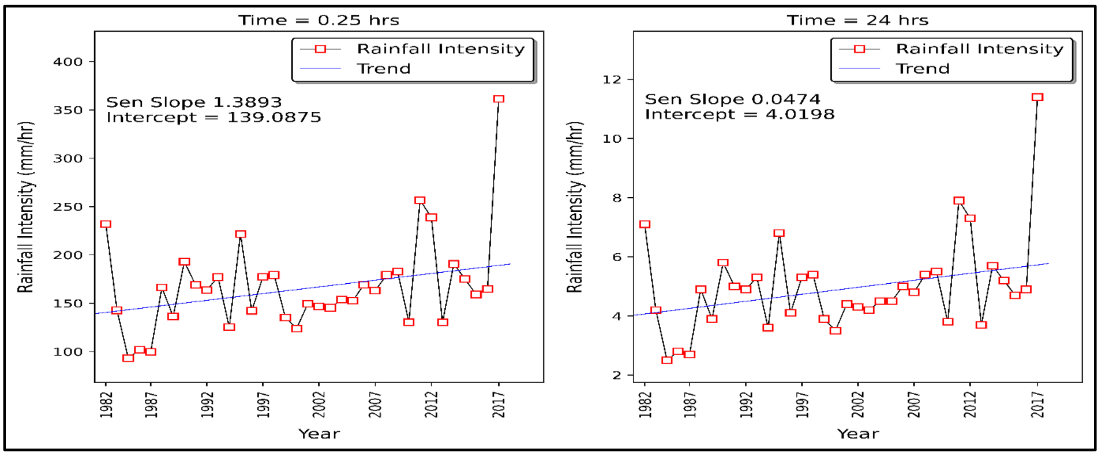

Fig. 5. 24-hourly AMS rainfall intensities trend pattern for MCIMD model downscaled durations for Benin City (1982-2017)

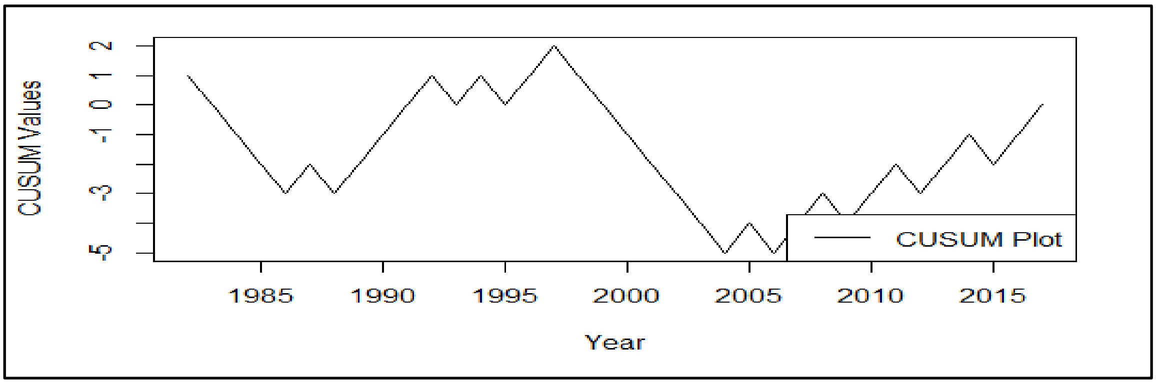

Fig. 6. Distribution-free CUSUM plot for 24-hourly AMS rainfall intensity for Benin

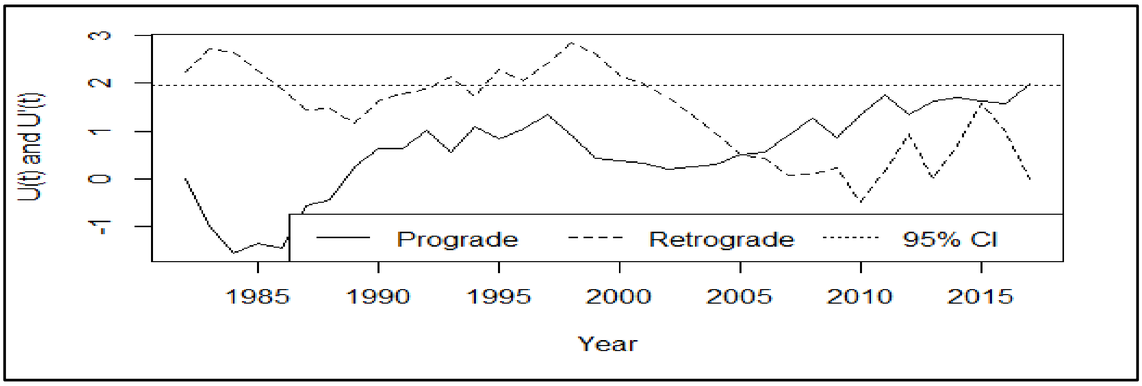

Fig. 7. Sequential Mann-Kendall plot for 24-hourly AMS rainfall intensity for Benin

3.2.4 Trend and variations in MK and Sen's slope test results

The Mann-Kendall and Sen's Slope tests results for Benin are presented in Table 2. The indices measured by the MK test for the trend are the p-value at alpha value of 0.05 (5% level of significance) and the standardized MK statistics compared to the critical Z-value at 1.96. The hypothesis examined for the MK test is that for Ha: Alternate hypothesis, there is a trend in the rainfall intensity over time, and for Ho: Null hypothesis, there is no trend in the rainfall intensity over time. Therefore considering the various result for the MK and Sen's Slope tests in Table 2, we have the following observations:-

The calculated p-value varied from 0.0312 to 0.0383, and 0.0359 to 0.0371 for IMD and MCIMD time series data, respectively. The p-values were less than the alpha value of 0.05 at a 5% level of significance. The MK statistic varied from 2.0710 to 2. 1550 for both IMD and MCIMD data series and were all greater than the critical Z-value of 1.96. The alternate hypothesis is accepted as trend exists in the time series data.

Sen's Slope test also showed that the magnitude of the slope varied from 0.0420 to 0.9574 and 0.0470 to 1.3893 for IMD and MCIMD time series data, respectively. The intercept, likewise varied from 3.8647 to 79.3963 and 4.0197 to 139.0875 for the IMD and MCIMD data series, respectively. The data series for Benin indicated the same trend pattern and variation in the value of magnitude of the slope and the intercept as those found in sister stations in the region such as Uyo [10]. That is to say there is an increase in value from a higher duration of 24 hours to a lower duration of 0.25 hours. The result obtained for Benin did not conform with the opinion of [37] who reported an insignificant trend on observed time series data for the study area. The Mann-Kendall result suggests that when developing the intensity-duration-frequency (IDF) model, the change in the behavioral parameter extremes such as shape, location and scale in the rainfall time series data must be put in-view in the rainfall data analysis especially for IDF modeling.

The Sen's Slope results also proved that the magnitude of the trend decreases as the duration of rainfall increased that is to say that shorter durations tend to exhibit higher values than longer durations [10].

3.2.5 Analysis of variations in magnitude and rainfall trend pattern

The results of the MK trend and Sen Slope tests result presented in Tables 2 also indicated that both tests exhibited a high degree of consistency. "They both showed a statistically significant positive trend increase in their values of computed variables for 24 hours higher duration to 0.25 hours lower durations. The observed performance in the consistency of both tests conforms with some earlier publications" [34,36,38,39].

The Sen's Slope estimator (SSE) used for the quantification of the rate of change in the magnitude of rainfall intensity showed a positive trend variation which are statistically significant for the study area. For instance, the slope, Q, and the rate of variation observed for the station from Table 2 is given as 0.0420 and 0.0474 mm/hr/year at 24 hours duration for IMD and the MCIMD data series, respectively, which translates to variation rate of 1.008 mm/year (10.08 mm/decade) and 1.1376 mm/year (11.376 mm/decade) for the IMD and MCIMD models, respectively.

The trend test for the 24-hourly monthly maximum series (MMS) in Fig. 3 also confirmed the test statistic, with a p-value of 0.00118 which is far less than the alpha value at a 5% significant level. Therefore, the 24-hourly AMS data could adequately serve as a representative sample for the time series data in IDF modeling for the prediction of rainfall intensity. The trend variation rate in extreme value precipitation is brought about by behavioral parameter extreme changes occasioned by climatic change. Human activity also generates greenhouse gas emissions with resultant land use changes. These factors result in extreme precipitation events that lead to landslides and flooding.

These results agreed with the publications of earlier research along the coastal stations of the Gulf of Guinea. For instance, [4] got 13mm/decade for Ghana, and [5] also had 55.2 mm/decade, and [10] had a variable rate of 21.288 mm/decade (for Uyo), for gauge stations in the Niger Delta. The results did not agree with those of [40], whose work was on the Nigerian hinterland and found a decreasing trend in the rate of the variability of rainfall and in the MK test statistic. These are evidence of climatic change variability in Nigeria whose trend shows rainfall increase in the coastal region [5,7,10] and decrease in the continental interiors [8,9].

4. CONCLUSION

The consequences of changing climate were found to exist for Benin City in this study. Statistically significant trends were found for Benin City with the p-values less than the alpha value of 0.05 at 5% level of significance. The calculated p-value varied from 0.0312 to 0.0383 and 0.0359 to 0.0371 for IMD and MCIMD time series downscaled data, respectively. Also, the MK |Z| statistic varied from 2.0710 to 2.1550 for IMD and 2.0844 to 2.0995 for MCIMD downscaling model series, which were both greater than the critical Z-value of 1.96.

The magnitude of the trend and variation rate contributed by climate change at 24-hour duration was 1.008 mm/year (10.08 mm/decade) and 1.1376 mm/year (11.376 mm/decade) for the IMD and MCIMD models, respectively. The rainfall pattern change point dates for Benin City were found to be from 2005 from where there continued to be a positive trend that intensified through the year 2015.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Hall MJ, O'Connel BE. Time Series Analysis of Mean Daily River Flow. Water and Water Engineering. 1972;5:125-133.

2. Houghton JT, Jenkins GJ, Ephraims JJ. Climate change. The IPCC Scientific Assessment, Intergovernmental Panel on Climate Change, Report by Working Group 1, CUP UK; 1990.
3. Douglas BC, Peltier WR. The Puzzle of Global Sea Level Rise. Physics Today. 2002;55(3): 35-40.
4. Ayensu A. Assessment of climate change and vulnerability trends in temperature and rainfall. J. Appl. Sci. Technol. (JAST). 2004;9(112):21-27.
5. Nwaogazie IL, Ologhadien I. Trend in climate change and vulnerability assessment of Nigerian Gulf of Guinea. Standard Scientific Research and Essays. 2014; 2(10): 516 -523.
6. Adejuwon, JO. Rainfall Seasonality in the Niger Delta Belt, Nigeria. Journal of Geography and Regional Planning. 2012;5(2):51-60.
7. Olaniyi OA, Funmlayo OA, Olutimehin IO. Review of climate change and its effect on nigeria ecosystem. International Journal of Environment and Pollution Research. 2014, 2(3): 70-81
8. Ebele NE, Emodi NV. Climate Change and its Impact in Nigerian Economy. Journal of Scientific Research and Reports. 2016;10(6):1-13.
9. Elisha I, Sawa BA, Lawrence EU. Evidence of climate change and adaptation strategies among grain farmers in Sokoto State, Nigeria. IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT). 2017; 11(3):1-7.
10. Sam MG, Nwaogazie IL, Ikebude C. Non-stationary trend change point pattern using 24-hourly annual maximum series (AMS) precipitation data. Journal of Water Resources and Protection. 2022;14:592-609.
DOI:https//doi.org/10.4236/jwarp.2022.148031.
11. Mann HB. Nonparametric tests against trend, Econometrica. 1945;13:245–259.
DOI:https://doi.org/10.2307/1907187.
12. Zhang Q, Liu C, Xu CY, Xu Y, Jiang T. Observed Trends of Annual Maximum Water Level and Streamflow during Past 130 Years in the Yangtze River Basin, China, Journal of Hydrology. 2006;324(1-4):255–265.
13. Kendall MG. Rank Correlation Methods, Griffin, London, UK; 1975.
14. Lehmann EL. Non-parametrics, Statistical Methods Based on Ranks, Holden-Day, San Francisco, California, USA; 1975.
15. Longobardi A, Villani P. Trend analysis of annual and seasonal rainfall time series in the Mediterranean Area. International Journal of Climatology. 2010;30(10):1538–1546.
16. Yanming Z, Jun W, Xinhua W. Study on the change trend of precipitation and temperature in Kunming City based on Mann-Kendall Analysis, in Future Computer, Communication, Control and Automation, vol. 119 of Advances in Intelligent and Soft Computing, Springer, Berlin, Germany. 2011;505-513.
17. Sen PK. Estimates of the regression coefficient based on Kendall's tau. Journal of the American Statistical Association. 1968;63(324):1379–1389.
DOI:https://doi.org/10.1080/01621459.1968.10480934
18. Baranowski R, Fryzlewicz P. WBS: Wild Binary Segmentation for Multiple Change-Point Detection. R Package Version 1.1. 2014.
19. Fryzlewicz P. Wild binary segmentation for multiple changepoint detection. Department of Statistics, London School of Economics, London; 2013.
20. Erdman C, Emerson JW. BCP: An R package for performing a bayesian analysis of change point problems. Journal of Statistical Software. 2007;23(3):1–13.
21. McGilchrist CA, Woodyer KD. Note on a distribution-free cusum technique. Technometrics. 1975;17:321–325.
22. Taubenheim J. An easy procedure for detecting a discontinuity in a digital time series. Zeitschrift für Meteorol. 1989;39:344–347.
23. Sneyers R. On the statistical analysis of series of observations. World Meterological Organizaion: Geneva, Switzerland; 1990.
24. Seabold S, Perktold J. Satsmodel: Econometric and statistical modeling with python. In 9th Python in Science Conference; 2010.
25. R Core Team R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria; 2021.
26. Patakamuri SK. Trendchange: Innovative trend analysis and time-series change point analysis, the R project for statistical computing; Viena, Austria; 2022.

27. Edo State Government (ESG). Ministry of Lands & Survey, Benin City, Edo State; 2009.
28. Sam MG, Nwaogazie IL, Ikebude C. Improving Indian Meteorological Department Method for 24-hourly Rainfall Downscaling to Shorter Durations for IDF Modeling. International Journal of Hydrology. 2021;5(2):72-82. DOI: 10.15406/ijh.2021.05.00268
29. Ramaseshan S. Urban hydrology in different climate conditions. lecture notes of the international course on urban drainage in developing countries. Regional Engineering College, Warangal, India; 1996.
30. Rashid M, Faruque S, Alam J. Modelling of short duration rainfall intensity duration frequency (SDRIDF) Equation for Sylhet City in Bangladesh. ARPN J. Sci. Technol. 2012;2:92-95.
31. Gilbert RO. Statistical methods for environmental pollution monitoring. John Wiley and Sons, New York; 1987.
32. Von Storch H, Navarra A. Analysis of climate variability: applications of statistical techniques. Springer Verlag, Berlin. 1995;352.
33. Hamed KH, Rao AR. A modified mann-kendall trend test for auto-correlated data. Journal of Hydrology. 1998;204:182-196.
34. Yue S, Pilon P, Phinney B. Cavadias G. The influence of autocorrelation on the ability to detect trend in hydrological series. Hydrological Processes. 2002;16:1807-1829. DOI:https://doi.org/10.1002/hyp.1095.
35. Yue S, Wang CY. The applicability of pre - whitening to eliminate the influence of serial correlation on the mann-kendall test. Water Resources Research. 2002;38:4- 1-4-7.
36. Sam MG, Nwaogazie IL, Ikebude C. Climate change and trend analysis of 24-hourly annual maximum series using mann-kendall and sen slope methods for rainfall IDF modelling. International Journal of Environment and Climate Change. 2022;12(2):44-60. DOI:10.9734/IJECC/2022/v121230628.
37. Ologhadien I. Assessment of the impact of climate change on intensity-duration-frequency (IDF) equations in Benin City, Nigeria. International Journal of Hydrology. 2019;3(2):107-113.
38. Shadmani M, Maron S. Roknian, M. Trend analysis in reference evapotranspiration using mann-kendall and spearman's rho test in arid regions of Iran. Water Resources Management. 2012;26(1):211-224.
39. Ahmad I, Tango D, Wang T, Wang M, Wagan B. Precipitation trends over time using Mann- Kendall and Spearman's rho tests in Swat River Basin, Pakistan, Advances in Meteorology. 2015; 431860:1-15.
40. Okafor GC, Jimoh OD, Larbi KI. Detecting changes in hydro-climatic variables during the last four decades (1975 – 2014) on downstream Kaduna River catchment, Nigeria. Atmospheric and Climate Sciences. 2017;7:161-17.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/97603