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MORPHOMETRIC CHARACTERISATION OF YEWA DRAINAGE BASIN, SOUTHWEST NIGERIA

Bello Abdulganiy Abayomi, Ajibade Tajudeen Lanre

School of Basic and Advanced Studies, Department of Geography and Planning, Faculty of Social Sciences, Lagos State University, Ojo, Lagos Nigeria.
Department of Geography and Environmental Management, Faculty of Social Sciences, University of Ilorin, Ilorin, Nigeria.

Email: yormybell@gmail.com

ABSTRACT

Morphometric analysis is a prerequisite for understanding the hydrological dynamics of a drainage basin's characteristics. This study focused on the morphometric characteristics of the Yewa drainage basin using GIS. The areal, linear, and relief morphometric parameters of the drainage basin were characterised using ArcGIS. The drainage map of the study area reveals a dendritic drainage pattern with a fourth-order stream network on a 4832.40 km² area. The mean bifurcation ratio of the basin is 2.03, indicating that the geological structures do not exercise a significant influence on the drainage pattern. The drainage density of the Yewa drainage basin is 0.256km$^{-1,}$ indicating coarse texture, high infiltration, and permeability with thick vegetation and moderate to low relief. The elongation ratio of 0.556 and the form factor of 0.243 reveals that the basin has an elongated shape. This present study gives an account of information about drainage patterns, stream behaviour, and morphometric setting of drainage within the network that support watershed management. The significance of morphometric analysis on the hydrological characterisation is discussed, and this study's relevance in water resources management and planning has been explicated.

Keywords: *Morphometric analysis, ArcGIS, drainage pattern, landform, stream order*

INTRODUCTION

Morphometric analysis is a duodecimal measurement and mathematical analysis of landforms (Kaur et al., 2014, Vaidya, et al.,2013), with the conformation of the earth’s surface, attribute, and landform dimension (Reddy et al., 2002; Sharma and Mahaja, 2020). This synthesis can be achieved by measuring the basin's linear, aerial and relief aspects and slope contribution (Nag et al., 2020; Rahel Hamad, 2020). Morphometric analysis is a scientific analysis of the shape and dimension of the earth’s surface that demonstrates the nexus between the hydraulic parameter and Morphological features of a drainage basin (Devrani et al., 2022). It demands measurement of linear dimension, gradient of the channel system and contributing spatial relation of the drainage basin (Nautiyal, 1994; Kannan,et al.,2018). The typical assessment of developing a quantitative morphometric analysis of any drainage basin provides good information about the geologic features of the rocks exposed and also the geophysics nature of the drainage basin (Umakant et al., 2017).

Furthermore, morphometric analysis is an essential method for prioritising sub-watersheds even without considering the soil chart (Khurana et al., 2020). According to Indrajeet et al. (2019), morphometric investigation of a drainage basin and channel network plays a crucial role in the agreement with the geo-hydrological conduct of the drainage basin and by expressing the predominant climate, geology, geomorphology, and structural antecedents of the catchment. This, however, stipulates valuable substance about the drainage characteristics of a basin (Aparna et al., 2015, Dubey et al., 2015).

Numerous quantitative measurements have been developed to describe valley side and channel slopes, relief, area, drainage system type, extent, and other variants. Attempts to relate statistically some parameters that shape drainage basin characteristics and basin hydrology have yielded significant outcomes (Indrajeet et al.,2019). Morphometric investigation of a drainage basin fully expresses the regime of dynamic balance that has been attained due to dealings between matter and energy (Indrajeet et al., 2019). This, however, provides not only a stylish statement of the landscape but also serve as a potent means of comparing the form and process of drainage basins that may be widely detached in space and time (Easthernbrook, 1993).

In Nigeria, morphometric characteristics of some river basins have been studied using conventional methods (Ogundele et al., 2013), among which the simplest method is the compound value method (Said et al.,2019; Pathan and Agnihotri, 2020). Manual derivation of the drainage system and the prospect of the stream order from the Survey of Nigeria Toposheets for such a physical exercise is time-consuming and tedious task. Supplying timely solutions to numerous challenges being confronted in the area of basin management calls for automated extraction techniques in evaluating the morphometric variables of drainage basins. This goal is being attempted in this research with the use of GIS technique.

Geographic Information System (GIS) is a versatile tool for creating information for the watershed, and it is very much useful for carrying out spatial analysis, thereby helping the decision makers in conceptualising befitting measures for a critically affected sphere with less time as it offers a great way to determine precise morphometric parameters for any basin (Rahmati et al. 2019). Most researchers have used GIS tools and remote sensing to study the morphometrical features of a watershed (Arulbalaji and Padmalal, 2020, Pathare and Pathare, 2020, Malik et al.,2019, Islam et al., 2021).

GIS and satellite image data proficiency have been used for assessing different terrain and morphometric variables of the drainage basins, and such have made it possible to do rapid and in-depth research on hydrological systems (Mahala, 2020). This supply a flexible environment and a potent tool for handling and analysing the spatial information, particularly future individuality and extraction of the information for a better understanding of watersheds. It is an impressive instrument not only for aggregation, depository, organisation and recovery of a plurality of spatial and non-spatial data but also for spatial synthesis and integration of these data to derive useful outputs and representation (Gupta and Srivastava, 2010, Mukherjee et al., 2009).

Basically, three essential aspects are used in analysing the drainage basin features. They are linear aspects, areal aspects, and relief aspects, which include stream order, stream length, bifurcation ratio, basin area and length, perimeter, drainage density, stream frequency, elongation ratio, circularity ratio, texture ratio and form factor ratio (Shreve,1966; Adelalu,2019). Therefore, this article aims to calculate the morphometric parameters of the Yewa river basin to comprehend the hydrological, geologic and morphological aspects of the domain within the context of future watershed prospecting using GIS.

MATERIALS AND METHODS

Study Location

The Yewa drainage basin covers an area of 4.382.4 km² with a perimeter of 346.55km^2 and it is a transboundary basin between Benin Republic and Nigeria. It is situated in the southwestern part of Nigeria and is located between latitudes 6.25^{0}N and 6.75^{0}N and longitudes 2.70^{0}E and 3.00^{0}E (Fig 1). The Yewa basin is an important drainage basin in Ogun-Osun River Basin Development Authority (Adeaga et al., 2019). This study area is situated within the tropical rainy climate (Af) in accordance with Koppen's climate classification (Adeaga, 2006., Ayanlade et al., 2021). The mean annual rainfall ranges between 1,150mm in the north to around 2,285 mm in the southern extremity. Two seasons are distinguishable in the Yewa drainage basin; a dry season from November to March and a wet season between April and October. The region is under the causation of the tropical continental (cT) and the tropical maritime (mT) air masses. The average monthly temperature ranges from 23°C in July to 36°C in February.

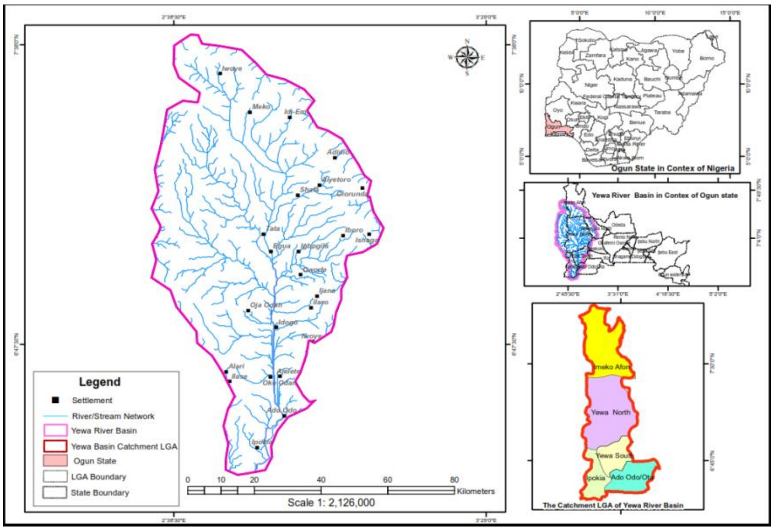

Figure 1. Map of the Study Area
(Source: Author, 2023)

The geology of the Yewa drainage basin is largely made up of two main rock types. The basement complex rock of the pre-Cambrian age comprises the older and the younger granites in the northern part (Geology of Part of Southwestern Nigeria, 1964; VON, 2004). The chief rock type in the drainage basin is basement complex rock (Granite formation) which falls under the gneissic group of rocks. It is essentially non-porous, and water is only found in the crevices and fissures of this consolidated rock formation. This basement complex primarily underlies the sedimentary layers, which consist of cretaceous, tertiary and quaternary sediments deposited in the coastal basin. The younger and older sedimentary rock of this southern part's tertiary and secondary age is under coastal plain formation.

The Yewa drainage basin has two main types of vegetation, viz-tropical rain forest and Guinea savanna. The tropical rain forest is found in the coastal areas of the southern part of the Yewa South LGA while the rest are Guinea savanna. The land use/landcover of Yewa drainage basin is classified as vegetation, wetland, waterbody, agricultural land and built-up, respectively (Oso and Odaibo,2021). The basin is drained by the Yewa river, its tributaries and many other streams such as Iseje, Awuko, Oniru, Ilo, Iju, among many others, which empties into the lagoon (Adeaga,et al 2019). The seasonality of stream flow of the basin varies widely in accordance with the climatic variability, and this is influenced mostly by the local seasonal cycle of precipitation.

Thus, the consideration of seasonality optimises water use and, thus, assists in watershed management and planning. This is because seasonality cycles are irregular. The annual peak in water flow is normally in June/July, but in the last few years it has occurred as early as May and as late as August, depending on climate influence. In view of this, the basin's yearly runoff is estimated at $35.4\times109m^3$ or a depth of runoff of 352mm per year (Adeaga, 2006). The basin with multitudes of industries downstream is gradually being urbanised due to the influx of people from the Lagos metropolis for socioeconomic activities.

Methods

Extraction of data and analysis of morphometric variables of the basin are structured by the combined use of the topographical map sheets as published by the Federal Survey of Nigeria (1970), at the scale of 1:50,000. The sheets are 278A N.E and 278a N.W, 278 S.E and Part of 278 S.W, 278 N.E and Part of 278 N.W & 259 S.E and Part of 259 S.W, published. The topographical data were used in the generation of the digital elevation model (DEM). The processing was done using CartoDEM obtained from Cartosat-I, which was downloaded from the BHUVAN website. The morphometric analysis of the drainage basin was computed through ArcGIS, a suitable instrument to obtain the morphometric parameters. The method involves the automated extraction techniques for evaluating the parameters of the Yewa drainage basin using DEM, ArcGIS and georeferenced FSN Toposheets.

The topographical maps were mosaiced and georeferenced with the help of ArcGIS version 10.3. After georeferencing of the images, they are corrected and re-sampled into a Universal Transverse Mercator basin boundary, drainage pattern and watersheds within the basin to understand the morphological parameters. The determination of the morphometric analysis involves the process of filling the sinks in DEM. Following the DEM fill, the flow path was measured. In order to generate a drainage system, flow aggregation was created based on the path of flow of each cell.

The basin boundaries were delineated at stream points to show water flows. The longest drainage length was digitised and converted to vector data using ArcGIS 10.3. The derived basin boundary was then converted to vector data called “shapefile” and named a watershed polygon from which the sphere and circumference of the Yewa drainage basin were measured in the attribute table of ArcGIS. Stream order was determined in accordance with Strahler (Munoth and Goyal, 2020) and stream length for each order in the Yewa drainage basin was determined using ArcGIS 10.3.

The stream numbers were found using the editor tool by mingling the stream segments of the identical order leading to the next higher order. These morphometric parameters are the basis for understanding the hydrological operation of the drainage basin. Figure 2 shows the flowchart of morphometric analysis carried out, while Table 1 shows the methodology used in computing each of the studied variables.

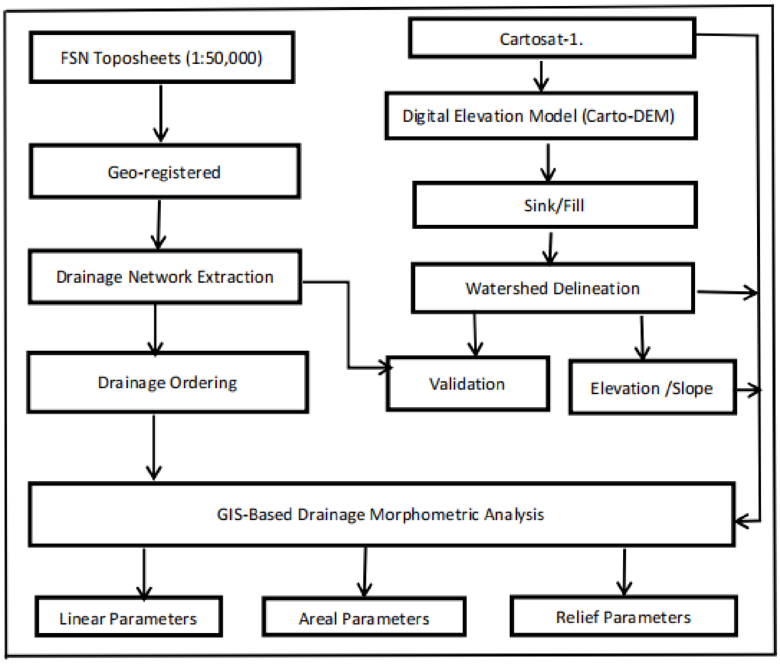

Figure 2: Flowchart of Morphometric Analysis
(Source: Adapted and modified from Madavi and Anshumali 2019)

Table 1: Standard Methods of Morphometric Parameters

Morphometric Parameter	**Symbol**	**Formula**	**Reference**
		Linear Parameters	
Stream Order	U	Heirarchical rank	Strahler (Munoth and Goyal, 2020)
Stream Number	NU	Nu=N1+ N2+....+ Nn	Horton (1945)
Stream Length	Lu (Km)	Length of the stream	Strahler (Jaiswal et al., 2015)
Mean Stream Length	Lsm (Km)	Lsm= Lu/Nu	Strahler (Jaiswal et al., 2015)
Stream Length Ratio	Lur	Lur= Lu/ (Lu-1)	Strahler (Jaiswal et al., 2015)
Birfucation Ratio	Rb	Rb= Nu/ Nu+1	Strahler (Jaiswal et al., 2015)
		Relief Parameters (Bdd)	
Minimum Elevation	(z)	GIS analysis / DEM	
Maximum Elevation	(Z)	GIS analysis / DEM	
Basin Relief	H(m)	H= Z-z	Strahler (Munoth and Goyal, 2020)
Relief Ratio	Rh (m)	Rhl= H/Lb	Schumm (Munoth and Goyal, 2020)
Relative Relief Ratio	R_r	R_r =H× 100/P	Schumm (Munoth and Goyal, 2020)
Ruggedness Number	R_n	$R_n = D_d \times (H/1000)$	Strahler (Munoth and Goyal, 2020)
		Areal Parameters(Bdd)	
Basin Area	A (Km^2)	GIS Analysis/DEM	
Perimeter	P	GIS Analysis/ DEM	
Basin Length	Lb (Km)	Lb = 1.312 $A^{0.568}$	Schumm (Munoth and Goyal, 2020)
Form Facror Ratio	F_f	$F_f = A/L_b^2$	Horton (Radwan et al., 2020)
Drainage Density	D_d	Dd=Lu/A	Horton (Radwan et al., 2020)
Draianage Texture	D_t	*Dt=Nu/P*	Horton (1945)
Circularity Ratio	R_c	$Rc=4\pi A/P^2$	Miller (MR et al., 2019)
Constant Channel Maintenance	C	*C=1/Dd*	Schumm (1956)
Elongation Ratio	R_e	$R_e = 2\sqrt{A/\pi}/L_b$	Schumm (Munoth and Goyal, 2020)
Length of Overland Flow	L_g	$L_g = 1/2D_d$	Horton (1945)

(Source: Adapted from Maddoli et al., 2021; Bharath et al., 2021)

RESULTS AND DISCUSSION

Basin Morphometry

The morphometric analysis of the drainage basin was computed through ArcGIS to obtain the morphometric parameters. The outcome of the morphometric investigation of the Yewa drainage basin is discussed under the three aspects of linear, areal and relief parameters.

Linear Aspect

Morphometric factors under this domain are the stream order, stream length, mean stream length, stream length ratio, and bifurcation ratio. The linear aspect map is indicated in Figure 3.

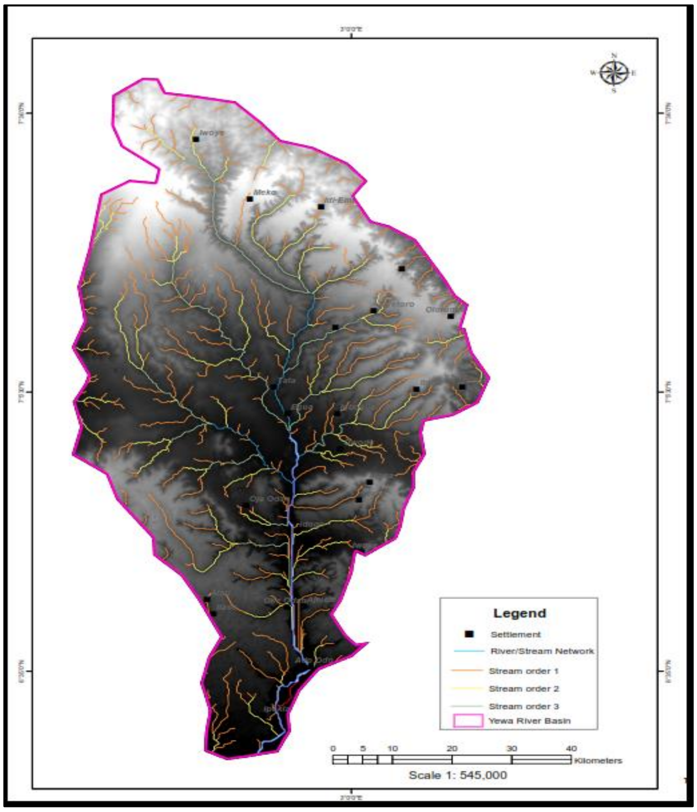

Figure 3: Linear Aspects Map
(Source: Author, 2023)

Table 2: Summary of Linear Aspects of the Study Area

Stream order(u)	Stream Number (Nu)	Stream Length (Lu) (km)	Mean Stream Length(Lsm)	Stream Length Ratio (Lur)	Bifurcation Ratio(Rb)
1st	118	625.3	5.29	-	-
2nd	69	313.3	4.54	0.86	1.7
3rd	30	105.1	3. 50	0.77	2.3
4th	14	76.5	5.46	1.56	2.1
Total	**231**	**1120.21**		**Ave=1.06**	**Ave Rb=2.03**

(Source: Author, 2023)

Stream Order (U)

The designation of stream orders is the first step in drainage analysis. In this study, it is observed that there is a decrease in stream frequency as the stream order increases. The trunk stream is the stream segment of the highest order. Based on Strahler (1952; 1964); Munoth and Goyal's (2020) system of stream order, the basin has been designated as a fourth-order basin (Fig.4). In this study, maximum stream order frequency is observed in the first-order stream (Table 2). Thus, a stream segment with no tributaries is a first-order stream; a second-order stream is formed by joining two first-order streams; where two second-order streams join, the stream is designated as third-order, and so forth.

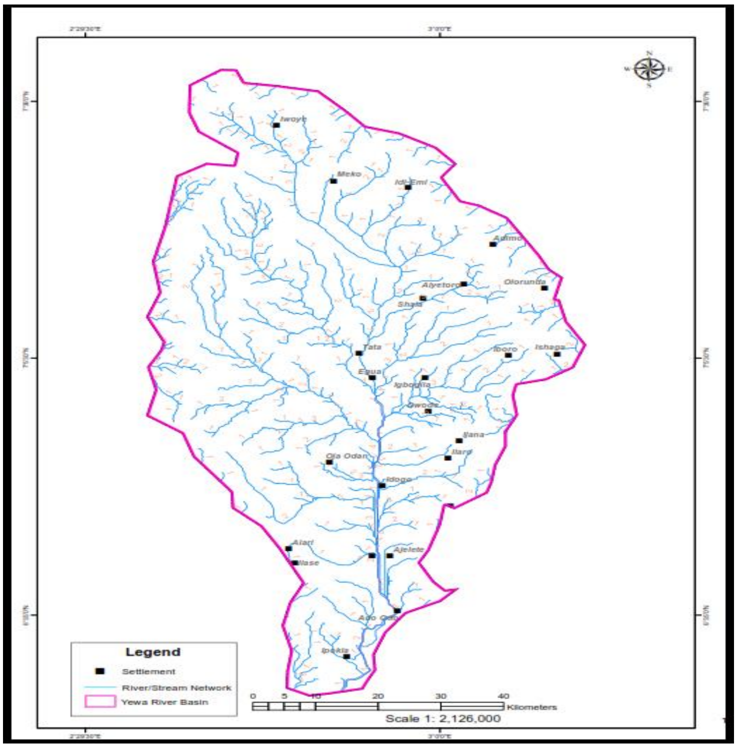

Figure 4: Stream Order
(Source: Author,2023)

Stream number

The stream segment is known as the stream number. Horton (1945) gave the law of stream numbers, which states that the number of stream segments of successively lower orders in a given basin tends to form a geometric series beginning with the single segment of the highest order and increasing according to a constant bifurcation ratio. The Yewa basin is a fourth-order stream, with 231 stream segments (Table 2), of which 118 are first-order streams, 69 are second-order, 30 are third-order, and 14 are fourth-order. According to Horton's principle, the number of streams is negatively correlated with the order, i.e. stream number decreases with an increase in stream order (Figure 5(a). A decrease in the number of stream segments with stream order is expected. According to Chow et al. (1988), when a channel of lower order joins a channel of higher order, the channel downstream sustains the highest of the two orders.

Stream number (Nu) here supports Horton's law, i.e. stream number decreases with an increase in stream order in this basin.

Stream Length (Lu)

Stream length represents an important hydrological feature as it reveals the characteristics of the surface runoff. The total lengths of the stream segment of each successive order is described by stream length based on Horton's law. The measurement of hydrological attributes of the bedrock and drainage extent is represented by stream length. The distribution of stream length varies widely with increasing order in the Yewa basin. The highest stream length (625.3km) is recorded for first order, followed by the second-order (313.2km), and third-order (105.09km) while the fourth-order (76.5km) is the lowest stream length (Table 2) .The stream length characteristics of the basin conform with Horton's (1945) second "law of stream length," which state that the average length of streams of each order in a drainage basin tends closely to approximate a direct geometric ratio. In general, the total length of stream segments decreases with increasing stream order (Figure 5(b). There exists an indirect relationship between the stream lengths and stream order and between the stream order and stream numbers, as indicated in (Figure 5c). This is in conformity with the general stream order rule (Strahler & Strahler, 2002; Adeaga, 2011), which emphasises that the number of stream segments decreases as the order increases.

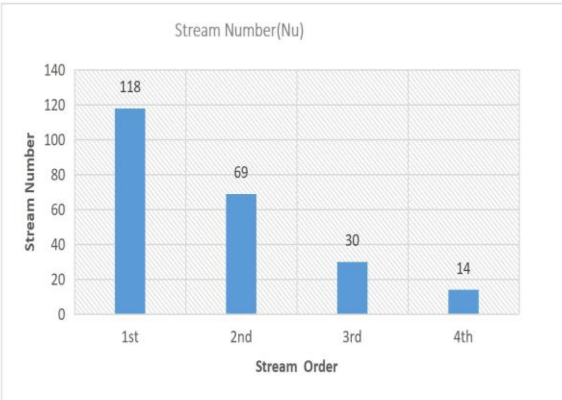

Figure 5a

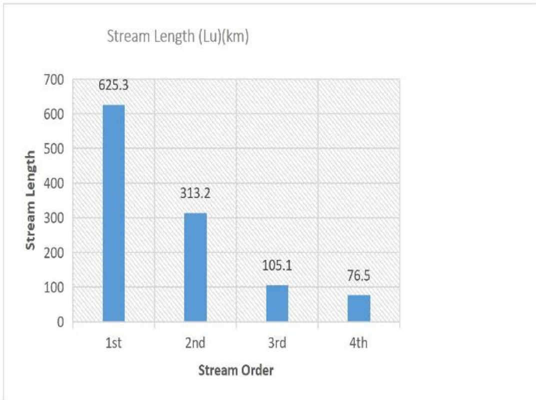

Figure 5b

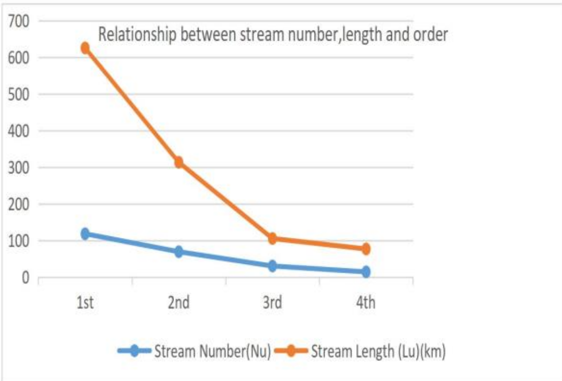

Figure 5c

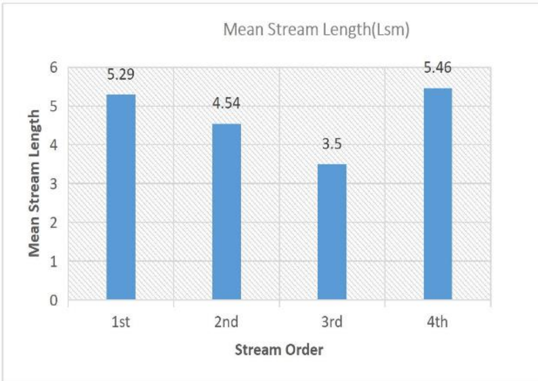

Figure 5d

Figure 5 a. Stream Order and Number b. Stream Length c. Relationship between Stream number, length and order in the Basin d. Mean Stream Length (Source: Author 2023).

The study reveals that the cumulative length of the stream segment is maximum in the first order. However, the difference is due to variants in relief and morphology. Thus stream segments of the first and second order are defined by steep to moderate slopes, while the third and fourth order stream segments occur in comparatively plain lands.

According to Sethupathi et al. (2011), wherever the bedrock and formation are permeable, only a small number of relatively longer streams are formed in a well-drained watershed, and a large number of streams of smaller length are developed where the bedrocks and formations are less permeable.

Mean stream length

Based on Strahler, (1964) and Munoth and Goyal (2020), the stream length is a distinctive property connected to the drainage system components and its related basins. The mean stream length of the basin (Table 2) highlights the distinctive size of the components of a drainage system and its tributary surfaces. The mean stream length of study area are 5.3 for the first order, 4.54 for the second-order, 3.5 for the third-order, and 5.47 for the fourth-order, respectively. Generally, the mean length of the stream segment of the Yewa drainage basin is maximum in the first order and decreases the length in the second and third order, respectively, but with an increase in the fourth order stream (Figure (5d). Deviation from its general linear behavior indicates that the terrain is characterised by variation in lithology and topography. This is an indication that the geological structures fairly disturb the drainage pattern According to Singh, (1980) and Singh and Singh (2020), the nonconformity from its general behaviour shows that the topography is characterised by low relief or moderate steep slope underlain by variable lithology and possible elevate across the river basin. The result conforms with Nisha, et al. (2016) study on morphometric analysis in basaltic Terrain of Central India using GIS techniques: a case study of Nagpur district, Maharashtra, Central India.

Stream length ratio

The ratio between the mean stream length of one order with that of the next lower order stream segments is termed stream length ratio. The calculated stream length ratio of the basin falls within the range of 0 to 1.56, with the fourth-order stream having a higher value of 1.56, as indicated in Table 2. This occurrence may be attributed to the variance in gradient and configuration, signalling the late youth stage of the geomorphic evolution of the study area streams (Vittala, 2004). The law of stream length by Horton (1945) characterised the means stream length of stream segments in a successive order of a basin such that the first stream, i.e. stream length, is the mean length of the segment of the first order. The stream length ratio between the streams does not precede any pattern in the study area. The variation in stream length ratio is a sign of differences between slope and topography; hence, it has an important control on discharge and different erosion stages of the drainage basin (Sreedevi et al., 2005).

Bifurcation ratio

The Bifurcation Ratio is the proportion of the total number of streams of a specified order to the total number of streams of the subsequent higher order (Jaiswal et al., 2015). It is indeed a dimensionless property that indicates the level of convergence among rivers of different stream orders in a watershed (Bharath et al., 2021). In addition, it is the basic parameter to explain the stream patterns of the basin, as the patterns are highly linked with the watershed topology and climate conditions. The bifurcation ratio of Yewa drainage basin varies from 1.7 to 2.3, as shown in Table 2. The mean bifurcation ratio is calculated as 2.03, which falls under the normal basin category; as expected, the number of segments of each order formed an inverse geometric sequence with the order number. The relatively low mean ratio depicts a relatively large range of variation for different regions or different environment dominates. This is an indication that the geological structures fairly disturb the drainage pattern. This is in conformity with the study of (Adeaga, 2011; Udozen et al.,2021) on morphometric analysis of lower enyong creek, southeastern Nigeria. The lower values of the bifurcation ratio are characteristics of the watersheds which have suffered fewer structural disturbances.

Table 3: Summary of Relief and Area Aspects of the Study Area

Parameter	**Symbol**	**Unit**	**Value**
Relief Aspects of the Study Area			
Highest Elevation	Z	m a.s.l.	1640.4
Lowest Elevation	z	m a.s.l.	82.02
Basin Relief	H	m	1558.4
Relief Ratio	Rh	-	10.85
Relative Ratio	Rr	-	0.045
Ruggedness Number	Rn	-	0.389
Areal Aspects of the Study Area			
Basin Length	Lb	km	143.61
Basin Area	A	Km^2	4382.4
Perimeter	P	km	346.6
Form Factor	Ff	-	0.24
Drainage Density	Dd	Km^2	0.256
Drainage Texture	Dt	km	0.667
Circulatory Ratio	Rc	-	0.458
Elongation Ratio	Re	-	0.566
Constant of Channel Maintenance	Cm	km	0.391
Length of Overland Flow	Lg	km	7.82

Source: Author 2023

Length of the Basin (Lb)

According to Schumm (1956), the length of the basin is the distance between the most remote part of the basin and its mouth. Also, according to Gardiner, (1990), the basin length is the distance between a basin mouth and a position on the periphery that seems to be equally distant from the basin outlet in all locations throughout the perimeter. It indicates the main channel where the highest runoff quantity occurs. The length of the basin of the Yewa drainage basin is 143.614 km, as indicated in Table 3. The implication of this is that it will take a drop of water and a long travel time to move from the remote part of the basin to its mouth. The basin's length is used in computing a time parameter, which measures the travel time of water through a basin. Consequently, this reflects how long it takes runoff to reach the discharge point at the basin. Therefore, longer distances and long travel times.

Basin Area (A)

A basin area is a specific area where precipitation is collected and drained to a final outlet. It directly influences the runoff volume from a watershed. Schumm (1956) established an interesting relation between the total basin areas and the total stream lengths, which are supported by the surface area where runoff drains. Also, the basin area is highly correlated with other basin parameters. The basin area of the Yewa basin is computed as 4382.4 km^2 by ArcGIS-10.3 software, as indicated in Table 3. The basin area is hydrologically important because it directly affects the size of the storm hydrograph and the magnitudes of peak and mean runoff. It is interesting that the maximum flood discharge per unit area is inversely related to the size of the catchment (Chorley, et al., 1957).

Perimeter (P)

The perimeter of a basin is defined as the entire stretch of its boundaries. It resembles the shape and size of the drainage basin. The elongation ratio and circulatory ratio are two parameters that are influenced by the basin perimeter. The perimeter of the Yewa drainage basin is calculated as 346.6 km as highlighted in Table 3.

Relief parameters

Basin relief, relief ratio, and relative relief and ruggedness number are some of the morphological factors under this sphere. Relief is the point of reference of the energy head from which expected energy can be ascertained (Pike, Evans and Hengl, 2009).

Basin relief (Bh)

According to Bharath et al. (2021), basin relief is mathematically characterised as the difference between the highest and lowest elevation of the basin. It greatly affects the slope of the basin and impacts the soil erosion susceptibility. Thus, the run-off and sediment transport rates also depend on it. The low value of basin relief indicates low run-off, low sediment transport, and the spreading of water within the basin. The basin's highest relief is 1,640.4m a.s.l., and the lowest relief is 82.02 m a.s.l. Basin relief is one of the important factors in understanding the geomorphic processes involved and landform characteristics. The total basin relief of the drainage basin is 1558.38m as highlighted in Table 3. This depicts a tendency towards extensive floodplain and wetland formation, most especially in the lower portion of the basin. It has been noticed that there exists a positive correlation between relief and drainage frequency in the basin (Figure 6). According to Girish et al. (2016), high relief tends to improve the inundation prime of the drainage system. Basin relief is an important factor in understanding the denudational characteristics of the basin (Sreedevi et al., 2004).

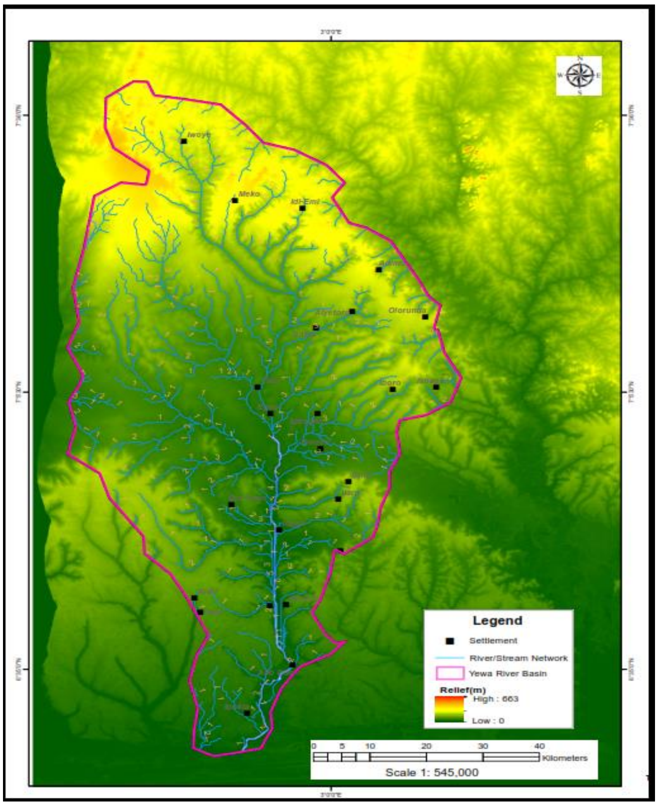

Figure 6. Basin Relief Characteristic Map.
(Source: Author 2023)

Relief Ratio (Rh)

The relief ratio is defined as the proportion of basin relief to the length of the basin (Bharath, et al., 20211). The relief ratio gives a better picture of relief aspects than compared to total relief. The relief ratio is the indicator of the erosion rate corresponding to the basin slope (Schumm 1956, Strahler, 1964). Relief controls the rate of conversion of potential to the kinetic energy of water draining through the basin. The loss of sediment per unit of area is closely correlated with the relief ratio. The relief ratio is directly proportional to the surface run-off and intensity of erosion (Schumm 1956). The value of the Relief ratio in the basin is 10.85, as highlighted in Table 3, indicating moderate relief and moderate slope. According to Patton (1988), the high values of the relief ratio indicate a steep slope and high relief and vice-versa. More so, relief ratio values (>0.20) indicate the presence of areas of steeper slope and higher relief underlain by resistant rocks (Vittala, et al., 2004). The relief ratio is an important morphometric variable used for the overall assessment of morphologic characteristics of terrain. Run-off is generally faster in steeper basins, producing more peak discharges and greater erosive power.

Relative relief (Rr)

Relative relief is defined as the proportion of basin relief to the basin's perimeter (Munoth and Goyal, 2020). Relative relief is the ratio of the peak basin relief to the perimeter of the basin. The relative relief of the Yewa drainage basin is calculated as 0.045, as highlighted in Table 3. This low relative relief ratio values are characteristic features of less resistant rocks. Thus, the elevation varies from 1640.40m to 82.02m, indicating that the land has a gentle to moderate slope.

Ruggedness number (Rn)
Ruggedness number is the product of basin relief and drainage density (Strahler,1964, Bharath, et al., 2021). The ruggedness number is a dimensionless number that expresses the geometric characteristics of the drainage system. It indicates the structural complexity of the terrain in association with relief and drainage density (Ozdemir, et al., 2009). It is a measure of surface unevenness (Selvan, Ahmad, and Rashid, 2011). Higher the value of the ruggedness number, the more rugged will be the topography and vice-versa (Strahler, 1956). The susceptibility of the area to soil erosion can also be deduced from this number (Rashid et al., 2017).The value of ruggedness number in the Yewa drainage basin is 0.398 (Table 3) which indicates the basin is prone to soil erosion.

Areal Parameters
Drainage density, stream frequency, texture ratio, form factor, circulatory ratio, elongation ratio, length of overland flow and constant channel maintenance parameters are grouped under areal parameters.

Drainage Density (Dd)
Drainage density is defined as the total length of streams of all orders per drainage area (Horton, 1945). Drainage density potentially affects both time of concentration and the magnitude of the flow. It enlarges the existing channel closeness in a basin. Drainage density provides a duodecimal measure of the travel time of water in the whole basin (Horton, 1945). The calculated drainage density value of the Yewa drainage basin is 0.256 $km^{-1,}$ as highlighted in Table 3 and indicated by the drainage density map in Figure 7. Generally, lower values of drainage density also tend to occur in granite, gneiss and schist regions. The chief rock type in the drainage basin is basement complex rock (Granite formation) which falls under the gneissic group of rocks.

The value is much less than the standard value of $0.65km^{-1}$. The basin, therefore, has a highly permeable subsoil and thick vegetative cover with low relief. Low drainage density leads to coarse drainage texture, as depicted by a low Texture ratio of 0.667km Hence, flow within the basin has a tendency towards a delayed time of concentration. Such difficulty might be due to the discrepancies in the rate at which flow is being funneled into the few available stream segments. The result is a low tendency towards evenly distributed runoff and rapid runoff into the secondary and tertiary streams. High drainage density implies an increase in flood peaks, whereas there is a decrease in flood levels in low drainage density (Pallard et al., 2009). Generally, drainage density and flood volume have a direct relation. Low drainage density mostly results in areas of highly impervious or permeable sub-soil material, dense vegetation and low relief.

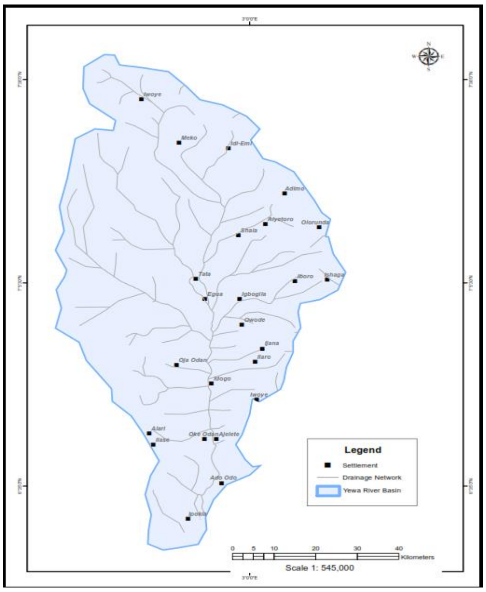

Figure 7. Drainage Network Map of Yewa Basin
(Source: Author, 2023)

Drainage texture/ texture ratio (Dt)
Drainage texture is the ratio of the total number of stream segments of all orders in a river basin to the perimeter of the basin (Rai et al.,2017). The categorisation of this drainage character is the same as the classification of drainage density (Vittala, et al., 2004; Abboud and Nofal, 2017). It is considered as the number of streams of basin present per perimeter of that area (Horton, 1945). The calculated drainage texture of the basin is 0.667km, as indicated in Table 3. Thus, the basin depicts a coarse texture in nature, which indicates the study area is less prone to soil erosion. Drainage texture is an important factor in the drainage morphometric analysis which depends on the underlying lithology, infiltration capacity, and relief aspect of the terrain (Schumm, 1956). Texture ratio is the most significant influencing factor in the drainage morphometric analysis, which depends on the underlying lithology, infiltration capacity and relief aspect of the terrain. It deals with the study of the relative spacing of drainage lines.

Form Factor (F_f)
The form factor is the ratio of the basin area to the square of the basin length (Horton 1932). The form factor value of a perfectly circular basin is usually less than 0.7854 (Chopra et al., 2005). A basin is elongated if the value is smaller than this. Strahler (1964) noted that the shape of a drainage basin may conceivably affect stream discharge characteristics. Long narrow basins with high bifurcations would be expected to have attenuated flood discharge periods, whereas rounded basins with low bifurcation ratios would be expected to have sharply peaked flood discharges. The form factor value of the Yewa drainage basin is 0.243. (Table 3). This indicates a lower value of the form factor represents the elongated shape and has attenuated discharge periods. According to Udozen et. al., (2021), The elongated basin with a low form factor indicates that the basin will have a flatter peak of flow for a longer duration. Thus, flood flows of such elongated basins are easier to manage than those of circular basins.

Circulatory Ratio (Rc)

The circulatory ratio is the proportion of watershed area to the area of a circle which has the same circumference as that of the basin perimeter (MR et al., 2019). The circulatory ratio is an important, dimensionless morphometric parameter indicating a basin's stages (Miller,1953). The Circulatory ratio values can attain a maximum of 1.0 where the outline of the basin is approaching near circularity (Miller 1953). The calculated circulatory ratio of the Yewa drainage basin is 0.46 as shown in Table 3, and it indicates an elongated shape. The obtained circulatory ratio has been influenced by the length and frequency of the streams, geologic structures, land use/ land cover, climate, relief and slope of the basin. Values of circulatory ratio help to identify the stage of watershed development, i.e., the lower value represents the younger stage, medium values represent the mature stage, and higher values represent the older stage of a watershed.

Elongation Ratio (Re)

The elongation ratio is the quantitative relation between the diameter of the circle with the comparable area and the maximum length of the basin (Schumm, I956). This indicates the shape of a basin. The ratio range between 0.6 and 1.0 and can be obtained across variety of climatic and geologic types. Nevertheless, it is the quantitative relation between the diameters of the circle of the same area and that of the drainage basin. Runoff discharge is more efficient in a circular basin than elongated one (Singh and Singh, 1997).

According to Strahler (1964), the elongation ratio determines the shape of the basin and can be classified based on these values; circular (0.9-1), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7), more elongated (< 0.5). Values near 1.0 are typical of regions of very low relief. The Yewa drainage basin has an elongated ratio of 0.566, indicating an elongated basin with low relief (Table 3). Elongated drainage basins have low side flow for a shorter duration and high main flow for a longer duration and are less susceptible to flood hazards (Oruonye et al., 2016). The elongation ratio is the proportion of the diameter of a circle whose area is the same as that of the watershed to the basin length (Munoth and Goyal, 2020). If the values are higher, it indicates the watershed is less elongated and vice-versa. Mustafa and Yusuf (1999) have noted that the flow of water in elongated basins is distributed over a longer period than in circular ones. This will influence the rate of runoff in the basin and possibly reduce the chance of flash flood occurrence in the basin. Further, the lower peak with longer duration as a result of the elongation ratios will possibly increase the infiltration rate, which, however, depends on other factors within the basin.

The Constant of Channel Maintenance (Cm)

The constant of Channel Maintenance is defined as the reciprocal drainage density (Munoth and Goyal, 2020). The constant of channel maintenance gives a quantitative expression of the base limiting territory required for the improvement of the length of the channel. It characterises the drainage area essential to maintain a unit length of the channel (Rekha et al., 2011, Rahaman et al., 2015), and it is affected by relief, geological and climatic parameters. It does not only depend on rock type permeability, lithology, climatic regime, vegetation cover, and relief but also on the duration of erosion and climatic history. The constant channel maintenance value of the Yewa drainage basin is 0.391km, as indicated in Table 3. Generally, the higher the C values of the basin, the higher the permeability of the rocks and vice versa (Shiubha, 2009, Wande and Rank, 2013; Rahaman et al., 2015). This invariably determines basin erodibility. Therefore, the Constant of channel maintenance that is higher than (>0.5km^2 /km) indicates the least erodible capacity and vice versa.

Length of Overland Flow

The length of overland flow is defined as the length of water flow over the ground before it gets concentrated into definite stream channels, and this is equivalent to half of the drainage density (Horton, 1945). The length of overland flow connects reciprocally to the average channel slope. It is significantly affected by infiltration (exfiltration) and percolation through the soil, both varying in time and space (Schmid,1997). The calculated length of overland flow of the Yewa drainage basin is 7.82km as shown in Table 3. It is the main individual parameter affecting a watershed's geographical and hydrological evolution. The high Length of the overland flow value indicates that the rainwater had to travel a relatively long distance before getting concentrated into stream channels (Chitra et al., 2011). This is a measure of the erodibility and the independent variable affecting both the hydrologic and physiographic development of the drainage basin. On the contrary, the shorter the length of overland flow, the faster the surface runoff from the streams.

CONCLUSION AND RECOMMENDATIONS

This study of the Yewa drainage basin reveals that the ArcGIS-based approach is a precious instrument for investigating various morphometric factors. Also, it is more appropriate and time-saving compared to the conventional methods. Morphometric parameters were analysed through linear, areal and relief aspects of the Yewa drainage basin, and it was revealed that the drainage network of the basin displays a dendritic pattern, which is an indication of uniformity of texture and this largely depends on the topography and geology of the land. The bifurcation ratio and drainage density show that the Yewa drainage basin is a normal basin with moderate permeable soil and coarse drainage texture. Further, the findings reveal that the Yewa drainage basin has a drainage density of 0.256 km$^{-1,}$ which indicates that the basin is less affected by geomorphologic and geological disturbances. These findings show that the soil is coarse textured. The form factor, circularity ratio and elongated ratio reveal that the basin shape is elongated with lesser relief, and the slope is characterised by a moderate relief ratio value. However, the variation in vegetation coverage, rock and soil types highlights the ecological importance of the basin area, which comprises several plant and animal species and their relation with physical surroundings. Thus, evaluation of the morphometric analysis of the basin using GIS and remote sensing helped us to understand terrain parameters such as infiltration capacity, runoff, lithology and relief which affect the hydrological process of the basin. The study indeed indicated certain relationships among several attributes of the morphometric aspects, and the developed morphometric factors would be of vast usefulness in river basin assessment and precedence for soil and water conservation and sustainable management of natural resources at the micro level. Specifically, this would immensely serve as a basis for water resource development and management.

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