ABUAD Journal of Engineering Research and Development (AJERD)
ISSN (online): 2645-2685; ISSN (print): 2756-6811

Volume 6, Issue 2, 183-191

Effect of Slope and Runoff Trends on the Hydrological Response of River Kaduna

Haruna GARBA[1], Zuwairat ABUBAKAR[2]

[1]*Department of Civil Engineering, Nigerian Defence Academy, Kaduna, Kaduna State*
hgarba@nda.edu.ng

[2]*Department of Agricultural and Bio-Environmental Engineering, Kaduna Polytechnic Kaduna State*
Zuwairaabubakar511@gmail.com

Corresponding Author: hgarba@nda.edu.ng, +2348020346775
Date Submitted: 29/05/2023
Date Accepted: 01/12/2023
Date Published: 12/12/2023

Abstract: *A monotonic upward/downward trends of hydrological variables was used to test the null hypothesis that slope and runoff trends have a significant impact on land use and land. The Mann-Kendall (M-K) and P- values statistical measurement were used to validate the null hypothesis against the observed data Relationships between gradients and climatic parameters for the hydrological response of Kaduna River was developed using geographic information tools (GIS). GIS maps of runoff, Digital Elevation Model (DEM), Land Use and Land were established Mann-Kendall (M-K) trend analysis was used to identify trends in climate parameters. The data used are precipitation, evapotranspiration, runoff, and temperature over a 30-year period from 1992 to 2021 obtained from the Kaduna State Water Authority and the Nigerian Meteorological Service. Results of the trend analysis of annual runoff and rainfall indicates the same M-K and P-values of 0.094 and 0.475which are all greeter than 0.05 significant level but the magnitude of Seen slope for rainfall and runoff are 5.130 and 0.016 demonstrating that rainfall is the major driving variable foe runoff generation. The annual evapotranspiration has M-K and P-values of 0.126 and 0.335 while the values for average annual temperature are 0.138 and 0.292. Land use in parts of the study area exhibits unstable ecosystems and vulnerable hilly terrain, suggesting that seasonal runoff and corresponding hydrological responses of rivers are dominated by changes in precipitation.*

Keywords: *Analysis, Evapotranspiration, Hydrologic, Temperature Rainfall. Runoff, Slope, Trend.*

1. INTRODUCTION

Water movement on slopes can narrow channels and valley floors. If the speed of slope migration into the channel is very slow compared to the material removal capacity of the river, the channel elevation may not change. The distribution of hydrological responses to precipitation includes time and space changes of water flow on landscapes. Impact of slopes and topography on the hydrological response of rivers is an important issue that can lead to flooding and silt flooding. The hydrological response of rivers is greatly influenced by topography and slope. If the infiltration rate is slower and subsequently reaches a constant value with increases in precipitation rate, runoff can occur in the form of land formations as additional surface water appears on the soil surface and fills surface depressions [1]. Surface roughness reduces land flow [1]. Surface roughness may vary due to differences in soil conditions, tillage conditions, surface debris, or the presence of live plant stems. Violent runoff of surface water is a hydrological process that can cause significant damage.

When surface water condenses, it has enough energy to erode soil particles, making the water denser and more active [2]. Surface runoff is formed when rainwater flows out of the ground and reaches rivers without penetrating into the ground. Land currents are the name given to this hydrological phenomenon [1]. Saturated land currents happen when the soil's storage capacity is constrained or when the soil is already saturated, and they happen when rainfall intensity surpasses the infiltration capacity. [3]. because the response of hydrological systems is nonlinear, precipitation is amplified in the hydrological response, especially in heterogeneous terrain [4].

The importance of slope convergence and divergence in hydrology was studied by [5, 6]. Hill plan convergence, cross-sectional depressions, and soil thinning tend to increase runoff from slope cross-sections, making surface currents particularly prone to flooding over time and prolonged rainfall. Continuous precipitation, temperature variations, evaporation and runoff all contribute to hydrological events such as floods, inundation and the formation of mud. Climate change, combined with land-use changes, has a significant impact on the hydrological processes of river basins and is closely linked to the availability of water resources and sustainability of local ecosystems. [7, 8] The M-K test is one of the most often used method for non-parametric test for detecting trends in time series [9, 10]. The monthly, seasonal, annual and decadal trends of seven hydro meteorological variables were analysed by [11] for stations in Akwa Ibom State Nigeria, at the 5% statistical significance level, the non-parametric M-K and Sens Slope estimator were used to detect if there was a positive or negative trends and the magnitude of the trends, revealed the consistency of performance in detecting the trends of the hydro meteorological values. The M-K test is recommended by the World Meteorological Organization for detecting trends in a set of hydrological data [12, 13]. It is also known for it strong consistency and appropriate to time series data [13].

Therefore, this study evaluated the impact of slope and climatic parameters on the hydrological response of the Kaduna River and determined the extent to which appropriate models would be used on the Kaduna River in the southern part of the state.

1.1 Study Area

The River Kaduna is the principal tributary of the Niger River. It originates in central Nigeria near Vom, on the Jos Plateau (Figure 1), 18 miles (29 km) southwest of Jos Town. After that, it travels 22 miles (35 km) northeast of Kaduna town before curving to the west. From that point on, it flows in a south-westerly and southern direction until it reaches Mureji, 550 kilometers (340 miles) away from the Niger. Though its lower half has carved out several gorges above its entrance into the vast Niger floodplains, including the 2-mile (3-kilometer) granite ravine at Shiroro, the majority of its path is through open savannah woodland. The 550-kilometer-long Kaduna River is the principal tributary of the Niger River in central Nigeria, 14]). It starts on the Jos Plateau near Vom and flows north-westerly and north-westward until it bends 35 km to the northeast of Kaduna town (Fig. 2). After that, it flows south-westerly and southerly until it reaches Murgi, where it empties into the Niger River. Much of its path passes through wide savannah woods, although its lower segment cut some gorges, including the granite ravine at Shiroro above its entrance into the vast Niger flood plains.

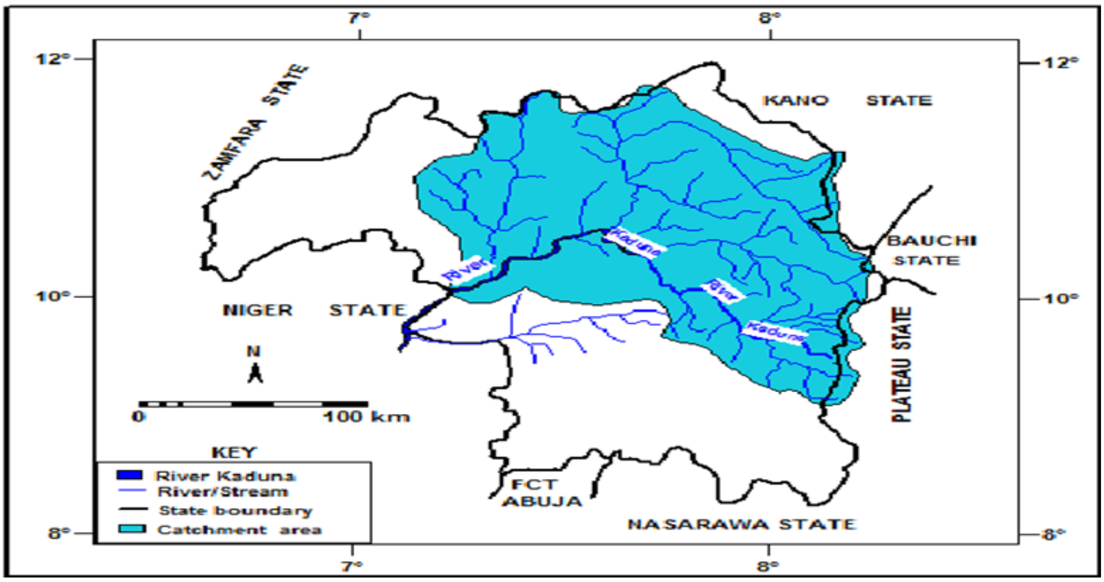

Figure 1: Map of river Kaduna

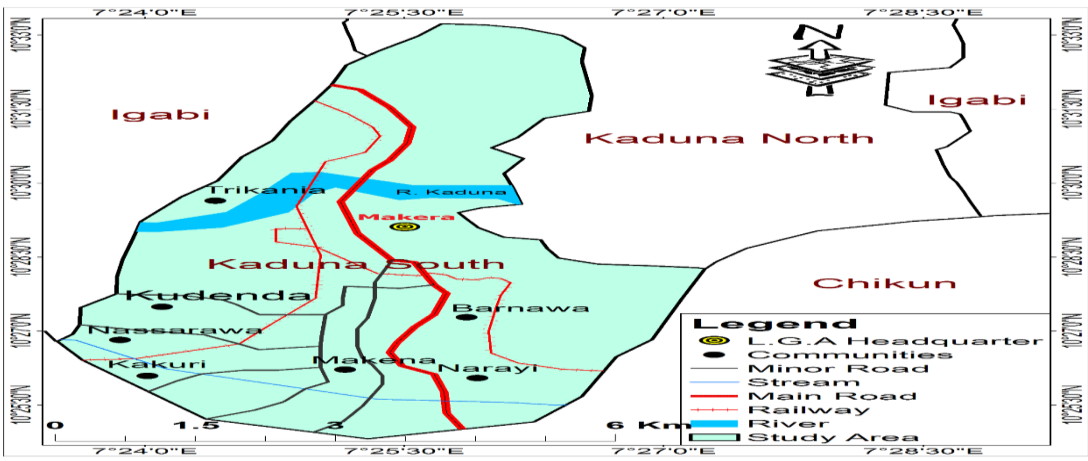

Figure 2: Map of river Kaduna at the southern part of Kaduna

2. MATERIALS AND METHODS

The time series data of meteorological and hydrological variables related to the Kaduna River was obtained from the following organizations: Kaduna State Water Corporation and Nigerian Meteorological Agency. The variables are: rainfall (mm), temperature, evapotranspiration rate (mm/day) and runoff (mm), for 30 years (1992-2022).

2.1 Establishing a GIS Data Base for Runoff, Digital Elevation Model, Land Use, and Land Cover and Altitude (SLOPE) Arc Maps is the first step carried out

The Arc GIS 10.1 and Google Earth Pro tools were used to extract high-resolution images from Google Earth, which were then georeferenced using the WGS84 datum and the Universe Transverse Mercator (UTM) projection system. Zone N

2.2 Trends Analysis

The total annual rainfall (mm), total monthly rainfall (mm), average annual maximum, average annual and monthly evapotranspiration rate (mm/day), and total annual and monthly runoff (m3/s), were analyzed using Kendall trend. The Mann-Kendall trend test is a frequently used non-parametric trend test, [13]. Using data from 1992 to 2021, monthly and annual trend analyses were carried out for rainfall, maximum and minimum temperature, evapotranspiration, and runoff in this study.

Trends, for all the period, were calculated using the Mann-Kendall test [7, 8)]. This test detects the presence of a monotonic tendency in a chronological series of a variable. It is a nonparametric method; that is, it makes no assumptions about the underlying distribution of the data, and its rank-based measure is not influenced by extreme values. This method mainly gives three types of information;

i. The Kendall Tau, or Kendall rank correlation coefficient, measures the monotony of the slope. Kendall's Tau varies between -1 and 1; it is positive when the trend increases and negative when the trend decreases.
ii. The Sen slope, which estimates the overall slope of the time series. This slope corresponds to the median of all the slopes calculated between each pair of points in the series.
iii. The significance, which represents the threshold for which the hypothesis that there is no trend is accepted. The trend is statistically significant when the p-value is less than 0.05. The non-parametric Mann-Kendall test is widely used in detecting trends of variables in meteorology and hydrology fields [1–3]. Statistic S can be obtained by Equation 1.

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign(x_j - x_k) \quad (1)$$

$$\mathrm{Sgn}(x_i - x_k) = \begin{cases} +1, if\,(x_j - x_k) > 0 \\ 0, if\,(x_j - x_k) = 0 \\ -1, if\,(x_j - x_k) < 0 \end{cases} \quad (2)$$

Where n is the length of the sample, x and x are from k=1, 2, n-1 and j= k+1, n. If n is bigger than 8, statistic S approximates to normal distribution. The mean of S is 0 and the variance of S can be acquired as follows:

$$\mathrm{var(S)} = \frac{n(n-1)(2n+5)}{18} \quad (3)$$

Then the test statistic Z is denoted by Equation (4)

$$Z = \begin{cases} \frac{S-1}{\sqrt{var(S)}}, \; if\; S > 0 \\ 0, if\; s = 0 \\ \frac{S+1}{\sqrt{var(S0}}, if\; S < 0 \end{cases} \quad (4)$$

If Z > 0, it indicates an increasing trend, and vice versa. Given a confidence level α, the sequential data would be supposed to experience statistically significant trend if |Z| > Z(1-α/2), where Z (1-α/2) is the corresponding value of P = α/2 following the standard normal distribution. In this study, 0.05 and 0.01 confidence levels were used. Besides, the magnitude of a time series trend was evaluated by a simple non-parametric procedure developed by Sen [4]. The trend is calculated by Equation 5

$$\beta = Median\left(\frac{X_j - X_i}{j-i}\right), \mathrm{j} > i \quad (5)$$

Where β is Sen's slope estimate. β>0 indicates upward trend in a time series. Otherwise the data series presents downward trend during the time period.

3. RESULTS AND DISCUSSION

3.1 GIS Maps

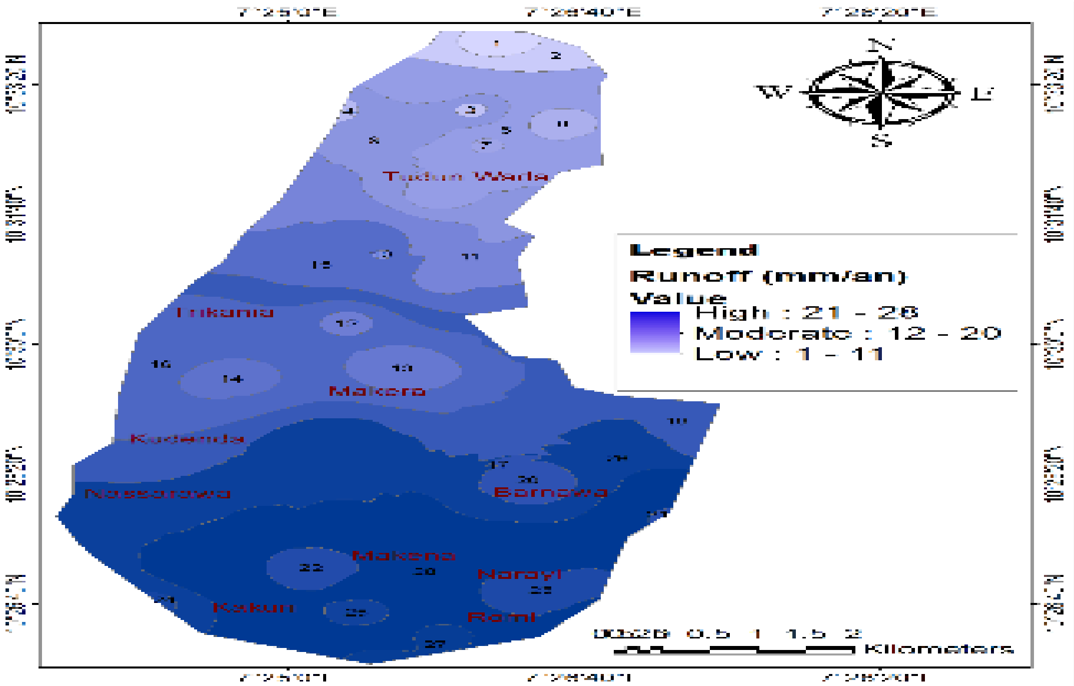

Figure 3 Runoff map of river Kaduna south

Figure 3 depict the runoff map in Kaduna south of the river. The runoff map is divided into three categories: high, moderate, and low. The high cover ranges from 21 mm/an to 28 mm/an, the moderate cover ranges from 12 mm/an to 20 mm/an, and the low cover ranges from 1 mm/an to 11mm/an. The most elevated part of the area, which is the upper part, has a low runoff range, whereas the lower part, which has a steep slope, has a moderate to high runoff range. The intensity, timing, and magnitude of precipitation changes caused by climate change will thus influence runoff response [14].

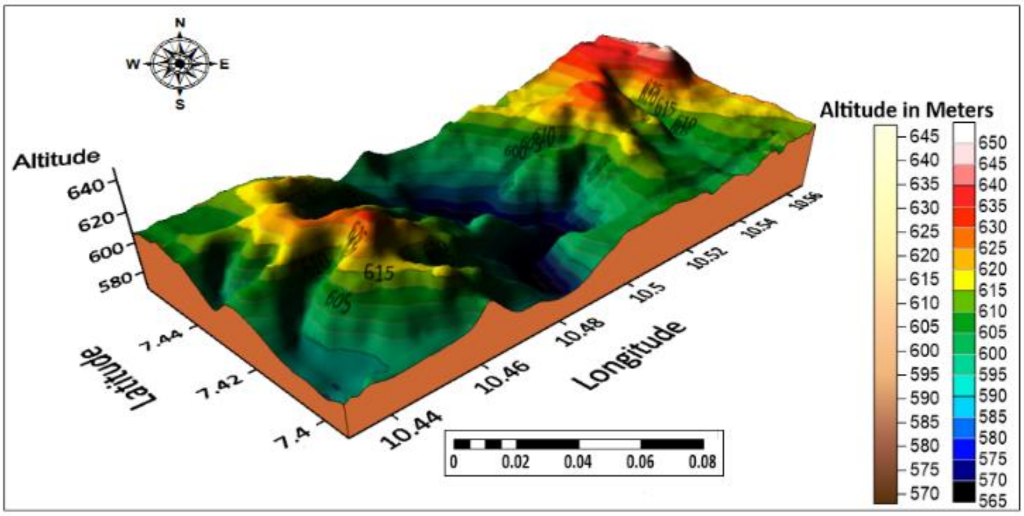

Figure 4: Digital elevation model (DEM)

Digital elevation model (DEM), and drainage map all are coordinated with the runoff map. Runoff therefore has an impact on River Kaduna hydrologic response under the influence of elevation (slope and terrain).

The continuous variation in relief throughout the entire area is depicted in the Digital Elevation Model (DEM). In digital form, a DEM shows the elevation of all points in a particular location. Figure 4 shows Kaduna South 3D Digital Elevation Model. Minimum height from MSL is 566, 0012817 km, The DEM shows an undulating pattern with altitudes varying from a minimum of 3700 m to a maximum of 650 m The consequence of this is that whenever the river volume increases, the downstream community will be flooded, the ecosystem will become fragile and the hill slopes will become unstable.

Figure 5 shows that four land use categories were identified within the study area. These include bodies of water, vegetated land, cultivated/open land, and built-up areas. Water bodies cover 636 km^2 (5%), vegetated land covers 3889 km^2 (30%), cultivated / open land covers 4875 km^2 (38%), and built-up areas cover 3479 km^2 (27%). It can be observed that the LULC for the year 2011 has a depleting water body analysis because the water body has reduced in hectares and percentage due to human activities. There are more built-up areas, less open land, and a corresponding decrease in vegetated land. Land use and land cover influence runoff generation and other human activities. According to the 2011 LULC analysis for the southern part of the Kaduna river, development, increased population, built-up areas, and other human activities have reduced the water body. As a result of human activities and population growth, increased rainfall will result in increased runoff generation with little or no drainage system, increasing the rate of runoff and a corresponding increase in River water height and may results to overflow (floods).

Figure 6 depicts the supervised LULC map in 2021. Water bodies, vegetated land, cultivated/open land, and built-up areas are examples of these. Further analysis, showed water bodies cover 589 km^2 (5%), vegetated land covers 2497 km^2 (19%), cultivation/open land covers 5897 km^2 (30%), and built-up areas cover 5897 km^2 (40%), that built-up areas have grew as a result of population expansion and development.. Build-up areas have taken up 40% of the available space. 30% of the land is cultivated, and 19% is vegetated. Because the water body only covers 5% of the area, we can clearly conclude that due to development in 2021, areas have occupied open land, which could pose a significant problem to the area because heavy rainfall can wreak havoc on the community.

Figure 7 displays a slope map, which is a topographic map that provides incredibly detailed information about changes in elevation, slope is the rate at which terrain features rise or fall. The soil map has four categories the highly slope covering (650-570 km), moderately slope (612-976 km), and low slope (565-974 km). The highest point on the map is the most elevated and sloppy; the rate of runoff at the upper point will be low due to the presence of high slope; the lower part of the map is flat with much high slope, moderate slope, and low slope; the rate of runoff here is high, and it flows through streams to the river. For a given soil, the faster the water runoff rate, the steeper the slope and the slower the rate of water infiltration. This indicates that the likelihood of a river overflow is high, which can cause flooding, increase erosion, and destroy economic activities, farming, and houses.

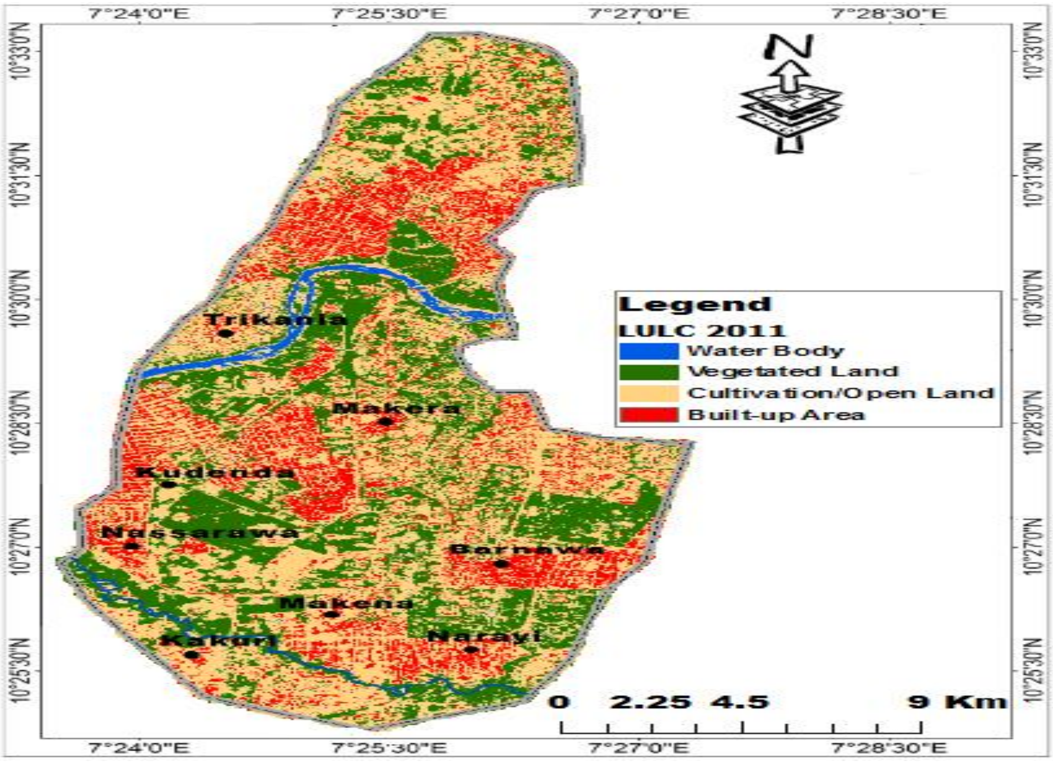

Figure 5: LULC for 2011

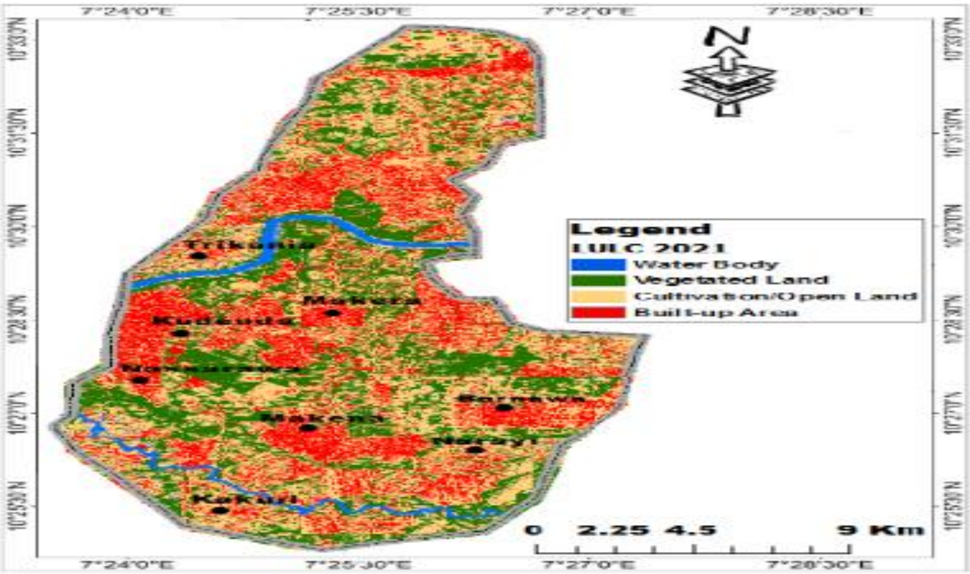

Figure 6: LULC for 2021

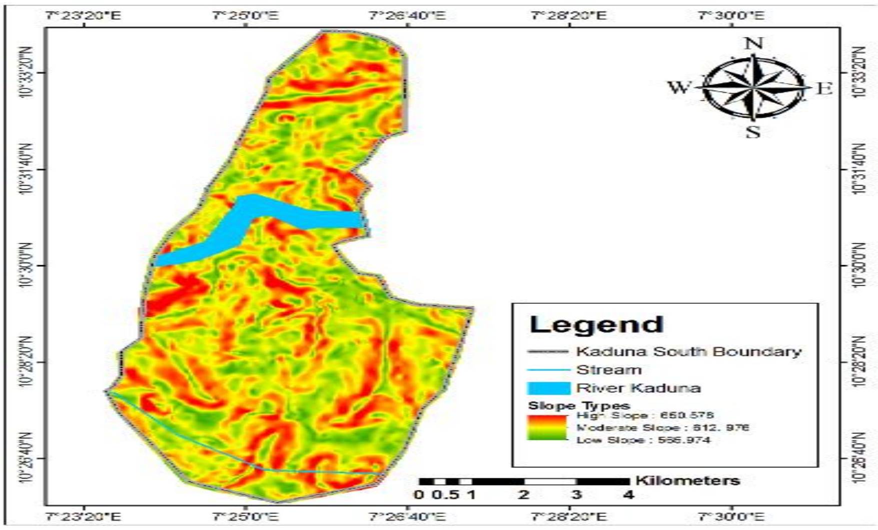

Figure 7: Slope map

3.2 Trends Analysis

Table 1: Result of the Mann-Kendall trend analysis for total annual runoff

Months, Annual.	Runoff (m^3/s) First Year	Last Year	N	M-k	p-value	Sen's slope slope	Lower bound (%)	Upper bound (%)
January	1992	2021	30	-	-	-	-	-
February	1992	2021	30	0.171	0.280	0.000	0.000	0.000
March	1992	2021	30	-0.106	0.468	0.000	0.000	0.000
April	1992	2021	30	-0.226	0.083	-1.000	-2.413	0.092
May	1992	2021	30	0.191	0.143	2.239	-0.600	4.317
June	1992	2021	30	0.094	0.475	0.804	-2.250	3.062
July	1992	2021	30	0,108	0.412	2.530	-2.780	6.292

Months, Annual.	Runoff (m^3/s)							
	First	Last	N	M-k	p-value	Sen's slope		
	Year	Year				slope	Lower bound (%)	Upper bound (%)
August	1992	2021	30	0.108	0.412	1.746	-1.468	5.482
September	1992	2021	30	-0.030	0.830	-0.867	-6.129	4.983
October	1992	2021	30	-	-	-	-	-
November	1992	2021	30	0.140	0.284	0.005	-0.004	0.015
December	1992	2021	30	-	-	-	-	-
Annual	1992	2021	30	0.131	0.318	0.016	0.014	0.050

Table 2: Results for Mann-Kendell's trend analysis annual Rainfall

Months, Annual.	Rainfall (mm)							
	First	Last	N	M-k	p-value	Sen's slope		
	Year	Year				slope	Lower bound (%)	Upper bound (%)
January	1992	2021	30	-	-	-	-	-
February	1992	2021	30	0.171	0.280	0.000	0.000	0.000
March	1992	2021	30	-0.106	0.468	0.000	0.000	0.000
April	1992	2021	30	-0.226	0.083	-1.000	-2.413	0.092
May	1992	2021	30	0.182	0.164	2.239	-0.600	4.317
June	1992	2021	30	0.094	0.475	0.804	-2.250	3.062
July	1992	2021	30	0,113	0.392	2.530	-2.780	6.292
August	1992	2021	30	0.126	0.335	1.746	-1.468	5.482
September	1992	2021	30	-0.030	0.830	-0.867	-6.129	4.983
October	1992	2021	30	-0.168	0.199	-1.122	-3.159	0.696
November	1992	2021	30	-0.258	0.106	0.000	0.000	0.000
December	1992	2021	30	-	-	-	-	-
Annual	1992	2021	30	0.094	0.475	5.130	-9.100	-18.500

Results of the analysis for total runoff in Tables 1 indicates that an annual M-K and p- values of 0.131 and 0.318>0..05 which is not statistically significant meaning that there is a strong evidence that slope, runoff trends affect land use and cover. Table 2 shows that from May to August, there is a positive trend because the Sen s slope and M-K values are both, the trend was estimated using the Mann-t Kendall's test, and the trend's magnitude was estimated using the Sens slope estimator. The rainfall p-value is 0.475, the M-k value is 0.094, and the magnitude S is 5.130, for rainfall and 0.016 for runoff. Tables 1 and 2 demonstrate that the trends in the runoff and rainfall values are the same. This demonstrates how rainfall is a significant determinant of runoff. Rainfall intensity, duration, frequency, and magnitude all have an impact on runoff generation [15]. A positive value of slope indicates that there is a positive value indicates a growing trend, while a negative value signifies a declining trend, in line with the work [16], additionally; a decreasing runoff might be as a result availability of canals for irrigation and power generation. The water table is lowered by a declining trend during the dry season; however, increased runoff during the wet season may cause the erosion of loosened land. Thus, in conclusion, precipitation during the dry season has no significant relationship with runoff.

The p-value for annual evapotranspiration is 0.126, which is not significant at the 5% confidence level, the M- K value is 0.335, (Table 3), the M-K and slope estimator of Sens slope annual trend decreasing from May to September. The result obtained for annual evapotranspiration is In line with the result of El-Nest [17]. The increasing trend for evapotranspiration prevails for the majority of the year, with the exception of the winter months of October through January. Even in these months, four stations showed a notable declining trend.

Table 3: Result for Mann-Kendall's trend analysis for Annual evapotranspiration

Months, Annual.	Evapotranspiration (mm)							
	First Year	Last Year	N	M-k	p-value	Sen's slope slope	Lower bound (%)	Upper bound (%)
January	1992	2021	30	0.099	0.454	0.005	-0.007	0.017
February	1992	2021	30	0.163	0.212	0.012	-0.008	0.027
March	1992	2021	30	-0.106	0.748	0.004	-0.010	0.016
April	1992	2021	30	0.044	0.392	0.004	-0.008	0.016
May	1992	2021	30	-0.021	0.887	0.000	-0.014	0;012
June	1992	2021	30	-0.117	0.372	-0.004	-0.016	0.006
July	1992	2021	30	-0.067	0.617	-0.002	-0.012	0.006
August	1992	2021	30	0.039	0.775	0.001	-0.004	0.008
September	1992	2021	30	-0.044	0.748	-0.001	-0.008	0.006
October	1992	2021	30	0.232	0.074	0.005	0.000	0.010
November	1992	2021	30	0.140	0.284	0.005	-0.004	0.015
December	1992	2021	30	0.172	0.187	0.003	-0.002	0.011
Annual	1992	2021	30	0.126	0.335	0.038	-0.043	0.107

Table 4: Results of the Mann-Kendall's trend analysis of average annual maximum temperature

Months, Annual.	Maximum temperature (^{0}C)							
	First Year	Last Year	N	M-k	p-value	Sen's slope slope	Lower bound (%)	Upper bound (%)
January	1992	2021	30	0.078	0.556	0.020	-0.054	0.099
February	1992	2021	30	0.113	0.392	0.026	-0.039	0.116
March	1992	2021	30	0.005	0.986	0.000	-0.047	0.036
April	1992	2021	30	0.198	**0.129**	0.033	-0.014	0.073
May	1992	2021	30	-0.067	0.617	-0.077	-0.038	0.023
June	1992	2021	30	-0.074	0.580	-0.077	-0.030	0.017
July	1992	2021	30	-0.081	0.544	-0.005	-0.031	0.014
August	1992	2021	30	-0.060	0.655	-0.007	-0.036	0.025
September	1992	2021	30	0.083	0.532	0.008	-0.019	0.033
October	1992	2021	30	0.154	0.239	0.024	-0.012	0.052
November	1992	2021	30	0.187	0.153	0.032	-0.008	0.078
December	1992	2021	30	0.009	0.957	0.004	-0.043	0.050
Annual	1992	2021	30	0.138	0.292	0.009	-0.006	0.026

Table 4 demonstrates a negative trend for the yearly average maximum temperature, the M-K value, and the Sens slope .The findings displayed demonstrated a declining trend for the months of May, June, July, and August, while there is a significant rising trend in a September and a October. This result is consistent with the findings of Pal, [18], who investigated the trend of the maximum temperature in Nepal.

4. CONCLUSION

The relationship between slope and hydrologic response was developed using a geographic information system (GIS). To compare the runoff on the Kaduna River and its influence on the river's hydrologic response, the DEM (digital elevation model), LULC (land use land cover), Runoff and. Slope maps were used to display the geographical and topographical representation of the area and how it has an effect on runoff and corresponding hydrological response.

The trends in hydrological and climate parameters were investigated, using the Mann- Kendall's and Sens slope estimators from the XLSTAT software, the monolithic upwards/downwards trends was investigated using the null hypothesis that slope and runoff affects land use and land cover. M-k and p- values of statistical measurement were used to validate the null hypothesis against the observed data. With M-K and P-values greater than the significant level, showed that there is evidence that the null hypothesis is true and the magnitude of slope demonstrate that rainfall is the major driving variable for runoff generation. The runoff's sensitivity, and maximum temperature to change in climate scenarios, as well as the separate and interacting effects of changes in meteorological elements of runoff, are investigated. The main reasons for the runoff changes are an increase in precipitation and a rapid increase in maximum temperature [19]. The runoff is most sensitive to maximum temperature changes during the wet season. As a result, variations in maximum temperature don't significantly affect runoff.

RECCOMENDATION

Further studies may take up how these hydrological responses of the River affects sedimentation, rate of erosion, and their effects on the local wildlife, plants, and people. The p-values can serve as an alternative to preselecting confidence level for hypothesis testing

REFERENCES

[1] Evans, R. (1980). Mechanisms of Water erosion and their Spatial and Temporal Control; an Empirical Viewpoint in Kirkby. Soil erosion, 109-128.
[2] Wischmeier, W.H. (1959). A Rainfall Erosion Index for a Universal Soil- Loss equation. Soil Science Society of American Journal 23(3), 246-249.
[3] Hibbert (1967). Factors affecting the Response of Small Watersheds to Precipitation of Humid areas. Forest hydrology.
[4] Shulze, R.E. (2000). Modelling Hydrological Response to Land use and Climate Change; A Southern African Perspective. Ambio 12-22.
[5] Iqbal, M., Wen, J., Masood M, U. & Adam, M. (2022). Impacts of Climate and Land use Changes on Hydrological Processes of the source Region of Yellow River, China. Sustainability.
[6] Alemu, M.G., Wubneh, M.A., Workut, A. (2022). Impact of Climate Change on Hydrological Response of Mojo River Catchment, Awash River Basin, Ethiopia. Grocerto International, 2152497.
[7] Mann, H.B. (1945) Non parametric test against trend.Econometrica, 13, 245.
[8] Kendel, M.G. Rank (1955). Correlation methods London. Charles Griftin,
[9] Haruna, G. & Udeme, U.U. (2023). Analysis of Trend in Meteorological and Hydrological Time Series Using Mann-Kendel and Sen’s Slope Estimator Test in Akwa Ibom State, Nigeria. International Journal of Environment and Climate Change 13(10), 1017-1035.
[10] Tabari, H. & Talaee, P.H. (2011). Aanlysis of trends in temperature data in arid and semi-arid regions of Iran, Global and Planetary Change.79(1-2), 1-10.
[11] Ashaw, A., Simane, B. Hassen, A. & Bantider, A. (2018). Variability and time series trend analysis of rainfall and temperature in non-central Ethiopia; Acase study in Woleka Sub Basin; Weather and Climate Extremes 19, 29-41.
[12] Garba, H., Ismail, A., Batagarawa, R.L., Ahmed, S. & Ibrahim, A. (2013). Climate change Impact on Sub-Surface Hydrology of Kaduna River Catchment. Open Journal of Modern Hydrology (3), 115-121. http://dx.doi.org//10.4236/ojmh.2013.32010.
[13] Fang, K. & Shen, C. (2017). Full Flow Regime Storage Stream Flow Correlation Pattern Provide Insight into Hydrologic Functioning Over the Continental US. *Water Resources Research.* 53(9), 8064-8083
[14] Hamed, K.H & Rao, A.R. (1998). A Modified Mann- Kendell Trend Test for Auto correlated Data. *Journal of Hydrology, 204,* 182-196
[15] Chew, W.S. (2004). Study of Sensitivity Analysis of the Flood Plain River Basin Parameter. International Conference on Water Sensitive Urban Design.
[16] Santos, J.C.N., Andrade, E.M. (2017). Effect of Rainfall Characteristics on Runoff and Water Erosion for different Land uses in Tropical Semiarid Region. Water Resources Management, 173-185.
[17] Yadav, R., Tripalhi, S.K., Granuth, H.I. & Dubey, S.K. (2014). Trend Analysis by Mann- Kendall’s for Precipitation and Temperature for thirteen districts of Uttarakh and. Journal of Agrometeorology 16(12)
[18] Pal, A.B., Khare, D., Mishra, P.K. & Singh, L. (2017). Trend Analysis of Rainfall, Temperature and runoff data: A case study of Rangood Water shed in Nepal. International Journal of Students Research Technology and Management.
[19] El-Nesr, M., Alazba, A. & Zreig, M.A. (2010). Analysis of Evapotranspiration Variability and Trends in the Arabian Peninsula. American Journal of Environmental Sciences, 6(6), 535-547.