Drainage Morphometric Analysis of the Yagachi Watershed Area, Karnataka State, India

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Abstract

The Yagachi River watershed in Karnataka State has been chosen for a thorough analysis to recognize the drainage system, morphometric features, and vulnerability of the watershed area to erosion. As a prerequisite to the analysis of morphometric features utilizing ArcGIS software, the stream networks and sub-watersheds (viz., SW01, SW02, SW03 and SW04) were delineated by making use of topographic sheets and the Digital Elevation Model (DEM). Yagachi watershed covers an area of 551.45 sq. km and observed predominant drainage patterns are sub-parallel and dendritic with sixth-order drainage. Higher stream orders (U=6), implying greater surface runoff and sediment load, and low mean stream length values in the upper reaches, signifying youthful morphological development and strong erosion potential, are characteristics of streams in the watershed. Drainage density values (1.262 to 1.930 km/km^2), particularly at upper reaches in the NW part of the watershed, fine to very fine drainage texture values (7.572 and 8.337), moderate to high values of length of overland flow (Lg) and constant of channel maintenance (CCM) indicate steep to moderate slopes, fairly significant surface runoff, and high erosive power of the streams and greater sediment load. The elongated form of the watershed is shown by the computed lower form factor (Ff) and elongation ratio (Re) values. Relief characteristics of the watershed area, although suggest that the study area is vulnerable to erosion and in youth stage, in reality, the area is characterised more by the features of the late mature stage of landform development. The observed anomaly is attributed to the mountain-plain environment as the steeply sloped hill ranges of Bababudan formations are located in the northwestern parts of the Yagachi watershed area. However, the sub-watershed SW03 with high stream length, drainage density and relief value with fine drainage texture is relatively more susceptible to erosion.

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Introduction

River networks have been the subject of extensive research by geoscientists, including hydrologists, since 1950.[1] Numerous general bivariate relationships have been found, and a wealth of literature on drainage watershed morphometry has contributed to understanding drainage evolution in the context of controlling variables in a specific geological terrain.[2] A naturally occurring geohydrologic unit known as a "watershed" distributes precipitation runoff to a single waterway and is categorized according to its geographic location.[3] Runoff is a crucial hydrological phenomenon with detrimental impacts, including excessive floods across the river basin area and soil erosion.[4] Planning for watershed management, recovery, and understanding basin hydrology all depend heavily on the evaluation of watershed morphology.[5] The study's findings can help with topographic understanding, basin nature, defining a good place for soil preservation and lowering flash floods in the region's flat terrain.[6] To understand how the basin will behave in different geologic and hydrologic situations, morphometric analysis of the basin is carried out by computing its various aspects.[5,6] Thus, the quantitative analysis of a watershed's drainage network offers helpful hints for comprehending the fluvial processes in a region.

The quantitative analysis of a watershed's drainage network offers helpful hints for comprehending the processes in a region. The physicochemical properties of the exposed rocks and the hydrological nature of the drainage watershed are well-informed by evaluating any drainage watershed using quantitative analysis methods.[7] Water management is crucial to the sustainability of the livelihoods of all stakeholders in semi-arid and arid areas. It is necessary to have precise knowledge of the topography, geomorphology, drainage system, dividing ridge between drainage, length of the stream, and geological setup of the area in order to manage watersheds effectively and carry out water conservation measures.[8] Because it offers information on the watershed's slope, physical characteristics of an area, quality of the soil, runoff characteristics, potential for surface water, and other characteristics, watershed planning requires drainage analysis based on morphometric factors.[9]

Yagachi watershed area is located in Hassan and Chikkamagaluru districts of Karnataka State with an area of about 551.45 sq. kms. The NW (north-western)

part of the Yagachi watershed area is characterized by hilly terrain belonging to the Bababudan Group of rocks of the Dharwar Super Group. Yagachi reservoir, located in the SE part of the watershed area, meets the water requirements for drinking and irrigation. Stream erosion from the north-western part and its subsequent deposition reduces the net storage capacity of the reservoir, which ultimately has an impact on socioeconomic conditions of the people living in the downstream area. In order to minimize the downstream impacts, identification of the vulnerable areas for stream erosion is warranted.

Limited research work on the drainage development, morphometry and groundwater potentiality of the Yagachi basin has been carried out by the earlier workers[10,11,12,13] (Gopalakrishna *et al.,* (2004); Suresh (2016); Poornima & Nyamathi (2017); (2018)) and this is the first attempt to comprehend how susceptible the basin is to erosion. The present paper aims to characterize drainage morphometry and to infer the vulnerability of the Yagachi basin to erosion by quantitatively determining various morphological attributes.

Study Area

In the Bababudan hills of the Chikkamagaluru District, the Yagachi River rises. It enters Hassan District in Belur Taluk, and Yagachi is the main tributary of the river Hemavathi. It collects water from the Biranji-halla and Vedavathi-halla in the west as it flows south and enters the river Hemavathi near the Gorur village of the Arkalgud taluk. The Yagachi dam, which spans the Yagachi river, was erected in 2001. The Yagachi watershed covers an area of 551.45 Km^2, located between latitudes 13º6′28″N and 13º23′19″N and longitudes 75º38′44″E and 75º54′8″ E. (Fig. 1), which falls in Survey of India topographical sheet Nos.48 O/11, 48 O/12, 48 O/15 & 48 O/16. The region is characterised geologically by rocks from the Dharwar Super Group with alluvium along the courses of ephermal streams of the Yagachi river. Archaean granitic gneisses dominate the bedrock. Geomorphologically, the area exhibits pediments, pediplains and plains with the veneer of detritus. A major type of soil in the research area is clayey skeletal, fine loamy soil developed over granitic gneisses. Other types of soils of lesser importance are loamy skeletal and silty clay soils. Alluvial soil covers the banks of the major stream. The research area's climate is categorised as tropical and is dominated by S.W. monsoon rainfall. Other sources of water are springs

and underground water. Yagachi has both perennial and non-perennial channels. Most of the streams in the area are of subsequent type, their flow direction is guided by joints in the underlying rocks.

The catchment area of river Yagachi has been subdivided into 4 sub-watersheds, taking the topographic divides into consideration (Fig. 1) and the physical characteristics of the sub-watersheds (Table 1). According to Table 1, the sub-watershed SW03, which is situated on the northern side, is the largest, with sub-watershed SW04, located to the east of the reservoir, being the smallest with an aerial extent of 14.304 sq. km.
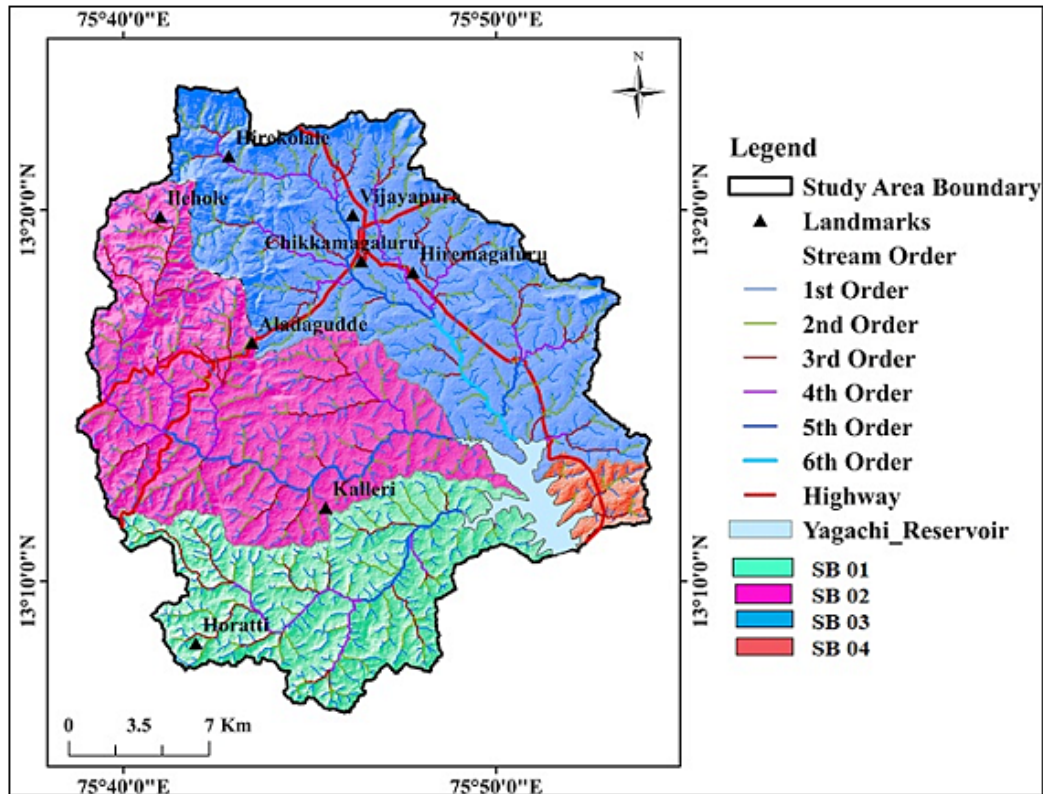

Fig. 1: Location Map

Table 1: Physical parameters of Yagachi river drainage watershed

Sub-watershed name	Area (A) (Km^2)	Watershed length (Lb) (km)	Perimeter (km)
SW01	122.054	19.207	91.69
SW02	187.448	22.017	86.105
SW03	215.649	29.385	99.338
SW04	14.302	5.461	28.777
Total	539.453	-	-

Materials and Methods

The toposheets Nos. 48 O/11, O/12, O/15, and O/16 published by Survey of India were scanned, saved in TIF format and brought to the ArcGIS environment using an interface where the map was georeferenced. Stream networks were extracted, and their orders were

digitized. The Yagachi watershed receives an average annual precipitation is 1600 mm, and the Yagachi river is found to be a sixth-order stream. The Earth Explorer website (https://earthexplorer.usgs.gov) was used to obtain the DEM of the SRTM with a 30 m resolution, which was then imported into the GIS environment.[44] Using ArcGIS 10.4 software, the sub-watershed boundaries were marked and subdivided into 4 sub-watersheds based on the topographic divide and directions of the water flow. The sub-watersheds were designated as SW01, SW02, SW03 and SW04. However, understanding the impact of precipitation-topography links in semi-arid ecosystems is critical for analysing

landscape sensitivity to changes in climate and vegetation cover.[14] This study encompasses only the assessment of the vulnerability of the watershed to erosion through the morphometric parameters and is thus quantitative in nature. Using GIS techniques, common parameters like stream lengths (R_L), number of streams for each stream order, basin area (A), length (L_b), and perimeter (P) were measured directly from the DEM.[41,45] The morphometric parameters relevant to assess the sub-watersheds vulnerability to erosion were computed by well-established methods (Table 2). The significance of each one of the parameters has been discussed in detail by Shaikh.[6]

Table 2: List of the morphometric parameters and methodology adopted for computation

	Parameters	Formulae	Variables	Reference
Linear parameters	Stream order	Hierarchical rank		[15]
	Bifurcation Ratio	$Rb=N\mu/N\mu+1$	Where Rb=Bifurgation ratio Nμ=No.of Stream segments of a given order Nμ+1=No. of stream segments of the next higher order	[16]
	Mean Bifurcation		R_{bm}=Average of bifurcation ratios of all orders Length of the steam (kilometers)	[15]
	Stream length			[17]
	Mean stream length	$L_{sm}=L_\mu \div N_\mu$	Lμ=Total stream length of order'μ'(kilometers) Nμ=Total no.of stream segments of order 'μ '	[15]
	Stream length ratio	$R_L=L_{sm} \div L_{sm}-1$	L_{sm}=Mean stream length of a given order and L_{sm}-1=mean stream length of next lower order	[17]
	Length of Overland Flow	Lg=1/2D	Where D=Drinage density (Km/Km^2)	[17]
	Watershed Perimeter		P=Outer boundary of drain -age watershed measured in Kilometers	[16]
	Watershed length	$L_b=1.312 \times A^{0.568}$	Lb=1.312xA0.568 A=Area	[16]
	Watershed area		from which water drains to a common stream and boundary determined by opposite ridges.	[15]
Areal parameters	Drainage Density	Dd=Lμ /A	where Dd =Drainage Density (Km/Km^2) and A=Area of the watershed (Km^2)	[17]
	Drainage Frequency	Fs =Nμ/A	Where Fs=Drainage Frequency. Nμ=Total no. of streams of all	[18]

			orders and A=Area of the watershed(km^2).	
	Infiltration Number	If=Dd×Fs	where Dd =Drainage Density (Km/Km^2) and Fs=Drainage Frequency	[19]
	Drainage Texture	Dt=Nµ/P	Nµ=No. of streams in a given order P=Perimeter (Kms)	[17]
	Form Factor Ratio	Rf=A/Lb^2	where A=Area of the water-shed and Lb=(Maximum) watershed length	[18]
	Elongation Ratio	Re=√(A/π)/Lb	where A=Area of the water-shed and Lb=(Maximum) watershed length	[16]
	Circularity Ratio	Rc=4πA/P^2	A=Watershed area (Km^2) and P=Perimeter of the watershed (Km)	[20]
Relief Aspects	Watershed Relief	H=Z-z	Where Z=Maximum eleva-tion of the watershed(m) and z=Minimum elevation of the watershed(m)	[16]
	Relief Ratio	R_h=H/Lb	H=watershed relief(m) and Lb=Watershed length(m)	[16]
	Dissection Index	Di=H/Ra	H=Watershed relief(m) and Ra=Absolute relief(m)	[21]
	Channel Gradient	Cg={H÷(π/2)×Clp}	H=watershed relief (m) and Clp=Longest dimension parallel to the principal drainage line (Kms)=Lb	[22]
	Slope analysis	DEM, GIS	--	[23]

Results

Unique patterns obtained by stream networks are the outcome of adjustments to the geologic composition of landforms. Yagachi river represents the 6th order stream order according to Strahler.[15] The major part of the Yagachi catchment area is characterized by sub-parallel and, to a lesser extent, dendritic drainage patterns (Fig. 2). The river follows the topography and flows according to the slopes of the Yagachi river. From a wide perspective, the dendritic pattern indicates the homogeneity of rocks and soils, while the sub-parallel drainage pattern comprises the streams that are almost parallel to each other and follow the regional slope. Subparallel pattern is largely noticed in the initial orders of the streams. Hence, it implies that the sub-parallel drainage pattern is essentially an initial drainage pattern.

Linear Parameters

Linear parameters are uni-dimensional parameters. The evaluated parameters and the results are presented in Table 3. The topological characteristics of the stream segments are shown in a linear aspect of a drainage network. A river's behaviour from start to end, combined with crustal and structural controls of the river basin, can be inferred from the evaluation of the linear parameters.[3,24]

In the Yagachi watershed area, the majority of streams (approximately 80%) are 1st order streams. As shown in Table 3, the sum of stream length (Lb) of all orders in the SW03 sub-watershed is higher than the other sub-watersheds, as is the watershed lag time, despite the fact that all sub-watersheds have similar vegetation cover, soil, and

underlying geology. Generally, the combined stream length (Lu) in the first order is the longest for the specified watershed, and stream length and stream order shows inverse relation. The inconsistency in the values of the stream length (Lu) is noticed in 3rd order streams of SW04 (Table 3). According to Strahler,[15] the L_{sm} of one order should be less than the next higher level. The Yagachi area also, it is noticed that the L_{sm} of the higher orders are less than the lower orders (Table 3). The values of the stream length ratio obtained following standard procedure[17] vary from 1.049 to 4.618 and are disorderly, as noticed in the majority of the sub-watersheds of the research area (Table 3). The obtained stream length ratio values do not show any definite pattern at the sub-watershed levels. The Rbm in the Yagachi watershed varies from 3.759 to 4.769 with respect to the sub-watersheds SW03 and SW02. The computed range of the Lg of the Yagachi SW's Lg varied from 0.631 to 0.965.
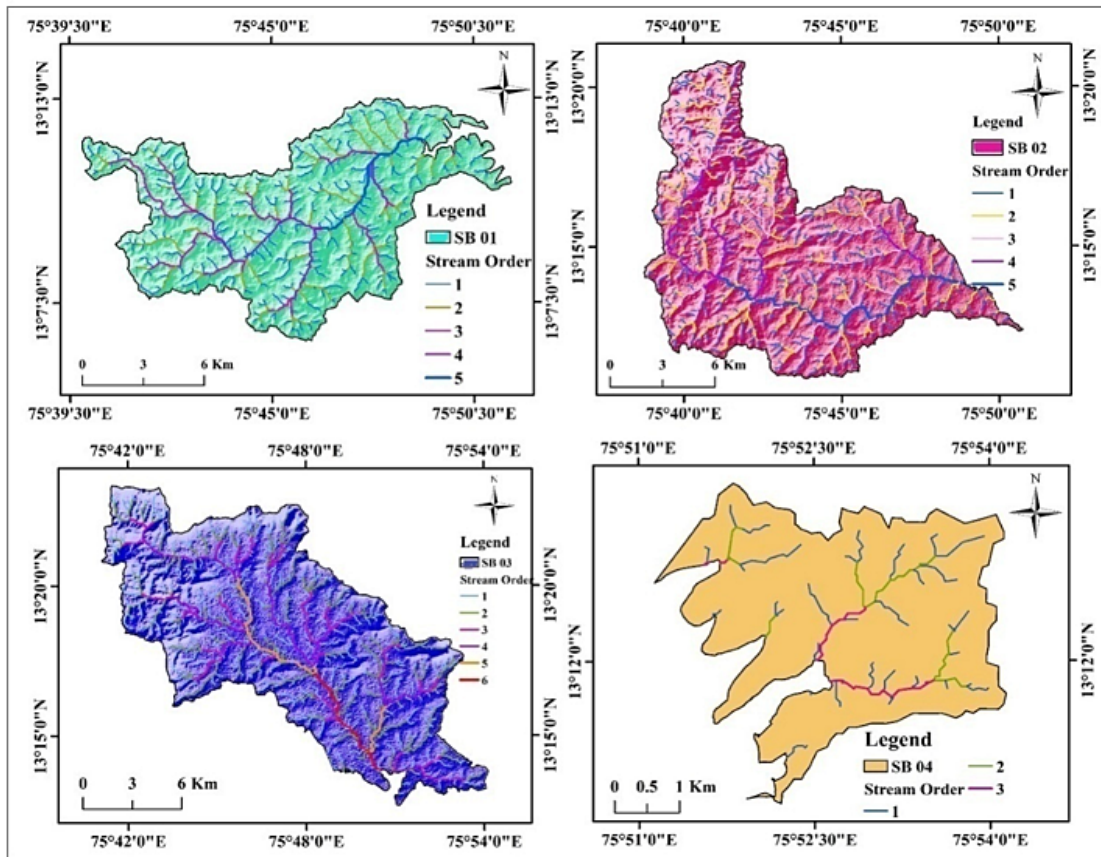

Fig. 2: Drainage patterns in 4 sub-watersheds of the Yagachi watershed area

Table 3: Linear parameters of the Yagachi Sub-watersheds

Sub-watershed Name	*U	*Nu	*Lu (Km)	*Lsm	*RL	*Rbm	*Lg (Km km²)
SW01	1	331	106.954	0.323	2.796	4.354	0.922
	2	66	59.617	0.903	2.527		
	3	15	34.227	2.282	2.373		
	4	3	16.248	5.416	1.489		

	5	1	8.062	8.062	-		
SW02	1	514	162.727	0.317	1.744	4.764	0.832
	2	109	60.295	0.553	3.512		
	3	23	44.661	1.942	2.599		
	4	5	25.236	5.047	3.756		
	5	1	18.958	18.958	-		
SW03	1	662	218.877	0.331	2.263	3.759	0.965
	2	122	91.325	0.749	2.065		
	3	31	47.942	1.547	2.353		
	4	10	36.634	4.545	1.249		
	5	3	13.634	4.545	1.789		
	6	1	8.131	8.131	-		
SW04	1	35	12.139	0.347	1.049	4.25	0.631
	2	7	2.551	0.364	4.618		
	3	2	3.362	1.681	-		
Total	1	1542	500.697	--	--	--	--
	2	304	213.738				
	3	71	130.192				
	4	18	77.883				
	5	5	40.654				
	6	1	8.131				

*Note: Refer Table 1., for parameters abbreviation.

Areal Parameters

A drainage watershed's regional characteristics show the impact of its lithology, geologic structure, climatic factors, and denudational history.[24] Areal aspects include many parameters and chosen one for the present analysis are listed in Table 2 and outcomes of the evaluation are presented in Table 4.

Table 4: Areal parameters of the Yagachi Sub-watersheds

Sub-watershed Name	SW01	SW02	SW03	SW04
*Dd (Km Km^{-2})	1.844	1.663	1.930	1.262
*Dt	4.538	7.572	8.337	1.529
*Fs (km^{-2})	3.408	3.478	3.844	3.076
*CCM (Km^2/Km)	0.542	0.601	0.518	0.792
*Re	0.183	0.396	0.318	0.441
*Rc	0.182	0.318	0.274	0.217
*Ff	0.331	0.387	0.25	0.48

*Note: Refer Table 1., for parameters abbreviation.

The research area's Drainage density (Dd) results vary from 1.262 to 1.930 km/km^2 (Table 4) and show little variation. According to,[26] the results point to terrain with gentle to steep slopes, medium-density, and less permeable rocks with medium precipitation. However, the present authors have observed high 'Dd' values at the upper reaches of the watershed, indicating relatively less permeable formations, high relief, and high runoff. Thus, higher drainage density values indicate higher runoff with greater flow velocity. Fs values changes between 3.076/km^2 and 3.844/km^2. The values observed in the Yagachi watershed do not vary much between the sub-watersheds. Stream frequency (Fs) is

highest in sub-watershed SW03 with a value of 3.844 Km^{-2}, followed by 3.478, 3.408 and 3.076 Km-2, respectively, in SW02, SW01 and SW04 sub-watersheds. In the current research, the CCM values changes from 0.542 to 0.792 Km^2/Km (Table 4). Result of the sub-watershed's form factor show that the form of the watershed varies from elongated (0.25) to near circular (0.48) in shape. The values of the circulatory ratio of the SW's of the Yagachi area range from 0.182 to 0.318. The greater

and lower values of the sub-watersheds Elongation Ratio of the Yagachi region are 0.183 and 0.441, respectively. According to Strahler[27] classification, the 'Re' results the Yagachi sub-watersheds indicate that they are more elongated. The texture ratio of the sub-watersheds, namely SW02 and SW03, falls in the category of fine texture ratio.[28] The remaining sub-watersheds, SW04 and SW01, belong to very coarse and coarse texture ratios, respectively.
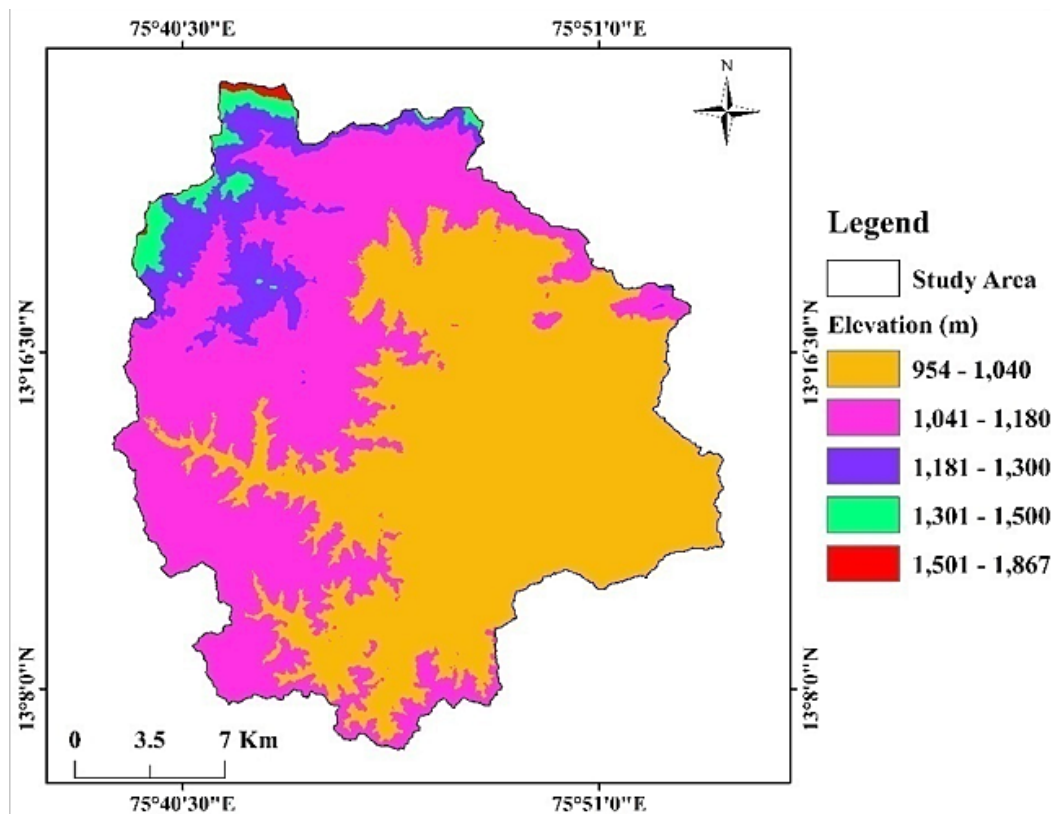

Fig. 3: Elevation interval map of the Yagachi watershed area

Relief Parameters
The area presents a mountain-plain environment (Fig. 3), and the Yagachi watershed's highest point in elevation is 1867 m above MSL, and the highest watershed relief value is 903 m above MSL The computed values of relief parameters have been presented in Table 5. Sub-watersheds do not show much contrast in their relief ratio values. However, all the sub-watersheds exhibit a moderate relief ratio, thus implying moderate vulnerability of the

area to erosion. In the current investigations, values of Ruggedness Number (Rn) vary from low (Rn=0.09) to high (Rn=1.74), as shown in Table 5. The ruggedness number values of SW03 (Rn=1.74) suggest a youthful stage of geomorphic development of sub-watershed areas and significant susceptibility to soil erosion. The 'Di' values varies from 0.186 to 0.484 (Table 5). The computation carried out by the present investigator shows that the channel gradient values fluctuate from 0.014 to 0.035 (Table 5), thus

signifying that the gradient is moderately gentle. The channel gradient values imply that the carrying capacity of the load by the streams in the study region will also be moderate.

Table 5: Relief parameters of the Yagachi sub-watersheds.

Sub-watershed Name	SW01	SW02	SW03	SW04
Minimum height above *MSL(m)	964	965	964	961
Maximum height above *MSL(m)	1184	1572	1867	1032
Watershed relief (H) (m)	220	607	903	71
Relief ratio (Rh) (km^2)	0.011	0.028	0.031	0.013
Ruggedness Number (Rn)	0.41	0.71	1.74	0.08
Dissection Index (Di)	0.186	0.385	0.484	0.484

*MSL- Mean sea level

Discussion

Determination of the morphometric parameters provides insight into the health condition of a watershed. Several drainage morphometric parameters evaluated in order to assess the state of the Yagachi watershed area brought to light several interesting factors. From the drainage map, the SW03 is categorized as a watershed of 6th order and higher stream orders are connected with increased flow. Thus, the sub-watershed SW03 has relatively higher discharges and velocity. As can be made out from Table 3, the length of all streams of all the orders in the SW03 sub-watershed is greater than the other sub-watersheds, so, also the watershed lag time, although all the sub-watersheds are covered with similar vegetation cover, soil, and underlying geology. The total length of streams in the first order is the greatest for the particular watershed, with Lu generally decreasing as U increases. The inconsistency in the values of the total stream length may be due to the sudden drop in elevation, suggesting morphological control on the watershed area. This anomaly is noticed in 3rd order streams of SW04. The R$_L$ of the stream orders changes due to topography and slope fluctuation circumstances and is positively connected with the watershed's surface water discharge and the stage of erosion. Generally, shorter lengths of stream indicate steep to moderate slopes and finer textures, whereas longer points to gentle to flat gradients and coarser textures. In the subject matter under investigation, it is denoted that the Lsm of the greater orders are shorter than the lower orders (Table 3). According to studies, mean stream length is lower in mountainous environments than it is in plain or plateau morphology.[29] At the higher reaches, low mean stream length values point to recent morphological development and considerable erosion potential. This corroborates well with the field observations wherein the N.W. portion of the research area is mountainous, and the rock formations belong to the more resistant Archaean Bababudan group of Dharwar Craton.

The anomaly in the data for the ratio of stream length may be caused by variations in geomorphic features and slope of the land[30-31] and indicates that its geomorphic development is in its late youth stages.[32] This conforms well to the field condition in the study area. Studies by[21,23,24,25] elsewhere reveal that the stream length ratios (R$_L$) in the mountain-plain front river basins are erratic. Because of the potential for differences in watershed geometry and lithology, the values of mean bifurcation ratio (Rbm) do not quite continue to be the same from one order to the next, despite the fact that they frequently do so throughout the series.[1] Elongated watersheds have low bifurcation ratio (Rbm) values, while circular watersheds have high bifurcation ratio values.[33] Therefore, watersheds with high "Rbm" values suggest early hydrograph maxima with a chance of flash flooding after storm events.[34] The Rbm of the Yagachi watershed varies from 3.759 to 4.769 with respect to the SW03 and SW02, and the present values indicate that there are no major structural disturbances in the area.[16,35,36] Moderate to high values of L$_g$ indicate moderate to high surface runoff.

From the obtained results, it may be inferred that the region is covered with less permeable to relatively impermeable soil and less vegetation.[36] The values also indicate less channel erosion.[16]

Drainage density (Dd) facilitates numerical measurement of runoff potentiality of the watershed[38] and landscape dissection. The 'Dd' values of the Yagachi sub-watersheds are by and large low, implying terrain with gentle to steep slopes, moderately dense vegetation, low relief, and less permeable conditions during moderate precipitation.[39] asserts that low "Dd" values typically reflect the places with thick vegetation, low relief, and coarse drainage texture that are particularly resistant to permeable subsurface material. However, the present authors have observed high 'Dd' values at the upper reaches of the watershed, indicating relatively less permeable formations, high relief, and high runoff. Thus, higher 'Dd' values indicate higher runoff with greater flow velocity. The stream frequency (Fs) values observed in the Yagachi watershed do not vary much between the sub-watersheds. Permeability, rate of infiltration, and watershed relief have all been linked to stream frequency.[40] Stream frequency of the Yagachi watershed reveals that the sub-watersheds are masked with a moderate amount of vegetation and have similar infiltration capacity. According to Smith[28] classification, SW04 has a very coarse drainage texture (Dt) value (1.529) and denotes that the watershed is made of low to moderate relief, highly resistant permeable material, while SW01 (4.538) has moderate texture, SW02 (7.572) and SW03 (8.337) have fine to very fine 'Dt' values (Table 4). Moderate values of constant channel maintenance (CCM) in the present case indicate a gentle sloping environment that all the sub-watersheds are moderately erodible,[16] implying medium relief, medium permeability and low to moderate surface runoff and longer durations for the discharge, thus facilitating high infiltration of water. Lower form factor (Ff) values indicate longer watersheds, flatter low-flow peaks that last longer, less erosion, and lower sediment transport capacities.[26,27,28,29] The majority of the sub-watersheds have a circularity ratio value of around 0.247, thus indicating a strongly elongated watershed, lower runoff, and permeable soil conditions. Low R_e values of the Yagachi sub-watershed imply their reduced risk of flash floods, and hence, earlier flood management is possible.[41]

The Elongated nature of the Yagachi watershed and consequent short flood discharge period is indicated by higher shape index values.[26]

The sub-watersheds of the Yagachi river have relief ratio values ranging from 0.013 to 0.031. Greater relief values indicate terrain with little infiltration and high runoff. Higher relief ratio (Rr) values denote mountainous terrains with slopes ranging from moderate to steep. Ruggedness number Rn values in the current study range from low (Rn=0.09) to high (Rn=1.74), as shown in Table 5. The 'Rn' values of SW03 (Rn=1.74) suggest a youthful stage of geomorphic development of sub-watershed areas and significant susceptibility for soil erosion. Dissection Index values indicate moderately dissected landscape and derivation of a moderate amount of sediment load. The slope of the study region is steep at a higher elevation, and it gradually decreases. The computation carried out by the present investigator shows that the channel gradient values range from 0.014 to 0.035, thus signifying that the gradient is moderately gentle. The channel gradient values imply that the carrying capacity of the load by the streams in the study region will also be moderate.

Conclusion

The morphological control has a bearing on the stream patterns and anomalies in the stream lengths noticed at various stream orders. Low stream lengths noticed at the initial order of the streams, and the anomalous values of the 'Rbm' may be attributed to the presence of the Bababudan range of hills in the NW part of the study area owing to which there is the sudden drop in elevation and steep slope. High drainage density values observed at the upper reaches of the streams supplement the observation. The SW03, with the highest total stream length in the Yagachi watershed, is characterised by relatively higher discharges and velocity. Analysis of the data on the morphometric parameters indicates a gentle sloping environment with medium permeability, low to moderate surface runoff and longer durations for the discharge. All four sub-watersheds are moderately erodible, implying that the watershed area is covered with relatively less permeable soil formations vegetation, further pointing to the low vulnerability of the area to erosion and also to channel erosion. However, the sub-watershed SW03

with high stream length, drainage density and relief value with very fine drainage texture is relatively more susceptible to erosion. High relief ratio values of SW03 cannot be considered to assess the stages of the geomorphic development of the watershed as the sub-watershed presents a mountain-plain environment. The subwatershed soil's vulnerability to erosion and the lowering of sediment deposition in the reservoir is crucial for balancing the ecology and agroeconomic conditions. Promoting the growth of vegetation in the barren plains reduces soil erosion. Contour plowing is the best approach for improving soil quality and composition by minimizing runoff, increasing moisture infiltration, and increasing moisture retention. Mixed farming, crop rotation, and grazing management are just a few of the measures available to decrease soil erosion.

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