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RESEARCH ARTICLE

Application of GIS and remote sensing in morphometric characterization of Ajilosun river basin, Ado Ekiti, Ekiti state, Nigeria

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Abstract

This study presents a morphometric analysis of the Ajilosun River basin in Ado-Ekiti, Nigeria, using Remote Sensing and GIS techniques. A 30 m Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model was processed using ArcGIS 10.2 hydrology and surface tools to extract drainage networks and derive linear, areal, and relief parameters based on Strahler's stream ordering system. The Ajilosun basin covers 249.054 km² and exhibits a fourth-order dendritic drainage pattern with a main channel length of 37.9 km. Linear analysis identified 84 first-order streams (50.3%), 43 second-order streams (26.9%), 27 third-order streams (16.6%), and 13 fourth-order streams (6.2%), indicating dominance of headwater streams and a relatively youthful geomorphic system. Drainage density (0.774 km/km²) and stream frequency (0.670 km/km²) are low, reflecting permeable subsurface materials and lower runoff potential. Basin shape indices including form factor (0.173), elongation ratio (0.47), and circularity ratio (0.365). Slope analysis shows values ranging from 0° to 52°, with mean and median slopes of 12.4° and 11.2°, indicating predominantly gentle to moderate terrain. Overall, the morphometric attributes suggest that despite low drainage density and an elongated shape, the basin is vulnerable to flooding and waterlogging during intense rainfall events. Recommended measures include routine desilting and maintenance of drainage channels, enforcement of controlled urban development, and integrated urban drainage planning to mitigate future flood risks in the rapidly urbanizing Ajilosun basin.

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1. INTRODUCTION

Morphometric analysis is defined as the quantitative assessment of landform characteristics and is based on the estimation of morphometric parameters. These parameters include stream order, stream length, circularity ratio, drainage density, dissection index, and ruggedness index, among others. The determination of these parameter values is vital for understanding the relationship between geomorphology and hydrological processes, including surface runoff, flood generation, and soil erosion, which may require the estimation of related relief morphometric measures over time (Gogoi *et al*., 2022). Quantitative morphometric studies also inform watershed prioritization for soil conservation and sustainable resource management. As these parameters evolve in response to environmental factors, the quantitative analysis of morphometric characteristics plays a crucial role in watershed prioritization for soil conservation and renewable resource management. Previous studies have demonstrated the use of morphometric analysis in various contexts, including the relationship between morphometric properties and hydrologic characteristics (Mahala, 2020); morphometrics and flash flood hazard (El-Fakharany & Mansour, 2021; Sharma *et al*., 2021); morphometrics and soil erosion potential (Arabameri, 2020). These studies compared linear, area, and relief parameters across either a single or multiple study areas to assess how these derived parameters influence phenomena such as flood, erosion, and runoff. For example, Mahala (2020) observed that the Kosi River basin drains a larger volume of water than the Kangsabati River basin due to its almost circular basin shape, in contrast to the elongated shape of the latter. Similarly, low values of the mean bifurcation ratio tend to a higher probability of flash flood, and a decrease in concentration time leads to a rise in the relief ratio (El-Fakharany & Mansour, 2021). These relationships provide useful information for prioritization in the management of river basins. Detailed morphometric analysis is therefore a great help to demonstrate the influence of drainage morphometric network on landforms, erosion, and runoff.

The river Ajilosun constitutes the main channel in Ado Ekiti's drainage basin flow, Nigeria. Efforts to improve the carriage capacity of the stream included concrete channelization and expanding, deepening, and re-routing its main downstream section (Nsiegbe *et al*., 2022; Arohunsoro *et al*., 2019). The Ajilosun River basin in Ado Ekiti, Ekiti State, is a critical component of the local hydrological system, providing water for domestic use, agriculture, and urban drainage. Rapid urbanization, deforestation, and unplanned development within the basin have increased its vulnerability to flooding and waterlogging, making it essential to understand the basin's morphometric characteristics for effective watershed management and flood mitigation. However, in recent times, waterlogging has become a major problem in the study area and has been attributed to deforestation and a haphazard pattern of development. Many of the past morphometric studies on the Ajilosun River Basin Rivers relied on manual field measurements using tapes, poles, and rods (Nsiegbe *et al*., 2022; Arohunsoro *et al*., 2019).

Historically, morphometric studies of the Ajilosun basin relied on non-GIS methods, including manual field measurements with tapes, rods, and poles (Nsiegbe *et al*., 2022). While these approaches provided baseline data, they were labor-intensive, time-consuming, and often limited in spatial coverage and accuracy. Errors in measurement and difficulties in integrating soil, slope, and geological data constrained the ability to comprehensively analyze the drainage network and predict hydrological responses.

Recent studies highlight the advantages of GIS and remote sensing techniques (Nnamani, 2025), which also allow efficient, accurate, and large-scale analysis of morphometric parameters. For instance, Mahala (2020) demonstrated how basin shape influences flood response, while El-Fakharany and Mansour (2021) linked morphometrics to flash flood hazards. Similarly, Arabameri (2020) showed the relevance of morphometric analysis in assessing soil erosion potential. The application of remote sensing and GIS offers a broader, more accurate, and efficient approach for morphometric assessment (Odiji *et al.,* 2021). In this study, the Ajilosun drainage basin was examined through the application of morphometric techniques.

This study, therefore, employs DEM-based GIS and remote sensing approaches to examine the current morphometric state of the rivers, compares new information on geology, slope, and soil to similar past studies, and relates the various morphometric aspects to the flooding condition in the drainage basin.

2. STUDY AREA

The study area is the Ajilosun River basin in Ado Ekiti, Ekiti State, Nigeria, located between longitudes 5°10′–5°15′E and latitudes 7°35′–7°38′ N (Figure 1). The basin covers 249.054 km^2, with soils dominated by clay and silty loam, and underlying rocks predominantly charnockite, migmatite, and porphyritic granite. The region has a tropical climate, with annual rainfall ranging from 1.2 to 1.4 m, distinct wet and dry seasons, and slopes ranging from gentle to steep. Government of Ekiti State. (n.d.). The basin exhibits a dendritic drainage pattern, with the main channel length of 37.9 km.

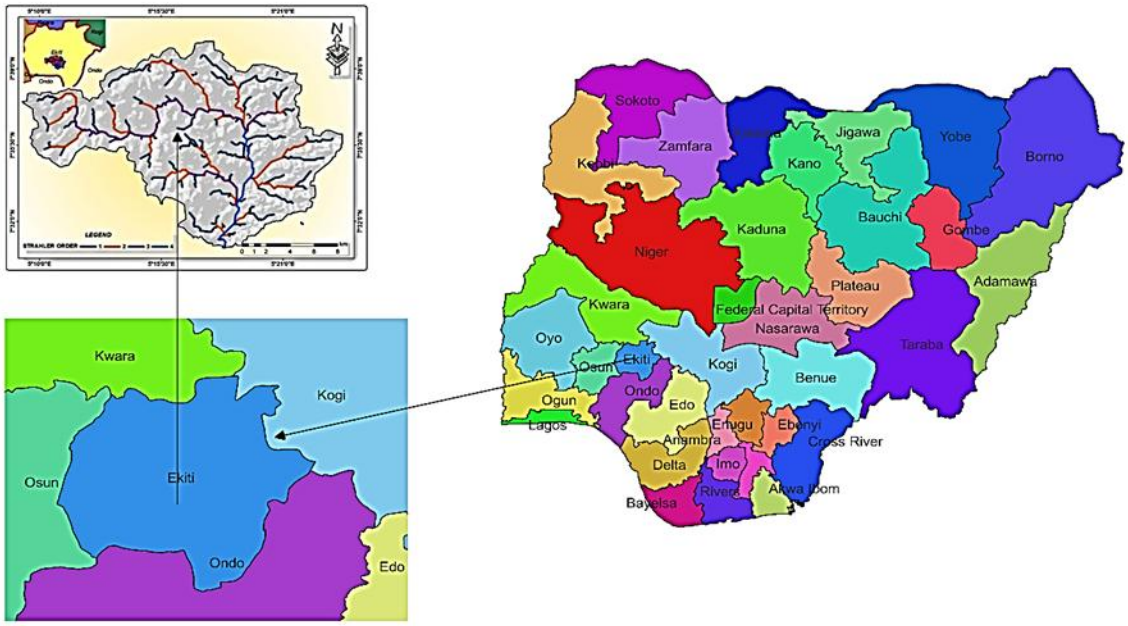

Figure 1: Study area

The study area includes a tropical climate, with distinct dry and wet seasons and a range of 1.2-1.4m of annual rainfall. The Precambrian era igneous and metamorphic rocks, which include the charnockite rocks, with medium and coarse grains, comprise the majority and make up about 86% total region, determining the drainage basin of the river Ajilosun. The mantle of the basin is composed of charnockite rock, forming highly erodible clastic materials such as silt and sand, and the drainage basin is over 64% developed and considered fully mature. The mantle used is built of charnockite rock makes up severely erodible clastic elements, such as silt and sand (Nsiegbe *et al*., 2022; *Arohunsoro et al.,* 2019).

The floodplains and valley of the river might be affected by the growing residents and a substantial increase in the number of locations. The drainage pattern of the Ajilosun drainage basin appears dendritic in nature, with streams originating from several portions of the study area. Hierarchical ordering is based on Strahler's ordering system, and the basin expanse is 24,905 hectares. The streams of first order are of short length but with a higher frequency compared to streams in subsequent orders. The stream parts at the fourth order remain the lowest in quantity. The drainage area is 249.054 km^2, and the perimeter of the study area is 92.6341 km, and has a steep slope along the south-west part. The gradient series of the basin is valued from 0.5° - 59.85° (with respect to the direction to which water flows along the North Pole origin). The gradient zone is classified into four main classes, which are gentle, slightly gentle, steep, moderate steep, steep, and very steep, with a greater percentage of the study area having a mildly steep to gentle slope. The most dominant rock type found in the study area is the Migmatite, followed by the porphyritic granite, the charnockitic, and the medium–coarse grained biotite granite, respectively. The soil type is clay and silty loamy, and both are evenly spread over the entire study area.

3. METHODOLOGY

3.1 Data Acquisition and Processing

A 30 m resolution Digital Elevation Model (DEM) of the basin was obtained from the Shuttle Radar Topographic Mission (SRTM). Additional geospatial datasets, including soil, geological, and drainage maps, were integrated into the analysis using ArcGIS 10.2. Morphometric parameters were extracted using standard GIS tools, supplemented with the Hydrology Toolset in ArcGIS for drainage characterization.

Figure 2 is a schematic representation of the methodological framework employed in this study. The initial phase involved a preliminary assessment using geospatial data obtained from digital elevation models, soil maps, and geological maps. Morphometric parameters, including both basic and derived parameters, were extracted directly from geospatial datasets using ArcGIS tools. The morphometric assessment encompassed linear, areal, and relief parameters. Information from soil and geological maps provided contextual data for the description of soil types and geological characteristics of the study area, complementing earlier non-digitized topographic map assessments based on field observations. The integrated analysis of morphometric, geological, and soil data enabled a comprehensive characterization of the topography, runoff patterns, and flood characteristics of the Ajilosun river basin.

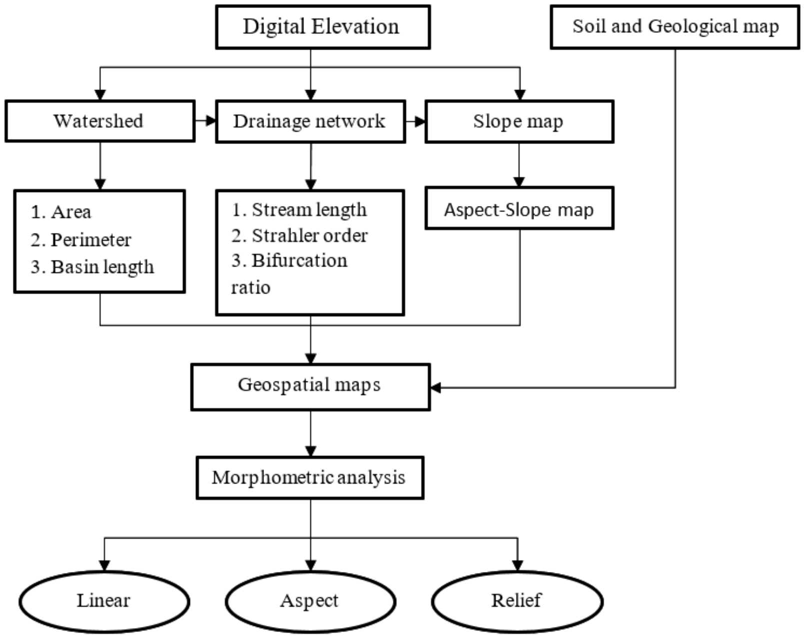

Figure 2: Schematic diagram of the methodological framework (Author's work, 2025)

3.2 Hydrological Preprocessing and Analysis

The Digital Elevation Model (DEM) was preprocessed to ensure accurate flow modeling. The steps included:

1. Fill – Depressions and sinks in the DEM were removed to ensure continuous flow paths.
2. Flow Direction – Each cell in the DEM was assigned a flow direction toward its steepest downslope neighbor.
3. Flow Accumulation – Cumulative flow into each cell was calculated to identify potential stream channels.
4. Stream Vector Extraction – A flow accumulation threshold was applied to define stream initiation points, with raster-to-vector conversion generating stream vector layers.
5. Basin Delineation – The basin boundary and sub-basins were delineated using the outlet point and flow direction grid.

3.3 Morphometric Parameter Computation

Linear, areal, and relief morphometric parameters were computed directly from the extracted drainage network and basin polygons using ArcGIS spatial analysis tools (Table 1). Linear aspects included stream order, stream number, stream length, and bifurcation ratio. Areal aspects included drainage density, stream frequency, form factor, elongation ratio, and circularity ratio. Relief aspects comprised slope, relief ratio, and relative relief. Integration with soil and geological datasets allowed a detailed assessment of geomorphology and hydrological behavior.

Table 1: Morphometric Analysis Parameters

Morphometric Aspect	Parameters	Derivation procedure	Description and reference
Linear aspect	Stream order (u)	u is the Strahler order	Stream order was classified according to Strahler's ordering system (Khatoon, 2022).
	Stream number (Nu)	Nu is the number of streams in an order 'u'	This count also followed Strahler's ordering system and was implemented in ArcGIS (Khatoon, 2022).
	Bifurcation ratio (Rb)	$R_b = Nu/(Nu+1)$, where Nu +1 is the number of streams in the next higher order.	This was computed as the ratio of the number of streams in an order to those in the next higher order (He *et al.,* 2024).
	Mean bifurcation ratio (R_{bm})	R_{bm} is the average of Rb across all orders 'u'.	This is the mean of bifurcation ratios across all hierarchical orders
	Stream length (L_u)	L_u is the length of the streams in a particular order	This is the Total length of all streams within a given order, including the main channel (Limaye, 2021).
	Mainstream length	The length of the main drainage channel	Length of the principal drainage channel from source to outlet
Areal aspect	Form factor (F_f)	$F_f = A/L^2$, where, A = Area of the basin and L = Length of the basin	This is the ratio of the area of the sub-basin to the square of the length of the basin (Klettner, 2019).
	Circulatory ratio (R_c)	$\mathrm{Rc} = 4\pi\mathrm{A}/2$, where, A = Basin area, P = Perimeter, and π = 3.14159	This is the Ratio of the basin area to the area of a circle having the same perimeter (Prakash, 2019).
	Drainage Density (D_d)	$D_d = \sum\frac{L}{A}$, where, $\sum L$ = Sum of all stream lengths and A = Basin area.	Total length of all streams per unit drainage area (Venkatesh & Anshumali, 2019)
	Stream frequency(F_s)	Fs = ΣNu / A, where ΣNu = Total number of streams and A = Basin area	Total number of stream segments of all orders per unit area
	Elongation ratio (Re)	Re = (2/L) × √(A/π), where L = Basin length and A = Basin area	This is the ratio of the diameter of a circle with an area equal to the basin area to the maximum basin length (He *et al.,* 2024).
Relief aspect	Basin slope (S)	S = (VI / HE) × 100, where VI = Vertical interval and HE = Horizontal equivalent	The maximum relief to horizontal distance along the longest dimension of the sub-basin parallel to the principal drainage line (He *et al.,* 2024).
Morphometric Aspect	Relief ratio (R_h)	Rh = H / L, where H = Maximum basin relief and L = Basin length	Ratio of maximum elevation difference to horizontal distance along the longest basin dimension (He *et al.,* 2024).
	Relative relief (Rhp)	Rhp = H / P, where H = Basin relief and P = Basin perimeter	Ratio of the maximum relief to the perimeter of the basin (He *et al.,* 2024).

3.3.1 Linear Aspects

The determination of stream orders constitutes the initial stage in morphometric analysis and was conducted according to Strahler's ordering system ((Khatoon, 2022). Stream order (u) represents the hierarchical ranking of streams based on their position and connectivity within the drainage network. First-order streams are the smallest unbranched tributaries originating from elevated, hilly terrain at the watershed headwaters. Second-order streams form at the confluence of two first-order streams, third-order streams result from the junction of two second-order streams, and so forth, with the main channel representing the highest order in the basin. Following stream ordering, each stream segment was numbered sequentially to facilitate the determination of stream length (Lu) and bifurcation ratio (Rb).

The bifurcation ratio (Rb) represents the relationship between the number of streams (Nu) in a given order to the number of streams in the next higher order, providing insight into the drainage network's branching pattern and the basin's hydrological response characteristics. The mean bifurcation ratio was calculated as the average of bifurcation ratios across all hierarchical orders. Linear aspect parameters, including stream length (Lu), stream number (Nu), and bifurcation ratios (Rb), were measured directly using ArcGIS geoprocessing tools from the drainage layer's attribute database, and their mean values were computed for subsequent analysis.

3.3.2 Areal Aspects
Areal morphometric parameters reflect the two-dimensional properties of the drainage basin and are influenced by the underlying geology, climate, and lithology. The principal areal parameters examined in this study include basin area (A), perimeter (P), stream frequency (Fs), drainage density, form factor (Ff), elongation ratio (Re), and circularity ratio (Rc). The watershed area is a fundamental parameter upon which several derived parameters depend and was calculated using ArcGIS spatial analysis tools applied to the delineated drainage basin polygon. The basin perimeter was similarly extracted from the watershed boundary layer. Drainage density (Dd), defined as the total length of all stream segments per unit basin area, is related to relief, basin morphology, and the distribution of stream networks. It indicates the closeness of channel spacing and reflects the basin's drainage efficiency.

3.3.3 Relief Aspects
Key relief parameters analyzed in this study include basin slope (S), relief ratio (Rh), and relative relief (Rhp). Basin slope was derived from the Digital Elevation Model (DEM) using ArcGIS spatial analyst tools, which calculate the maximum rate of elevation change between each cell and its neighbours. The relief ratio represents the ratio of maximum elevation difference (relief) to the horizontal distance along the longest dimension of the basin parallel to the principal drainage line. Relative relief is the ratio of basin relief to the basin perimeter, providing a normalized measure of terrain ruggedness.

4. RESULTS

4.1 The Drainage Basin Characteristics
The drainage outline of the Ajilosun River is a fourth-order dendritic drainage system based on Strahler order classification (Khatoon, 2022). Migmatite is the dominant rock type, followed by porphyritic granite and charnockite rocks. The soil types are generally clay and silty loam, consistent with earlier observations (Arohunsoro *et al.*, 2019). The basin covers 249.054 km^2 with high relief areas reaching 692m above sea level. Few spots within the study area are very steep, with a larger portion having a gentle-mild slope, making it prone to flooding in the event of extreme precipitation. The main channel has a length of 37.9km. The climate in the area is seasonal, characterized by a wet and a dry period and a short period of no rainfall known as August break.

The next subsection presents the morphometric parameters that describe the structure and behaviour of the drainage system.

4.2. Morphometric Analysis
Morphometric parameters, including linear, areal, and relief aspects, were computed using GIS-based hydrological tools. These parameters provide insight into the basin’s hydrological response, structural controls, and susceptibility to erosion and flooding.

4.2.1. Linear Aspects
4.2.1.1 Stream Order, Stream Number, and Drainage Network
Stream order (u) represents the first parameter computed in a drainage system’s morphometric analysis. A total of 167 stream segments were delineated using ArcGIS (Table 2). A total of 167 stream segments were delineated using ArcGIS (Table 2). First-order streams dominate the network (84 streams; 50.3%), followed by second-order (43), third-order (27), and fourth-order streams (13). This inverse relationship between stream order and stream number is typical of natural drainage systems. The dominance of first-order

streams suggests high headwater activity. These streams often ephemeral, are sensitive to fluctuations in groundwater levels, seasonal dryness, land-use change, and urban encroachment. They also possess narrow widths and are particularly susceptible to clogging due to refuse dumping, a common occurrence in settlements around the basin.

A direct relationship exists between stream order and channel width: higher-order streams tend to be wider (Downing, 2012). In the Ajilosun Basin, first-order streams are short, numerous, and act as the primary contributors to upstream runoff.

4.2.1.2 Stream Length (Lu)

A total of 193km is the whole length of all the rivers flowing in all hierarchical orders. Of these, about 50.3% (97km) are first-order streams, 26.9% (52km) are second-order streams, 16.6% (32km) are third-order streams, and the fourth-order streams, being shortest in length, are 6.2% (12km) of the total stream length (Table 2). The first-order streams are the farthest from the outlet point, followed by the second, third, and fourth-order streams (closest to the outlet points). The main channel extends from the upper limit of the drainage basin to the outflow point and has a length value of 37.9km.

4.2.1.3 Bufurcation Ration (Rb)

Bifurcation ratios range from 1.59 to 2.07 across orders, with a mean value (Rbm) of 1.87 (Table 2). These values indicate that the basin is underlain by relatively homogeneous lithology (Khatoon, 2022). Low Rb values suggest high time of concentration, delayed peak discharge, and increased potential for runoff accumulation in an urbanizing landscape. These characteristics align with observations in similar basins in southwestern Nigeria (Abayomi & Lanre, 2023; Aiyelokun *et al*., 2017).

4.2.1.4 Morphometric Interpretation of Linear Parameters

The predominance of low-order streams (>50%) suggests a youthful and actively eroding basin, a phenomenon also reported in Himalayan watersheds (Mishra *et al*., 2023; Butt, 2025). Although the Ajilosun Basin exhibits gentle slopes, its youthful morphology increases erosion susceptibility in disturbed or exposed areas.

Table 2: Linear Morphometric Parameters of the Ajilosun River

S/N	Parameter	Symbol	Numerical Value
1	Bifurcation ratio: Order 1–2	Rb	1.95
	Order 2–3		1.59
	Order 3–4		2.07
2	Mean bifurcation ratio	Rbm	1.87
3	Total number of stream orders	Nu	4
4	Sum of stream numbers in each order	N1–N4	84, 43, 27, 13
5	Total length of all streams (km)	Lu	193
6	Length of overland flow (km)	Lg	0.645

4.2.2 Areal Aspets

Areal morphometric parameters describe the drainage texture, infiltration capacity, and hydrological response of the basin.

4.2.2.1 Drainage density (Dd)

The drainage density of 0.774 km/km² reflects a low channel network density. Low values indicate permeable soils, gentle slopes, and reduced surface runoff. This aligns with conditions in similar basins in southwestern Nigeria (Aiyelokun *et al*., 2023).

4.2.2.2 Stream Frequency (Fs)

The stream frequency is 0.670 km/km², classified as low. Low Fs suggests a slower hydrological response and may be attributed to lithological resistance and urban surface sealing in parts of the basin. The measured value of Fs in this study can be classified as low, and therefore, the variation may be attributed to differences in lithology and initial resistance of rocks to erosion (Obeidat *et al.,* 2021)

4.2.2.3 Form factor (Ff)

The form factor is a measure of the basin's area to its squared length (Venkatesh & Anshumali, 2019). The direction of stream flow is impacted by the catchment area's shape (Rai *et al.,* 2019). A key part in determining the catchment area's shape is the form factor. A perfectly elongated basin has an Ff value of '0', and an Ff value of '1' indicates near-circular characteristics of the basin (Görü & Karadeniz, 2018). The form factor in this research area has a value measured as 0.173. High Ff values are indicative of a circular basin with peak flows occurring in a short time, while low values indicate an elongated basin with peak flows occurring over a longer duration (Prabhakaran & Jawahar, 2018).

4.2.2.4 Circularity Ratio (Rc)

The area ratio for a basin to a circle of a comparable size is known as the circulatory ratio (Khatoon, 2022). This aspect is a depiction of the catchment area's form characteristics. Rc values range from minimum circularity to maximum circularity, from 0 to 1. The basin's Rc is measured as 0.365.

4.2.2.5 Elongation Ratio (Re)

An important metric to assess a sub-basin area's form is the elongation ratio. In addition, it is a significant aspect of basin form (Ali and Singh, 2022). The Re value of 0.47 confirms an elongated basin shape, implying subdued geomorphic control (Khatoon, 2022).

4.2.3 Relief Aspects

4.2.3.1 Relief Ratio (Rr)

The relief ratio (0.023) of the basin reflects gentle to moderate slopes, consistent with the predominantly flat terrain

4.2.3.2 Relative Relief (Rhp)

The proportion of the relief amount to the watercourse zone's perimeter is termed relative relief. The Relative Relief of the river basin is 0.89, indicating moderate relief variation across the basin

4.2.3.3 Slope Analysis

Slope values range from 0° to 52°, with 65% of the basin below 15°, and only 10% above 40°. The terrain is largely flat to moderately sloped, consistent with earlier relief indicators (Figure 3).

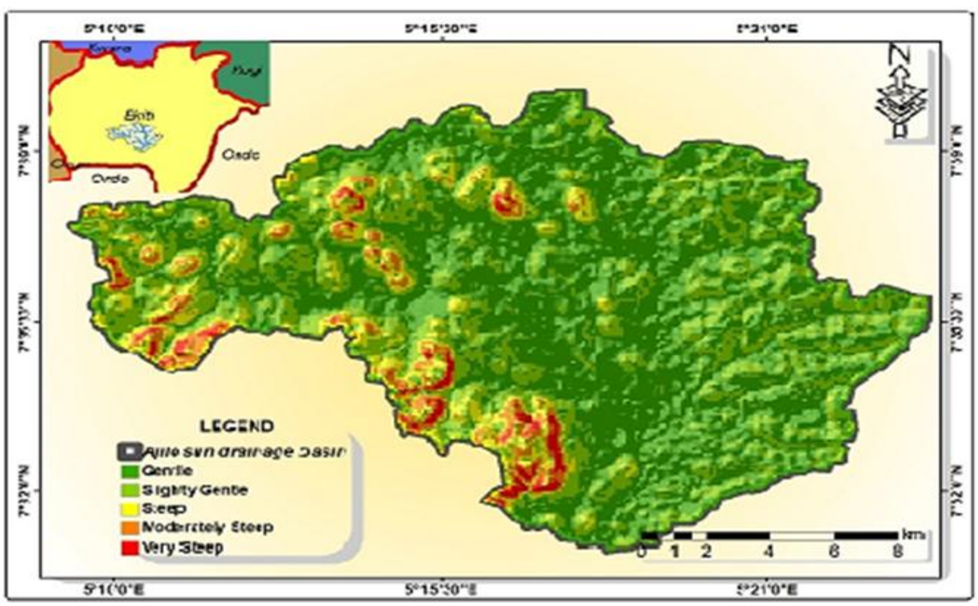

Figure 3: Ajilosun Basin Slope Map

4.2.3.4 Aspect Analysis

Figure 5 shows the study area's aspect map. An aspect refers to a part or a section of a particular thing or feature. In relation to a drainage basin, it determines the direction that a surface's slope faces horizontally. This influences the section in which there is a high flow of water or the path through which water flows. The resulting raster map displays aspect values' range direction, with the northerly feature ranging from 0° to 22.5°, and the slope facing the north-east with values between 22.5° and67.5°. The eastward feature is signified by the arrays between 67.5° and 112.5°, and the southerly feature by the array 157.5° to 202.5°. The aspect map's visual interpretation shows westerly parts with both easterly and north-easterly aspects.

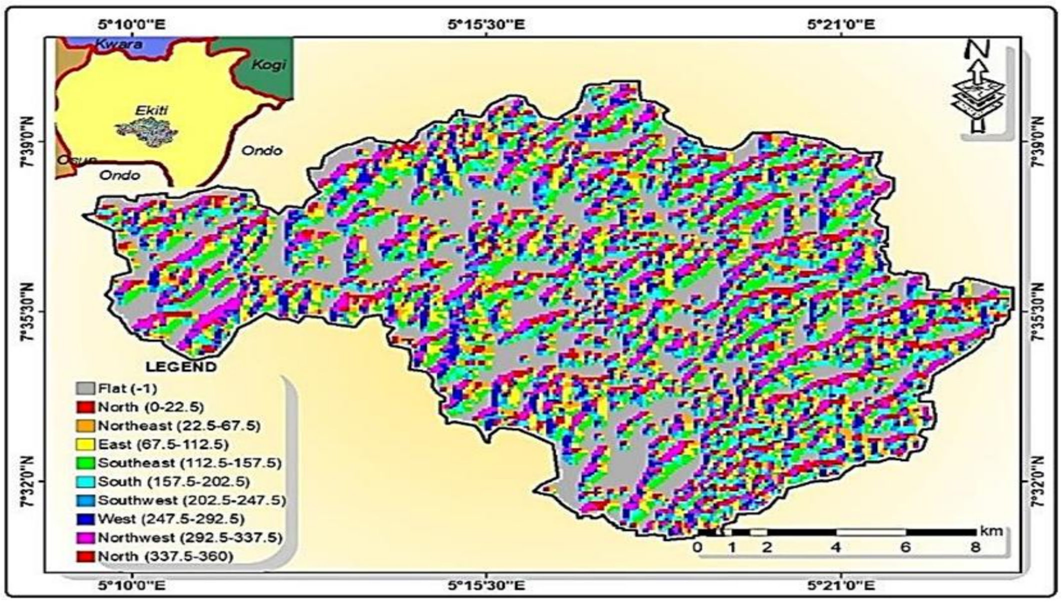

Figure 5: Aspect map of Ajilosun Drainage basin

5. DISCUSSION

The results of this study demonstrate the feasibility of using GIS and remote sensing technology for morphometric analysis. The morphometric characteristics, low drainage density, high proportion of first-order streams, and elongated basin shape imply slow runoff response, but urbanization intensifies flood risk. Expansion of impervious surfaces, unplanned settlements, and dumping of waste into streams reduce infiltration and obstruct drainage channels. These factors increase the likelihood of waterlogging and prolonged flooding even in areas with generally low drainage density.

Comparative studies in Nigeria (Temitope *et al*., 2020; Ocheri *et al*, 2025) indicate that similar elongated, low-density basins in urbanizing regions experience significant flood hazards, highlighting the interactive effect of basin morphometry and human activities.

6. CONCLUSION

This morphometric analysis of the Ajilosun river basin using GIS techniques has successfully characterized the hydrological and geomorphological properties of the 249.054 km² watershed. The study reveals critical findings with significant implications for watershed management and flood risk mitigation in this urbanizing area. The basin exhibits a fourth-order dendritic drainage pattern with a low mean bifurcation ratio of 1.87, indicating homogenous rock layers and a high time of concentration. The dominance of first-order streams (84 streams representing 50.3% of total stream length) confirms a young geomorphological setting. The low drainage density (0.774 km/km²) and stream frequency (0.670 km/km²) indicate gentle gradients, high infiltration capacity, and relatively slow surface runoff response. The basin's elongated shape, evidenced by the form factor (0.173), elongation ratio (0.47), and circularity ratio (0.365), suggests that peak discharge will occur over extended durations rather than as rapid events. The predominantly gentle to moderate slopes (0°–52°) with a low relief ratio of 0.023 confirm the relatively flat topography. These characteristics create significant flood management concerns, particularly given rapid urbanization.

Several critical implications emerge from this analysis. The low drainage density and stream frequency suggest limited natural drainage capacity, making the basin vulnerable to surface water accumulation during heavy rainfall. The high concentration time means prolonged recession periods once flooding occurs. The predominance of ephemeral first-order streams, susceptible to clogging from debris and refuse dumping, highlights the urgent need for proper waste management practices.

This study shows that GIS-based morphometric analysis provides a strong scientific basis for improving watershed management and flood control in the Ajilosun River basin. The basin's morphometric characteristics reveal vulnerabilities that require immediate actions such as routine channel maintenance, strict zoning enforcement, and improved waste management. Long-term resilience will depend on installing detention systems, establishing riparian buffer zones, and developing an integrated drainage master plan that aligns with natural flow patterns. Effective governance, through a basin-level management authority, community engagement, and strict compliance monitoring, is essential for sustaining these interventions.

The morphometric parameters also provide a solid foundation for advanced GIS-based modeling frameworks, such as those using HEC-HMS and SWAT, enabling accurate flood forecasting, assessment of land-use change impacts, and evaluation of future climate scenarios. Integrating these models into planning will enhance adaptive capacity, improve decision-making, and support sustainable development within the basin.

It is recommended that **r**egular maintenance and clearing of first-order streams to prevent clogging from debris and urban waste. Also, development of urban drainage master plans that preserve natural flow paths, integrate retention basins, and limit impervious surface expansion in flood-prone areas should be prioritized.

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