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Research Article

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Time Series Analysis of River Discharge, Water Stage, and Rainfall at Lokoja Section of Benue River, Kogi State, Nigeria

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ABSTRACT
This study carried out a time analysis of river water level (stage), rainfall, and discharge in the Lokoja section of River Benue and assessed their implications for flooding. The specific objectives that guided the study were focused on monthly and annual variability in water level, rainfall, and discharge are examined, along with their interrelationships. Data on water level and discharge were acquired from the Nigeria Hydrological Services Agency (NHSA), Abuja covering 22 years (2001 -2021), while rainfall data were obtained from the Nigeria Meteorological Agency (NiMet), Lagos Operational Headquarters. Time series analysis was carried out using the Least Square Regression Model. The significance of the trend was tested using the student's t-test at a 0.05 (95%) confidence level. While descriptive statistics employed are mean, standard deviation, and coefficient of variation. The results indicate a decline in water levels from January to April, followed by a significant rise from May to October. Annual water levels show a significant positive trend over 21 years ($R^2 = 0.2968$, $r = 0.5448$), with notable fluctuations. Peak discharge exhibits a fluctuating monthly pattern, with a significant increasing trend over the years ($R^2 = 0.2451$, $r = 0.4951$), indicating potential flood risks. Monthly rainfall varies significantly, with notable peaks between April and August. Although annual rainfall shows a slight increasing trend, it's not statistically significant. Strong correlations exist between peak discharge and water levels ($r \approx 0.982$), while relationships between discharge and rainfall, and water levels and rainfall are moderate. Multiple regression analysis reveals water level significantly influences discharge ($\beta \approx 30.27$, $R^2 = 0.960$). The study recommends implementing seasonal water management plans to address seasonal fluctuations, enhancing flood forecasting systems, adopting adaptive management strategies, investing in long-term monitoring and research, and promoting stakeholder collaboration. These measures aim to improve water resource management resilience, flood preparedness, and response capabilities in the face of climate variability and change.

Keywords: Time Analysis, River Water level (Stage), Rainfall, Discharge, Lokoja

Introduction

Rivers are essential components of Earth's hydrological cycle, serving as critical sources of freshwater and playing pivotal roles in regional ecosystems and human societies. Understanding the dynamic behaviour of river systems is of paramount importance for effective water resource management, flood forecasting, and environmental protection [1]. This follows that sustainable management of water resources is critical to ensuring socioeconomic development and environmental sustainability within a catchment area. Therefore, analyzing hydro-climatic variables such as river discharge, water level, and rainfall is crucial for the management and utilization of water resources in any river basin [2]. These variables provide valuable insights into the intricate dynamics of river basins, which are complex systems influenced by various natural and anthropogenic factors.

In this context, a comprehensive analysis of river discharge, water level, and rainfall patterns within the Lokoja section of the Benue River Basin holds significant promise in shedding light on the hydrological behaviour of this critical waterway. Time series analysis therefore offers a systematic approach to examining the temporal variations and interdependencies among these variables. The Benue River Basin, as a whole, plays a vital role in providing water resources for agriculture, industries, and domestic use to a substantial portion of the

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population. However, as climate change continues to impact the frequency and intensity of hydrological events such as flooding, and alterations in rainfall patterns, it is imperative to comprehensively study the hydrological dynamics of regions like the Makurdi section of the Benue River [3,4]. This would no doubt create better understanding of the temporal variations and interrelationships between river discharge, water level, and rainfall in this area. According to John and Liviu, river discharge is directly influenced by meteorological runoff (precipitation minus evaporation) and drainage basin area [5]. The relationship between rainfall and the water level of a river, also known as the river stage, is a critical aspect of hydrology. Rainfall within a river's watershed or catchment area directly affects the volume of water that enters the river, and intense or prolonged rainfall events can lead to rapid increases in the river water stage.

Furthermore, water level, known as gauge height or stage, indicates the elevation of the free surface of a body of water relative to a specified vertical datum. Understanding the river stage is crucial for analyzing how much water is moving in a stream at any given moment. Variability in rainfall characteristics, river discharge, and water level are key drivers of the hydrological behaviour of rivers, impacting the frequency and magnitude of floods. This knowledge is essential for flood prediction, risk analysis, and mitigation strategies. Additionally, river discharge and water level variability due to changes in rainfall patterns are major determinants of river morpho-dynamics [6]. Discharge monitoring is not only vital for anticipating floods and water scarcity but also aids in detecting climatic and environmental changes.

Empirical studies have demonstrated that hydrological changes, including river discharge and water level, occur across various spatial scales, from local to global [7-9]. The global hydrological cycle has already begun responding to observed climate change and global warming, impacting the quantity and quality of water resources [10]. Moreover, different regions around the world have witnessed increasing river discharge under various climatic conditions. For instance, Xu and Luo reported consistent trends toward warmer and wetter conditions and increased river discharge in specific sub-catchments in China, indicating a direct relationship between rainfall patterns and river discharge and water level within a catchment area [9].

In Nigeria, surface water is indispensable for critical sectors like agriculture, power generation, and fisheries, particularly in rain-fed agriculture regions. The temporal variability of river regimes in the Lokoja section of the river Benue, which is the second largest river in the country, is of particular importance. Limited works have been done on changes in discharge and water level in this area, despite the increasing frequency of devastating flood events. Therefore, this study seeks to analyze the temporal variability in rainfall, river discharge, and water level in the Lokoja section of the river Benue.

The study of river discharge, water level, and rainfall within a river basin is crucial for understanding the hydrological processes that shape the behaviour of rivers and their surrounding environments. These variables are interconnected and influence each other, impacting water availability, flood management, and ecosystem health. Moreover, rivers are vital components of Earth's hydrological cycle and play a crucial role in the distribution of water resources, ecological balance, and sustainable development. In recent years, the increasing frequency and intensity of extreme weather events, coupled with the effects of climate change, have brought significant attention to the study of river discharge, water level, and rainfall patterns [11]. The Makurdi section of the Benue River represents a critical area for such investigation due to its significance in local water management, flood control, and socioeconomic activities. Hence, accurate analysis and understanding of river discharge, water level, and rainfall patterns are essential for effective flood risk assessment, disaster preparedness, and water allocation in this area.

The variations in discharge and water level of a river constitute its hydrological regime, which is influenced by climate, especially rainfall, and the nature of the Earth's surface and subsurface [6]. These factors, in turn, influence flooding in a catchment. There is an increasing need to understand the variability of hydrological processes such as river discharge, water level, and rainfall in view of the impact from changing climate and human activities such as land use change, construction of reservoirs and dams, and water abstraction [12,13].

Time series analysis of these parameters can provide insights into long-term trends, seasonal variations, and extreme events, helping local authorities and stakeholders make informed decisions for sustainable water resource management [14]. Investigating the historical trends and patterns of river discharge, water level, and rainfall in the Makurdi section can contribute to our understanding of the area's vulnerability to climate change. This knowledge is crucial for devising adaptive strategies and policies that mitigate the adverse impacts of changing hydrological conditions on the local population, ecosystems, and infrastructure. In recent times, the Lokoja section of the Benue River has witnessed an increasing frequency of river, flash, and urban flood events with an impact on livelihoods and the environment. These floods are connected to the amount of rainfall and the release of water from the Lagdo Dam, resulting in high water levels and discharge over this area. From the available literature, this issue has not received the desired attention, despite the increasing frequency of floods and their impact on Lokoja. This suggests that relatively few studies have analyzed temporal variability in the hydrological regimes of the river Benue in terms of rainfall, river discharge, and water level in the Lokoja section of the river.

In order to fill this gap, this study is designed to analyze the temporal variability in rainfall, river discharge, and water level in the Lokoja section of the river Benue and examine its implications for flooding in this area. Conducting a time series analysis of river discharge, water level, and rainfall at the Makurdi section of the Benue River is a significant endeavor that holds the potential to inform critical decisions in water resource management, flood control, climate adaptation, and ecosystem preservation. The findings of this research can provide valuable insights for policymakers, researchers, and stakeholders working towards sustainable development and resilience in the face of changing hydrological conditions of the river.

Material And Methods

Study Area

Lokoja, the capital of Kogi State in central Nigeria, is strategically located at the confluence of the Niger and Benue Rivers. Lokoja is located between Latitude 70 45’N - 70 51’N and Longitude 60 41’E - 60 46’E., (Figure 1). Its geographical positioning has historical and commercial significance, serving as a major administrative and trading hub. The earliest settlers included the Bassa-Nges and Oworos, with various Nigerian ethnic groups, such as Yoruba, Igala, Hausa, and others, residing in the area today. Lokoja experiences a tropical savanna climate with distinct wet and dry seasons, and its vegetation mainly consists of savanna grasslands and riparian zones near rivers. The city’s geology falls within the Benue Trough, composed of sedimentary formations like sandstone, shale, and limestone. Lokoja’s soils vary from fertile alluvial soils near riverbanks to sandy and lateritic soils in upland areas. Its relatively flat relief, low-lying floodplains, and the confluence of two major rivers make Lokoja prone to seasonal flooding, while these rivers also serve as key transportation routes. Economically, Lokoja thrives on agriculture, with crop cultivation and fishing being prominent activities. The city is a commercial center, supported by its role as a transportation hub and its administrative functions. Lokoja’s population was estimated at 195,261 in 2006, with a diverse mix of ethnic groups and growing urbanization due to economic opportunities.

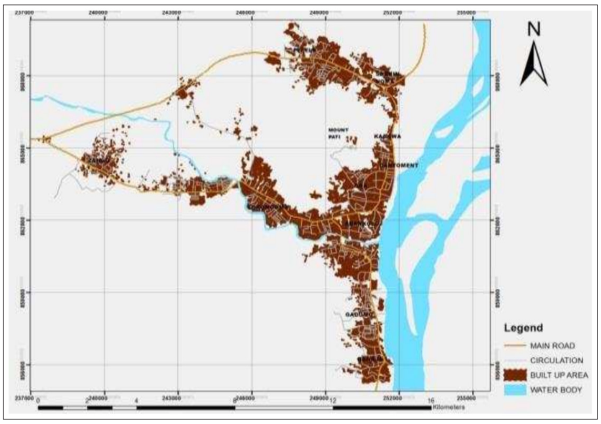

Figure 1: Lokoja and Its Built-up Areas

Result and Discussion

Variations in Peak Monthly and Annual Water Level at the Lokoja Section of River Benue

Figure 2 presents the monthly pattern of peak water levels at the Lokoja section of the Benue River. During January, the mean monthly water level stood at 365.00 cm3, declining slightly to 326 cm3, 329.00 cm3, and 334.00 cm3 in February, March, and April respectively. This indicates that the water level over the Lokoja section of the Benue River reached its lowest point between February and April, coinciding with the peak dry season transition. As rains typically commence in April, there was a slight uptick in the peak monthly water level to 368 cm3, followed by a gradual increase reaching 487.00 cm3 in June and peaking at 1,284.00 cm3 in September. October maintained a high peak water level at 1272.00 cm3, which then slightly decreased to 1099.00 cm3 in November, and sharply dropped to 510.00 cm3 in December. These findings highlight that August, September, and October experience exceptionally high-water levels, contributing to the frequent flooding observed in the study area during this period.

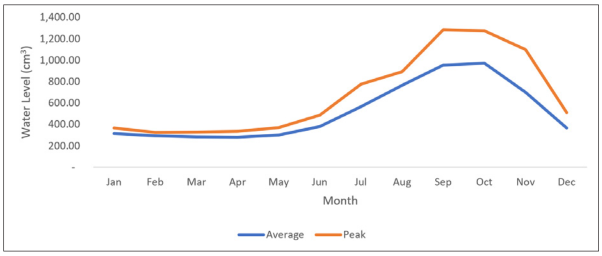

Figure 2: Monthly Pattern of River Water Level at Lokoja (2001-2021)

The mean monthly pattern of water level indicates a strong relationship between the monthly rainfall regime and the water level of Benue River at Makurdi section of the river. This follows that rainfall over this area is one of the major determinants of monthly fluctuation in water level over river Benue and consequently the frequency and severity of flood occurrences in this area.

Besides the mean peak monthly water level, the result shows that there are some years with extreme water level events in the study area. For instance, a 1284.00cm3 water level occurred in September 2012 which is the highest for the study period. This caused a devastating flood, leading to the loss of lives and property not only in Makurdi but across Benue Basin. Similarly, in October 2017, the water level was 1094-86cm3 which resulted in the occurrence of a flood within Makurdi town. From the result, it is evident that years with very high-water stage particularly in August, September, and October all experienced floods of varying magnitude and severity.

The result further shows that water levels in December and January are relatively higher than in February, March, and April due largely to the rate of evaporation occasioned by monthly temperature patterns. For instance, the temperatures are at their peak in February and March in Makurdi leading to a higher rate of evaporation and consequently sharp decline in water level in those months. In addition to the temperature factor, the tributaries that feed river Benue at the Makurdi section exhibit seasonal patterns with some of them drying up during the peak of the dry season leading to a drastic reduction in the water level of the main river.

The monthly water level pattern reflects a strong link between the rainfall distribution and the water level of the Benue River at the Lokoja section. This underscores the significance of rainfall in driving the monthly fluctuations in the river’s water level and, by extension, the occurrence and intensity of floods in the area.

The result of the trend analysis of annual water level is presented in Figure 3 and Table 1.

Table 1: Summary of Variables

Variable	Discharge (m^3/s)	Water level (cm^3)	Rainfall (mm)
Mean	19,200.86	909.50	1291.59
Standard Deviation	5,829.25	189.38	242.54
Coefficient of Variation (%)	30.36	20.83	18.78

Regression (R^2)	0.2451	0.2968	0.0059
Correlation (r)	0.4951	0.5448	0.0768
Calculated t Value	2.4828	2.8318	0.3268
Critical t Value	1.73	1.73	1.73
Significance	**	**	*

Source: Computed from NHSA and NiMet Data (Appendices I-III), (2023)

The result indicates a significant positive trend at the rate of 17.04, with regression (R^2) and correlation (r) values of 0.2968 and 0.5448. The positive significant trend is evident as the calculated t value of 2.8318 is greater than the critical t value of 1.73. The mean, standard deviation from the mean, and the coefficient of variation were found to be 909.50 cm^3, 189.38 and 20.83%. This suggests that the annual water level in the study area can either increase or decrease by 189.38 cm^3 which translates to a relatively moderate percentage variation of approximately 21%. This implies that water level fluctuation at the Lokoja section of the river Benue has been moderately stable and predictable with minimal uncertainty in the last 21 years.

The findings also highlight notable years, such as 2012, which saw the highest water level recorded at 1284.00cm^3, and 2020, registered at 1189.00cm^3. In addition, years like 2015 (1162.25cm^3), 2018 (1122cm^3), and 2019 (1009cm^3) experienced significant water level fluctuations. These occurrences, all within the past decade, suggest a trend of rising water levels, posing potential risks of severe flooding in the region. This upward trend is primarily attributed to increased rainfall and sediment accumulation in the Benue River channel over the same period.

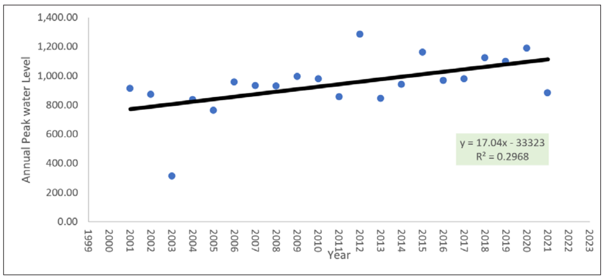

Figure 3: Annual River Water Level at Lokoja (2001-2021)

Variations in Peak Monthly and Annual Discharge at the Lokoja Section of River Benue

Figure 4 presents the monthly pattern of peak discharge at the Lokoja section of the Benue River. The result indicates a peak discharge of 4133.00 m^3/s, 3407.00 m^3/s, 3460.00 m^3/s, and 3372.4 m^3/s in January, February, March, and April respectively. This indicates that the discharge over the Lokoja section of the Benue River reached its lowest point in February during the peak dry season just as the case with water level. With the onset of rains in March/April, the discharge responded in May after a month time lag with discharge rising from 4193.6 m^3/s in May to 6597.4 m^3/s in June and peaking at 31,692.00 m^3/s in September. In October and November, discharge maintained high values at 31,236.00 m^3/s and 24,800 m^3/s, and sharply dropped to 7090 m^3/s in December. Again, this result suggests that August, September, and October experienced exceptionally high discharge just as the water level with attendant flood risks.

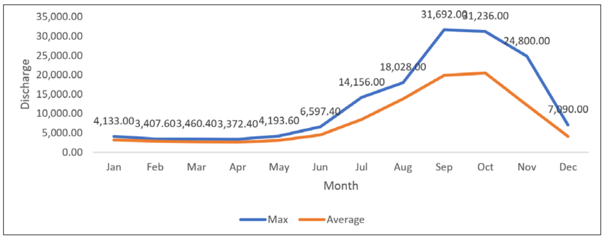

Figure 4: Monthly River Discharge at Lokoja (2001-2021)

The result of the trend analysis of annual discharge is presented in Figure 5 and Table 1. The result indicates an increasing trend at the rate of 476.58, with regression (R^2) and correlation (r) values of 0.2451 and 0.4951. The positive trend is found to be significant at 0.05 (95%) confidence level given that the calculated t value of 2.4828 is greater than the critical t value of 1.73. The mean, standard deviation from the mean, and coefficient of variation were found to be 19,200.86 m^3/s, 5,829.25 and 30.36%. This suggests that the annual discharge in the study area could increase or decrease by 5,829.25 m^3/s which translates to a relatively high percentage variation of approximately 30%. This implies that the fluctuation in river discharge at the Lokoja section of the river Benue has been relatively unstable and unpredictable with moderate to high uncertainty in the last two decades.

The findings also highlight notable years, such as 2012, which saw the highest discharge recorded at 31,692 m^3/s, followed by 2020, with 28,082 m^3/s. Other years with significantly high discharge are 2015 (27,091 m^3/s), 2018 (25,612 m^3/s), and 2019 (24,800 m^3/s). These high discharge values were all recorded within the past decade, suggesting a rising trend in river discharge at Lokoja, with potential risks of severe flooding in the region of the Niger-Benue Basin, Nigeria. The significant upward trend can be connected to increased rainfall and the resultant increase in water level.

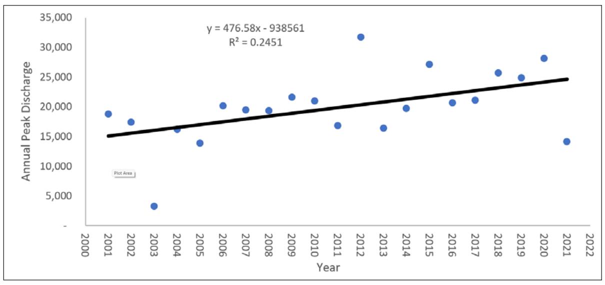

Figure 5: Annual River Discharge at Lokoja (2001-2021)

Variations in Monthly and Annual Rainfall Amount at the Lokoja

The result of the monthly fluctuation in rainfall amount at Lokoja is presented in Figure 6. The result indicates that generally, the monthly average rains are trace amounts ranging from 0.00 mm to 17.39 mm between January and March on the one hand; and 2.83 mm and 0.19 mm in November and December on the other hand. The result shows that the effective rains start in April with an average monthly amount of 110.9 mm for the study period and peak at an average monthly amount of 220.52 mm in August. The monthly rains remained substantially very high in September (215.65 mm) and October (136.64 mm) which mark the cessation of rainfall.

The result further shows some extremely high monthly rainfall amounts in August 2012 (427.20 mm), July 2001 (423.50 mm), August 2007 (397.80 mm), and August 2019 (352.8 mm). This suggests that the heavy rains are concentrated between July and September in Lokoja areas of the Niger-Benue Basin which indicates a very high probability of flood occurrence in these months and in October due to the one-month time lag in rising water level and discharge.

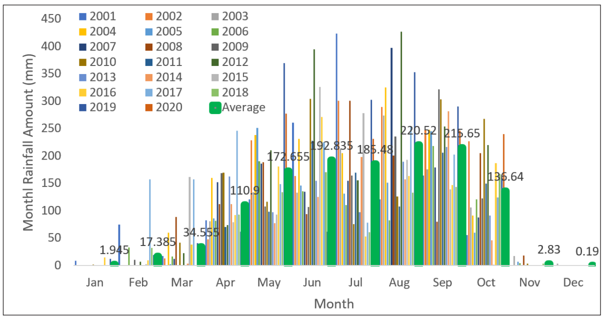

Figure 6: Monthly Rainfall Amount over Lokoja (2001-2021)

The result of the trend analysis of annual rainfall amount is presented in Figure 7 and Table 1. The result indicates a slightly increasing trend at the rate of 3.2396, with regression (R2) and correlation (r) values of 0.0059 and 0.0768. The positive trend is not significant at a 0.05 (95%) confidence level given that the calculated t value of 0.3268 is less than the critical t value of 1.73. The mean, standard deviation from the mean, and coefficient of variation were found to be 1291.59 mm, 242.54, and 18.78%. This suggests that the annual rainfall amount in the study area could increase or decrease by 242.54 mm which translates to a low percentage variation. This implies that the fluctuation in annual rainfall amount at the Lokoja relatively stable and predictable in the last two decades.

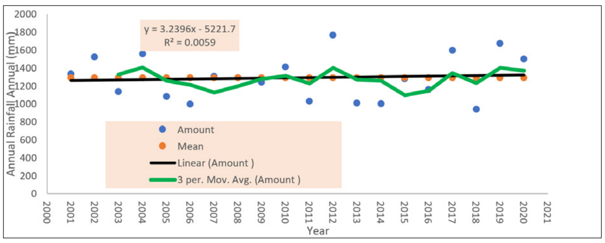

Figure 7: Annual Rainfall Amount over Lokoja (2001-2021)

Relationship among rainfall, water level (stage), and discharge in Lokoja

The result of the correlation analysis that shows the relationship among rainfall, water level, and discharge in Lokoja is presented in Table 2. The correlation matrix shows the correlation coefficients among three variables: peak discharge, peak water level, and rainfall amount. Correlation coefficients measure the strength and direction of the linear relationship between two variables, ranging from -1 to 1.

Table 2: Correlation Matric of Hydro-climatic Variables

	Peak Discharge	Peak Water Level	Rainfall Amount
Peak Discharge	1		
Peak Water Level	0.982026	1	
Rainfall Amount	0.343732	0.353785	1

Source: Computed from NHSA and NiMet Data (Appendices I-III), (2023)

The result shows that the correlation coefficient between peak discharge and peak water level is very high, with a value of approximately 0.982. This indicates an extremely strong positive linear relationship between these two variables. This follows that when peak discharge increases, Peak Water Level also tends to increase proportionally, and vice versa. This high correlation suggests that changes in one variable can be very reliably predicted by changes in the other. The result further indicates that the correlation coefficient between peak discharge and rainfall amount is moderate, with a value of approximately 0.344. This indicates a positive linear relationship between these two variables, but the relationship is not as strong as that between peak discharge and peak water level. A correlation of around 0.344 suggests that there is a discernible relationship between rainfall and peak discharge, but other factors may also influence peak discharge.

Similarly, the correlation coefficient between peak water level and rainfall amount is also moderate, with a value of approximately 0.354. This suggests a positive linear relationship between these two variables, but again, it's not as strong as the correlation between peak discharge and peak water level. Like with peak discharge, rainfall amount contributes to changes in peak water levels, but other factors may also play a role.

Overall, the correlation matrix indicates that peak discharge is strongly correlated with Peak Water Level, suggesting a direct and highly predictable relationship between these two variables. Both peak discharge and peak water level have moderate correlations with rainfall amount, indicating that while rainfall does influence these variables, its effect is not as pronounced as the relationship between peak discharge and peak water level. These results provide valuable insights into the interrelationships between these hydrological variables, which can be crucial for various applications such as flood forecasting, water resource management, and infrastructure planning. The result of the multiple regression involving river discharge as a dependent variable Y and two independent variables water level and rainfall amount X1 and X2 is presented in Tables 3 and 4.

Table 3: Summary Regression Output

Regression Statistics	
Multiple R	0.982034
R Square	0.964391
Adjusted R Square	0.960435
Standard Error	1188.129
Observations	21

Table 4: Regression Coefficients of Water Level and Rainfall Amount of Discharge

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-8601.25	1659.876	-5.18186	6.27E-05	-12088.5	-5113.98
Peak WL	30.27362	1.463723	20.68261	5.39E-14	27.19845	33.34879
Rainfall	0.1022	1.150861	0.08881	0.930216	-2.52007	2.315665

Source: Computed from NHSA and NiMet Data (Appendices I-III), (2023)

This regression analysis aims to predict a river discharge (dependent variable, Y) using two independent variables: Peak WL (Peak Water Level) and Rainfall. The results indicate that the correlation coefficient between the observed and predicted values of the dependent variable (multiple R) is approximately 0.982, indicating a strong positive linear relationship between the independent and dependent variables. The R^2 which represents the proportion of the variance in the dependent variable that is predictable from the independent variables is approximately 0.964 indicating that about 96.4% of the variance in the dependent variable is explained by the independent variables. The adjusted value R^2 is 0.960 which is slightly lower than R^2 for the number of predictors in the model which suggests that regression model is highly suitable for predicting river discharge in Lokoja and by flood occurrence. Adjusted value R^2 penalizes excessive use of predictors that don't improve the model significantly.

The result further shows that the intercept which is the value of the dependent variable when all independent variables are zero is approximately -8601.25. peak water level coefficient of 30.27362 indicates that for each unit increase in peak water level, the river discharge (dependent variable, Y) is expected to increase by approximately 30.27362 units, holding all other variables constant. In the same vein, rainfall coefficient of 0.1022 suggests that for each unit increase in rainfall, the river discharge (dependent variable, Y) is expected to increase by approximately 0.1022 units, holding all other variables constant which suggests that water level is the major determinant of rainfall.

From the result, it is evident that the model suggests that peak water level has a statistically significant positive effect on the dependent variable, with a coefficient of approximately 30.27. However, Rainfall does not appear to have a statistically significant effect on the dependent variable, as its coefficient is not significantly different from zero (p-value = 0.93). Overall, this model indicates that peak water level is a significant predictor of the dependent variable, while rainfall does not significantly contribute to explaining the variance in the dependent variable.

Table 5 presents the results of an analysis of variance (ANOVA) for a multiple regression model. ANOVA is a statistical technique used to partition the total variance observed in a dataset into different components, which in this case are regression, residual, and total variance. The result indicates Degrees of Freedom (df) of (Regression: 2, Residual: 18 and Total: 20), while Sum of Squares (SS) attributed to the regression model, which measures the amount of variance in the dependent variable that is explained by the independent variables is 6.88×10^8. The value of the residual is 2.54×10^7 - the sum of squares of the residuals, which are the differences between the observed values and the values predicted by the regression model. It represents the unexplained variance in the dependent variable. The value of sum of squares of the total variances in the dependent variable is 7.14×10^8. It is the sum of the regression and residual sum of squares. The mean sum of squares for the regression is obtained by dividing the sum of squares of the regression by its degrees of freedom. In this case, it is 3.44×10^8

Table 5: ANOVA

	df	SS	MS	F	Significance F
Regression	2	6.88E+08	3.44E+08	243.7477	9.2E-14
Residual	18	25409692	1411650		
Total	20	7.14E+08			

Source: Computed from NHSA and NiMet Data (Appendices I-III), (2023)

The value of F-statistic (F) which is the ratio of the mean square due to regression to the mean square of the residuals is 243.7477. It indicates the strength of the relationship between the independent and dependent variables. While the Significance F is the p-value associated with the F-statistic. It tells us the probability of obtaining the observed F-statistic if the null hypothesis (that all regression coefficients are zero) is true. In this study, the p-value is 9.2×10^{-14}, which is extremely low. Therefore, we reject the null hypothesis and conclude that at least one of the independent variables has a significant relationship with the dependent variable. Overall, the ANOVA table provides valuable information about the overall significance of the regression model and the individual contributions of the independent variables in explaining the variance in the dependent variable. In this study, the regression model as a whole is highly significant, as indicated by the very low p-value, and the F-statistic suggests a strong relationship between the independent (river discharge) and dependent variables (water level and rainfall).

The study by Gentilucci, Djouohou, Barbieri, Hamed and Pambianchi on trend analysis of streamflows in relation to precipitation in Central Italy, partly agrees with the findings of this present study [15]. Both research studies focus on analyzing the relationship between precipitation, river/stream flow, and climate change impacts, particularly in the context of changing rainfall patterns and their consequences on water resources. For instance, both studies recognize the significance of climate change in altering precipitation patterns and subsequently impacting water resources. The studies utilize correlation analysis to explore the relationships between different variables such as rainfall, water levels, and discharge and found significant correlations between these variables that provide insights into how they interact. However, while Djouohou, Barbieri, Hamed and Pambianchi observes a decrease in precipitation during the earlier period (1964–1979) and an increase during the later period

(2005–2020), the present study reports a slight increasing trend in annual rainfall over the 21-year period (2001–2021), although it's not statistically significant [15]. This disparity in findings regarding precipitation trends could stem from differences in geographic locations and data sources. In terms of streamflow trends, while Djouohou, et al, reported a decreasing trend in streamflows within the studied basin, whereas the current study indicates a significant positive trend in annual water levels over the 21-year period [15]. These discrepancies might be attributed to variations in watershed characteristics, climate dynamics, and/or data analysis techniques.

Similarly, the findings of a study by Malede, Agumassie, Kosgei, Linh, and Andualem, on the analysis of rainfall and streamflow trend and variability over Birr River watershed, Abbay basin, Ethiopia indicate some level of agreement with the present study [16]. Both studies reported not reveal statistically significant changes in rainfall. On the other hand, streamflow exhibited a statistically significant increasing and decreasing pattern. They both establish a significant relationship between rainfall, streamflow, and other hydrological variables. There are equally areas of discrepancies between the Malede, Agumassie, Kosgei, Linh, and Andualem, and the present study [16]. While Malede, Agumassie, Kosgei, Linh, and Andualem, finds inconsistent trends and change points in streamflow, the current study identifies significant increasing trends in water levels and discharge, indicating potential flood risks [16]. In addition, Malede, et al. indicates that rainfall patterns did not significantly change, whereas the present study observes significant monthly rainfall variations and slight increasing trends annually, although not statistically significant [16].

In the same vein, Zaghloul, Ghaderpour, Dastour, Farjad, Gupta, Eum, Achari and Hassan reports that precipitation showed an insignificant decrease between 1950 and 2019 in Northern Canada, however, winter water flow in the upper ARB has been slowly and steadily increasing since 1956 because of the rising temperatures and the subsequent slow melting of snowpacks/ glaciers [17]. This underscores that fact that rainfall is the sole determinant of discharge and water level which is consistent with the findings of this present study. Conversely, a study conducted by Ogunjo, Olusola and Olusegun on the River Niger study identifies decreasing trends in minimum, mean, and maximum discharge values, whereas this present study highlights a significant positive trend in annual water levels and peak discharge [18]. However, Ogunjo, Olusola and Olusegun, suggests a recovery in mean discharge at certain stations after 1980, which is not consistent with this study that emphasizes notable fluctuations in water levels and discharge patterns over the years without indicating a clear recovery trend [18]. These differences can be attributed to differences in time scale and methodological approach and the spatial context of these studies. Nevertheless, both studies underscore the need for tailored approaches and location-specific studies to effectively manage river basins and mitigate risks associated with floods and droughts.

Furthermore, Olayinka-Dosunmua, Adzandeha, Hamid-Mosakua, Okoliea, Nwiloa, and Ogbeta, study on Assessing River Benue flow data for flood mitigation and management in Adamawa catchment, Nigeria is consistent with the findings of this study [19]. Both studies focus on analyzing river flow dynamics and their implications for flooding, albeit in different sections/regions of the same basin and with slightly different methodologies. They agree on the importance of understanding historical patterns and seasonal variations in river flows for effective flood mitigation. Both studies employ time series analysis to assess trends and fluctuations in river levels and discharge. However, while Olayinka-Dosunmua et al. specifically investigate the Adamawa catchment and emphasize the exceedance of danger levels for designed flood discharges, Despite these differences, both studies found a significant variation in discharge which underscore the need for improved water management strategies and flood forecasting systems to address the challenges posed by changing weather patterns which is one of the principal contributor to the observed variation in river discharge in these regions [19].

Conclusion and Recommendations

The study reveals a distinct seasonal pattern in water levels and discharge at the Lokoja section of the Benue River, with low levels during the dry season and significant peaks during the wet season, particularly from August to October. Long-term trends show increasing water levels and discharge over the past two decades, attributed to factors like increased rainfall and sediment accumulation. The high variability in these patterns highlights the need for adaptive management to mitigate flooding risks, especially in years of extreme discharge. The research establishes a strong correlation between peak discharge and water levels, providing a predictive model for flood forecasting. Recommendations include implementing seasonal water management plans, enhancing flood forecasting systems, adopting adaptive management strategies, investing in long-term monitoring, and promoting stakeholder collaboration.

References

1. Adati RG, Tyokumbur M, Oche O. Climate Variability and River Benue Discharge in Nigeria. Global Journal of Environmental Science and Management. 2017. 3: 277-286.
2. Vorosmarty CJ, McIntyre PB, Gessner MO, Dudgeon D, Prusevich A, et al. Global threats to human water security and river biodiversity. Nature. 2010. 467: 555-561.
3. Adeyeri OE, Ologunorisa ET. Hydrological analysis of the impact of land use changes on the hydrological behavior of Benue River Basin. Environmental Monitoring and Assessment. 2019. 191: 120.
4. Ologunorisa TE, Okon US, Ogban FU. Climate Variability and Trends in Rainfall and Temperature in the Benue River Basin, Nigeria. American Journal of Environmental Protection. 2019. 7: 42-50.
5. John DM, Liviu G. Encyclopedia of Ocean Sciences (Third Edition), Ocean Interfaces & Human Impacts. 2019.
6. Mark RH, Piret PB, Evan RJ. Global quantitative analyses of river discharge variability and hydrograph shape with respect to climate types. Earth-Science Reviews. 2020. 200: 102977.
7. Lahmer W, Pfützner B, Becker A. Assessment of land use and climate change impacts on the mesoscale. Physics and Chemistry of the Earth, Part B: Hydrology, Oceans and Atmosphere. 2001. 26: 565-575.
8. Coulthard TJ, Mark GM. How sensitive are river systems to climate and land-use change? A model-based evaluation. Journal of Quaternary Science. 2005. 16: 347-351.

9. Xu H, Luo Y. Climate change and its impacts on river discharge in two climate regions in China. Hydrology and Earth System Sciences. 2015. 19: 4609–4618.
10. Bates BC, Kundzewicz ZW, Wu S, Palutikof JP. Climate change and water. Technical paper of the Intergovernmental Panel on Climate Change. Geneva: IPCC Secretariat. 2008.
11. IPCC. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. 2014.
12. Oki T, Kanae S. Global hydrological cycles and world water resources. Science 2006. 313: 1068-1072.
13. Xu Zhang LM. Breaching Parameters for Earth and Rockfill Dams. Journal of Geotechnical and Geoenvironmental Engineering. 2010. 135.
14. Shrestha S, Babel MS. Application of time series analysis for trend assessment of river discharge and precipitation in the Bagmati River Basin, Nepal. Journal of Hydrology: Regional Studies. 2016. 5: 108-123.
15. Gentilucci M, Djouohou SI, Barbieri M, Hamed Y, Pambianchi G. Trend Analysis of Streamflows in Relation to Precipitation: A Case Study in Central Italy. Water. 2023. 15: 1586.
16. Malede DA, Agumassie TA, Kosgei JR, Linh NTT, Andualem TG. Analysis of rainfall and streamflow trend and variability over Birr River watershed, Abbay basin, Ethiopia. Environmental Challenges. 2022. 7: 100528
17. Zaghloul MS, Ghaderpour E, Dastour H, Farjad B, Gupta A, et al. LongTerm Trend Analysis of River Flow and Climate in Northern Canada. Hydrology. 2022. 9: 197.
18. Ogunjo S, Olusola A, Olusegun C. Predicting River Discharge in the Niger River Basin: A Deep Learning Approach. Applied. Science. 2024. 14: 12.
19. Olayinka-Dosunmua DN, Adzandeha AE, Hamid-Mosakua AI, Okoliea CJ, Nwiloa PC, et al. Assessing River Benue flow data for flood mitigation and management in Adamawa catchment, Nigeria. 2022.