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Research Article

ANALYSIS OF RAINFALL AND DISCHARGE REGIME CHARACTERISTICS OF A SEGMENT OF RIVER BENUE IN ADAMAWA STATE, NIGERIA

[1, *]Aliyu Ahmed Tijjani, [2]Aishatu Muhammadu Mubi and [3]Aminu Ahmed Marafa

[1,3]Department of Disaster Management, Adamawa State Polytechnic Yola
[2]Department of Geography Modibbo Adama University, Yola

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Abstract

River discharge regime refers to the seasonal variation in the volume of water flowing through a river system between wet and dry seasons. This study examined the rainfall and discharge regimes of a section of the River Benue in Yola, Adamawa State, Nigeria. Specifically, the study assessed the characteristics of rainfall and river discharge, investigated their temporal trends, examined the relationship between rainfall and discharge, and developed a regression model to determine the influence of rainfall on river discharge. The study utilized 40 years of rainfall and discharge records covering the period from 1986 to 2025 for Yola and Numan meteorological stations. The data were obtained from the Upper Benue River Basin Development Authority (UBRBDA), Yola. The Mann–Kendall test was employed to determine the presence and significance of trends in annual rainfall and discharge, while the Kendall correlation coefficient was used to assess the strength and direction of the relationship between the two variables. Linear regression analysis and ANOVA were further applied to model the relationship between rainfall and discharge and assess the statistical significance of the model. The results of the Mann–Kendall test revealed a statistically significant decreasing trend in mean annual discharge, with a Z-value of −2.8687 and a p-value of 0.004122, indicating strong evidence against the null hypothesis of no monotonic trend. In contrast, annual rainfall exhibited no statistically significant trend, with a Z-value of 0.42604 and a p-value of 0.6701, suggesting insufficient evidence to reject the null hypothesis. The correlation analysis produced a Kendall's tau-b coefficient of −0.045, indicating a very weak negative association between mean annual discharge and total annual rainfall. However, the relationship was not statistically significant, as demonstrated by the p-value of 0.701. Similarly, the regression analysis showed that total annual rainfall was not a statistically significant predictor of mean annual discharge, with an ANOVA p-value of 0.470. The findings therefore indicate that the observed decline in river discharge over the study period cannot be adequately explained by variations in annual rainfall alone, suggesting the possible influence of other climatic, hydrological, or anthropogenic factors on the discharge regime of the River Benue.

Keywords: Rainfall, Discharge, Discharge Regime.

INTRODUCTION

Climate change plays a fundamental role in altering rainfall and discharge regimes by intensifying the global water cycle, resulting in more extreme, volatile, and unpredictable water movement across the Earth's surface. Rising global temperatures increase the atmosphere's capacity to hold moisture, leading to heavier, more frequent extreme precipitation events, while simultaneously causing faster evaporation that intensifies droughts in other regions. The Spatio-temporal variations in rainfall and river discharge regimes indicates that, precipitation variability, usually intensified by climate change, directly affect hydrological extremes thereby making dry seasons drier and wet seasons wetter, often increasing the likelihood of both floods and droughts in the same region. The river Benue has been experiencing yearly flooding incidences as a result of high rainfall and discharge regimes which causes the overflow of its floodplains. Factors such as topography, drainage basin, human activities of dam construction, water abstraction for irrigation, and land-use conversion, changes in vegetation cover (e.g., forest to cropland) can significantly alter natural flow patterns of the river and there is no clear distinction between roles played by climate and those of anthropogenic factors. This research analyzed the rainfall and discharge regimes characteristic of the segment of the river Benue stretched from Jimeta to Numan in Adamawa state Nigeria with a view of finding the trends and relationship between rainfall and discharge and develop a model for the relationship which are critical in flood prediction, water resource management, environmental monitoring and climate change assessments within the study area. The discharge of a river is usually surface runoff from precipitation plus base flow from groundwater minus evaporation and anthropogenic withdrawals from and discharges to the river. For planning purposes, precipitation in a river basin has usually been assumed to be stationary. Annual precipitation, maximum annual precipitation, maximum annual flood discharges, and other hydrologic parameters are often considered to be stochastic quantities and probability density functions, such as normal distribution, log-normal distribution, Gumbel distribution, are applied to their statistical distributions (Chow *et al.,* 1988; Ponce, 1989; Maidment, 1992; Dingman, 2002). Discharge regime of a river is the seasonal variation in discharge between dry and wet seasons of the year as applicable in study area. The discharge regime of a river can vary considerably along the length of a river in timing and in seasonal characteristics. The discharge regimes are characterized by little variations of input parameters with low dependence on climate, relatively low hydraulic heads that decrease upward, resulting in converging and ascending flow, high TDS of ground waters, chemical precipitation, accumulation of transported material matter, reducing conditions and positive anomalies of geothermal heats and gradient (TÓth, 1999). The hydrological regime defines the

Corresponding Author:** ***Aliyu Ahmed Tijjani,
Department of Disaster Management, Adamawa State Polytechnic Yola

state and responses of a river system with relation to the climatic system and the catchment's physical geographic characteristics (Wrzesi´nski, 2005). Different flow regime patterns can be treated as some "preferred states" of the runoff system, which are more or less stable. In order to identify a change in any pattern for whatever reason, it is necessary to adequately describe its initial state (Krasovskaia and Gottschalk, 2002). Multi-year variations in river discharge may result from environmental changes at a local scale caused by human activity or at regional and global scales caused by climate changes. Hydrological data, including river discharge, may, therefore, serve as an indicator of climate changes (Wrzesi´nski, 2014). Longterm fluctuations of hydrological and meteorological quantities have been the object of attention of hydrologists and climatologists since the beginning of the 20th century (Stojkovic *et al.,* 2015). (Pekarova *et al.,* 2003) tested the annual discharge time series of selected large rivers in the world for wet and dry periods and identified the 28–29-year and 20–22-year cycles of extremes occurrence.

The relationship between rainfall and river discharge are so complicated, and understanding how they interact requires some local studies, this is because, factors influencing hydrological processes on the earth surface not only vary from time to time, but also over space (Dzarma *et al.,* 2020). As rain falls on the ground it flows through several ways to reach to stream channels, (Suleiman, 2014). The proportion of rainfall that does not evaporate or percolate into the ground flows over the soil surface as surface runoff, whilst the remainder infiltrates through the soil and flows beneath the surface to a stream as sub surface flow (Nicandrou, 2010). This rainfall-discharge relation is typical of most tropical rivers, where the influence of ice or snow on the transformation of rainfall to stream flow is negligible or non-existent. The correlation analysis between rainfall and discharge, does not exhibit perfect relationship, it can be recognized that other underlying factors apart from rainfall play significant roles in influencing river discharge in the River Kilange catchment (Dzarma *et al.,* 2020). (Krajewski *et al.,* 2019) made the same review, when they assert that, the difference between the exact factors driving changes in water resources such as land use or climate change, which occur simultaneously in watersheds, are not possible to differentiate with the few variables analyzed. (Kahyaa and Kalayci 2004) observed a decreasing trend of streamflow for the basins located in western Turkey was found, whereas the basins located in the eastern part showed no trend. (Jiang*et al.,* 2007a, b) reported a significant increasing trend in summer precipitation at many stations in the Yangtze River basin in China and a significant increasing trend in river discharge in the middle and lower regions of the basin. In the Euphrates Basin in Turkey, (Yenigun *et al.,* 2008) observed a higher number of significant decreasing trends in minimum stream flow compared with significant decreasing ones. While no trend was found for annual maximum stream-flow in the basin, one decreasing trend was obtained for annual mean stream-flow. (Feng*et al.,* 2011) found significant increasing trends in annual and seasonal temperature in the Nenjiang River Basin, northeastern China, whereas annual and seasonal precipitation in the basin did not show any significant trend. In addition, a significant decreasing trend in annual spring and autumn stream-flow was demonstrated. (Kriauciuniene *et al.,* 2012) evaluated trends in temperature, precipitation and river discharge over the Baltic States and showed an increase in annual and seasonal temperature in all regions of the Baltic States. They also found an increasing trend for winter precipitation and a decreasing one for spring, summer and autumn series. Winter discharge series increased by 20%–60% in all regions, whereas spring discharge decreased by 10%–20% in western region. Tabari *et al.,* (2011a) examined the temporal trends of precipitation at 41 stations in Iran for the period of 1966–2005, and the results showed a significant decreasing trend in annual precipitation series at seven stations. In addition, the number of significant trends in the winter season was higher than that in the other seasons. The trends and variability of rainfall and discharge at the River Kilange catchment in Adamawa State, Nigeria, Rainfall and discharge time series data with 27 years observations (1987 to 2013) using the Pearson's Product Moment Correlation found that mean monthly rainfall and discharge were moderately and positively correlated (r = 0.534, P=0.001) and Graphical representation of the data in the study area, however, shows a decreasing trend in the annual mean rainfall, but an increasing trend in the river discharge which is due to improper land management practice (Dzarma*etal.,* 2020). (Muhammad*et al.,* 2017) on impact of rainfall fluctuation on river discharge in Hindukush region Pakistan observed that at Chitral which is a dry metrological station, it has a very low contribution in river discharge during summer months as compared to other meteorological stations and despite the low rainfall occurrence, there found a good correlation (0.722**) with discharge in river Swat due to the long time period data regarding rainfall.

Study Area

The study area is a segment along the River Benue stretching to a distance of 60km and covered2771km^2 of the riparian zone from the river bank extending from Jimeta bridge to Numan Bridge in Numan Local Government at the confluence of the river Benue and River Gongola at Numan. The area lies between latitude 9° 15' 00" N to 9° 35' 00" N and longitude 12° 3' 00" E and 12° 28' 00" E and on an average altitude of 286m above sea level.

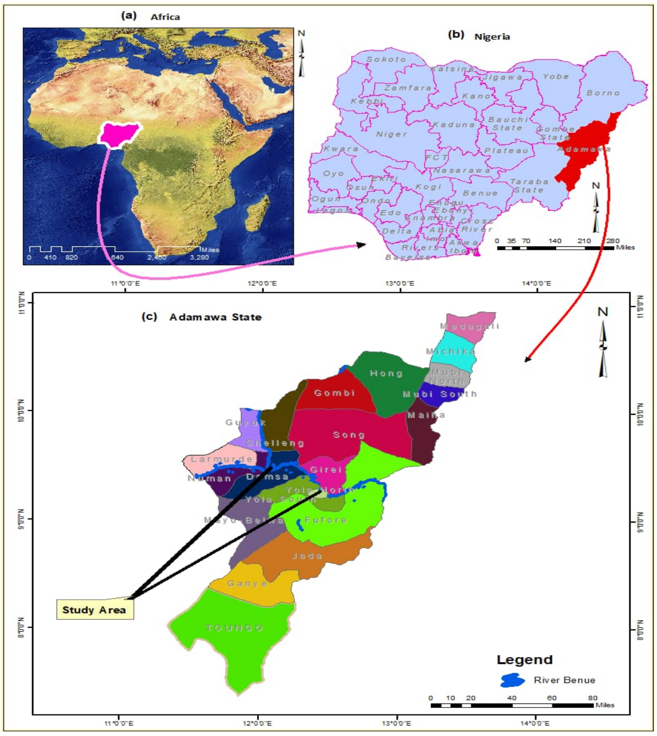


Figure 1. Adamawa State Showing Segment of the River Benue in the Study area

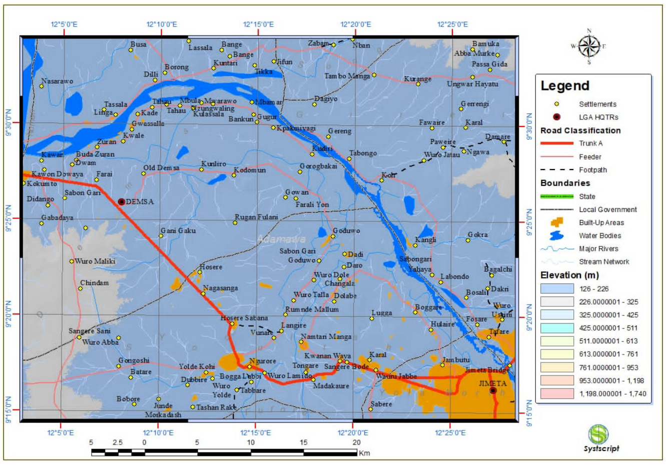
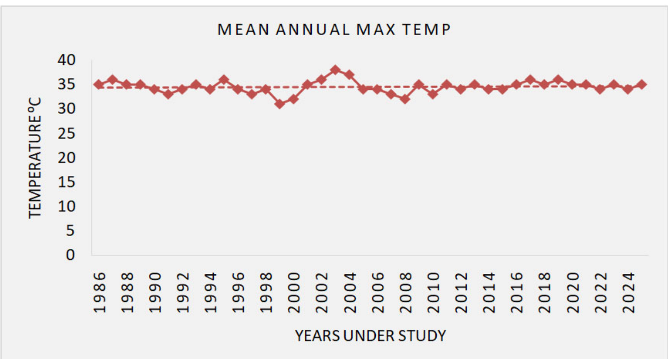


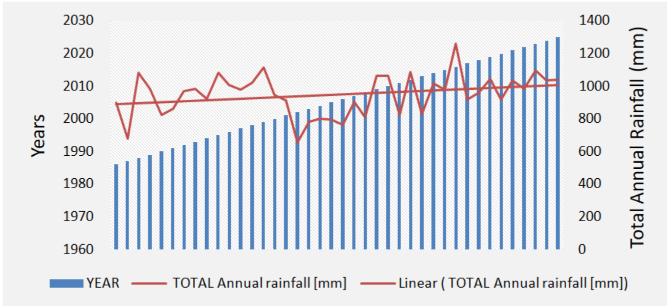
Figure2. Segment of a River Benue in Adamawa State from Jimeta Bridge to Numan at the Confluence of River Gongola and River Benue Showing the Study Area

The study area is characterized by undulating floodplains in the south and west and sedimentary rocks of clastic group which could be clean having silica cement, matrix rich greywacke and the arkosic type. The main drainage system in the study area is the River Benue which flows within a depression less than 150 meters above mean sea level. The river is characterized by sand bars (within the channel) and point bars along the channel banks, thus changing the plan form of the river. The Benue River flows all year round with the peak in the month of august to October in the wet season and the primary and significant tributary of the River Benue within the study area is River Gongola which is at confluent with the river near the numan bridge which is largely considered a seasonal river at its upper course and act as more perennial at its lower course and other smaller tributaries of river Benue within the study area are river mayoine and river koh which are all seasonal. The study area lies within the Sudan savannah zone which is marked with a tropical climate that is characterized by dry and wet seasons. The dry season commence in November and ends by March while the raining season commence in April and ends in October. Climate is the most important cause of flood in the study area, as the climate change high amount of rainfall is recoded at the upper course of the river and lead to inundation of the floodplains. The temperature is generally high throughout the year with maximum temperature fluctuating between 33°C and 41°C. The rainy season last for about seven months with mean annual rainfall of 800mm to 1000mm, whereas 1260.1mm of rainfall was recorded in 2016 (UBRBDA, 2016) which is the highest in 40 years from 1986 to 2025.



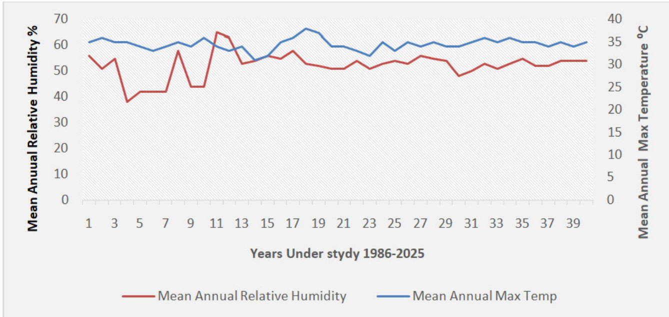
Source: UBRBDA

Figure3. Mean Annual Maximum Temperature for years under study



Source: UBRBDA

Figure4. Total Annual Rainfall for the study period



Source: UBRBDA

Figure 5. Mean Annual Maximum Temperature and Mean Annual Relative Humidity

Rainfall characteristics such as intensity and duration are the major climatic conditions that seasonally vary within the study area, and the variation in rainfall influences other climatic variables such as temperature and humidity, see figure 5.

MATERIALS AND METHODS

Data and Sources

The study utilized rainfall and river discharge data obtained from the Upper Benue River Basin Development Authority (UBRBDA), Yola, covering a 40-year period from 1986 to 2025. The rainfall data were collected from the Yola Meteorological Station, while discharge records were obtained from both Yola and Numan hydrological stations.

Methods of Data Analysis

The tool for data analysis for this study is Microsoft excel was used for the descriptive analysis like bar graphs, line graphs and SPSS statistical software package were used for quantitative analysis of the data.

Analysis of Rainfall and Discharge

The rainfall and discharge characteristics of the River Benue segment within the study area were analyzed using both descriptive and inferential statistical techniques. Rainfall and river discharge data covering a 40-year period, from 1986 to 2025, were obtained from the Upper Benue River Basin Development Authority (UBRBDA), Yola. The rainfall records were obtained from the Yola station, while discharge data were collected from both Yola and Numan hydrological stations. Bar graphs were employed to illustrate the annual trends and distribution of rainfall (mm) and river discharge, as well as the mean monthly variations recorded at the Yola and Numan stations. Descriptive statistical parameters, including maximum, minimum, mean, median, standard deviation, range, variance, coefficient of variation, coefficient of skewness, and coefficient of kurtosis, were calculated for the annual rainfall and discharge datasets. These statistical measures were used to examine the spatial and temporal variability in rainfall amounts and river discharge patterns within the study area.

Statistical trend analysis of the discharge data was conducted to provide an understanding of possible hydrological changes and variations occurring at monthly, seasonal, and annual timescales. The Mann–Kendall test, a non-parametric and distribution-free statistical method, was employed to determine whether annual rainfall and river discharge exhibited statistically significant increasing or decreasing monotonic trends over the study period at the respective stations. The test was used primarily as an exploratory technique to identify significant changes and assess the magnitude and direction of trends in the observed datasets.

The correlation coefficient was used to determine the strength and direction of the relationship between rainfall and river discharge. In addition, linear regression analysis was employed to examine and model the relationship between the two variables. A simple linear regression model was adopted, with one variable serving as the independent variable (predictor) and the other as the dependent variable (response). The regression model was used to establish the extent to which variations in rainfall could explain changes in river discharge, with the relationship represented by a fitted straight line and evaluated using the resulting residuals.

RESULTS AND DISCUSSION

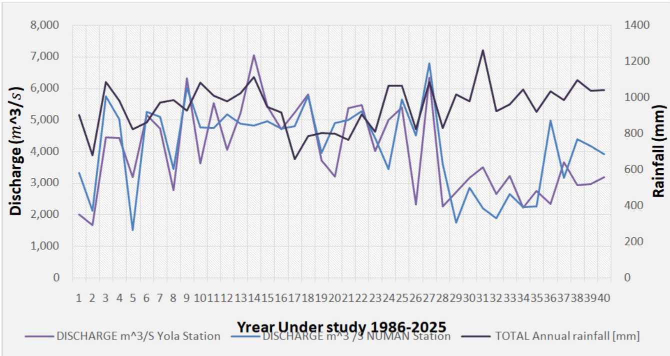
Rainfall and Discharge Characteristics of the Segment of River Benue in Adamawa State

The analysis of rainfall and river discharge in the study area involved the use of descriptive and statistical measures, including mean, median, standard deviation, coefficient of skewness, coefficient of kurtosis, and correlation coefficient. These statistical parameters were employed to examine the characteristics, variability, and relationship of total annual rainfall and discharge at the Yola and Numan stations.

The rainfall distribution pattern along the River Benue segment extending from Jimeta Bridge to Numan Bridge demonstrates considerable seasonal variability. At Yola Station, the annual rainfall totals recorded between 1986 and 2025 varied considerably throughout the study period. The highest annual rainfall of 1260.1 mm was recorded in 2016, while the lowest value of 656.7 mm occurred in 2002 (Figure 4). The number of rainy days also varied during the study period, ranging from a maximum of 94 days in 2018 to a minimum of 57 days in 2020 (Figure 7).

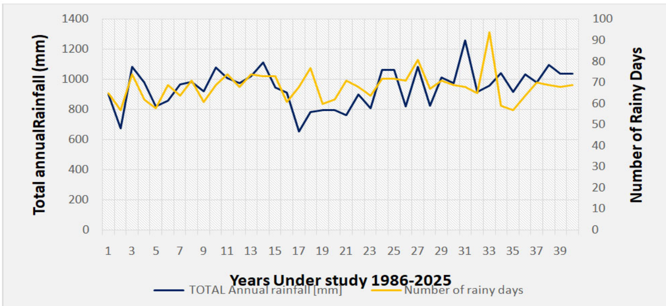
Similarly, the discharge regime at Yola Station exhibited substantial temporal variability. Annual discharge values ranged from a minimum of $2215m^3/s$ recorded in 2019 to a maximum of $7040m^3/s$ recorded in 1999 (Figure 6). At Numan Station, the discharge pattern also showed considerable variation, with the lowest discharge value of $1{,}500m^3/s$ occurring in 1990 and the highest value of $6800m^3/s$ recorded in 2012 (Figure 6).

The observed seasonal variation in rainfall plays an important role in determining the discharge regime and associated fluvial processes along the River Benue. The rainy season generally begins around April and continues until October. Following the onset of rainfall in April, river discharge gradually increases, resulting in the initiation and intensification of fluvial processes, particularly erosion and sediment transportation. Peak river flows generally occur between August and September, corresponding with the period of high rainfall and increased catchment runoff. From October onward, rainfall and river discharge gradually decline, resulting in reduced fluvial activity and increased opportunities for sediment deposition. The accumulation of sediments along the river channel contributes to the development of depositional features and may subsequently influence changes in channel morphology.



Source: UBRBDA

Figure 6. Pattern of rainfall and discharge along the segment for Yola and Numan stations 1986-2025



Source: UBRBDA

Figure 7. Shows the distributional pattern of rainfall and number of rainy days along the selected segment of the study

The statistical distribution of rainfall in the study area indicates a range of 603.4 mm, with a mean annual rainfall of 948.38 mm and a median of 969.3 mm. Since the mean value is lower than the median, the distribution exhibits a slight negative (left) skewness, indicating a greater concentration of the lower rainfall values toward the left side of the distribution. The standard deviation of the rainfall dataset is 120.61 mm, indicating the extent of variation in annual rainfall around the mean. The calculated coefficient of skewness for total annual rainfall at Yola Station is −0.0577, indicating a very slight negative skewness and a distribution that is close to symmetrical. The coefficient of kurtosis is 0.3055, suggesting a relatively moderate degree of peakedness and tail distribution in the rainfall data (Table 1).

Table1. Preliminary analysis of rainfall and discharge of a segment of River Benue at Yola station and Numan station from 1986-2025

Measures/Indicators	Rainfall mm Yola station 1988-2022	Discharge $\boldsymbol{m^3/s}$Yola Station 1986-2025	Discharge$\boldsymbol{m^3/s}$Numan Station 1986-2025
Mean	948.38	4193	4087
Median	969.3	4040	4474
Standard Deviation	120.6129	1315.48	1385.37
Coefficient of Skewness	-0.0577	0.1872	-0.3074
Coefficient of Kurtosis	0.3055	-0.9973	-0.9492
Range	603.4	4825	5300
Lowest Annual Rainfall/Discharge	656.7 (2002)	2215 (2019)	1500 (1990)
Highest Annual Rainfall/Discharge	1260.1 (2016)	7040 (1999)	6800 (2012)
Slope of linear regression between rainfall and discharge	0.5687		
Coefficient of Kurtosis (k)	0.3055	-0.9973	-0.9492
Highest Monthly Rainfall/Discharge	473.8 Aug (1989)	4800 Oct (1999)	6240 Sept (2001)
Lowest Monthly Rainfall/Discharge	0.3 Nov (2002)	40 Apr (1991)	40 Feb and Jan (2014 and 2015)

For river discharge, the statistical distribution at Yola Station for the period 1986–2025 produced a mean of $4193m^3/s$, a median of 4,040 [unit], a range of $4825m^3/s$, and a standard deviation of $1315.48m^3/s$. At Numan Station, the corresponding mean discharge was $4087m^3/s$, with a median of $4474m^3/s$, a range of $5300m^3/s$, and a standard deviation of $1385.37\ m^3/s$. At Yola Station, the mean discharge is greater than the median, indicating a positive (right) skewness in the distribution. This suggests that relatively higher annual discharge values extend toward the right-hand side of the distribution. In contrast, the mean discharge at Numan Station is lower than the median, indicating a negative (left) skewness, with relatively lower discharge values extending toward the left-hand side of the distribution.

The calculated coefficient of skewness for discharge at Yola Station is 0.1872, indicating a slight positive skewness and an asymmetrical distribution. Conversely, Numan Station recorded a skewness coefficient of −0.3074, indicating a slight negative skewness. The coefficient of kurtosis for discharge was −0.9973 at Yola Station and −0.9492 at Numan Station. The negative kurtosis values indicate that the discharge distributions at both stations are platykurtic, characterized by relatively lighter tails and a flatter distribution compared with a normal distribution (Table 1).

Monthly Trend Analysis of Rainfall and Discharge

The highest and lowest mean monthly rainfall and river discharge recorded along the studied segment of the River Benue at Yola and Numan stations during the period 1986–2025 show considerable seasonal variability. The highest monthly rainfall recorded was 473.8 mm in August 1989. This relatively high rainfall value corresponds with the period when rainfall intensity and the number of rainy days is generally elevated, particularly during August and September, which represent part of the peak rainy season in the study area. In contrast, the lowest monthly rainfall of 0.3 mm was recorded in November 2002. This low value corresponds with the period following the cessation of the rainy season, when rainfall becomes considerably reduced.

With respect to river discharge, the highest monthly discharge recorded at Yola Station was $4800m^3/s$ in October 1999, while Numan Station recorded its highest monthly discharge of $6240m^3/s$ in September 2001. The occurrence of peak discharge during September and October is associated with the seasonal hydrological response of the River Benue basin, following the period of intense rainfall during August and September. The high discharge observed during this period may also be influenced by upstream reservoir operations, including water releases from the Lagdo Dam in Cameroon, which can contribute to increased downstream flow in the River Benue.

The lowest discharge recorded during the study period at Yola Station was $40m^3/s$ in April 1991. At Numan Station, the minimum discharge value of $40m^3/s$ was recorded in February 2014 and January 2015, respectively. These low-flow conditions correspond with periods of limited rainfall and reduced catchment runoff. The monthly rainfall and discharge variations are presented in Table 1 and Figures 8, 9, and 10.

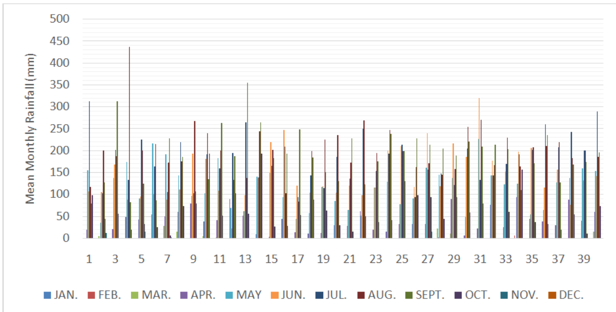


Figure8. Monthly Total Rainfall Distribution Yola and Numan from 1986-2025

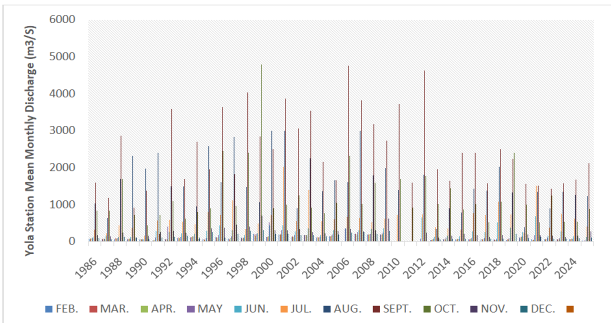


Figure9. Mean Monthly Discharge (m^3/s) Yola Station from 1986-2025

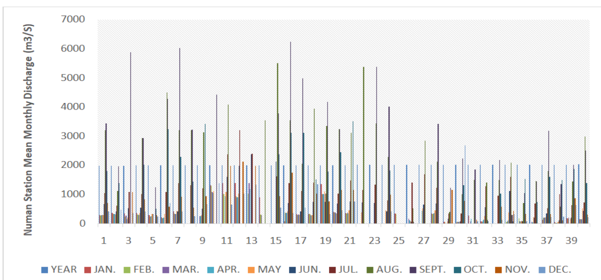


Figure10. Mean Monthly Discharge (m^3/s) For Numan Station from 1986-2025

Table 2. Nonparametric Correlations between rainfall and discharge of the study area

Correlations				
			Mean Annual discharge	Total Annual rainfall [mm]
Kendall's tau_b	Mean Annual discharge	Correlation Coefficient	1.000	-.045
		Sig. (2-tailed)	.	.701
		N	35	35
	Total Annual rainfall [mm]	Correlation Coefficient	-.045	1.000
		Sig. (2-tailed)	.701	.
		N	35	35

Mann-Kendell's Test Analysis of the Annual Rainfall and Discharge Trends

The Mann-Kendall test results for the annual discharge data reveal a statistically significant trend that warrants careful consideration in water resource management and environmental planning. With a calculated Z-value of -2.8687 and a corresponding p-value of 0.004122, the test indicates strong evidence against the null hypothesis of no monotonic trend in mean annual discharge. This implies that over the study period, there has been a discernible pattern of decreasing discharge levels.

The negative Z-value and the associated negative Kendall's tau coefficient (approximately -0.341) signify a clear decreasing trend in annual discharge. This trend is crucial as it suggests that, on average, the volume of water passing through the discharge point each year has been declining. Such a finding is not merely statistical but carries significant implications for both ecological and human systems reliant on consistent water availability.

From an environmental standpoint, declining discharge can disrupt aquatic habitats and biodiversity, affecting ecosystems dependent on stable water flows. Moreover, in regions where agriculture or industry relies heavily on predictable water resources, reduced annual discharge levels may pose challenges to sustainable development and economic stability.

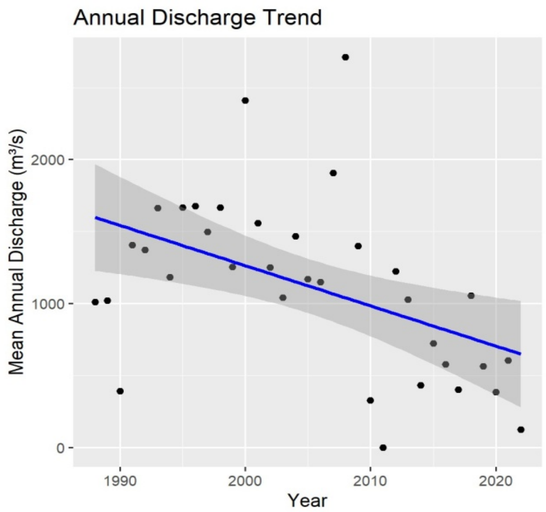


Figure 11. Mean Annual Discharge Trends

The Mann-Kendall test conducted on the annual rainfall data yielded a non-significant p-value of 0.6701, indicating that there is insufficient evidence to reject the null hypothesis of no monotonic trend in annual rainfall over the study period. This statistical result suggests that while there may be variability in annual rainfall amounts from year to year, there is no clear upward or downward trend discernible from the data analyzed.

The calculated Z-value of 0.42604 and the small Kendall's tau coefficient of approximately 0.052 further support this interpretation. These values suggest a very weak positive correlation, indicating a slight tendency towards increased annual rainfall, although this tendency is not statistically significant. Such findings are crucial for understanding regional climate dynamics, as they indicate that annual rainfall patterns in the study area exhibit variability without demonstrating a consistent trend towards wetter or drier conditions over the years examined.From an environmental and societal perspective, these results imply a need for cautious interpretation and adaptive planning in water resource management and agriculture. While the absence of a significant trend alleviates concerns of a definitive shift in rainfall patterns, it underscores the importance of continued monitoring and preparedness for potential climate variability. This approach ensures that strategies for water conservation, agricultural planning, and infrastructure development are responsive to evolving climatic conditions and local environmental dynamics.

Correlation analysis between rainfall and discharge of the study area

Table presents nonparametric correlations, specifically Kendall's tau_b coefficients, between Mean Annual Discharge and Total Annual Rainfall (mm) over a study period of 40 years. Kendall's tau_b is used here due to its suitability for assessing correlations in ranked data, such as annual discharge and rainfall measurements, where precise numerical values are less critical than the relative ordering of observations.

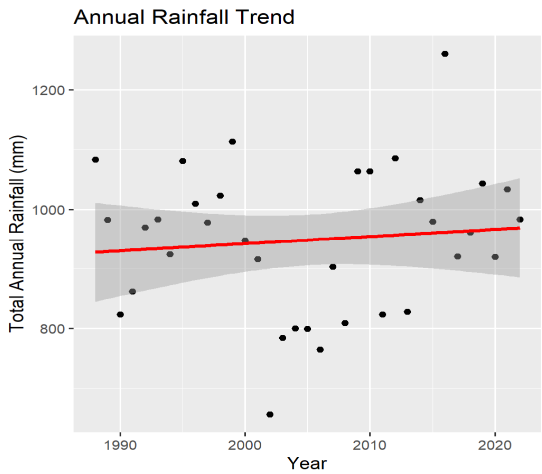


Figure 12. Total Annual Rinfall Trends

In examining the correlation between Mean Annual Discharge and Total Annual Rainfall, the table shows a tau_b coefficient of -0.045. This indicates a very weak negative correlation between the two variables. However, the associated p-value of 0.701 suggests that this correlation is not statistically significant at the conventional significance level of 0.05. This lack of statistical significance implies that variations in annual discharge do not consistently correspond to variations in annual rainfall within the dataset analyzed. From an environmental and hydrological perspective, these findings suggest that while there may be some relationship between annual discharge and rainfall, this relationship is not strong enough to infer predictable changes in discharge solely based on variations in rainfall amounts. Factors beyond annual rainfall, such as local topography, land use changes, and human interventions in water systems, likely contribute significantly to annual discharge patterns.

Linear Regression Analysis of Rainfall and Discharge of the Study Area

Table 3. Linear Regression Model

Model Summary[b]			
Model	R	R Square	Std. Error of the Estimate
1	.126[a]	.016	616.57261

a. Predictors: (Constant),Total Annual rainfall [mm]
b. Dependent Variable: Mean Annual discharge (M^3/Sec)

The model summary table presents key statistical metrics that assess the relationship between Total Annual Rainfall (mm) and Mean Annual Discharge (m^3/s) over the study period. The coefficient of determination (R Square) is a measure of how much of the variance in Mean Annual Discharge can be explained by variations in Total Annual Rainfall. In this case, the R Square value of 0.016 indicates that only approximately 1.6% of the variability in Mean Annual Discharge can be attributed to changes in Total Annual Rainfall alone. This low R Square suggests that Total Annual Rainfall is not a strong predictor of Mean Annual Discharge in the model.The Standard Error of the Estimate provides insight into the accuracy of predictions made by the model. Here, the relatively high Standard Error of the Estimate of 616.57261 M^3/Sec indicates considerable variability around the predicted values of Mean Annual Discharge based on Total Annual Rainfall. This variability underscores the uncertainty in using Total Annual Rainfall alone to forecast Mean Annual Discharge accurately.

Table 4. Regression ANOVA

Regression ANOVA[a]						
Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	203298.756	1	203298.756	.535	.470[b]
	Residual	12545338.732	33	380161.780		
	Total	12748637.487	34			

a. Dependent Variable: Mean Annual discharge
b. Predictors: (Constant), Total Annual rainfall [mm]

The regression ANOVA table indicates that the p-value associated with the F-statistic for Total Annual Rainfall as a predictor of Mean Annual Discharge is 0.470. This p-value suggests that the model, as currently formulated, does not provide sufficient evidence to reject the null hypothesis. Therefore, based on this analysis, Total Annual Rainfall alone does not significantly predict variations in Mean Annual Discharge at the conventional significance level of 0.05. These results underscore the limitations of using rainfall data alone to explain the observed variability in discharge levels, highlighting the need for considering additional factors in hydrological modeling and resource management strategies.

Table 5. Regression Coefficients

Coefficients[a]						
Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	T	p-value.
1	(Constant)	1722.419	826.079		2.085	.045
	Total Annual rainfall [mm]	-.632	.864	-.126	-.731	.470

a. Dependent Variable: Mean Annual discharge

The coefficients table presents the relationship between Total Annual Rainfall (mm) and Mean Annual Discharge (M^3/Sec) based on the linear regression model. The analysis focuses on understanding how changes in rainfall may influence discharge levels over the study period. The coefficient for Total Annual Rainfall [mm] is reported as -0.632, indicating that, on average, a one-unit increase in Total Annual Rainfall results in a decrease of approximately 0.632 M3/Sec in Mean Annual Discharge. This negative coefficient suggests a potential inverse relationship between rainfall and discharge, implying that higher annual rainfall might correspond to lower discharge volumes, although the strength and significance of this relationship require further scrutiny.

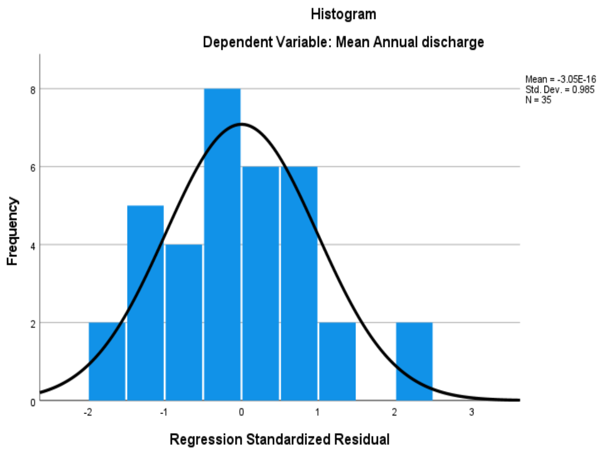


Figure 13. Regression Standardized Residual

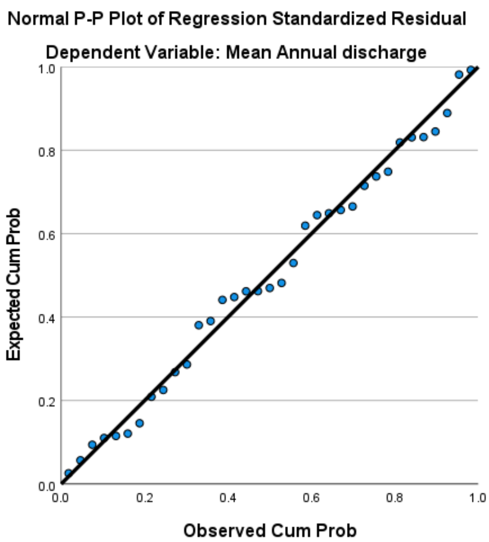


Figure 14. Normal P.P plot of Standardized Residual

The p-value is 0.470, which is notably higher than the conventional threshold of 0.05 for statistical significance. This high p-value indicates that the coefficient for Total Annual Rainfall [mm] is not statistically significant in predicting variations in Mean Annual Discharge. Therefore, the observed relationship between rainfall and discharge in the model may be due to random variability rather than a reliable predictor. These findings suggest that while there is a numerical association between rainfall and discharge levels, this association does not hold under statistical scrutiny. Factors beyond rainfall, such as local hydrological conditions, land use practices, and seasonal variations, likely exert stronger influences on discharge patterns. Consequently, relying solely on rainfall data to predict discharge levels may oversimplify the complex dynamics of hydrological systems.

Conclusion

The study examined the relationship between rainfall and river discharge regimes within the study area and found that the relationship between the two variables was weak and statistically insignificant. Although variations in annual rainfall may have some influence on annual river discharge, the results indicate that rainfall alone does not provide a sufficiently strong basis for explaining or predicting changes in annual discharge. This suggests that other factors may contribute substantially to the observed discharge patterns within the River Benue system.

Possible contributing factors include variations in local topography, changes in land use and land cover, catchment characteristics, human activities and interventions within the river system, as well as variations in upstream flow regulation and flood events associated with releases from the Lagdo Dam in Cameroon. These factors may interact with rainfall and influence the quantity and timing of water reaching the study stations.

Furthermore, the linear regression analysis, based on the regression ANOVA results, indicates that total annual rainfall is not a statistically significant predictor of mean annual discharge at the 5% significance level ($\alpha = 0.05$). Therefore, the study concludes that variations in annual rainfall alone cannot adequately explain the observed changes in mean annual discharge during the study period. A more comprehensive assessment incorporating additional climatic, hydrological, catchment, and anthropogenic variables would provide a better understanding of the factors controlling the discharge regime of the River Benue in the study area.

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