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QUANTITATIVE MORPHOMETRIC ANALYSIS OF STREAMS IN EXTREME HUMID AREAS A CASE STUDY OF THE UM-MAWIONG RIVER BASIN, MAWSYNRAM, MEGHALAYA

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Abstract
Quantitative morphometric analysis of the drainage system is essential to characterising a watershed, as all the hydrologic and geomorphic processes occur within the river basin or watershed. Consequently, this plays a crucial role in understanding the hydrological attributes of a drainage basin to the terrain feature and its flow patterns, thus enabling the estimate of the incidence of infiltration and runoff and other related hydrological characteristics of a watershed, which strongly impacts soil and water resource conservation. The study area selected is the Um-Mawiong River basin in Mawsynram, Meghalaya. The basin shows a dendritic pattern that highlights the homogeneity in the texture of the bedrock that significantly influence the pattern of the stream network. Results suggest that the stream frequency of the basin is 19.10 km^2, suggesting a faster surface runoff and less infiltration. In addition, it has an Elongation ratio of 0.75, indicating an elongated basin shape. The current study demonstrates that the implementations of G.I.S. techniques are trustworthy, efficient, and capable of managing extensive databases for managing river basins. The present study tries to analyse the basin's linear, areal, and relief aspects using a G.I.S. environment and manipulated for different calculations. The analysis reveals that the total number of stream segments and length are maximum in first-order streams and decrease as stream order increases. The drainage density exhibits a high degree of positive correlation, i.e., 0.87, with its frequency suggesting an increase in stream population concerning increasing drainage density and vice versa.

Keywords: morphometric analysis, G.I.S., remote sensing, river basin, river morphology, extreme humid areas, Meghalaya

1. Introduction

According to Strahler (1969), morphometry measures the shape or geometry of any natural form, including those of plants, animals, and terrain features. Conversely, morphology depicts the quantification and mathematical investigation of the configuration of the earth's surface and the shape and aspects of its landforms (Agarwal, 1998 & Reddy et al., 2002). The stream profile analysis and the stream gradient index proved significant in the quantitative and scientific description of drainage basins (Hack, 1973). Rai and Syiemlieh (1999) pointed out that the study of the drainage characteristics reveals that the rocks' structure plays an essential role in the evolution of drainage and controls both on granite and gneisses, having a pertinent effect on drainage development. Streams are dynamic landforms subject to rapid channel shape, size, and flow pattern changes.

Morphometric analysis of drainage basins is a crucial area of interest. It helps assess the groundwater potentiality of a drainage basin and enables the locating of favorable sites to construct reservoirs (Sreedevi et al., 2005; Avinash et al., 2011; Mishra et al., 2011; Jasmin & Mallikarjuna, 2013). Several studies suggest that the morphometric properties of the river basin are good indicators influencing the drainage development and neo-tectonic activity operating in the area (Nag & Chakraborty, 2003; Das et al., 2011; Bali et al., 2011; Demoulin, 2011).

In their recent studies on the directional analysis of drainage networks and morphotectonic features, Pecsmány et al., (2021) found that the results from the assessment of the direction of the valleys, joint set strikes, and lineaments suggest that the formation of the drainage network in the south-eastern part of Bükk Region significantly influences the structural evolution.

Analysing the morphometric parameters of any drainage basin provides valuable insight into revealing the hydro-morphological attributes and comprehending the current geologic variations, topographic data, and structural setup of any river basin (Sherin & K.S.A., 2022). Similarly, an area's geological and tectonic settings can be examined with the analysis of the drainage network, which played a decisive role in the evolution of the drainage network (Vágó, 2010).

Rao et al. (2009) stated that the attainment of the state of dynamic equilibrium is possible due to the interaction between matter and energy. Further, an in-depth Geographical Information System (G.I.S.) and Remote Sensing analysis was conducted to assess the geo-hydrological attributes of the four sub-watersheds of Agra district, Uttar Pradesh.

Tamma Rao et al. (2012), in their paper, emphasized that G.I.S. and Remote Sensing are significant techniques for updating the drainage surface water bodies and evaluating the morphometric parameters of the two sub-watersheds of West Godavari district, Andhra Pradesh. Further, an attempt was made to highlight the morphometric analysis of the two sub-watersheds of the West Godavari district under different physiographic conditions.

The advent of G.I.S. techniques and remote sensing in morphometric analysis has become more accurate with outstanding results (Williams, 1972; Mesa, 2006; Lyew-Ayee et al., 2007; Altin & Altin, 2011; Buccolini et al., 2012). The above techniques have become an effective tool that has overcome the problems of water resource planning and management. The main objective of this research is to highlight the morphometric analysis of the Um-Mawiong River basin. Quantitative morphometric analysis provides a basis for implementing water management strategies.

Quantitative morphometric analysis is a suitable method to describe the relationship between different drainage parameters of the same basin, and the simulation of the hydrological nature of various drainage basins is necessary by conducting a correlation study of the morphological and hydrological characteristics of the basin. The analysis of the drainage system and the evaluation of its characteristics can only be understood through morphometric analysis, as it produces the essential hydrogeological information of the area. (Salunke & Wayal, 2021). Therefore, the primary goal of this research is to access, describe, and evaluate the linear, areal, and relief attributes using data retrieved from the Survey of India (S.O.I.) toposheets using G.I.S. techniques in the Um-Mawiong River basin of Mawsynram, Meghalaya.

2. Regional Setting

The area chosen for this research is a river basin locally known as Um-Mawiong located in Mawsynram, which stands on the southern slope of the Meghalaya plateau, facing the Bangladesh plain. The region experiences a subtropical monsoonal climate with a humid rainy season from June to September and a dry and cold season from November to May. The mean annual temperature is closely related to elevation and varies from 24 °C in the foothills to 16 °C at the highest elevations. The southern escarpment of the Meghalaya Plateau firmly controls the annual rainfall distribution pattern, and about 80 percent of the yearly precipitation occurs between June and September (Ryntathiang, 2014).

The Um-Mawiong River basin extends from 91.95 to 92.0 east longitude and 25.416667 to 25.53333333 north latitude (Fig. 1) and falls under the jurisdiction of the Mawsynram (C&RD) Block. The area experiences an extreme humid climate with a distinct wet season (Lyngdoh & Ryntathiang, 2023); it is famous for receiving the second-highest rainfall in the world after Cherrapunjee, amounting to an average of 12,500 mm annually, resulting in a strong, fluvially dominated landform. The Umngi Valley surrounds the study area from the north and west and the Bangladesh Plains in the south and east. Further, it is separated from the Cherrapunjee platform by the Umiew River valley.

The study area is significantly dominated by a limestone belt in an east-west trending low ridge with karst topography. The soft kopilli sandstone and shales form low hills through which multiple north-south flowing streams pass (Panda, 1983). The various geological units were demarcated and delineated based on the geological

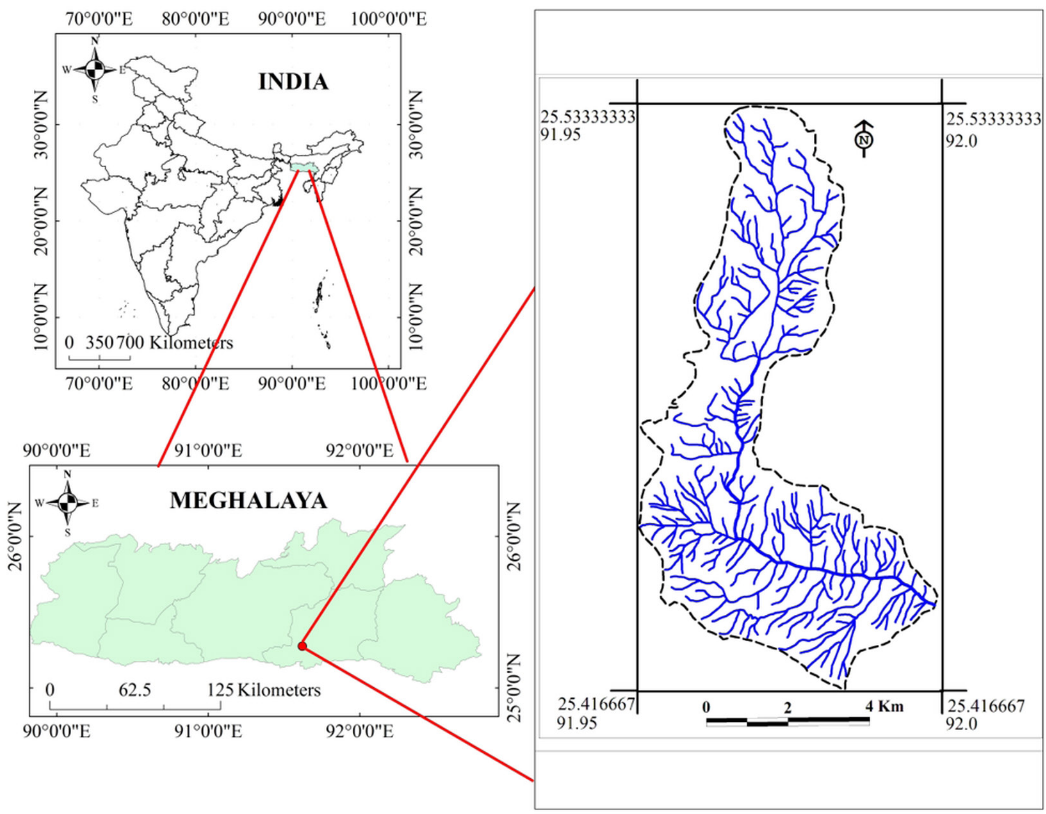

Fig. 1. Location of the Study Area

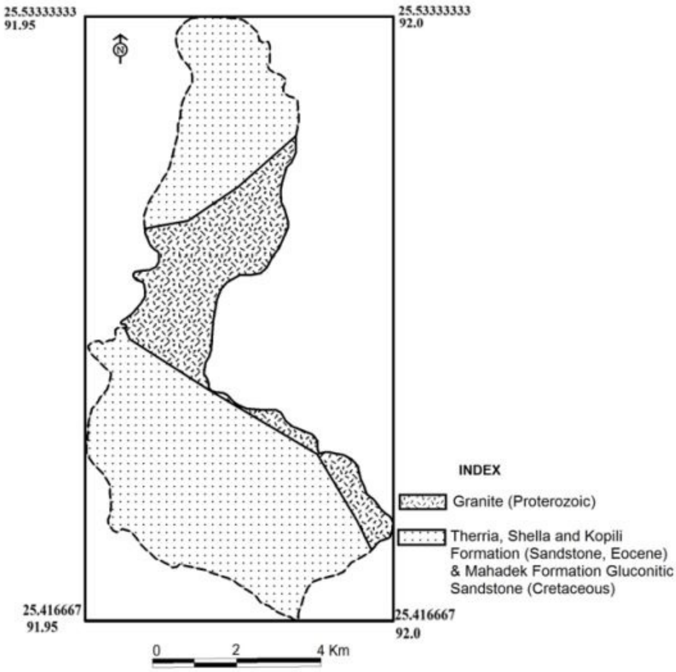

Fig. 2. Geological Map of the Study Area

map retrieved from the Geological Survey of India. Based on geology, the study area is divided into two units (Fig. 2). The sandstone formations (Therria, Shella, and Kopilli formations) cover the majority of the basin (10.77 km^2), indicating that the river basin has considerable porosity. However, the granite complex (3.68 km^2) indicates limited erosion. On the other hand, the river basin is distinguished by a moderate topography that reflects the ruggedness of the basin, with steep slopes ranging between 30.96° and 45°.

The predominant lineaments, approximately 64 percent in the study area, are aligned in the NE-SW direction, with only 36 percent oriented in the NW-SE direction (Fig. 3). The NE-SW lineaments are significantly concentrated in the upper part of the basin. In contrast, the NW-SE lineaments are concentrated in the lower part, indicating the effect of the large fault in the south. Rivers and streams also align with these lineaments to a large extent. Consequently, the study area diverse geology and topography dominated by numerous residual hills present various landform features (Ryntathiang, 2014).

3. Materials and Methods

The quantitative morphometric parameters of the Um-Mawiong River basin were identified via topographic maps obtained from the Survey of India bearing the Toposheet No: 78 0/11/SW with an R: F 1:25, 000 and a contour interval of 20 meters.

Secondly, a scanned image of the topographical map where the Um-Mawiong River basin is located is retrieved and georeferenced with the help of MapInfo G.I.S. software 8.5. Further, the base, lineament, and drainage maps of the river basin were digitized, extracted, and prepared from the scanned topographical map. Similarly, with the help of MapInfo G.I.S. software 8.5, a stream network map was also created by digitizing the stream network within the basin area.

Thirdly, using MapInfo G.I.S. software 8.5, each contour line and its values were digitized and entered, and, with the help of the interpolation method, a digital elevation model (D.E.M.) of the Um-Mawiong River

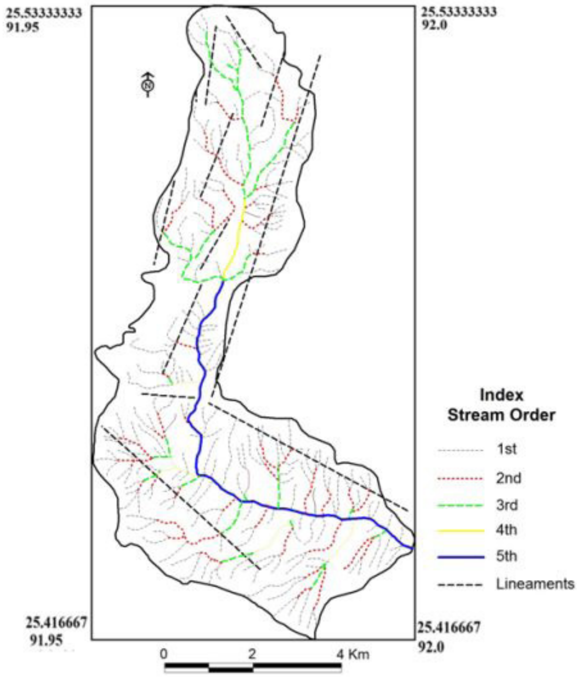

Fig. 3. Lineament of the Study Area

basin was created, enabling better insight into morphometric studies of drainage basins.

Finally, the quantitative morphometric analysis was performed with MapInfo 8.5 GIS software to find out the parameters such as stream order, stream length, basin length, drainage density, stream frequency, texture ratio, bifurcation ratio, form factor, circularity ratio, constant channel maintenance, constant elongation and ruggedness ratio, etc., of the river basin. Further, the drainage map and the digital elevation model of the Um-Mawiong River basin are illustrated (Fig. 4 and Fig. 5).

Finally, for the delineated river basin, the formula for calculating the various quantitative morphometric parameters is retrieved from the formula suggested by Horton (1945), Miller (1953), Strahler (1957), Schumn (1956), and Nookaratnam (2005), as shown in Table 1.

4. Results and Discussions

The analysis of the quantitative morphometric parameters of the catchment area provides significant information about the geological and geographical conditions. The drainage map (Fig. 4) indicates water availability in the basin, and the digital elevation model (Fig. 5) calculates the basin's slope. A combination of quantitative morphological and hydrological parameters defines the nature of the basin in the present study. The quantitative morphometric analysis of the river basin using a G.I.S. environment to find linear, areal, and relief aspects proves significant, giving accurate and desirable results. The result reveals that the basin's total area is 14.45 km^2, and the perimeter is 23.07 km. The maximum length of the basin is 5.66 km for the study area. The computed result of the detailed characteristics of the Um-Mawiong River basin is shown in Table 1. Further, the various quantitative morphometric parameters of the Um-Mawiong River basin are identified and highlighted below:

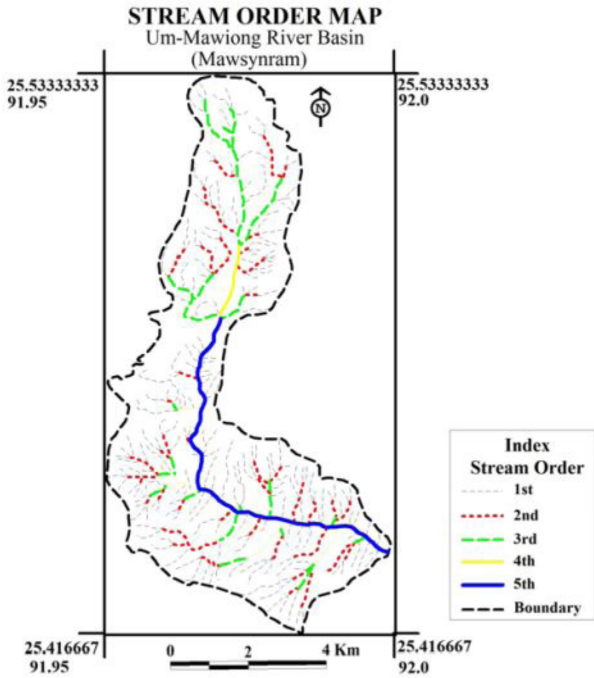

Fig. 4. Drainage / Stream Order Map

Linear Aspects

The Um-Mawiong River originates from around Rangsohkham Village. It is a swift-flowing river that flows in a southerly direction as the area's slope faces southward and joins the Surma Valley of Bangladesh. This swift-flowing river which forms many rapids, waterfalls, deep gorges, potholes, caves etc (Ryntathiang, 2014). The following paragraph highlights and analyses the various morphometric parameters identified. The values of these parameters (Table 2) are recorded and obtained as per methods proposed by researchers in the study area.

Stream Numbers and Stream Order (Nu)

Stream numbers refer to the number of stream segments in each order or to the precise relationship between basin orders and stream numbers. According to Horton (1945), the number of stream segments of gradually lower orders in a particular basin tends to form various geometric series, beginning with the single highest-order

Table 1. Detail characteristics of the Um-Mawiong River Basin

Stream Order	No of Stream	Stream Length (km)	Average stream length	Area (%)	Area (Km)	Drainage Density (Dd)	Drainage / Stream Frequency (Fs)
1	202	57.8	0.29	62.82	9.08	4.00	13.98
2	48	16.5	0.34	17.9	2.59	1.14	3.32
3	19	8.5	0.45	9.2	1.33	0.59	1.31
4	6	3.6	0.6	3.88	0.56	0.25	0.42
5	1	5.7	5.7	6.2	0.90	0.39	0.07
Total	276	92.1	7.38	100	14.45	6.37	19.10

Table 2. Linear aspect parameters use for quantitative morphometric analysis of the Um-Mawiong River basin

Sl. No	Quantitative Morphometric Parameter	Formula	Units	Um-Mawiong River Basin
1.	Basin length (Lb)	Obtained from MapInfo 8.5 GIS Software	km	5.66
2.	Stream number (Nu)	Nu = N1 + N2 +...+ Nn	-	276
3.	Total Stream Length (Lu)	Lu = L1 + L2 + ...+Ln	km	92.1
4.	Mean Bifurcation ratio (Rbm)	Average of bifurcation ratios of all orders	-	4.13

segment and increasing according to a constant bifurcation ratio.

The results from the study reveal that the number of streams decreases as the stream order increases in the basin. A sum of 276 streams has been identified in the Um-Mawiong River basin, out of which 73.18 percent falls in the first order, 17.39 percent in the second order, 6.88 percent in the third order, 2.17 percent in the fourth order and 0.36 percent in the fifth-order stream. Further, a high percentage of first-order streams (more than 70 percent) denote structural cracks, primarily as the river

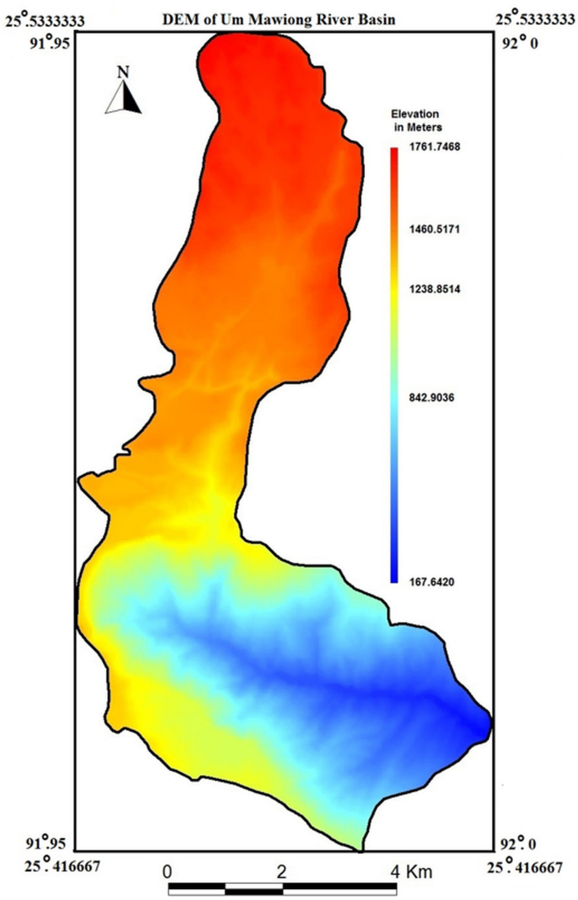

Fig. 5. DEM of Um-Mawiong River Basin

Table 3. Calculated number of streams of the Um-Mawiong River Basin
(x = Stream Number; y = Log of Stream Number)

Stream Order	No of Stream segment	Stream Length (km)	x	y	Cumulative mean
1	202	57.8	1	2.31	62.82
2	48	16.5	2	1.68	74.36
3	19	8.5	3	1.28	83.56
4	6	3.6	4	0.78	87.133
5	1	5.7	5	0	92.802
Total	276	92.1	15	6.04	400.675

Table 4. Regression statistics of stream numbers and stream order and regression statistics of cumulative mean stream length and stream order of the Um-Mawiong River Basin

Regression Statistics	Stream Numbers and Stream Order	Cumulative Mean Stream Length and Stream Order
Multiple R	0.98	0.84
R Square	0.95	0.70
Adjusted R Square	0.94	0.60
Standard Error	0.39	1.00
Observations	5	5

basin's lineaments and fractures (Sherin & K.S.A., 2022), as depicted in Fig. 3.

Stream order gives an idea of its size and the approximate index of stream flow. The categorization of streams has been demonstrated to be a significant indicator of stream discharge, stream size, and drainage area (Strahler, 1957), and the stream order indicates the magnitude and estimated index of stream flow. Consequently, greater discharge is significantly influenced by higher stream order (Farhan et al., 2016; Umrikar, 2017). The Um-Mawiong River basin is a fifth-order basin with a dendritic pattern where the first and second-order streams dominate the river basin with 202 and 40 streams, respectively. The maximum number of streams in the first order indicates that the topography has matured (Singh & Awasthi, 2011). Further, the greater number of streams observed in the first-order stream in the Um-Mawiong River basin suggests a complex topography and the compactness of the bedrock lithology (Sherin & K.S. A., 2022).

It is clear from Table 3 that the computed value of stream numbers does not match the actual values of stream numbers. However, the deviations drop from lower to higher orders. The regression line plotted on the semi-log graph (Fig. 6 and Fig. 7) almost validates Horton's law of stream number as the value of the coefficient of correlation is 0.98. The percentage variance explained is 95 % in stream number and stream order, while the coefficient of correlation of the cumulative mean stream length and stream order is 0.84, and the percentage variance is 70 %, as shown in regression statistic Table 4.

Stream length

Stream indicates chronological developments of the stream segments, including interlude tectonic disturbances. According to Strahler (1964), the mean stream length reveals the characteristics and size of components of a drainage network, and it is a contributing surface.

Indicating that the watershed evolution follows erosion laws acting on geologic material with uniform weathering erosion features is the fact that the mean length of

Table 5. Stream length of the Um-Mawiong River basin

Stream Order	No of Stream	Stream length (km)	Percentage (%) of Stream length
1	202	57.8	62.75
2	48	16.5	17.9
3	19	8.5	9.22
4	6	3.6	3. 93
5	1	5.7	6.2
Total	276	92.1	100

Table 6. Bifurcation ratio of the Um-Mawiong River basin

Stream order	1st & 2nd Order	2nd & 3rd Order	3rd & 4th Order	4th & 5th Order
Bifurcation ratio	5.45	4.57	5	1.5

channel segments of a given order is higher than that of the next lower order but less than that of the next higher order (Nag & Chakraborty, 2003).

According to Waikar and Nilawar (2014), first-order stream length is often high and reduces as stream order rises. Small stream lengths imply steep slopes and fine texture, whereas high stream lengths represent smooth gradients. The first, second, and third-order streams are mainly found in the hilly terrain with longer stream lengths because they are appropriate for the steep slope. On the other hand, the fourth, fifth, and sixth-order streams are found in gentle and flat terrain characterized by lesser slopes (Sherin & K.S. A., 2022).

From Table 5, it is evident that the length of the first-order streams constitutes 62.75 % of the total stream length, with second-order (17.9 %), third-order (9.22 %), fourth-order (3.93 %) and fifth-order (6.2 %). The total percentage of the first and second-order stream length constitutes 80.65 % of the total percentage of the total stream length. The stream length results show that first-order streams are short and are found in the upstream area; similar observations are confirmed by Sherin & K.S.A. (2021) in the Thutapuzha watershed, suggesting that steep slopes and finer texture characterize the study area, whereas longer lengths of the stream are typically indicative of low gradients (Strahler, 1964).

The analysis reveals that the stream segment's total length is maximum in the first-order stream and decreases as the stream order increases. The law of stream length, as given by Horton (1945), states that the cumulative mean lengths of stream segments of successive higher-order increase in geometrical progression beginning with the mean length of the first-order segments with a constant length ratio.

Bifurcation ratio (Rb)

Schumm (1956) defined the bifurcation ratio (Rb) as the ratio of the total number of stream segments of a single order to that of the next higher order in a drainage basin; it is a dimensionless quantity that represents the degree of integration between streams of different orders in a drainage basin. Horton (1945) believed Rb to be a relief and dissection index.

Table 6 reveals that the Rb between consecutive orders is nearly consistent, ranging from 1.5 to 5.45 due to the catchment's similar geological and lithological development, with a mean Rb of 4.06. The highest bifurcation ratio between the first and fourth-order streams is 5.45, indicating the highest overland flow and discharge. Strahler (1964) and Srinivasa et al., (2004) stated that the higher values of the Rb show a strong structural control in the drainage pattern; conversely, lesser values

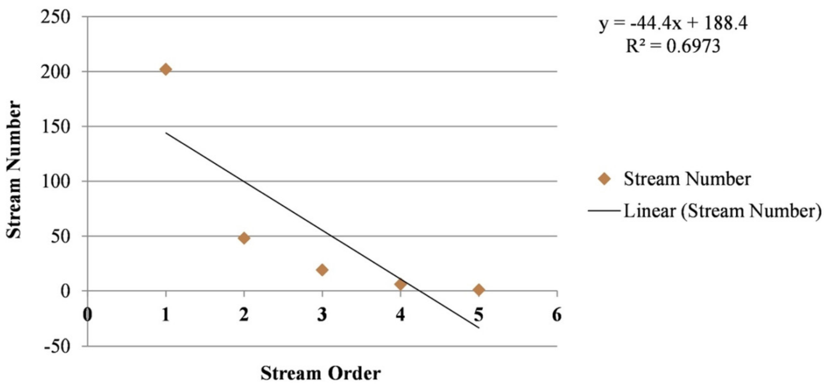

Fig. 6. Relationship between Stream Number and Stream Order

indicate that the watershed is insignificantly affected by structural disturbances. The mean bifurcation ratio (Rbm) for a given basin is 4.13, indicating that the structural disturbances do not affect the drainage pattern of the basin, which is comparable to the mountainous or highly dissected area (Horton, 1945; Sherin & K.S.A., 2021), as shown in Table 2.

Areal Aspects

Basin area

Basin area is the total area of the surface contributing to all the channels in the basin along with all the inter-basin areas. The area of a basin is determined from the adjacent basin by the drainage divide. The drainage divide is demarcated based on the extension of first-order streams, contour lines, and topographic features. The basin area of the Um Mawiong basin is 14.45 km^2, and the perimeter is 23.07 km.

Drainage Frequency or Stream Frequency (Fs):

Stream frequency or drainage frequency measures the number of streams per unit area. According to Horton (1932), stream frequency is the overall number of stream segments per unit area of orders. The occurrence of stream segments in any region depends on the structure of rocks, vegetational cover, amount of rainfall, and soil permeability. The result depicted in Table 1 suggests that the Fs is highest with 13.98 km in the first order and 0.07 km in the fifth order, which corresponds to the flat topography and small ridges with numerous tributaries and distributaries, resulting in an elongated drainage with the highest Fs. On the contrary, the poor Fs correspond to the rugged topography and steep barren slopes. The Fs of the Um-Mawiong River basin 19.10 km^2 as shown in Table 7.

Drainage Density (Dd)

Drainage density (Dd) refers to the total stream lengths per unit area. According to Chorley, 1969, Dd is a significant quantitative measure of the landscape dissection and runoff potential. Horton (1945) defines Dd as the ratio of the total length of all stream segments in a specific drainage basin to the basin's total area.

High drainage density denotes weak or impermeable material, sparse flora, and high relief (Hajam et al., 2013; Sherin & K.S.A., 2021). Table 1 shows the Dd is highest in the first stream order with 4 km and decreases with the increased stream order, exhibiting a high degree of positive correlation (.87). This shows an increase in stream population concerning increasing Dd and vice versa. In the present study, the Dd of the Um-Mawiong River basin is 6.37 km (Table 7), which belongs to high drainage density. High Dd in

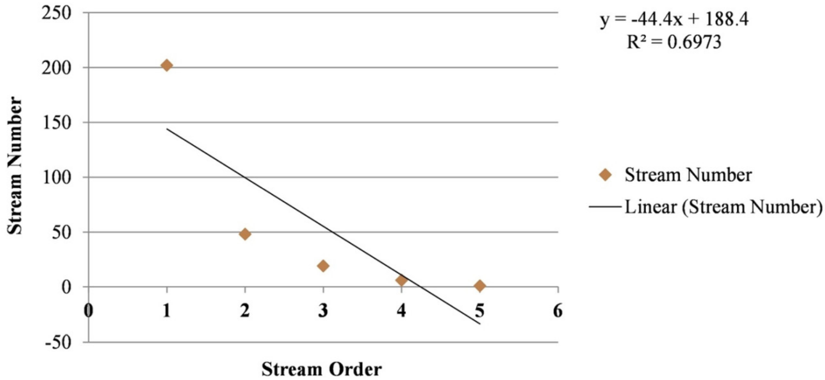

Fig. 7. Relationship between Mean Stream Length and Stream Order

this area may be due to the high ruggedness of the topography.

A relatively higher Dd is observed in the latter while comparing the Dd of the Thutapuzha watershed of Kerala with the Um-Mawiong River basin of Mawsynram. However, the lower Dd value suggests that the Thutapuzha watershed is characterized by highly resistant rock, dense vegetation, and low relief of surface nature (Ahmed et al., 2010; Sherin & K.S. A., 2022).

Form factor (Ff)

In addition to the elongation ratio, basin shapes, and related hydrologic characteristics can be understood from the form factor (Ff). As per Horton (1932), the Ff is the ratio of the area of the basin and the square of the basin length. The Ff value would always be more significant than 0.78 for a perfectly circular basin (Khare et al., 2014; Strahler, 1964). The smaller the value of the Ff, the more elongated the basin (Chopra et al., 2005). Basins with high values of form factors have high peak flows for shorter duration (Farhan & Anaba, 2016; Singh & Singh, 2011). In line with these, the results of the morphometric analysis showed that the value of the Ff of Um-Mawiong is 0.45. These Ff number falls under a small category (Chopra et al., 2005). Both watersheds have elongated shape, which is consistent with the result of the elongated ratio. The Ff of the Um-Mawiong River basin is 0.45, which infers that the study area is less elongated if compared with the Thutapuzha watershed Ff of 0.22, an elongated basin as a result of lower peak flow of longer duration (Sherin & K.S. A., 2022) as shown in Table 7.

Table 7. Areal aspect parameters use for quantitative morphometric analysis of the Um-Mawiong River basin

Sl. No.	Quantitative Morphometric Parameter	Formula	Units	Um-Mawiong River Basin	Remarks
1.	Drainage density (Dd)	Dd = Lu /A	Km	6.37	-
2.	Stream frequency (Fs)	Fs = Nu / A	km^2	19.10	-
3.	Form factor (Ff)	Ff = A / L2	-	0.45	Elongated basin
4.	Circularity ratio (Rc)	Rc = 4πA / P2	-	0.341	Elongated basin
5.	Elongation ratio (Re)	Re = 2* (A/π) 0.5/Lb	-	0.75	Elongated basin
6.	Drainage texture (T)	T = Nu/P	km	11.96	-
7.	Constant of Channel Maintenance (C)	C = 1/Dd	km	0.157	-

Circulatory ratio (Rc)

The other areal morphometric parameter analysed was the circularity ratio. The circulatory ratio (Rc) is a significant quantitative morphometric measure expressed as the ratio of the basin area (A) to the area of a circle having an identical perimeter as the basin (Miller, 1953; Strahler,1964). The length and frequency of streams, geological structure, land use and land cover, climate, relief, and slope of the basin considerably impact the value of the Rc. According to Miller's (1953) description, the value of the circularity ratio varies from 0 to 1.0. The higher the ratio, the more circular the shape of the basin and vice-versa (Miller,1953). The Rc of the Um-Mawiong River basin is 0.341. while comparing the results, with the Thutapuzha watershed of Kerala having a Rc of 0.18, results suggest that both the study area has a Rc value of <0.5, indicating an elongated shape and an elongated basin (Sherin & K.S. A., 2022) as shown in Table 7.

Elongation ratio (Re)

Schumm (1956) defined elongated ratio (Re) as the diameter of the circle of the same area in the basin to the highest basin length. Values near 1.0 represent regions of shallow relief. In contrast, values from 0.6 to 0.8 represent regions of strong relief and steep ground slopes (Schumm, 1956). The Re of the Um-Mawiong River basin is 0.75, indicating that it is an elongated basin occurring on very high relief and steep slope area, as depicted in Table 7.

Drainage texture (T)

Drainage texture (T) is the totality of the stream segments of all stream orders per perimeter of an area (Horton, 1945). The drainage texture depends upon several natural factors such as rainfall, climate, soil types, rocks, relief, vegetation, infiltration capacity, relief, and basin development stage (Smith, 1950).

Smith (1950) classified T into five different textures, and these are as follows: (I). very coarse (<2), (II). coarse (2–4), (III). moderate (4–6), (IV). fine (6–8), and (V). very fine (>8). However, drainage texture that exceeds ten and above are characterized by fine to ultra-fine texture that may have been created by a combination of several geomorphological processes (Sherin & K.S. A., 2022). The texture of the entire Um-Mawiong River basin is 11.96 km, which indicates that the Um-Mawiong River basin has a fine texture, showing that both erosion and dissection rates are high, as shown in Table 7.

Constant of channel maintenance (C)

A constant of channel maintenance (C) is the inverse of drainage density and expressed as the area of basin surface needed to sustain a unit length of stream channel, expressed in km^2/km. C depends on the rock type, permeability, climatic regime, vegetation cover, relief, climate history, and erosion duration (Schumm, 1956). The C is extremely low in areas of close dissection (Dutta & Sarma, 2015). The C of the Um-Mawiong River basin is 0.157 km, as depicted in Table 7, indicating a deficient value inferring close dissection.

Relief Aspects

Basin Relief (Bh)

The basin relief is calculated as the difference between the highest and lowest absolute heights, providing information on an area's relative rejuvenation (Strahler, 1954; Schumm, 1954), and the erosional pressures and denudational rates are a direct result of higher Bh value (Sherin & K.S. A., 2022). The Um-Mawiong River basin's highest and lowest reliefs are 1550 meters and 200 meters, respectively, and the total basin is 1350 meters, as shown in Table 8, denoting strong runoff and gravity-driven water flow.

Table 8. Areal aspect parameters use for quantitative morphometric analysis of the Um-Mawiong River basin

Sl. No	Quantitative Morphometric Parameter	Formula	Units	Um-Mawiong River Basin
1.	Maximum absolute relief height in the basin (H)	-	m	1550
2.	Minimum absolute relief height in the basin (L)	-	m	200
3.	Basin relief (Bh)	Bh = H - L	m	1350
4.	Relief ratio (Rh)	Rh= Bh / Lb	-	0.014
5.	Ruggedness Index (Rn)	Rn = Dd*H/1000	-	8.6

Relief ratio (Rh)

The relief ratio (Schumm 1954, 1956), representing the mean slope of a basin, is beneficial for elongated basins (Morisawa, 1962). The Rh maximum value indicates a steep slope and high relief. Conversely, its lowest value indicates a low slope (Sherin & K.S. A., 2022). The Rh of the Um-Mawiong River basin is 0.014, as depicted in Table 8, indicating the exposure of basement rocks as small ridges and mounds with lower slope values (Vittala et al., 2004; Sherin & K.S. A., 2022). However, the result suggests that the value of the Rh decreases while the length of the basin increases. Further, the Um-Mawiong River basin is highly elongated, which indicates that the length of the basin is high, for which the value of the Rh is low.

Ruggedness number (Rn)

The ruggedness number (Rn) is the product of basin relief and drainage density (Strahler, 1957). An extremely high value of ruggedness number occurs when both variables are significant and the slope is steep but long (Kusre, 2016). The Rn value of the Um-Mawiong River Basin is 8.6 (Table 8), indicating steep slopes and roughness of the basin and the structural complexity of the area.

5. Conclusion

The analysis of various quantitative morphometric attributes of the Um-Mawiong River basin reveals the significance of morphometric studies in research in landscape classification and categorization and river basin evolution studies. The Um-Mawiong River basin is of the fifth order, indicating a dendritic pattern, and the results of the morphometric analysis provide information related to basin development on priority. The Um-Mawiong River basin mean bifurcation ratio of 4.13 indicates that the geologic formations do not significantly control the drainage pattern, which is equivalent to extensively dissected mountain watershed with mature topography and higher drainage integration (Sherin & K.S. A., 2022). The drainage density of the basin is 6.37 km, suggesting that the area is courser in nature and characterized by weak or impermeable material, sparse vegetation, and high relief (Hajam et al., 2013), leading to high surface runoff and extreme humid climate, suggesting a moderate and well-drained river basin (Sherin & K.S. A., 2022). The basin form factor is 0.45, the elongation ratio is 0.75, and the circularity ratio is 0.34. Similarly, as the shape of the Um-Mawiong River basin is elongated in nature, the sub-units will have lower flood peaks but longer duration flood flows, allowing for flood management (Sherin & K.S. A., 2022) and preventing lateral erosion. The stream frequency obtained for the study is 19.10 km^2, and the value of stream frequency for the river basin reveals a positive correlation with the drainage density of the area, indicating the increase in stream population concerning the increase in drainage density. The stream frequency depends more or less on the rainfall and the region's physiography.

The G.I.S. technique provides a more precise analysis of the quantitative morphometric parameters than traditional methods, which take time. The morphometric analysis of different sub-basins shows a variation in their characteristics related to the hydrological response of the basin. The elongated nature of the Um-Mawiong River basin indicates that the basin is influenced by structure and tectonics. Despite the complexity of the hydrological system, the assessment and examination of various quantitative morphometric parameters give adequate information about the river basin's terrain characteristics and hydrological behavior (Sherin & K.S. A., 2022). Hence, it would be concluded from the study that the drainage morphometric parameters have considerable potential to unveil the hydro-morphological characteristics of any river basin and integrate this with any conventional watersheds.

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