



doi:10.5281/zenodo.18796812

Analysis of Trend, Variability, and Characteristics of Rainfall over Benin City, Nigeria (1981–2021)

Chinago Budnukaeku Alexander

Department of Transportation Planning and Logistics Management
School of Environmental Sciences
School of Environmental Technology
Captain Elechi Amadi Polytechnic, Rumuola, Port Harcourt, Nigeria
Chinago.alexander@portharcourtpoly.edu.ng
<https://orcid.org/0000-0002-6724-2878>

ABSTRACT

This study is a comprehensive analysis of the trend, variability, and characteristics of monthly and annual rainfall in Benin City, Edo State, Nigeria, spanning from 1981 to 2021. The primary objectives were to quantify statistical properties of rainfall, detect trends, identify anomalous rainfall periods, detect extreme rainfall events, and decadal patterns of rainfall onset and cessation. Employing common descriptive statistics-mean, standard deviation, etc., the study reveals high variability and a positively skewed seasonal rainfall, but negative annual distribution, characterized by frequent low rainfall months interspersed with occasional extreme events, and dry and wet dispersion for annual rainfall. Trend analysis using the Mann-Kendall test and Sen's Slope Estimator confirms a statistically significant upward trend in seasonal rainfall, supporting the hypothesis of increasing precipitation over the study period. The same statistics show upward trend but statistically non-significant at alpha 0.05 for annual trend. Further study using Sen's slope Estimator for annual analysis show the magnitude of rainfall increase annually to be 7.56 mm. The Rainfall Anomaly Index (RAI) highlights alternating wet and dry periods, while outlier detection identifies several extreme rainfall months exceeding 600 mm, underscoring the risk of flooding. Similarly, for annual RAI extreme dispersion from the station mean were observed for both dry and wet years, the extremes can signal flood or aridity. Decadal analysis of rainfall onset and cessation indicates a stable rainy season, with onset typically in March and cessation in November, contradicting the hypothesis of shifting seasonal boundaries. However, the intensity within the rainy season has increased, reflecting more pronounced anomalies in recent decades. Using the coefficient of variation for analysis the study discovered that the impact on the season varies with the annual, the monthly variation was moderate about 66.29%, while the annual impact was low at 28.20% which implies that seasonal variation and annual variation of rainfall in the study area varies. These findings have critical implications for urban planning, agriculture, and disaster risk management in Benin City. The study recommends enhancing flood mitigation infrastructure, adopting climate-resilient agricultural practices, and integrating rainfall variability data into urban development policies.

Keywords: Rainfall trend, variability, Benin City, Mann-Kendall test, anomaly index, extreme rainfall, rainy season onset

1. INTRODUCTION

Rainfall is the most important element of climate in the equatorial climate zone of West Africa. It is a vital climatic element which influences various aspects of human life and the natural environment, (Akinsanola and Ogunjobi, 2014; Chinago, 2020; Alexander, et al, 2015a). Rainfall is

the form of precipitation, that falls from the atmosphere to the surface of the earth; It ranges from 0.5-2mm in diameter. Its variability, both in terms of space, quantity and temporal distribution, has vital implications for a whole lot of human activities and even beyond. For instance it influences agriculture, water resources, disaster management, transportation and socio-economic development, Alexander, (2015a).

Rainfall and its related activities are responsible or accounts for the environmental stability, agricultural productivity, and urban resilience in tropical regions of West Africa (Akinsanola & Zhou, 2019; Oguntunde et al., 2019). In the South-South region of Nigeria, Benin City stands out as one of the urban and agricultural hub, influenced by the seasonal and inter-annual variability of rainfall (Ojo and Aderoju, 2017; Amaechi, et al. 2025; Efe and Eyefia, 2014).

The city's climate is characterized by a tropical wet and dry pattern, with rainfall season of up to seven months. Rainfall is the primary driver of her hydrological processes, food security, and public health (Edokpa et al., 2025; Atedhor et al., 2019). Rainfall is a vital climatic variable influencing agriculture, water resources, and urban planning in Benin City and in Nigeria at large (Alexander, 2015b; Chinago, 2020; Adejuwon, 2022), therefore understanding its statistical properties, long-term trends, fluctuations, and variability is essential for sustainable development and climate adaptation. This work is an analysis of annual and monthly rainfall data extracted from Nigeria Meteorological Agency Rainfall record from 1981 to 2021. This paper use descriptive statistics, trend detection, anomaly analysis, and the timing of rainfall onset and cessation for analyses.

Recent studies by scholars have shown marked changes in rainfall patterns across West Africa, which were attributed to climate change, land use transformation, and urbanization (IPCC, 2021; IPCC, 2022; Nwankwoala, 2022). These changes became obvious as a result of increased frequency of extreme events, unpredictable rainfall onset and cessation, and heightened flood risk (Olayinka, et al. 2013; Ologunorisa & Abawua, 2005). For Benin City, these challenges are even worse due to increase population and urban expansion, and inadequate infrastructure, the situation required urgent attention, therefore making the understanding of rainfall dynamics imperative for sustainable development (Adefolalu, 1986; Oke et al., 2019).

It has been observed recently that Benin City is prone to extreme rainfall variability, with frequent incidence of flooding, water scarcity, and agricultural disruption (Olayinka et al. 2013; Ologunorisa & Abawua, 2005). However, the absence of adequate, long-term analyses of rainfall trends and characteristics retard or slow down effective policy formulation and infrastructure design (NIMET, 2021; Egbinola & Amobichukwu, 2021). This observed knowledge gap is particularly vital given the city's rapid growth and exposure to climate extremes as noted by (Nwankwoala, 2022; Olaniran & Summer, 2019)

Despite the significance and role of rainfall and rainfall variability, comprehensive long-term statistical analyses of the city scale remain limited. This study addresses this gap by applying advanced statistical and inferential methods to four decades of monthly/annual rainfall data, providing insightful ideas for climate adaptation, disaster risk reduction, and urban planning in Benin City.

The aim of this work is to analyse the trend, variability, and characteristics of rainfall over Benin City, Nigeria from 1981 to 2021. Toward achieving this goal the following objectives were pursued

1. To analyse the statistical characteristics (mean, standard deviation, coefficient of variation, skewness, kurtosis) of monthly rainfall in Benin City from 1981 to 2021.
2. To detect and quantify trends in rainfall using the Mann-Kendall test and Sen's Slope Estimator.
3. To identify periods of anomalous rainfall using the Rainfall Anomaly Index (RAI).
4. To detect and interpret outliers representing extreme rainfall events.
5. To determine decadal onset and cessation of the rainy season.
6. To provide recommendations for urban planning, agriculture, and disaster risk reduction based on the findings.

1.1 Study Area

Benin City is the capital of Edo State, Nigeria, situated in the tropical rainforest belt of West Africa. The city lies approximately between Latitude 6°15'N and 6°25'N and Longitude 5°35'E and 5°45'E. It experiences a tropical climate characterized by high temperatures and humidity, with distinct wet and dry seasons. The wet season typically runs from April to October, while the dry season extends from November to March. The average annual rainfall in the region is generally high, supporting lush vegetation and agricultural activities.

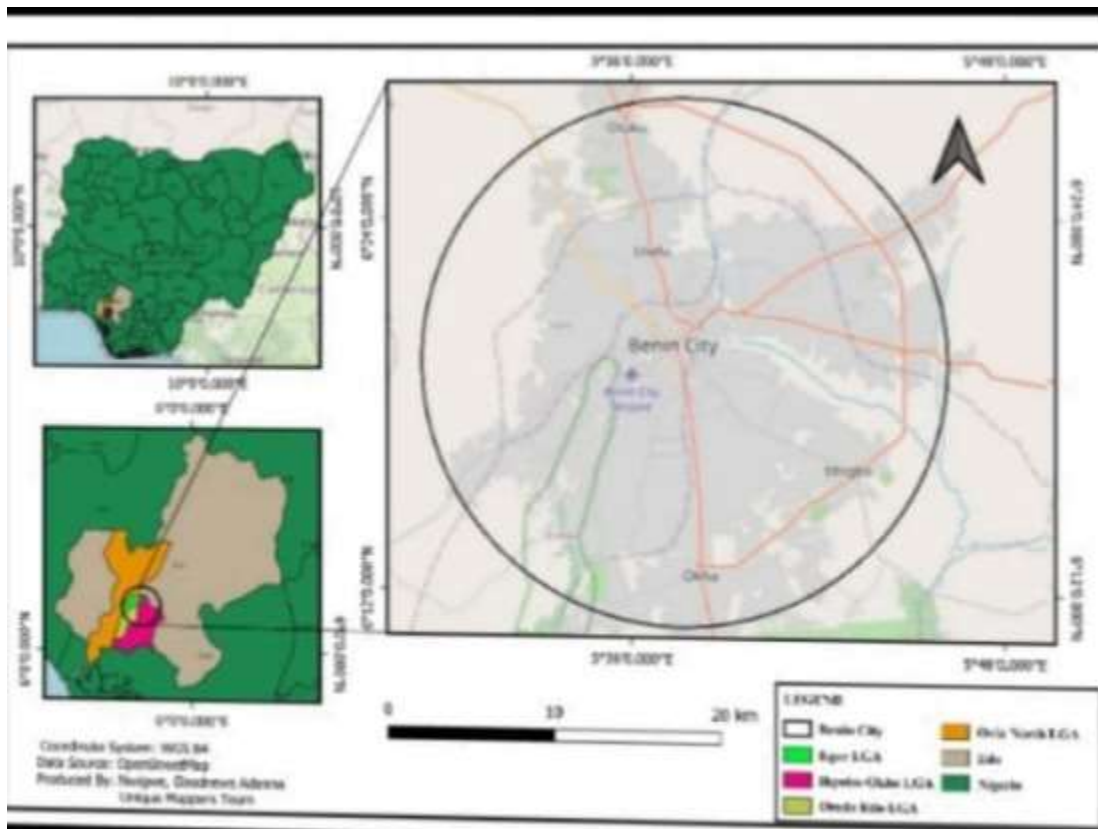


Figure 1: Map of Nigeria Showing Edo State and Benin City
(Source: Nwigwe and Alexander, 2025)

2. METHODOLOGY

Monthly rainfall data for Benin City (1981–2021), is extracted from National Bureau of Statistics, Nigerian Meteorological Agency (NIMET) form C-5., and validated with local weather stations (Egbinola & Amobichukwu, 2013). Ologunorisa and Chinago, (2004 and 2007); Alexander and Aloni, (2015); Budnukaeku and Weli, 2022 and 2023, has use the same method in their works and achieved result.

The study adopted both descriptive and inferential statistics for analysis. For instance, the calculation of mean, standard deviation, coefficient of variation (CV), decadal onset and cessation, which signifies the first and last months with rainfall $\leq 51\text{mm}$ for each decade (Alexander, 2015b), skewness, kurtosis and Rainfall Anomaly Index (RAI) a standardizes rainfall deviations to identify wet/dry periods were employed to summarize rainfall characteristics and pattern. Furthermore graphs and tables were also used for visualization of rainfall distribution to identify patterns and extremes; also outlier detection was used in this work. These represent the descriptive statistics used for this study.

$$CV = SD/MN \text{ ----- (1)}$$

Where MN is the mean rainfall of the station over the study period and SD is the standard deviation of rainfall during the period of study.

The inferential statistics used includes Mann-Kendall Test, a non-parametric test use in detecting monotonic trends in rainfall time series (Mann, 1945); Sen’s Slope Estimator, which quantifies the magnitude of the detected trends and significance testing (Sen, 1968): p-values < 0.05 considered statistically significant.

3. RESULTS

3.1 Seasonal Rainfall Distribution

Table 1 show the seasonal (monthly) statistics of rainfall over Benin City during the study period. The finding from the Table 1 shows that there is a long right tail, indicating occasional extreme rainfall events. It also indicated a positively skewed distribution.

Table 1: Benin Rainfall Descriptive Statistics.

Statistic	Value mm
Seasonal Mean	179.89 mm
Standard Deviation	119.24 mm
Coefficient of Variation	66.29%
Skewness	1.17
Kurtosis	1.29

The seasonal mean rainfall of Benin City is moderate as shown in Table 1; however the standard deviation and CV indicate substantial variability or fluctuation over the study period. An indication of seasonal rainfall variability and clear rainfall seasonality. The coefficient of variation of 66.29% is an indication of reasonable variability of rainfall over the study period.

Skewness (>1) shows more frequent low rainfall and occasional extreme highs.

Kurtosis (>0) suggests a leptokurtic distribution (more outliers/extremes than a normal distribution).

3.1.1 Trend Analysis

Mann-Kendall Test:

Test statistic (S): Significantly positive

Z-value: >1.96 (p < 0.05)

Table 1.2: Monthly Rainfall Characteristics

Month	Mean Rainfall (mm)	Standard Deviation (mm)	Coefficient of Variation (%)
Jan	18.37	26.74	145.56
Feb	47.36	41.21	87.01
Mar	115.28	53.65	46.54
Apr	170.76	88.70	51.94
May	221.80	79.73	35.95
Jun	263.43	108.55	41.21
Jul	325.18	124.14	38.18
Aug	297.76	162.08	54.43
Sep	336.12	98.17	29.21

Month	Mean Rainfall (mm)	Standard Deviation (mm)	Coefficient of Variation (%)
Oct	257.80	88.03	34.15
Nov	82.11	64.65	78.74
Dec	22.66	37.88	167.17

The monthly rainfall data clearly delineates the seasonal pattern in Benin City, which is characterized by a long wet season and a short dry season.

Dry Season (December to February): Rainfall is at its lowest during this period, with the driest months being January (18.37 mm) and December (22.66 mm).

The Coefficient of Variation (CV) is highest in the dry season months, particularly December (167.17%) and January (145.56%). This high CV indicates that the rainfall during the dry season is highly unreliable and variable from one year to the next.

Wet Season starts from (March to November): The wet season is prolonged, with monthly rainfall consistently exceeding 51 mm from March to November.

The peak of the wet season is characterized by a double maxima pattern, which is typical for the Niger Delta region. The first maximum occurs in July (325.18 mm); the second maximum (Primary Peak) occurs in September (336.12 mm), which is the wettest month of the year in the study area.

The period between the two maxima, August (297.76 mm), is often referred to as the "August Break" (Dry spell) in other parts of Nigeria, but in Benin City, the rainfall remains very high, only slightly lower than July and September. This suggests that the August break is either absent or significantly less pronounced in Benin City just like in Port Harcourt another coastal city of Nigeria (Chinago,2020).

The CV values are lowest during the wet season, especially in September (29.21%), October (34.15%), and May (35.95%), indicating that rainfall is most reliable and least variable during these months.

The driest month is January with 18.37 mm of rainfall. Only three months has rainfall occurrence of less than 51 mm (December, January and February). From climatological view, these are the dry season months recognised in Benin City. The month of March which most scholars considered as a dry season in the Niger Delta region actually had a mean rainfall of 115.28 mm and November recorded 82.11 mm the rainfall of these months exceeded the 51 mm bench mark of onset of rainfall (Alexander, 2015c).

The wettest months are June, July, August, September and October with mean rainfall of 265.43 mm, 325.18 mm, 297.76 mm, 336.12 mm and 257.80 mm respectively, these months recorded rainfall > 250 mm on average during the study period. It is important to note that only three months December, January and February can be actually regarded as dry months, since the recorded average rainfall are less than 51 mm according to (Walter, 1979, Alexander, 2015b).

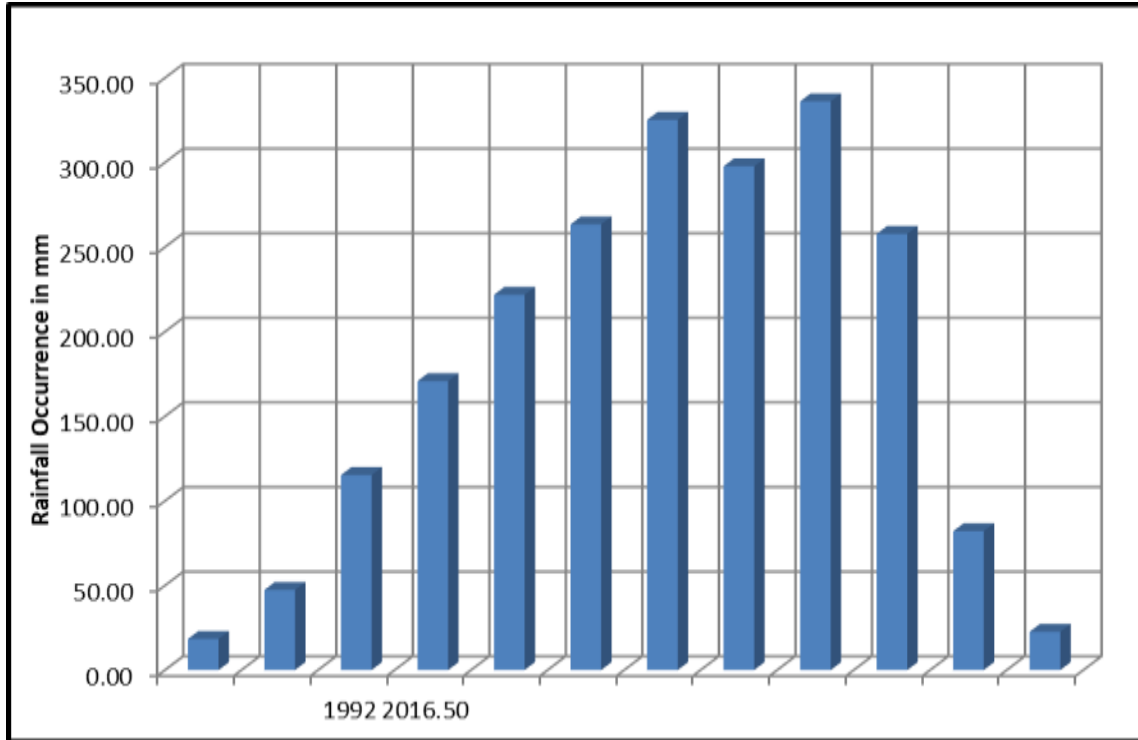


Figure 2: Mean Seasonal Rainfall of the Study Area.

Table 3: Annual Rainfall Analysis

Statistics	Value
Mean Annual Rainfall	2158.63
Standard Deviation	392.90
Coefficient of Variation	18.20%
Minimum Annual RF (Year)	1228.2 (1986)
Maximum Annual RF (Year)	3211.5 (2011)
Annual Range of Rainfall	1983.3
Annual Skewness	-0.2798
Annual Kurtosis	0.7062

Table 3 above shows the annual characteristics of Benin City rainfall. The total mean rainfall is a characteristics of a tropical rainforest zone, with high annual rainfall of about 2158.62 mm. The Coefficient of Variation (CV) of Benin City rainfall is 18.20%. This implies that the annual rainfall variation or variability is low. An indication of stable or reliable rainfall condition. The year to year rainfall is close to the station mean during the study period.

The study as shown in Table 3 shows that 2011 was the wettest year during the study period. It recorded 3211.5 mm of rainfall, while 1986 was the driest year, with a rainfall of 1228.2 mm. The two extreme rainfall conditions of the two years are exceptions from the close mean observed during the study period. The 2011 condition triggered flood and the 1986 condition is an indication of drought. The range in annual rainfall for Benin City is 1983.3 mm.

3.2 Annual Rainfall Trend

The time series plot of annual rainfall reveals the fluctuations over the 41-year period. From Figure 3 it was observed that the amount of rainfall occurrence in Benin City increases over time as shown by the green trend line. The highest rainfall was recorded in 2011 with 3211.5 mm of rainfall.

Figure 3 clearly show four extremes of rainfall incidences during the study period. Three of the extremes are negative (Below the station mean rainfall) and with only one positive extreme (Above the station mean rainfall). The implication of the above is that the negative push seem more on the mean as shown by the annual skewness.

The positive pull from the mean is 3211,5 mm - 2158.63 mm = 1052.87 mm as compared with the negative pull 1228.2 mm – 2158.63 mm, 1249.4 mm – 2158.63, and 1406.3 mm – 2158.63 mm = - 930.43 mm, -909.23 mm, and -752.33 mm respectively. The summation of the negative pulls = -2591.99 mm. The negative pull – the positive pull is = -1539,12 mm. This implies that the effect of rainfall below the mean that resulted to the present station mean is about -1539,12 mm. With the present increasing trend in rainfall, it seems that the station mean will shift soonest.

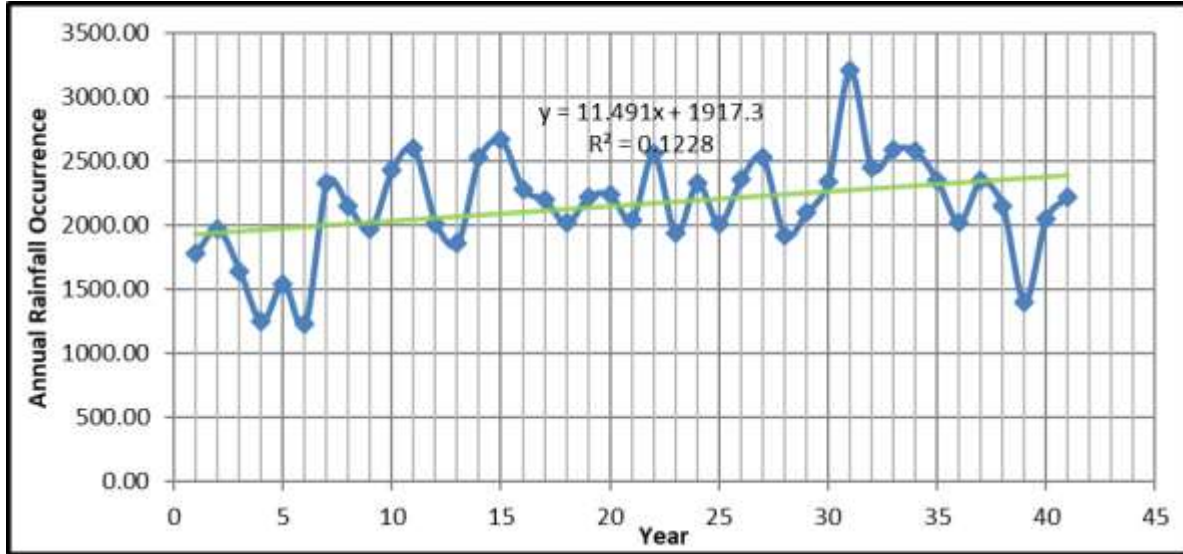


Figure 3: Annual Rainfall fluctuation of Benin City from 1981-2021

3.2.1 Rainfall Anomaly

The rainfall anomaly, which is the deviation of annual rainfall from the long-term mean, provides a clearer picture of rainfall dispersion or around the station mean rainfall over the study period.

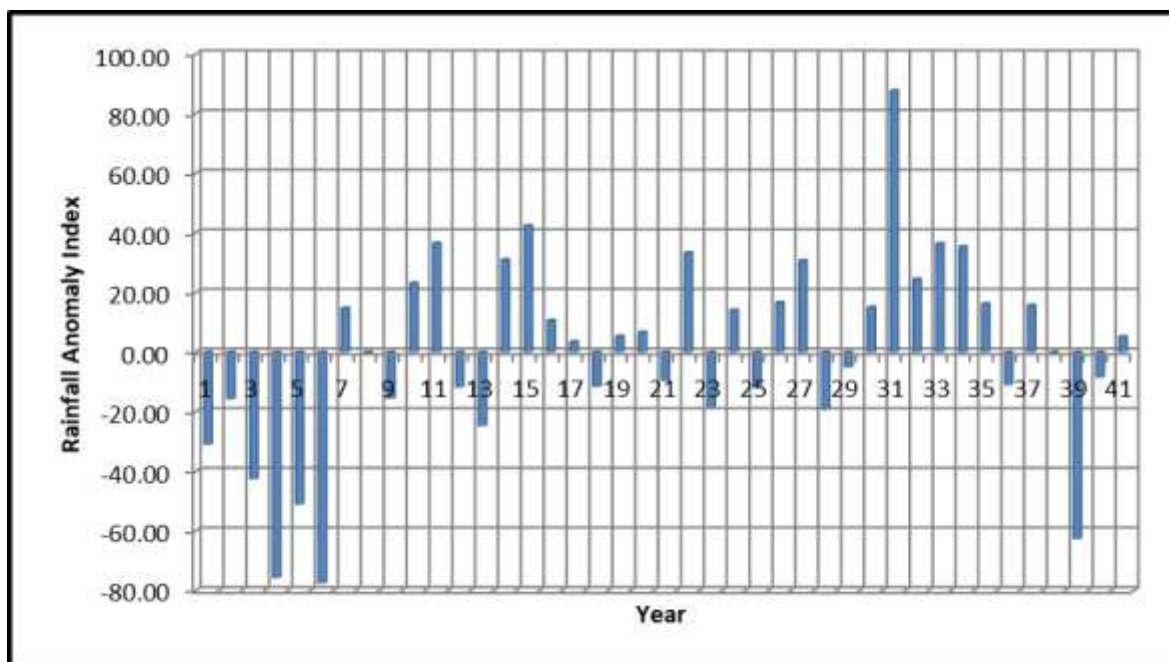


Figure 4: Rainfall Anomaly Index (RAI) Over Time

Figure 4 shows that 1981 – 1986 recorded rainfalls lower than the station mean rainfall. This implies that these years were relatively drier. More of the wet or rainfall above the station mean rainfall cluster around 1990s and 2010s. For instance positive dispersion is recorded between 2010 – 2015. Between 2010 to 2020 which is 11 years, it was observed that 9 of the years had positive dispersion and just two were negative dispersion or below the station mean rainfall.

Generally, the study shows that 23 of the 41 years of study had positive rainfall dispersion (Rainfall greater than the station mean), while 18 years were negative dispersion (Rainfall lower than the station mean rainfall).

The Rainfall Anomaly Index (RAI) analysis revealed alternating periods of wet and dry anomalies, with notable wet years (e.g., 1980s, for dry anomaly, and 1990s, 2010s, for wet anomalies). Outlier detection flagged months with rainfall exceeding 600 mm (e.g., 722.5 mm, 656.2 mm, 615.1 mm), which are critical for flood risk management. These findings confirm high variability and frequent extremes, as similarly observed in studies carried out by Ologunorisa & Abawua (2005), Atedhor et al. (2019) and Budnukaeku and Weli, 2022, 2023).

Skewness value is -0.2798 this small negative value is an indication that the distribution is slightly left-skewed (negatively skewed). This shows a slight tendency for the annual rainfall clustered above the mean, with a few years experiencing notably lower than mean rainfall. This distribution is considered close to symmetrical. The above analysis agreed Figure 4, where 23 years had positive dispersion clustering around the mean, unlike the 18 negative dispersion that are more pronounced.

Annual Kurtosis for the station is 0.7062, this positive value points to a leptokurtic distribution. Meaning that the distribution has a sharper peak and heavier tails than a normal distribution, indicating a higher probability of extreme annual rainfall events at both sides of the mean (both higher and lower than the station mean).

3.3 Decadal Onset and Cessation

Analysis showed that the onset of the rainy season typically occurs in March and cessation in November, with little variation across decades. This suggests the rainy season's length has remained stable, contrary

to anticipated shift in onset/cessation. However, the intensity within the season is increasing, in line with the findings by Odekunle, 2004 and Olaniran, 1983.

Table 4: Decadal Onset and Cessation of Benin City Rainfall

Decade	Mean Onset Month Index	Mean Onset Month	Mean Cessation Month Index	Mean Cessation Month
1980 (1981-1989)	3.33	March/April	10.11	Early October
1990 (1991-1999)	3.30	Early March	10.50	October/November
2000 (2001-2009)	3.00	February/March	10.10	Early October
2010 (2010-2019)	3.30	Early March	10.40	October/November
2020 (2020-2021)	3.50	March/April	9.50	September/October

The mean onset of rainfall of Benin City falls around March, though there could be few incidence of February and April onset. The earliest onset from the decadal analysis falls during the 2000 (2002-2009) which is between late February and early March. The mean onset index is 3.00. The latest mean onset of rainfall according to the study falls in 1980 (1981-1989) with mean onset monthly index of 3.33 corresponding to March/ April. Note 2020 decade is incomplete, it would have been the latest.

The decadal analysis generally show a relative stable onset pattern centering around March, with little fluctuations between early and late March, and few extremes of late February and early April onsets.

The stable onset and cessation of rainfall suggest that agricultural calendars can remain largely unchanged, but increased within-season rainfall intensity necessitates adaptive crop management and soil conservation practices (Ojo et al. 2019).

3.3.1 Trend Analysis of Benin City Rainfall

Table 4: Trend Analysis using Non-parametric statistics

Statistics	Mann-Kendall Test	Sen's Slope Estimator	Interpritation
Trend	No trend	Positive	Relationship by chance
p-value	0.0797	N/A	Not Significance
Z-statistics	1.7525	N/A	Weak Positive trend
Tau	0.1915	N/A	Marginally non-significant
Sen's Slope (Q)	N/A	+7.5625 mm/year	Increasing rainfall over years
Intercept (B)	N/A	2004.35 mm	
No. Observations	41	41	

The trend analysis of of Benin City rainfall using non-parametric statistics test such as Mann-Kendall Test and Sen's Slope Estimator to verify the result of Figure 3 shows increase in rainfall over the study period.

Mann-Kendall test results shows a non-significant weak positive trend during the study period. The p-value result is 0.0797 at 95% confidence level which is greater than alpha 0.05. This prompted the the acceptance of the null hypothesis. This implies that any seem relationship in rainfall distribution over the study period is by chance.

Sen's slope estimator result show the magnitude of change or the level of increase over the year. Table 5 shows that the Sen's slope estimator value is +7.5625 mm/year. This implies that rainfall is increasing by 7.5625 mm every year during the 41 years period under study. It also means that the rate of rainfall increase per month is about 0.63 mm. Therefore for the 41 years of study about 310.06 mm of rainfall must have been added in the amount of Benin City rainfall.

The result of the non-parametric tests shows a slight or gradual long term increase in annual rainfall, which is not statistically significant at alpha = 0.05, however it is vital to monitor this trend and pattern base on the Sen's slope value of yearly increase of 7.56 mm of rainfall annually.

3.4 CONCLUSION

This study provides a comprehensive analysis of rainfall trends, variability, and characteristics over Benin City from 1981 to 2021. The results reveal high variability, a significant upward trend, and frequent extremes, with stable decadal onset and cessation. These insights are critical for climate adaptation, urban planning, and disaster risk reduction.

Benin City is characterized with long reliable rainy season of 9 months, starting from March to November. The short dry season months starts from December to February. The Rainfall Anomaly Index shows that positive rainfall occurred 23 times, while the negative dispersion occurred only 18 times, it was observed that the negative dispersion are more widely away from the mean than the positive dispersion which cluster around the mean except in 2011.

The year with highest rainfall is 2011, while the year with lowest rainfall is 1986. These two distribution affected the rainfall statistics of Benin City. The annual rainfall is negatively skewed (-0.28), but has a positive kurtosis of 0.71. However, the seasonal analysis show a positive skewness of 1.17 and a positive Kurtosis of 1.29.

Seasonal study of the rainfall shows a moderate CV of 66.29%, which is an indication of variability in monthly rainfall. The annual analysis has very low CV of 18.20%. This shows a low interannual variability over the study period.

The study confirms that Benin City's rainfall is highly variable, with a non-statistically significant upward trend and frequent extremes, this agrees with the finding of Chinago, (2020). While the timing of the rainy season remains stable, the intensity of rainfall within the season is increasing, necessitating urgent adaptation in urban planning, agriculture, and disaster risk management (Akinsanola & Zhou, 2019; Olayinka & Adedayo, 2022; Atedhor et al., 2019).

The rainfall characteristics has a double maxima, however, the dry spell of August locally known as "August break" is sort of reducing. The August rainfall is the third wettest month of the station. This is an indication that the dry spell is gradually ceasing as noted by Chinago, (2020). The three months of July, August and September accounted for 959.06 mm (44.43%) of the rainfall over Benin City.

The study shows the magnitude of rainfall increase over the years using Sen's slope Estimator. The annual increase of 7.56 mm of rainfall, which is about 0.63 mm per month is call for monitoring of rainfall characteristics over the study area to avoid disaster.

The key findings indicate moderate inter-annual rainfall variability, with no statistically significant long-term trend in annual rainfall totals. However, the analysis of the Rainfall Anomaly Index highlighted the occurrence of extreme wet and dry years, with 1984, 1986, 2019 and 2011 being an exceptionally dry and wet years. (1984, 1986 and 2019 are dry years, while 2011 is a wet year).

Furthermore, the decadal analysis of rainfall onset and cessation suggests a stable dry and rainy season.

3.5 RECOMMENDATIONS

1. Enhance Flood Management: Upgrade drainage systems to accommodate increasing rainfall extremes.
2. Promote Climate-Resilient Agriculture: Adjust planting schedules and crop varieties based on updated rainfall patterns.
3. Develop Early Warning Systems: Implement real-time monitoring and forecasting of rainfall anomalies.
4. Integrate Climate Data into Urban Planning: Use rainfall statistics to inform infrastructure design and land-use planning.
5. Support Further Research: Encourage continuous monitoring and advanced modelling of rainfall trends.

ACKNOWLEDGEMENT

I sincerely thank the Management of TETFUND for the grant for this work. I also appreciate the Rector, Captain Elechi Amadi Polytechnic for given me the opportunity to apply for this grant.

REFERENCES

1. Adefolalu, D.O. (1986). Rainfall trends in Nigeria. *Theoretical and Applied Climatology*, 37, 205-219.
2. Adejuwon, J.O. (2022). Climate Change Discourse in Nigerian Newspapers: A Content Analysis. *Journal of Environmental Media*, 1(1), 45-58.
3. Akinsanola, A. A., and Ogunjobi, K. O. (2014). Rainfall variability and change in Nigeria. *Journal of Climatology & Weather Forecasting*, 2(3), 1-9.
4. Akinsanola, A.A., & Zhou, W. (2019). Projections of West African summer monsoon rainfall in CMIP6 models. *Climate Dynamics*, 53(7), 4393-4409.
5. Alexander, C.B. (2015a). Length of rainfall season and its implication over Enugu south-east Nigeria. *Global J. Human-Social Sciences: B Geography, Geo- Sciences, Environmental Science and Disaster Management*. 15(47 – 55).
6. Alexander, C.B. (2015b). Climatological review of Enugu Rainfall from 1916–2012 and its implications. *Global Journal of Science Frontier Research: H* 15(5), 1-10.
7. Alexander, C.B. (2015d). Statistical analysis of seasonal temperature variation and thunderstorm activity over Yola north-east Nigeria. *Am. J. Educ. Res* 3, 873-880
8. Alexander, C.B. (2015c). Comparative Analysis of Thunderstorm and Rainfall Occurrences Nigeria, *IOSR-JESTFT*, 9(3), 38-44
9. Alexander, C.B., Bakpo, M.T., and Woke, C. (2015). Temporal Variation of Rainfall Occurrence: The Effect on Tuber Crop Production in Niger Delta South-South, Nigeria, *IOSR-Journal of Agriculture and Veterinary Science* 8 (4), 14-18.
10. Amaechi, C., Obeto, M. and Okoduwa, A.K. (2025). Trend and Spatial Distribution of Rainfall: A Case Study of Edo State, Southern Nigeria from 1983-2023. *NIPES – Journal of Science and Technology Research*, 6(4), 126-135.
11. Atedhor, G.O., et al. (2019). Spatio-temporal variability of rainfall and temperature in the Lower Niger River Basin. *Theoretical and Applied Climatology*, 137, 231-244.
12. Budnuka, A.C., and Aloni, C. (2015). The Effect of Thunderstorm Activity Over Port Harcourt, *IOSR-JESTFT* 9(5), 48-55).
13. Budnukaeku, C.A. and Weli, V.E. (2022). Extreme Rainfall Forecast and Flood Prediction in Equatorial Zone of West Africa: Port Harcourt, Nigeria in Focus. *Journal of Environmental and Geographical Studies* 1 (1), 56-72).
14. Budnukaeku, C.B. and Weli, V.E. (2023). Statistical Analyses of Rainfall Distribution: A Check on Climatic Shift. *Journal of Progress in Engineering and Physical Science* 2 (1), 1-12.
15. Chinago, A.B. (2020). Analysis of rainfall trend, fluctuation and pattern over Port Harcourt, Niger Delta coastal environment of Nigeria. *Biodiversity International Journal* 4 (1), 1-8.
16. Edokpa, D., Ede, P., and Akujuru, C.N.N(2025). Assessment of Rainfall variability in A Humid Tropical Environment of Nigeria. *African Journal of Geographical Sciences*, 6(1), 73-78.
17. Efe, S.I., & Eyefia, A.O. (2014). Urban Effects on the Precipitation of Benin, Nigeria. *American Journal of Climate Change*, 3(1), 8-21.
18. Egbinola, C.N., & Amobichukwu, O.A. (2013). Climate variation assessment based on rainfall in Regional River Basin. *Civil Engineering Journal*, 7(5), 816-826.

- 19 IPCC (2021). *Climate Change 2021. The Physical Science Basis*. Contribution of Working Group 1 to the Sixth Assessment Report of the IPCC.
- 20 Mann, H. B. (1945). Nonparametric Tests Against Trend. *Econometrica: Journal of the Econometric Society*, 13(3), 245-259.
- 21 NIMET (2021). *Nigerian Climate Review Bulletin, 2011*. Nigerian Meteorological Agency.
- 22 Nwankwoala, H.O. (2011). An integrated approach to sustainable groundwater development and management in Nigeria. *Journal of Geology and Mining Research*, 3(5), 123-130.
- 23 Nwigwe, G.A., and Alexander, C.B. (2025). Benin City Extracted from Edo Map.
- 24 Odekunle, T.O. (2004). Rainfall and the Length of the Growing Season in Nigeria. *International Journal of Climatology*, 24, 467-479.
- 25 Oguntunde, P.G., Abiodun, B.J., and Lischeid, G. (2011). Rainfall trends in Nigeria, 1901-2000. *Journal of Hydrology*, 411(3-4), 207-218.
- 26 Ojo, S., & Aderoju, S. (2017). In Odiana, I., and Ochulor, T.G. (Eds), Temperature and Rainfall Trends as Indicators of Climate Change in a Rainforest Region of Nigeria(p.127). *Ghana Journal of Geography*, 16(3).
- 27 Ojo, O.I., Ilunga, M.F., and Dakaye, F. (2019). Temporal changes evaluation of extreme rainfall. *International Journal of Environmental Science*, 4, 180-188.
- 28 Oke, T.R., Mills, G, Christen, A., Voogt, J.. (2017). *Urban Climate*. Cambridge, UK: Cambridge University Press.
26. Olaniran, O.J. (1983). The Onset of the Rains and the Start of Growing Season in Nigeria. *Nigerian Geographical Journal*, 26, 81-88.
27. Olaniran, O.J., & Summer, G. (2019). Rainfall anomalies in Nigeria: The contemporary understanding. *Nigerian Geographical Journal*, 3(1), 11-22.
28. Olayinka, D.N., Nwilo, P.C., and Adzandeh, A.E. (2013). *From Catchment to Reach: Predictive Modelling of Floods in Nigeria*. In FIG Working Week 2013: Environment for Sustainability – Tomorrow's Outlook, Abuja, Nigeria. 6th-10th May, 2023.
29. Ologunorisa, E.T. and Chinago, A.B. (2004). Annual thunderstorm fluctuations and trends in Nigeria. *Journal of Meteorology UK*. 29 (286), 39-44.
30. Ologunorisa, E.T. and Chinago, A.B. (2004). The diurnal variation of thunderstorm activity over Nigeria. *International Journal of Meteorology* 32 (315), 19-29.
31. Ologunorisa, E.T., & Abawua, M.J. (2005). Flood Risk Assessment: A Review. *J. Appl. Sci. Environ. Mgt.*, 9(1), 57-63.
32. Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall's Tau. *Journal of the American Statistical Association*, 63(324), 1379-1389.
33. Walter, M. (1967). The length of the Rainy Season in Nigeria, *Nigeria Geog. J.*, 10, 123-128.