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Morphometric analysis of the Ekole River as a consequence of climate change: A case study in Yenagoa, Bayelsa State, Nigeria

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Abstract *— The effect of climate change on the morphometric features of the Ekole River in Yenagoa, Bayelsa State, Nigeria, is investigated in this study. The study employs morphometric analysis, which includes area, perimeter, mean stream length, drainage density, stream frequency, and basin length, as well as other factors like elongation ratio, form factor, shape factor, relief ratio, and density, with the assistance of the Shuttle radar topography mission (SRTM) and ArcGIS software. The Ekole River has an area of 83.76 km^2 and a perimeter of 100.75 km, according to the findings. The average stream length was 0.41 km, and the average bifurcation ratio was 2.15. The drainage density was 2.28 km/km^2 and the stream frequency was 5.56. The elogation ratio, form factor, shape factor, and relief ratio were also determined to be 0.20, 0.32 km/km, 3.14, and 3.11, respectively. These findings reveal that the Ekole River has a comparatively low discharge density and a dendritic drainage structure. The elongation ratio, form factor, and relief ratio, on the other hand, indicate that the basin of the river is comparatively elongated and narrow, with low relief. The present condition of the Ekole River is thought to be the result of climate change, which has impacted the river's hydrological processes. Finally, this research sheds light on the effects of climate change on the Ekole River and its morphometric features. Climate change has changed the river's hydrological processes and affected its morphometric parameters, according to the results.*

I. INTRODUCTION

Climate change is a global phenomenon that has significant impacts on natural systems and human activities worldwide. One of the major consequences of climate change is its impact on the hydrological cycle, which affects rivers and their morphology (Mahala, 2020). Rivers are vital resources for humans, providing water for irrigation, domestic use, and transportation, and are also important ecosystems that support a wide range of aquatic and terrestrial life (Mangan *et al*., 2019). Morphometric analysis provides a valuable tool to investigate the changes in river morphology and their responses to environmental and anthropogenic factors. Morphometry is the quantitative analysis of the physical characteristics of a river system, including its shape, size, relief, and drainage network (Rajasekhar *et al*., 2020). This approach can provide insights into the hydrological characteristics, sediment transport, and ecological processes of rivers and help identify changes in river systems due to climate change. As stated by Ebiegberi and Eteh (2023), Morphometric analysis is a useful technique in understanding the hydrological processes, geomorphology, and ecology of rivers" (Eteh et al., 2021). The study of river morphometry can help identify the key drivers of river systems, such as climate, geology, and land use, and how these factors affect the river's characteristics. Therefore, analyzing the morphometry of rivers is crucial for understanding their response to climate change and for developing effective management strategies for fluvial systems. The Ekole River in Nigeria is an example of a river system that has undergone significant changes as a result of shoreline activities (Eteh et al., 2022). The river is located in the Niger Delta region, which is known for its high rainfall and complex river systems. The Ekole River is an important resource for the surrounding communities, providing water for irrigation, fishing, and domestic use. However, changes in precipitation patterns and land use have affected the river's morphology, with potential implications for its hydrology, sediment transport, and ecological processes. The study highlights the importance of considering the effects of climate change on river morphology in the management and planning of fluvial systems. The study underscores the need for effective management strategies that consider the impacts of climate change on river systems and that involve local communities in the planning and management of their natural resources. Therefore, in this study, morphometric analysis is used to investigate the hydrological activities of the Ekole River and their responses to environmental and anthropogenic factors resulting in climate change.

II. STUDY AREA

The region is located in the center of the Niger Delta and is made up of structures created by sedimentation, as shown in Figure 1. It is located between Latitude 4º47'0"N and 4º57'30"N, and Longitude 6º14'0"E and 6 22'30"E. The region's terrain is mostly level, with elevations reaching only 36 meters as seen in Figure 3 with Ekole river link to Nun River and Epie creek. According to Reyment, (2018) when the South American plate split from the African plate, an unsuccessful rift junction formed, culminating in the formation of the Niger Delta Basin. This procedure started in the late Jurassic era and lasted until the mid-Cretaceous period. As a consequence of this rift, various faults developed, leading to the formation of thrust faults. (Reijers, 2011). These formations comprise the Akata Formation and the Agbada Formation, both of which are paralic delta front facies. The Benin Formation is made up of a continental estuary facies. The Akata Formation's base lithostratigraphic age varies from Paleocene to Holocene. (Reyment, 2018; Etu–Efeotor, 1997). The Akata Formation is made up of deep marine sediments under great pressure and low density. The megamarine facies is composed of thick shales, turbidite sands, and trace quantities of silt and clay, indicating that it developed on a shallow marine shelf depositional environment. (Etu-Efeotor, 1997).

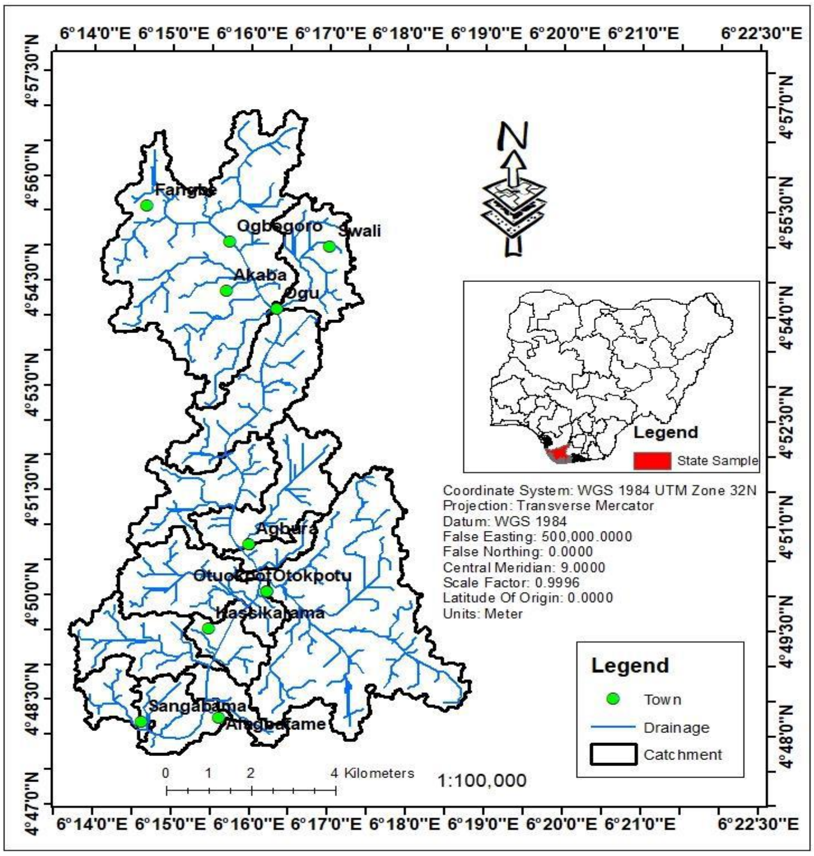


Fig.1: Location map of the study area

III. MATERIALS AND METHOD

Data Collection

This study's data was collected from both primary and secondary sources. GPS coordinates for sample sites were acquired as primary data, while secondary data were obtained from the Shuttle Radar Topographic Mission (SRTM), retrieved from https://dwtkns.com/srtm30m. Using the ArcGIS 10.6 software and the Universal Transverse Mercator (UTM) 32N coordinate system, these data sources were integrated into a shared projection using remote sensing and geographic information system technologies. The Digital Elevation Model created from SRTM data gave a comprehensive picture of the elevation values and distribution in the area.

Data processing

The research approach made use of a Geographical Information Systems and hydrology tools. The data was analyzed using ArcGIS software and Arc Hydro utilities. These tools were used to analyze the SRTM data in order to create the Digital Elevation Model and define the features of the drainage areas based on the elevation data.

IV. RESULTS AND DISCUSSION

In achieving our result, remote sensing techniques was used to obtain data on the river channel's length, width, and sinuosity. Remote sensing techniques have several advantages over traditional field surveys, including the ability to capture data over large areas quickly and efficiently, even in remote or inaccessible regions. The Remote sensing data was integrated into GIS software, allowing for the analysis of multiple parameters and the creation of detailed maps and models. The stream order and total stream length are important morphometric parameters that were deployed in this study to understand the characteristics of the river basin and climate change. The Table 1 below shows the summary of the stream order and total stream length result. The Table 1 and Figure 2 shows that the Ekole River has 5 stream order which amount in total 466 streams, with 237 being first-order streams, 121 second-order streams, 55 third-order streams, 40 fourth-order streams, and 13 fifth-order streams in Figure 2 . The total stream length of the river is 191.4 km, with the majority of the length being contributed by the first-order streams.

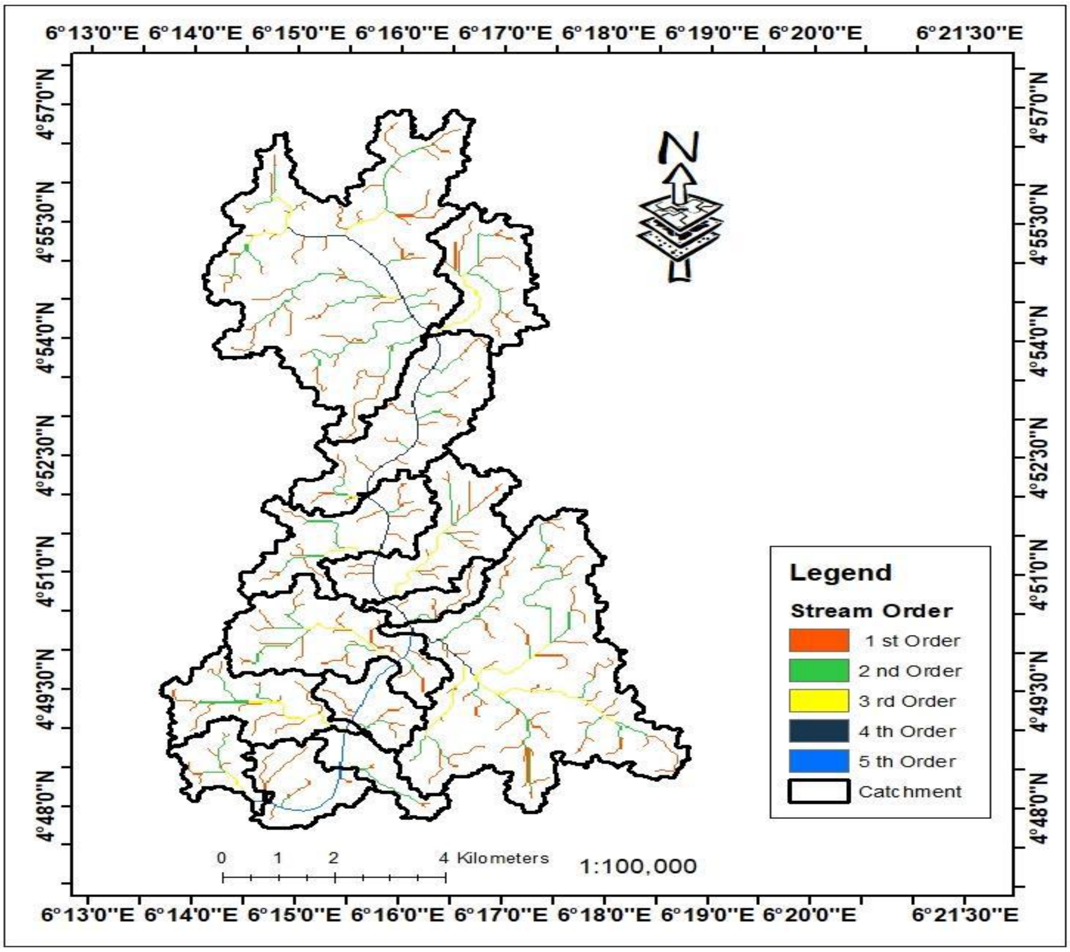
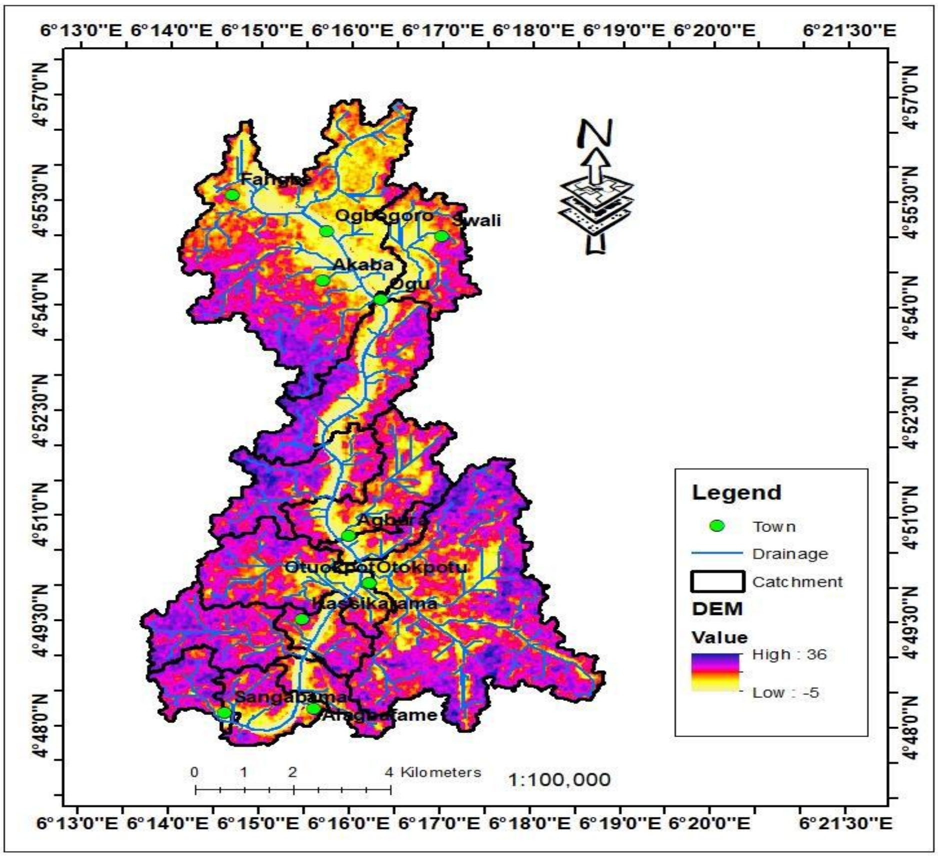


Fig.2: Stream order catchment in Ekole River



Figurer 3: Digital elevation map of the study area

Table 1: Stream characteristic of Ekole River

S/N	Stream order	Stream no (Nu)	Total stream length(Lu)
1	1st Order	237	98
2	2nd Order	121	51.98
3	3rd Order	55	21.75
4	4th Order	40	13.72
5	5th Order	13	5.41
		∑,Nu= 466	∑,LU = 191.4

Table 2: Results of morphometric parameter of river basin in Ekole River and it Formula, definition and reference

S/N	NAME	FORMULA	DEFINITION	REFERENCE	RESULTS
1	Area (A)		The total area of a basin or watershed.		83.76 km^2
2	Perimeter (P)		The total length of the boundary or outline of a basin or watershed.		100.75 km
3	Mean Stream Length (Lsm)	Lsm = A/Dd	The average distance between the outlet and all the points along the main channel in a basin or watershed.	Horton (1945)	0.41 km

4	Mean Bifurcation ratio (Rbm)	Rbm = N/N-1	The average ratio of the number of streams of the next order to the number of streams of the current order in a basin or watershed.	Horton (1945)	2.15
5	Drainage Density (Dd)	Dd = L/ A	The total length of all the streams and channels in a basin or watershed divided by the total area of the basin or watershed.	Horton (1945)	2.28 km/km^2
6	Stream Frequency (Fs)	Fs = N/L	The number of streams and channels per unit length in a basin or watershed.	Strahler (1957)	5.56
7	Drainage Texture (T)	T = Fs/Fd	A measure of the texture of a basin or watershed based on the ratio of drainage density to stream frequency.	Schumm (1956)	12.68 km/km
8	Texture Ratio (Rt)	Rt = Lb/Lsm	The ratio of the basin length to the mean stream length in a basin or watershed.	Schumm (1956)	4.62 km/km
9	Basin Length (Lb)	No formula needed.	The distance from the outlet of a basin or watershed to the farthest point along the main channel of the basin or watershed.		16.23 km
10	Circulatory Ratio (RC)	RC = (P^2/4πA)	A measure of the circularity of a basin or watershed based on the ratio of the area of the basin or watershed to the square of its perimeter.	Miller 1953	0.1
11	Elongation Ratio (Re)	Re = Lmax/Lmin	The ratio of the maximum length to the minimum width of a basin or watershed.	Horton (1945)	0.2
12	Form Factor (Ff)	Ff = 4πA/P^2	A measure of the shape of a basin or watershed based on the ratio of its area to the product of its maximum length and minimum width.	Schumm (1956)	0.32 km/km
13	Length of overland flow (Lg)	Lg = A/T	The distance that water travels overland from the farthest point in a basin or watershed to the outlet.	Strahler (1952)	1.14 km/km
14	Shape factor (Bs)	Bs = 0.25(Pc/P)^(2/3)	A measure of the shape of a basin or watershed based on the ratio of the square of its perimeter to the product of its area and length of overland flow.	Schumm (1956)	3.14
15	Relative relief (R)	R = Hmax/Hmean	The ratio of the difference between the highest and lowest elevations in a basin or watershed to the mean elevation of the basin or watershed.	Strahler (1952)	0.03 km
16	Relief ratio (Rn)	Rn = Hmax/Hmin	The ratio of the highest elevation (Hmax) to the lowest elevation (Hmin) within a specified area.	Melton (1958)	3.11
17	Ruggedness number (Rn)	Rn = ΣH/ L	A measure of the vertical variation in elevation within a drainage basin, calculated as the mean absolute difference in elevation between adjacent grid cells.	Strahler (1957)	0.07

19	Dissertative index (Di)	$Di = \Sigma(d^2) / [\Sigma(d)]^2$	A measure of the degree to which a particular geographic region has been studied or documented in academic literature. It is typically calculated as the ratio of the number of published articles or dissertations about the region to the region's total area.	Strahler (1964) and Schumm (1956)	0.89

The results from Table 2 shows that the area of the basin, which is 83.76 km^2, is the first morphometric measure. The basin's big area makes it susceptible to climate change effects such as increased runoff and inundation from increased precipitation. The basin's length is 100.75 km, which indicates the basin's form and area, which can influence water flow. The Ekole River has a typical stream length of 0.41 km. This parameter is critical in calculating the time it takes for water to move through the waterway. With less precipitation anticipated in the area as a result of climate change, the Ekole River's short stream length may result in a decrease in river flow and, as a result, a decrease in the quantity of water accessible for the towns that depend on the river for their water supply. The mean bifurcation ratio (Rbm) of 2.15 shows that the river basin is in its early stages and that the system of rivers is denser. The Ekole River's drainage density (Dd) is 2.28 km/km^2, which is high and suggests that the basin's channels have limited water holding capacity. This measure is significant in the context of climate change because an increase in precipitation may result in an increase in runoff, which may cause flooding and erosion, resulting in land loss. The Ekole River has a stream frequency (Fs) of 5.56, showing a high number of streams in the watershed. Because variations in precipitation trends can affect the quantity and geographic distribution of streams in the basin, this measure is significant in evaluating the effect of climate change on the basin's hydrology. The basin length (Lb) is 16.23 km, indicating that the basin is modest. The circulatory ratio (RC) of 0.10 shows that the region is elongated and has a low degree of circularity, with a low possibility for flooding. The elongation ratio (Re) of 0.20 suggests that flooding is unlikely in the region. The form factor (Ff) of 0.32 km/km indicates the structure and geometry of the basin, and the length of overland flow (Lg) of 1.14 km/km indicates the terrain of the basin. The shape factor (Bs) of 3.14 shows that the region is elongated in shape. The relief ratio (Rn) of 3.11 indicates that the draining density and relief are both substantial. The ruggedness number (Rn) of 0.07 indicates a comparatively flat terrain that could overflow in the case of heavy rain. Finally, the basin is elongated and has a low degree of bifurcation and the dissertation index (Di) of 0.89.

V. CONCLUSION

Climate change has influenced the topography of the Ekole River watershed by changing the hydrological processes that regulate the basin's creation. Changes in precipitation patterns, temperature, and other climate factors have impacted the basin's water equilibrium. The decrease in precipitation has resulted in a decrease in streamflow, which has impacted the basin's draining network. The reduction in streamflow has also resulted in a reduction in the erosion and deposition processes that form the basin's environment. Furthermore, rising temperatures have increased evapotranspiration, reducing the quantity of water accessible for hydrological processes. The decrease in water availability has also resulted in a decrease in vegetation cover, which has increased surface runoff and soil erosion in the basin, affecting morphometric parameters such as drainage density, stream frequency, and relief ratio. As a result, the morphometric analysis of the Ekole River has revealed that the basin has a dendritic drainage pattern, with a low relief and high drainage density.

VI. RECOMMENDATION

It is recommended that policymakers and stakeholders in the area take measures to create and execute effective climate change mitigation and adaptation strategies. This could include measures such as enhancing land-use practices to reduce erosion and sedimentation, encouraging replanting and conservation efforts to protect river areas, and creating early warning systems to notify communities of imminent flood or drought conditions.

REFERENCES

[1] Ebiegberi Oborie and Eteh Desmond Rowland, (2023). "Flood influence using GIS and remote sensing based morphometric parameters: A case study in Niger delta region," Journal of Asian Scientific Research, Asian Economic and Social Society, vol. 13(1), pages 1-15.

[2] Eteh D. R. ., Lolade, A. A. ., Nicholas, D. O. ., Opukumo, A. W. ., & Omonefe, F. (2022). The Environmental Impact of Shoreline Changes and Land Use/Land Cover Change Detection in the Niger Delta Region using Geospatial Technology. *Journal of Asian Scientific Research*, *12*(4), 237–248. https://doi.org/10.55493/5003.v12i4.4650

[3] Eteh, D., Akpofure, E., & Otobo, S. (2021). GIS & Remote Sensing Based Morphometric Parameters and Topographic Changes of the Lower Orashi River in Niger Delta. *Journal of Atmospheric Science Research*, *5*(1), 1–10. https://doi.org/10.30564/jasr.v5i1.3873

[4] Etu–Efeotor, J. O. (1997). Fundamentals of petroleum geology. Paragraphic publications, Port Harcourt, Nigeria, Press page 135.

[5] Horton RE, (1945). Erosional development of streams and their drainage basins: Hydrophysical approach to quantitative morphology. Bulletin of Geological Society of America. 5:275-370

[6] Mahala, A. (2020). The significance of morphometric analysis to understand the hydrological and morphological characteristics in two different morpho-climatic settings. Applied Water Science, 10(1), 1-16. https://doi.org/10.1007/s13201-019-1118-2

[7] Mangan, P., Haq, M. A., & Baral, P. (2019). Morphometric analysis of watershed using remote sensing and GIS—a case study of Nanganji River Basin in Tamil Nadu, India. Arabian Journal of Geosciences, 12, 1-14.

[8] Melton MA, (1958). Correlation structures of morphometric properties of drainage systems and their controlling agents. Journal of Geology. 66:442-460.

[9] Miller N. A, 1953. Quantitative geomorphic study of drainage basins characteristics in clinish mountain area, Verginia and Tenssesse. Columbia University. 30. (Technical Report No. 3).

[10] Rajasekhar, M., Raju, G. S., & Raju, R. S. (2020). Morphometric analysis of the Jilledubanderu river basin, Anantapur District, Andhra Pradesh, India, using geospatial technologies. Groundwater for Sustainable Development, 11, 100434. doi.org/10.1016/j.gsd.2020.100434

[11] Reijers, T. J. A. (2011). Stratigraphy and Sedimentology of the Niger Delta. Geologic, The Netherlands, 17(3), p.133-162

[12] Reyment RA (2018) Ammonitologist sensu latissimo and founder of Cretaceous Research Bengtson. P Cretaceous Research-1926-2016, 88, 5-35.

[13] Schumm SA. 1956. Evolution of drainage systems and slopes in Badlands at Perth Amboy, New Jersey. Bull. Geol. Soc. Amer.; 67:597-646

[14] Strahler AN. (1957). Quantitative analysis of watershed geomorphology. Trans, Am Geophys Union. 38:913.

[15] Strahler AN. (1964). Quantitative geomorphology of drainage basins and channel networks. In: Chow VT, editor. Handbook of applied hydrology. New York (NY): McGraw Hill; p. 4–76
https://dwtkns.com/srtm30m