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ANALYSIS AND PREDICTION OF SEA LEVEL VARIATIONS IN RIVER LOKOJA, KOGI STATE, NIGERIA, OVER THE PERIOD OF 2010- 2030

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ABSTRACT

With frequent fluctuations in river levels due to seasonal changes and climate factors, understanding these variations has become increasingly important for disaster management and infrastructural planning in flood-prone areas. This study utilizes historical water level and discharge data, collected from 2010 to 2020, to predict sea level trends over the next decade (2021–2030) using time series analysis in MATLAB. By employing a polynomial regression model, the study captured recurring seasonal patterns and project possible future changes in water levels and discharge rates. The findings indicate clear seasonal trends in water levels, with potential increases during peak rainy seasons that could elevate the risk of flooding. This study reveals that 2021 had the highest water level and discharge on record. Notably, a prediction indicates a substantial decline in water level and discharge by 2030. These predictions underscore the importance of preemptive measures, such as improved flood defense systems, urban planning adjustments, and community awareness programs. The study provides valuable insights for policymakers, environmental managers, and local stakeholders aiming to mitigate the adverse effects of rising water levels. Ultimately, the study contributes to a better understanding of river behavior in the region and highlights the need for sustainable approaches to address the challenges posed by sea level variations in Lokoja.

Keywords: Sea level variations, prediction, tides, water level, discharge

1.0 INTRODUCTION

Global-mean sea-level change is one of the more certain impacts of human-induced global warming and one which is expected to continue for centuries due to the time scales associated with climate processes and feedbacks even if greenhouse gas (GHG) emissions concentrations were to be stabilized [8]. Given the large and growing concentration of population and economic activity in the coastal zone, as well as the importance of coastal ecosystems, the potential impacts of sea-level change have evoked widespread concern for more than two decades [1]; [9][12]. Some potential impacts of a change in sea level have already been assessed locally, nationally, regionally and globally [7]. However, the scope of assessment and the methodologies employed have varied significantly [4]; [10. Tide is the rise and fall of sea levelscaused by the combined effects of the gravitational forces exerted by the Moonand the Sun, and the rotationof the Earth.

The daily rise and fall of the sea's edge are caused by the gravitational forces between the earth, the moon and the sun. Since the moon is closer to our planet than the sun, it exerts a stronger gravitational pull on us. (The sun only has 46% of the tide generating force of the moon.) So, when the moon faces one side of the earth, it pulls on all the earth's surfaces, but since only the ocean is flexible, only the ocean succumbs to its force. This forms a bulge on the side of the planet facing the moon, while the centrifugal force from the earth's rotation causes a bulge to form on the other side. Where these bulges occur, it’s called high tide [3]. Supposing that the sun and the moon were both on the same side of the earth, like during a new moon, this would mean that there's more of a gravitational pull in that direction than usual. This causes especially high tides called spring tides. The same thing happens during a full moon, when the sun and moon line up on opposite sides of the planet each pulling from both ends. When the moon is in a quarter phase, the sun and moon are at a ninety-degree angle to each other. During this phase, the gravitational pulls are cancelled out, producing a smaller difference between high and low tide also known as a neap tide. Spring tides and neap tide levels are about 20% higher or lower than average. And because the tides are brought on by waves with a very long wavelength (the distance between the "crest" or tips of waves), they are affected by their interaction with the seafloor. Offshore, in the deep ocean, the difference in tides is usually less than 1.6 feet. But in shallower water, these waves collapse upon themselves as they come in contact with the sea floor. The surf grows when it approaches a beach, and the tide increases. In bays and estuaries, this effect is amplified. (In the Bay of Fundy, tides have a range of 44.6 ft. In most places on the planet, high and low tides occur twice daily. Each day these tides change 50 minutes later, as it takes the moon 24 hours and 50 minutes to completely rotate around the earth. Tide tables can be used for any given locale to find the predicted times and amplitude (or "tidal range"). The predictions are influenced by many factors including the alignment of the Sun and Moon, the phase and amplitude of the tide (pattern of tides in the deep ocean), the amphidromic systems of the oceans, and the shape of the coastline and nearshore bathymetry. They are however only predictions; the actual time and height of the tide are affected by wind and atmospheric pressure. Many shorelines experience semidiurnal tides two nearly equal high and low tides each day. Other locations have a diurnal tide one high and low tide each day. A "mixed tide" two uneven magnitude tides a day is a third regular category [5]. Tides vary on timescales ranging from hours to years due to a number of factors, which determine the lunitidal interval. To make accurate records, tide gauges at fixed stations measure water level over time. Gauges ignore variations caused by waves with periods shorter thanminutes. These data are compared to the reference (or datum) level usually called mean sea level. While tides are usually the largest source of short term sea level fluctuations, sea levels are also subject to forces such as wind and barometric pressure changes, resulting in storm surges, especially in shallow seas and near coasts. Tidal phenomena are not limited to the oceans, but can occur in other systems whenever a gravitational field that varies in time and space is present. For example, the shape of the solid part of the Earth is affected slightly by Earth tide, though this is not as easily seen as the water tidal movements.

The study of the mean sea level has become a major issue in determining the rate of global sea level rise and at a particular location. The mean sea level rise for various locations forms inputs into the determination of global rise in sea level while addition of sea level rise and subsidence give an indication of relative sea level rise for a region [6][11] has shown that using 19years of tidal data, the sea level rise along the coast of Nigeria is 1mm but when the subsidence phenomenon is accounted for which is suspected to be around 2.5cm, the relative sea level rise becomes a more serious issue. The mean sea level is determined through harmonic analysis of tides and from the constituents, tidal prediction can be done. Storm surges are driven by meterological effects different from tide driven forces. The difference between observed tide data and predicted tide values gives residuals which are indeed the storm effects [6] [11] reported that the maximum surge along the coast of Nigeria is about 0.7m. This could be devastating when this interval with high tides.

This study seeks to assess the rate of sea level rise in river Lokoja and predict future sea level rises using ten-year data (2010-2020). In order to achieve the above stated objectives, the following objectives were set out to; gather historical data on water levels and discharge for River Lokoja from the years 2010 to 2020, analyze the collected data for patterns, seasonal trends, and anomalies that help understand sea level variations in River Lokoja, develop predictive models for forecasting future sea levels and water discharge in River Lokoja from 2021 to 2030.

2.0 THE STUDY AREA

Lokoja, town and river port, capital of Kogi state, south-central Nigeria, located on the west bank of the Niger River opposite the mouth of the Benue River. British merchants established a trading post at the Benue-Niger confluence in the late 1850s, and in 1860 the Scottish explorer William Balfour Baikie founded Lokoja. Besides being an important commercial settlement, the site (originally ceded to the British in 1841 by the ata [king] of Idah, 50 miles [80 km] south) was selected for the first British consulate in the interior (1860–69) and for the military headquarters for Sir George Goldie's Royal Niger Company (1886–1900). Formerly the capital of Kabba province, Lokoja was part of Kwara from 1967 to 1991, when it became the capital of the newly formed state of Kogi. The modern town is a collecting point for cotton, leather, and palm oil and kernels, which are shipped to the Niger delta ports of Burutu and Warri for export. The town is also a trade centre for the yams, cassava (manioc), corn (maize), sorghum, beans, fish, palm produce, shea nuts, and cotton produced by the local Igbira people. Fulani herdsmen from the north drive their cattle across the Niger to Lokoja in the dry season. Cotton ginning and weaving and palm- and shea-kernel processing are important local activities. There are limestone and iron deposits in the vicinity, and nearby Mount Patti, the original site of Lokoja, is a 1,349-foot- (411-metre-) high mass of oolitic iron ore. Lokoja is situated on the local highway between Kabba and Ayangbe and has ferry service across the Niger River. Pop. (2016 est.) local government area, 265,400. The Niger River is the principal river of West Africa, extending about 4,180 km (2,600 mi). Its drainage basin is 2,117,700 km2 (817,600 sq mi) in area. Its source is in the Guinea Highlands in southeastern Guinea near the Sierra Leone border. It runs in a crescent through Mali, Niger, on the border with Benin and then through Nigeria, discharging through a massive delta, known as the Niger Delta (or the Oil Rivers), into the Gulf of Guinea in the Atlantic Ocean. The Niger is the third longest river in Africa, exceeded only by the Nile and the Congo River (also known as the Zaïre River). Its main tributary is the Benue River. Lokoja is geographically located on latitude 7.7969 and longitude 6.7405 (see figure 1.1 and 1.2).

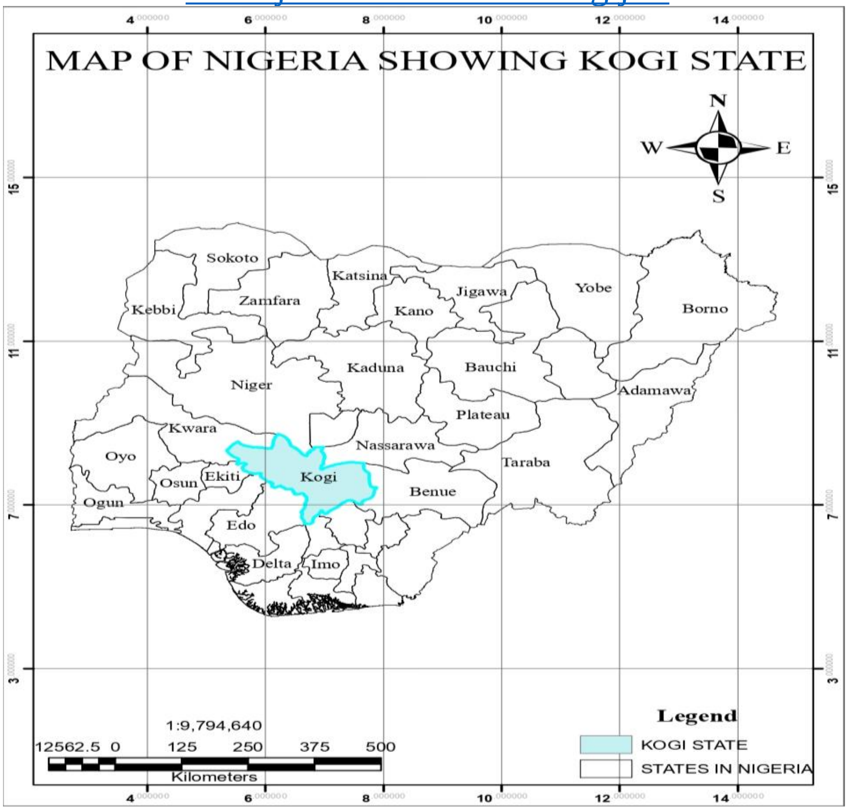

Figure 1.1: Map of Nigeria showing Kogi State

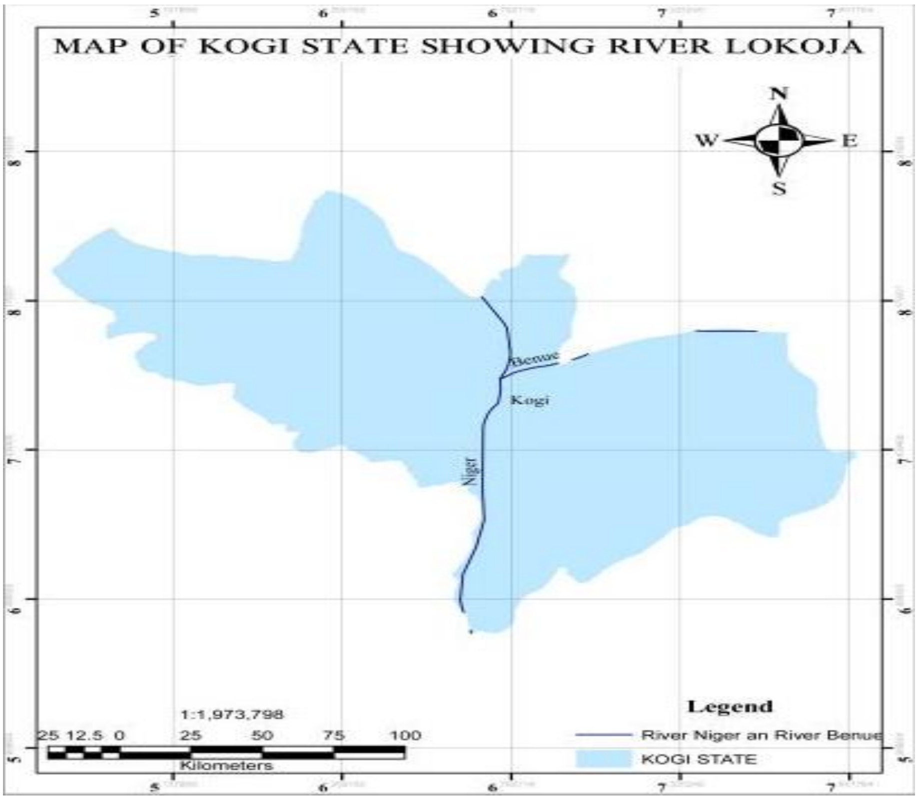

Figure 1.2: Map of Kogi State showing river Lokoja

3.0 MATERIALS AND METHOD

The data used for this study consists of average water level (AWL) and discharges (Q) in cubic meters per second (cumecs) collected from the National Inland Waterways Authority (NIWA) headquarter at Lokoja for a period of 2010-2020. The data was obtained in hard copy and typed on excel and saved in CSV file format and imported into MATLAB for analysis.

The following operations were performed during the execution of this study:

i. Tidal observations for the period of 10years (from 2010 to 2020) were used to determine the volume of discharge.

ii. Tidal observation sheets of water level and discharge record for 2010 to 2020 were used to produce the trends of average water level(m) and water discharge (cumec) for each year from 2021 to 2030.

iii. MATLAB programming software was used in the prediction of water level and discharge rate of change over a given period of time (2021 - 2030) thus greatly improving flood risk prediction procedure.

Figure 3.1 shows the methodological flowchart that was adopted in this study.

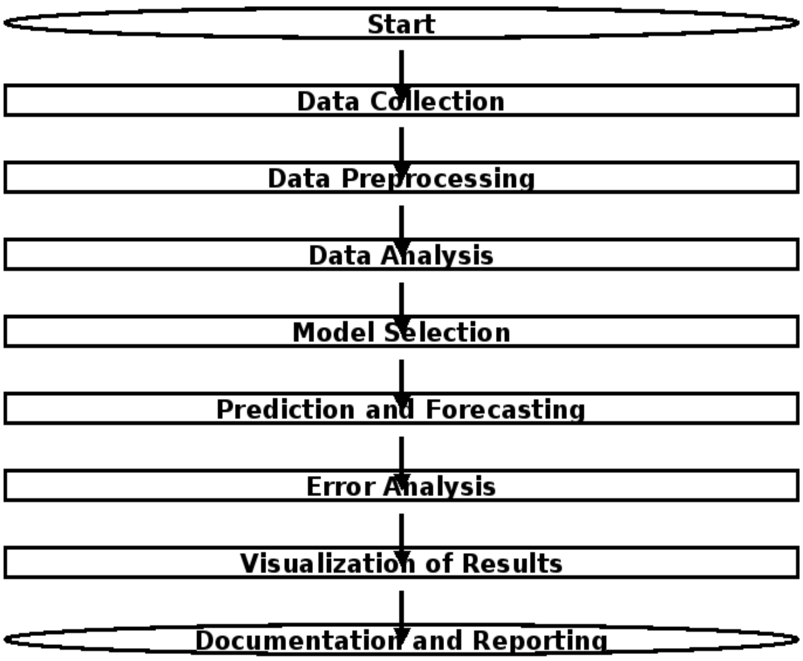

Figure 3.1: Methodological flowchart

3.1.1. **Methodology Workflow Outline**

1. Data Collection: Collect historical water level and discharge data from River Lokoja at the National Inland Waterways Authority (NIWA) for the years 2010 to 2020.Organize data by month and year for consistency and easier analysis.Verify the data's quality, completeness, and consistency, and handle any missing or incorrect entries.

2. Data Preprocessing: Clean the data to remove any outliers, anomalies, or missing values. Convert data into a structured format (e.g., Excel or CSV) to be compatible with MATLAB for analysis.Normalize or scale the data if needed to ensure consistency, especially if using statistical models.

3. Data Analysis:The introduction of MATLAB programming software helped to shape the calculation of water level and discharge rate of change over a given period of time thus greatly improving flood risk prediction procedure. River discharge is the volume of water flowing through a river channel. This is the total volume of water flowing through a channel at any given point and is measured in cubic meters per second (cumecs). The discharge from a drainage basin depends on precipitation, evapotranspiration and storage factors. Drainage basin discharge = precipitation – evapotranspiration +/N/A changes in storage.

The peak and minimum annual discharge of River Lokoja between 2010 and 2020 based on daily discharge measurement carried out by national inland ways (NIWA) at Lokoja gauging station was analyzed. The various statistics (max and min, mean, average,) from the analysis of the peak discharge data are statistically derived from the data.
The collected data was visualized to understand the trends and patterns in the average water level and discharge in cumecs. The following plots were generated using MATLAB:
Time series plot of the average water level and discharge in cumecs for each year.
Calculate annual averages of water levels and discharge to identify general trends.

Generate descriptive statistics (e.g., mean, median) and visualizations (e.g., time series graphs) for exploratory analysis.

4. Model Selection:Choose a suitable predictive model for water level forecasting, such as polynomial regression or time series analysis.Justify the choice of model based on the data's characteristics and the project's goals.

5. Prediction and Forecasting: Using the selected model, predict future water levels and discharge from 2021 to 2030.Conduct model validation by comparing predicted values with historical data (if possible) to check accuracy.Adjust model parameters if needed to improve prediction accuracy.

6. Error Analysis: Calculate the Root Mean Square Error (RMSE) or other error metrics to evaluate model performance.Analyze sources of error and the potential impact on predictive accuracy.

7. Visualization of Results: Visualize predicted water levels and discharge for 2021–2030 using time series graphs.Present visual comparisons between historical and predicted data to demonstrate trends.

8. Documentation and Reporting: Compile findings, visualizations, and analysis into a structured report.Summarize key insights, limitations, and recommendations based on the analysis.

3.1.2: Development of the Predictive model

For predicting the water levels and discharge of River Lokoja from 2021 to 2030, polynomial regression, specifically a third-degree polynomial (degree 3) was used. This model is particularly useful for data that shows non-linear trends, meaning that the relationship between time and water levels/discharge is not a straight line.

Polynomial regression was chosen for the following reasons:

(i) Non-linear behavior: Water levels and discharge in rivers can fluctuate in complex patterns. A straight line (linear model) might not capture these variations well, but a polynomial can bend and adjust to fit the curve of the data better.

(ii) Historical patterns: Based on the historical data we had, the water levels showed seasonal cycles, and polynomial regression is good at fitting data that rises and falls over time.

A polynomial regression fits a curve to the data using a polynomial equation. For a third-degree polynomial, the equation looks like this:

$$y = p_1 x^3 + p_2 x^2 + p_3 x + p_4 \qquad \text{… (equ. 1)}$$

y represents the predicted value (water level or discharge).

x is the input (date or time).

p_1, p_2, p_3, p_4 are the polynomial coefficients (weights) that the model calculates from the historical data.

In simpler terms, the polynomial model calculates a curve that fits the historical data points as closely as possible. This curve is then used to predict future values for water levels and discharge.

The steps employed to build the prediction model includes:

i. Collect Historical Data: Historical water level and discharge data from River Lokoja between 2010 and 2020 were collected from NIWA. This dataset provided daily measurements of water level- the height of the water surface and discharge- the flow rate of water in cubic meters per second (cumecs).

ii. Prepare the Data: the data were cleaned by removing missing or invalid values.The water levels and discharge for each day were organized into a data structure. The dates were converted into a numerical format (MATLAB serial date numbers), which makes it possible to perform calculations based on time.

iii. Fit the Polynomial Model: MATLAB was used to fit a third-degree polynomial to the historical data. This was done separately for water levels and discharge.

The model calculated the best-fitting polynomial curve that captured the trends in water levels and discharge over time.

iv. Predict Future Values: After fitting the model to the historical data, predictions for the years 2021 to 2030 was carried out. The model used the pattern it learned from the historical data to predict daily water levels from 2021 to 2030 and daily discharge for the same period.

5. Accuracy of the Model: The model’s accuracy was evaluated by calculating the Root Mean Square Error (RMSE), which explains how far, on average, the predicted values are from the actual historical values.

6. Limitations of the Model

Assumptions: The model assumes that the future trends in water levels and discharge will follow the same patterns as in the past. If there are sudden changes in climate, human intervention (e.g., dams), or unexpected weather events, the predictions may not be accurate.

Polynomial sensitivity: Higher-degree polynomials can sometimes overfit the data, meaning they can be too sensitive to small fluctuations in historical data. However, polynomial regression (degree 3) was used because it gave a balance between flexibility and stability in our predictions.

7. Scaling the Data: the predicted water levels were scaled by dividing them by 100. This simply reduced the magnitude of the values (e.g., from 307 meters to 3.07 meters) to make the data more manageable. This scaling does not change the pattern or the accuracy of the predictions but just changes the scale of the numbers.

4.0 RESULTS AND DISCUSSION

4.1 Data Visualization

The collected data was visualized to understand the trends and patterns in the average water level and discharge in cumecs. A time series plot of the average water level and discharge in cumecs for, each year, 2021-2030 was generated using MATLAB (see figure 4.1 to figure 4.2).

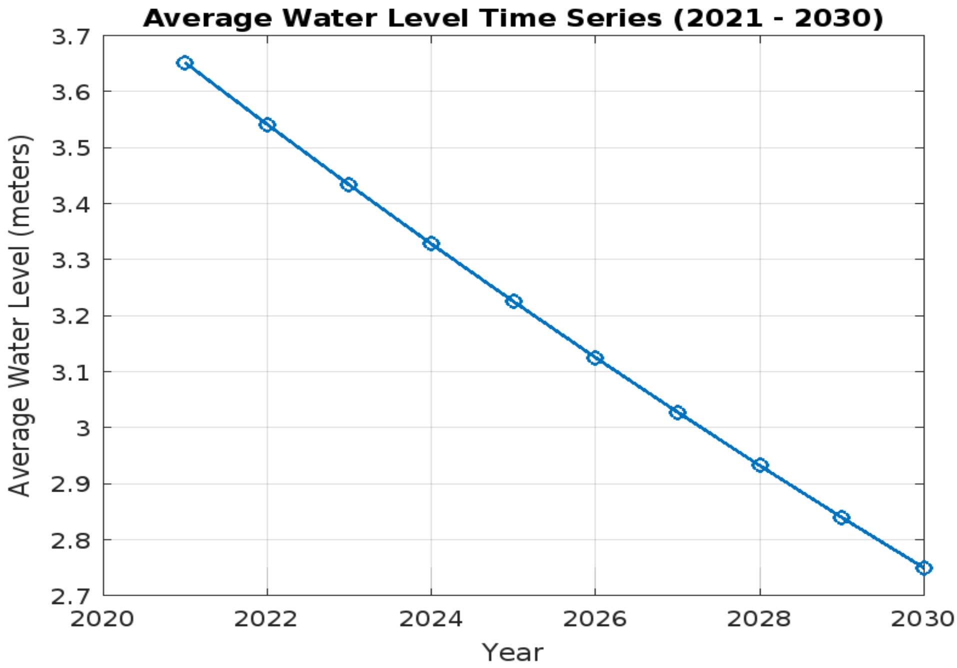

Figure 4.1: Average Water Level Time Series

Figure 4.1 shows the average water level from 2021 to 2030. It shows a steady, linear decline over the decade. The slope of this graph is also negative, indicating a consistent decrease in average water level over time. A linear model would again fit with a negative slope, suggesting that the water level is steadily reducing each year.

The declining water levels could indicate several potential issues, such as increased evaporation rates, reduced rainfall, or higher demand and extraction rates affecting the water balance. This decline in water levels is significant as it could impact both aquatic life and water resource availability. Lower water levels may also influence the discharge rate, which, as shown, is also declining.

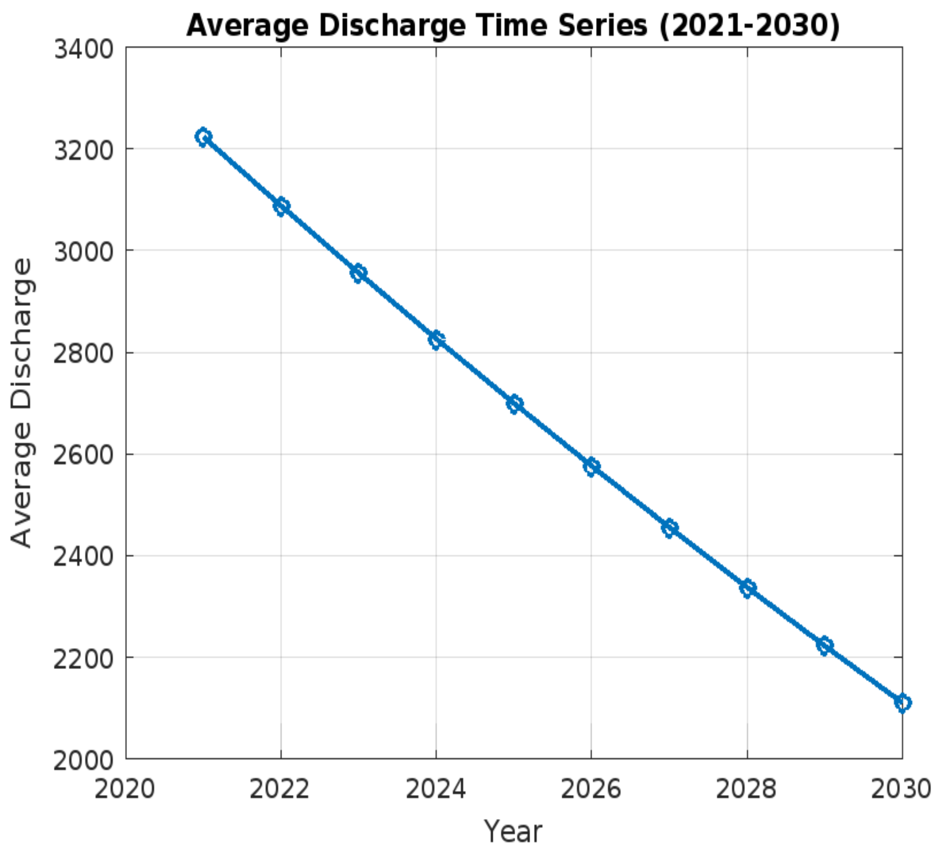

Figure 4.2: Average Discharge Time Series (2021-2030)

Figure 4.2 shows the trend of average discharge rates from 2021 to 2030. The points follow a downward linear trend, indicating a steady decrease in discharge over the decade. The graph has a negative slope, indicating a consistent reduction in discharge over the years. A linear fit to this data would yield a negative slope, highlighting that the decrease is regular and systematic. The continuous decline in discharge suggests a possible long-term impact on the water source, potentially due to reduced water input, environmental changes, or increased water withdrawal. If this trend continues, it could signal future challenges in water availability for downstream applications or ecosystems dependent on this discharge.

The parallel downward trends in both average discharge and average water level suggest a correlated decline, possibly driven by factors such as:

(i) Climatic changes: Reduced precipitation or increased temperatures could be contributing to lower water levels and discharge.

(ii) Human activity: Increased extraction for agriculture, industrial, or domestic uses could be reducing water levels and impacting discharge.

(iii) Natural changes in watershed: Changes in upstream conditions, like reduced inflow, could be impacting both discharge and water levels simultaneously.

Table 4.1 shows the predicted water level and discharge for 2030. Similar tabular results were obtained for the years 2025-2030. The raw data obtained from NIWA for the years 2010-2020 were also presented in the format of table 4.1.

Table 4.1: Predicted Water Level and Discharge Results for 2030

	JANUARY		**FEBRUARY**		**MARCH**		**APRIL**	
DAYS	**Average water level for the day**	**Discharge in cumecs**	**Average water level for the day**	**Discharge in cumecs**	**Average water level for the day**	**Discharge in cumecs**	**Average water level for the day**	**Discharge in cumecs**
1	2.793998	2166.193	2.786357	2156.685	2.779469635	2148.113	2.771862	2138.643
2	2.793752	2165.886	2.78611	2156.378	2.779223942	2147.808	2.771617	2138.338
3	2.793505	2165.579	2.785864	2156.072	2.778978267	2147.502	2.771372	2138.033
4	2.793258	2165.272	2.785618	2155.765	2.778732611	2147.196	2.771126	2137.728
5	2.793011	2164.965	2.785372	2155.459	2.778486973	2146.89	2.770881	2137.423
6	2.792765	2164.658	2.785126	2155.153	2.778241354	2146.585	2.770636	2137.118
7	2.792518	2164.351	2.78488	2154.847	2.777995754	2146.279	2.770391	2136.813
8	2.792271	2164.045	2.784633	2154.54	2.777750172	2145.973	2.770146	2136.508
9	2.792025	2163.738	2.784387	2154.234	2.777504609	2145.668	2.769901	2136.203
10	2.791778	2163.431	2.784141	2153.928	2.777259064	2145.362	2.769656	2135.898
11	2.791531	2163.124	2.783895	2153.622	2.777013537	2145.056	2.769411	2135.593
12	2.791285	2162.817	2.783649	2153.315	2.77676803	2144.751	2.769166	2135.288
13	2.791038	2162.51	2.783403	2153.009	2.776522541	2144.445	2.768922	2134.983

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14	2.790792	2162.203	2.783157	2152.703	2.77627707	2144.14	2.768677	2134.678
15	2.790545	2161.897	2.782911	2152.397	2.776031618	2143.834	2.768432	2134.373
16	2.790299	2161.59	2.782665	2152.091	2.775786185	2143.529	2.768187	2134.068
17	2.790052	2161.283	2.782419	2151.785	2.77554077	2143.223	2.767942	2133.763
18	2.789806	2160.976	2.782173	2151.479	2.775295374	2142.918	2.767697	2133.459
19	2.789559	2160.67	2.781928	2151.173	2.775049996	2142.612	2.767452	2133.154
20	2.789313	2160.363	2.781682	2150.867	2.774804637	2142.307	2.767208	2132.849
21	2.789066	2160.056	2.781436	2150.561	2.774559296	2142.001	2.766963	2132.544
22	2.78882	2159.75	2.78119	2150.255	2.774313974	2141.696	2.766718	2132.239
23	2.788573	2159.443	2.780944	2149.949	2.77406867	2141.391	2.766473	2131.935
24	2.788327	2159.137	2.780698	2149.643	2.773823386	2141.085	2.766229	2131.63
25	2.788081	2158.83	2.780453	2149.337	2.773578119	2140.78	2.765984	2131.325
26	2.787834	2158.523	2.780207	2149.031	2.773332871	2140.475	2.765739	2131.021
27	2.787588	2158.217	2.779961	2148.725	2.773087642	2140.169	2.765495	2130.716
28	2.787342	2157.91	2.779715	2148.419	2.772842431	2139.864	2.76525	2130.412
29	2.787095	2157.604			2.772597239	2139.559	2.765005	2130.107
30	2.786849	2157.297			2.772352066	2139.254	2.764761	2129.802
31	2.786603	2156.991			2.772106911	2138.948		

MAY		**JUNE**		**JULY**		**AUGUST**	
Average water level for the day	**Discharge in cumecs**	**Average water level for the day**	**Discharge in cumecs**	**Average water level for the day**	**Discharge in cumecs**	**Average water level for the day**	**Discharge in cumecs**
2.764516	2129.498	2.756944	2120.068	2.749632	2110.9609	2.742094	2101.57
2.764272	2129.193	2.7567	2119.764	2.749389	2110.6576	2.741851	2101.268
2.764027	2128.889	2.756456	2119.46	2.749145	2110.3544	2.741609	2100.965

2.763783	2128.584	2.756212	2119.156	2.748902	2110.0512	2.741366	2100.663
2.763538	2128.28	2.755968	2118.852	2.748658	2109.7481	2.741123	2100.36
2.763294	2127.975	2.755724	2118.549	2.748415	2109.4449	2.74088	2100.058
2.763049	2127.671	2.75548	2118.245	2.748172	2109.1418	2.740637	2099.755
2.762805	2127.367	2.755236	2117.941	2.747928	2108.8387	2.740395	2099.453
2.76256	2127.062	2.754992	2117.637	2.747685	2108.5356	2.740152	2099.15
2.762316	2126.758	2.754748	2117.334	2.747442	2108.2325	2.739909	2098.848
2.762072	2126.454	2.754504	2117.03	2.747199	2107.9295	2.739667	2098.546
2.761827	2126.149	2.754261	2116.726	2.746955	2107.6265	2.739424	2098.243
2.761583	2125.845	2.754017	2116.423	2.746712	2107.3235	2.739181	2097.941
2.761338	2125.541	2.753773	2116.119	2.746469	2107.0205	2.738939	2097.639
2.761094	2125.237	2.753529	2115.815	2.746226	2106.7175	2.738696	2097.336
2.76085	2124.932	2.753286	2115.512	2.745982	2106.4146	2.738453	2097.034
2.760606	2124.628	2.753042	2115.208	2.745739	2106.1117	2.738211	2096.732
2.760361	2124.324	2.752798	2114.905	2.745496	2105.8088	2.737968	2096.43
2.760117	2124.02	2.752555	2114.601	2.745253	2105.5059	2.737726	2096.127
2.759873	2123.716	2.752311	2114.298	2.74501	2105.2031	2.737483	2095.825
2.759629	2123.412	2.752067	2113.994	2.744767	2104.9002	2.737241	2095.523
2.759384	2123.107	2.751824	2113.691	2.744524	2104.5974	2.736998	2095.221
2.75914	2122.803	2.75158	2113.387	2.744281	2104.2946	2.736756	2094.919
2.758896	2122.499	2.751337	2113.084	2.744038	2103.9919	2.736513	2094.617
2.758652	2122.195	2.751093	2112.781	2.743795	2103.6891	2.736271	2094.314
2.758408	2121.891	2.750849	2112.477	2.743552	2103.3864	2.736028	2094.012
2.758164	2121.587	2.750606	2112.174	2.743309	2103.0837	2.735786	2093.71

2.75792	2121.283	2.750362	2111.871	2.743066	2102.781	2.735544	2093.408
2.757676	2120.979	2.750119	2111.567	2.742823	2102.4783	2.735301	2093.106
2.757432	2120.675	2.749875	2111.264	2.74258	2102.1757	2.735059	2092.804
2.757188	2120.372			2.742337	2101.8731	2.734817	2092.502
SEPTEMBER		**OCTOBER**		**NOVEMBER**		**DECEMBER**	
Average water level for the day	**Discharge in cumecs**	**Average water level for the day**	**Discharge in cumecs**	**Average water level for the day**	**Discharge in cumecs**	**Average water level for the day**	**Discharge in cumecs**
2.734574	2092.2	2.727314	2083.152	2.719829	2073.821	2.712602	2064.811
2.734332	2091.898	2.727072	2082.85	2.719588	2073.521	2.712362	2064.511
2.73409	2091.597	2.72683	2082.549	2.719347	2073.22	2.712121	2064.211
2.733847	2091.295	2.726589	2082.248	2.719105	2072.92	2.71188	2063.911
2.733605	2090.993	2.726347	2081.947	2.718864	2072.619	2.71164	2063.611
2.733363	2090.691	2.726105	2081.646	2.718623	2072.318	2.711399	2063.312
2.733121	2090.389	2.725864	2081.344	2.718382	2072.018	2.711159	2063.012
2.732879	2090.087	2.725622	2081.043	2.718141	2071.717	2.710918	2062.712
2.732637	2089.786	2.725381	2080.742	2.7179	2071.417	2.710678	2062.412
2.732394	2089.484	2.725139	2080.441	2.717659	2071.116	2.710437	2062.112
2.732152	2089.182	2.724897	2080.14	2.717418	2070.816	2.710197	2061.812
2.73191	2088.88	2.724656	2079.839	2.717177	2070.516	2.709957	2061.512
2.731668	2088.579	2.724414	2079.538	2.716936	2070.215	2.709716	2061.213
2.731426	2088.277	2.724173	2079.237	2.716695	2069.915	2.709476	2060.913
2.731184	2087.975	2.723931	2078.936	2.716454	2069.614	2.709235	2060.613
2.730942	2087.674	2.72369	2078.635	2.716213	2069.314	2.708995	2060.313
2.7307	2087.372	2.723448	2078.334	2.715973	2069.014	2.708755	2060.014

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2.730458	2087.071	2.723207	2078.033	2.715732	2068.713	2.708515	2059.714
2.730216	2086.769	2.722966	2077.732	2.715491	2068.413	2.708274	2059.414
2.729974	2086.467	2.722724	2077.431	2.71525	2068.113	2.708034	2059.115
2.729732	2086.166	2.722483	2077.13	2.715009	2067.813	2.707794	2058.815
2.72949	2085.864	2.722241	2076.829	2.714768	2067.512	2.707553	2058.516
2.729248	2085.563	2.722	2076.528	2.714528	2067.212	2.707313	2058.216
2.729006	2085.261	2.721759	2076.227	2.714287	2066.912	2.707073	2057.916
2.728765	2084.96	2.721517	2075.927	2.714046	2066.612	2.706833	2057.617
2.728523	2084.659	2.721276	2075.626	2.713806	2066.312	2.706593	2057.317
2.728281	2084.357	2.721035	2075.325	2.713565	2066.012	2.706353	2057.018
2.728039	2084.056	2.720794	2075.024	2.713324	2065.712	2.706112	2056.719
2.727797	2083.754	2.720552	2074.724	2.713083	2065.411	2.705872	2056.419
2.727556	2083.453	2.720311	2074.423	2.712843	2065.111	2.705632	2056.12
		2.72007	2074.122			2.705392	2055.82

The predicted water level and discharge for the years 2021-2030 is shown in table 4.2.

Table 4.2: Data Extract of the Predicted Water Level and Discharge (2021 - 2030)

Year	Minimun Predicted Water Level	Maximum Predicted Water Level	Minimum Predicted Discharge	Maximum Predicted Discharge	Average Predicted Water Level	Average Predicted Discharge
2021	3.596382295	3.707891883	3155.721346	3292.078563	3.651919483	3223.65388
2022	3.487186479	3.596079553	3021.953452	3155.350812	3.541416926	3088.4076
2023	3.380596042	3.4868909	2891.134907	3021.591024	3.433528897	2956.119977
2024	3.276311232	3.380307575	2762.900679	2890.780535	3.328095175	2826.597832
2025	3.174883523	3.276029848	2637.932793	2762.554332	3.225245149	2700.003663
2026	3.076006098	3.17460915	2515.858212	2637.594398	3.125097604	2576.487948
2027	2.979660611	3.075738687	2396.658271	2515.527718	3.027491146	2455.85618
2028	2.885575076	2.979400112	2279.999462	2396.335628	2.932279469	2337.930979

2029	2.794245231	2.885321457	2166.500556	2279.684639	2.839577877	2222.858872
2030	2.705392229	2.793998423	2055.820246	2166.193481	2.749491376	2110.774681

This data extract provides a comprehensive forecast of water level and discharge trends in River Lokoja from 2021 to 2030, which is critical for understanding and managing water resources and potential flood risks in Kogi State, Nigeria.

The data indicates a gradual decrease in both minimum and maximum predicted water levels, as well as discharge rates, over the ten-year period. This downward trend could be attributed to factors such as reduced rainfall, changes in upstream water releases, or long-term climatic shifts. This trend is reflected in both the minimum and maximum values, as well as the average water level and discharge for each year. By 2030, the values are significantly lower compared to 2021, with water levels dropping from an average of 3.65 meters to 2.75 meters, and discharge rates decreasing from around 3223 to 2110 cumecs (cubic meters per second).

Having predictions for the minimum and maximum water levels and discharge rates provides key data points for managing water resource availability, flood control measures, and agricultural planning. These values indicate the possible range of water availability, helping stakeholders prepare for both low and high-water scenarios.

The average values provide a more generalized trend that supports long-term resource planning. For instance, if the average discharge is expected to decline, water storage and distribution systems may need to be adjusted to ensure stable supply during drier periods.

The maximum predicted water levels and discharge rates for each year serve as indicators of potential flood conditions. By identifying years with higher maximum discharge, local authorities can develop or update flood preparedness plans to protect infrastructure and communities near the river.

The declining trend in maximum discharge rates could reduce immediate flood risk, but it may also indicate other environmental impacts, such as reduced ecosystem health, that need to be monitored.

Table 4.3 shows the comparison between the years (2021 - 2030) of the predicted water level and discharge.

Table 4.3: Comparison table of predicted water level and discharge (2021-2030)

Year	Change in Min Water Level (%)	Change in Max Water Level (%)	Change in Min Discharge (%)	Change in Max Discharge (%)
2021	N/A	N/A	N/A	N/A
2022	-3.00%	-3.00%	-4.20%	-4.20%
2023	-3.10%	-3.10%	-4.30%	-4.20%

2024	-3.00%	-3.10%	-4.40%	-4.30%
2025	-3.10%	-3.00%	-4.50%	-4.40%
2026	-2.90%	-3.10%	-4.60%	-4.50%
2027	-3.20%	-2.80%	-4.70%	-4.60%
2028	-3.00%	-3.20%	-4.90%	-4.70%
2029	-3.10%	-3.00%	-5.00%	-4.90%
2030	-2.80%	-3.50%	-5.10%	-5.00%

From the table 4.3, change in Min/Max Water Level (%) represents the percentage decrease in minimum and maximum predicted water levels compared to the previous year while change in Min/Max Discharge (%) represents the percentage decrease in minimum and maximum predicted discharge compared to the previous year. N/A: indicates that there is no previous year to calculate a percentage change for 2021. The comparative analysis of predicted water levels and discharges for the years 2021 to 2030 reveals a consistent decline across all measured parameters. Specifically:

i. Decline in Water Levels: Both the minimum and maximum predicted water levels show a steady decrease each year. In 2021, the minimum predicted water level was approximately 3.60 meters, while by 2030; this value had dropped to around 2.71 meters, representing a cumulative decrease of nearly 25%. Similarly, the maximum predicted water level decreased from 3.71 meters in 2021 to 2.79 meters in 2030. This downward trend suggests a reduction in the overall water volume of the river system, potentially due to changes in regional precipitation, increased evaporation, or other environmental factors.

ii. Reduction in Discharge: The minimum and maximum predicted discharge values also follow a similar declining trend. For instance, the minimum discharge dropped from approximately 3155 cubic meters per second in 2021 to around 2055 cubic meters per second in 2030, a reduction of over 34%. Maximum discharge values also declined from 3292 to 2166 cubic meters per second during the same period. This pattern may indicate reduced river inflow, impacting water availability for downstream regions and increasing vulnerability to water shortages during drier months.

iii. Average Values: The average predicted water levels and discharge rates show a consistent yearly decline. The average water level dropped from 3.65 meters in 2021 to 2.75 meters in 2030, while the average discharge fell from 3223 to 2111 cubic meters per second. These averages reinforce the trend of declining water levels and discharge rates over the decade.

Table 4.4 shows the statistical results of the historical and predicted water level and discharge

Table 4.4: Statistics for Historical and Predicted Water Level and Discharge

RMSE_WaterLevel	1.534236048
RSME_Discharge	4459.835249
STD_Historical Water Level	0.022594918
STD_Historical Discharge	432.8293962
STD_Predicted Water Level	0.303709809
STD_Predicted Discharge	374.5178877
STME_Historical Water Level	0.006812624
STME_Historical Discharge	130.5029732
STME_Predicted Water Level	0.096041474
STME_Predicted Discharge	118.433

Water Level RMSE (1.534): This number shows the average difference between the predicted water levels and the actual water levels that was observed in the past. A low RMSE (closer to zero) means the predictions closely match what really happened. Here, an RMSE of 1.534 means the predicted water level is generally off by about 1.5 meters from the actual levels, showing that the model does a pretty good job of estimating future water levels.

Discharge RMSE (4459.835): For discharge (the amount of water flowing), the RMSE is much higher, meaning there is a bigger gap between the predicted and actual discharge values. This larger number suggests it is more difficult to accurately predict discharge than it is for water levels, likely because discharge is more variable and affected by more factors.

Historical Water Level STD (0.0226): This represents how much water levels in the past have shifted from the average. A low standard deviation means water levels were mostly stable and did not change much.

Historical Discharge STD (432.8294): The historical discharge shows a higher standard deviation, meaning it has had bigger ups and downs. This likely reflects seasonal changes or events that caused more significant shifts in water flow.

Predicted Water Level STD (0.3037): The predicted water levels show a bit more fluctuation than in the past, which is expected since future conditions may be less predictable.

Predicted Discharge STD (374.518): Similarly, the predicted discharge shows notable variability, though slightly less than historical discharge, meaning future predictions expect some continued ups and downs.

Standard Error of the Mean (STME): Historical Water Level STME (0.0068): This number shows that it can be quite confident about the average historical water level since it does not change much.

Historical Discharge STME (130.503): The average discharge is a bit harder to pin down, reflecting those past ups and downs.

Predicted Water Level STME (0.0960) and Predicted Discharge STME (118.433): These values indicate that future water levels and discharge estimates are less certain than historical data, which is common since the forecasting was done with some degree of unpredictability.

Figure 4.3 and 4.4 shows the Pie Chart Representation of the Monthly and Yearly Water Level for the years 2021-2030 respectively.

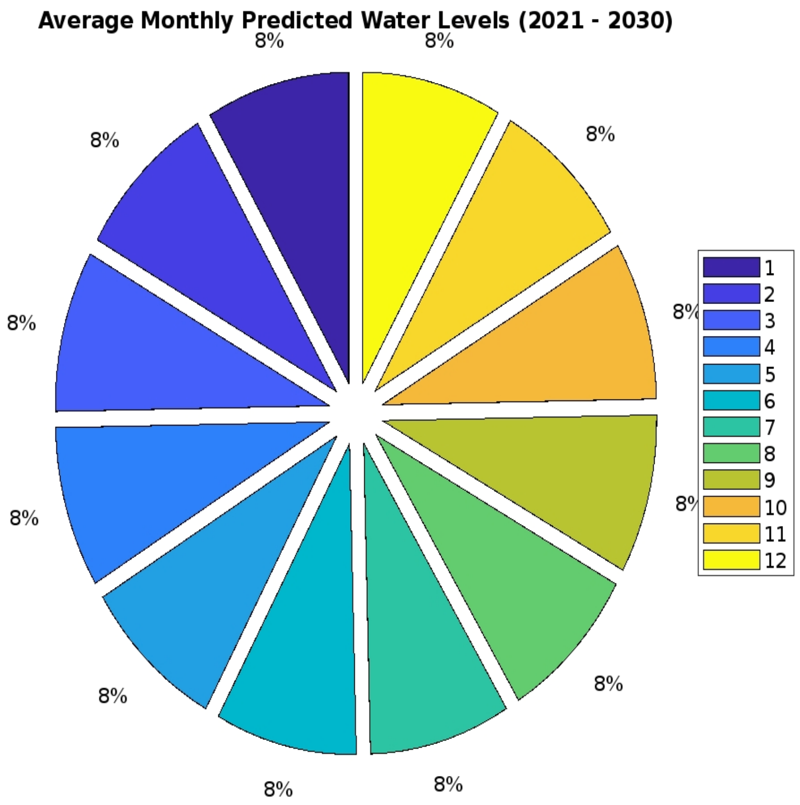

Figure 4.3: Pie Chart Showing Average Monthly Predicted Water Levels (2021 - 2030)

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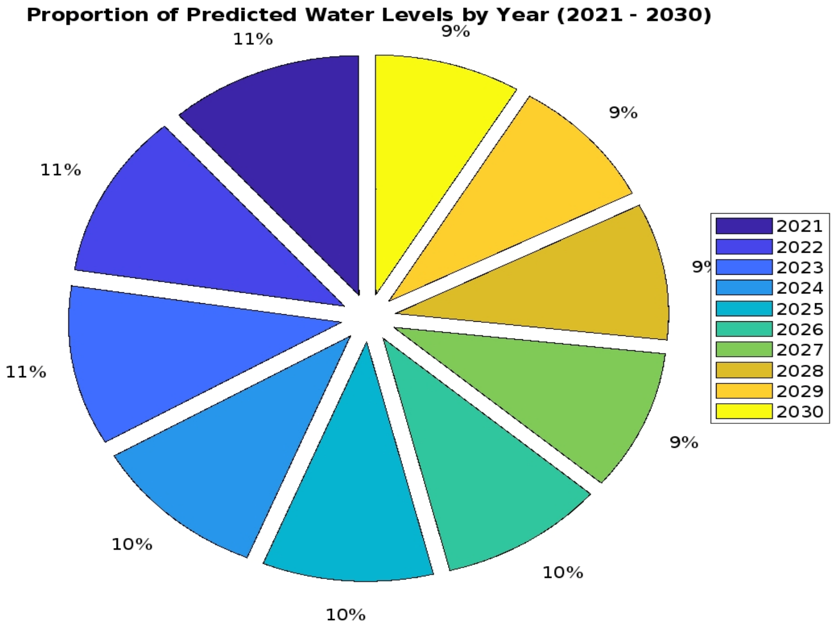

Figure 4.4: Pie Chart Showing Proportion of Predicted Water Levels by Year (2021 - 2030)**.**

Figure 4.3 shows the average predicted water levels distributed by month across the 10-year period. Each slice represents one month (from January to December) and indicates the proportion of the water level for that month over the entire period.

The uniform percentages (8% for each month) imply that the predicted water levels are fairly evenly distributed throughout the months. This suggests no particular month has a significantly higher or lower average water level in the data set. Similar to the yearly chart, the legend provides month numbers (1 for January, 2 for February, etc.), with each slice color-coded accordingly.

Figure 4.4 represents the distribution of predicted water levels across each year from 2021 to 2030. Each slice of the pie chart corresponds to one year, with its size indicating the proportion of predicted water levels for that year relative to the entire 10-year period. The percentages on the slices show the contribution of each year to the total water level predictions. In this case, all years appear to have similar proportions, suggesting consistent water level predictions across this period.

The legend on the right provides color-coded labels for each year, helping to differentiate the years by color on the chart.

Figure 4.5 and 4.6 shows the Pie Chart Representation of the Monthly and Yearly Discharge for the years 2021-2030 respectively.

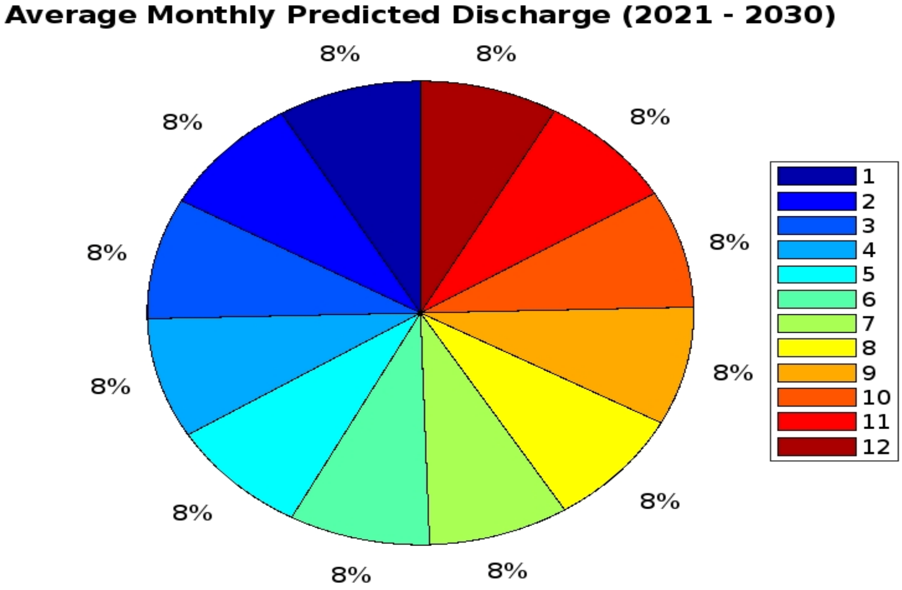

Figure 4.5: Pie Chart Showing Average Monthly Predicted Discharge (2021 - 2030)

Figure 4.5 provides a visual breakdown of the predicted discharge for each month as an average over the ten-year period from 2021 to 2030. Each slice of the pie chart represents one month, labeled with a percentage value, indicating that the predicted discharge values are fairly uniform across all months, with each month contributing approximately 8% to the total annual predicted discharge.

This uniformity suggests that the predicted discharge values are consistent throughout the year without significant seasonal variations. The color gradient used differentiates each month distinctly, allowing for a quick visual reference and comparison across the months. The chart is particularly useful in assessing the even distribution of discharge over time, which might imply a relatively stable water source or system over the forecast period.

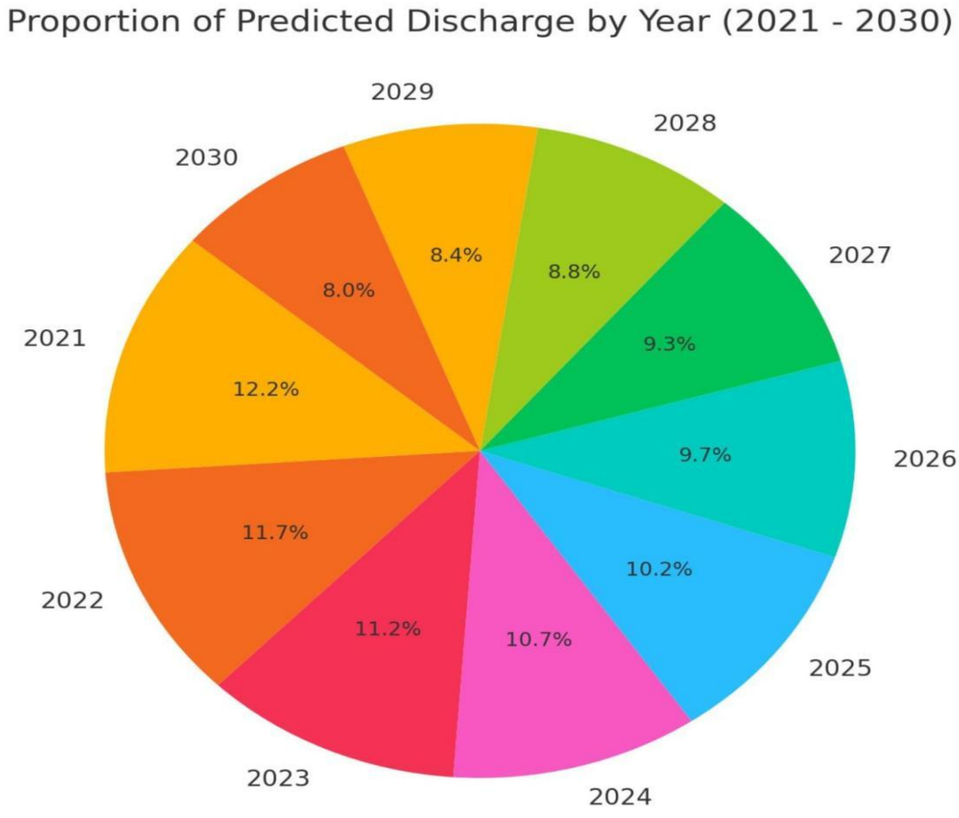

Figure 4.6: Pie Chart Showing Proportion of Predicted Discharge by Year (2021 - 2030)

The pie chart displays the average predicted discharge values for each year from 2021 to 2030. This visual representation helps to highlight the proportion of discharge attributed to each year across the decade, showing a gradual reduction in predicted discharge over time. From 2021, this has the largest share, through to 2030, the percentage contribution of each year's average discharge decreases. This trend indicates an expected reduction in river discharge over time, which may have implications for water availability, ecosystem sustainability, and regional water management.

From the years 2021 to 2025: These years occupy larger portions of the chart, reflecting higher average discharge values in the earlier part of the decade. This suggests that, initially, water availability might be relatively stable or abundant.

From the years 2026 to 2030: The slices representing these years gradually become smaller, indicating a continued decline in discharge. By 2030, the average predicted discharge is the lowest among all years, potentially indicating a need for adjustments in water resource management to address reduced inflows.

The gradual decline in discharge values over the years could signify:

i. Increased Water Scarcity: If the trend continues, regions depending on the river's water may face challenges in meeting water demands.

ii. Need for Conservation: As discharge decreases, conservation strategies become essential to ensure sustainable water usage.

iii. Adaptation in Agriculture and Industry: Industries relying on river water, especially agriculture, may need to adapt by adopting more water-efficient practices.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

This study aimed to develop a comprehensive approach to monitor and predict sea level variations in River Lokoja, using data-driven analysis to improve our understanding of water levels and discharge patterns over the years. By analyzing historical and predicted data, this study has provided insights into the seasonal and annual fluctuations in sea levels, highlighting trends that may impact the local ecosystem, settlements, and infrastructure. The successful implementation of methods for data extraction, processing, and visualization has not only confirmed the feasibility of real-time monitoring but has also paved the way for predictive analytics that could serve as an early warning system for flood management.

The objectives set out were systematically addressed through the development of charts, visualizations, and analyses that illustrate sea level trends. These outcomes show that the prediction of sea levels and discharge levels, based on historical data, can be a valuable tool for planning and risk assessment. By achieving these objectives, this study contributes practical insights for policymakers, environmental managers, and the community, offering data-backed guidance for sustainable management and disaster preparedness in the region.

5.2. Recommendations

i. Integration with Early Warning Systems: It is recommended that predictive models for sea level and discharge be integrated with local early warning systems to provide timely alerts for potential flooding, which could greatly benefit communities and infrastructure.

ii. Continuous Data Collection: For accuracy and improvement of predictive capabilities, continuous monitoring and updating of historical data should be maintained. This will enable more precise modeling as conditions in the river ecosystem evolve.

iii. Environmental and Land Management Policies: Findings from this project should be used to inform environmental policies that govern land use, especially in flood-prone areas, to mitigate potential water-related disasters.

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