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Assessment of morphometric characteristics for Agrani river basin in Maharashtra, India using geospatial information technology (GIS)

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Abstract
The morphometric characteristics of river basin is easily evaluated by using integration of Remote Sensing (RS) and Geographic Information Systems (GIS). The benefits of this integration include saving time and effort as well as improving the accuracy of the analysis. Moreover, this technique is appropriate for describing the river basin and its streams. In this study, a detailed morphometric analysis of the Agrani river basin has been performed using the Shuttle Radar Topography Mission (SRTM). The performed morphometric analysis includes linear, areal, and relief aspects. The results of the morphometric analysis reveal that the catchment can be described as of sixth stream order and consists of an area of 1918.05 km^2. Additionally, the basin is characterized by a relatively high mean value of bifurcation (4.32). The drainage density value of 1.1 km/km^2 confirms the highly resistant or permeable subsoil material, dense vegetation and low relief.

Keywords: GIS, morphometric characteristics, watershed characteristics, Agrani river basin

1. Introduction
India is agriculture based country. In 2016, agriculture and allied sectors accounted 15.4% of the India's total GDP with 31% work force in 2014 (Anonymous). The Indian agriculture is dependent on monsoon and monsoon is erratic in nature. This creates uneven distribution of water in most of the part of the country. Therefore there is need to work on the watershed management and development to overcome the water scarcity in these areas. Before working on watershed there is need to know the basic morphological characteristics of that watershed.
Morphometric is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Agarwal, 1998; Obi Reddy *et al*., 2002) [1, 13]. The morphometric analysis of the drainage basin and channel network play a vital role for understanding the geo-hydrological behavior of drainage basin and expresses the prevailing climate, geology, geomorphology, structural, etc. antecedents of the catchment. The relationship between various drainage parameters and the aforesaid factors are well recognized by many workers (Horton, 1945; Strahler, 1957; Melton, 1958; Pakhmode *et al*., 2003; Gangalakunta *et al*., 2004) [6, 19, 9, 14, 4].
Geographical Information System (GIS) techniques are now a day used for assessing various terrain and morphometric parameters of the drainage basins and watersheds, as they provide a flexible environment and a powerful tool for the manipulation and analysis of spatial information. The main objective of the present study is to analyze the linear and areal morphometric characteristics of Agrani River in southern part of Maharashtra state by using Geographical Information System (GIS), as so far no exhaustive work on the morphometric investigation of the region has been carried out. This study gives an insight into the different geo-hydrological characteristics of the drainage basin which in turn help in the management of the water and other natural resources of the area.

2. Study area
The Agrani River, a tributary of Krishna River that extends across 107 villages, which are part of five Talukas in Sangli district and one taluka of Belgavi district of Maharashtra and Karnataka state respectively. It covers an area of 1918.05 km^2. It is a life line of drought-prone area in sangali district. The average annual rainfall of the area, which falls in the rain shadow region, is around 350-450 mm. As the area is located on an acute slope, the rainwater flows away.

3. Methodology

The morphometric analysis of the Agrani river basin was prepared based on published topographic maps on a 1:50,000 scale and also on SRTM data. SRTM has created an unparalleled data set of global elevations. It is freely available for modelling and environmental applications. It is a fast and inexpensive way for morphometric analysis. The data were taken from the http://srtm.usgs.gov/data/obtaining.html and then imported to the ArcGIS. Based on the data we prepared the slope and topographic elevation maps with contours for the watershed.

River basin parameters *viz* area, perimeter, length, stream length, stream order were also calculated which were later used to calculate other parameters like bifurcation ratio, stream length ratio, stream frequency, drainage density. Relief, relief ratio, elongation ratio, circularity index, and form factor were evaluated with the help of established mathematical equations as shown in Table 1. The morphometric parameters were divided into three categories: linear, areal and relief aspects of the basin.

Table 1: Formulae for computation of morphometric parameters

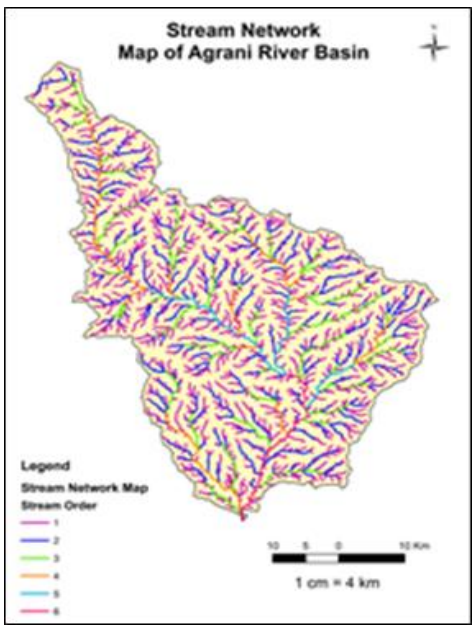
Parameter	Formula	Reference
Steam Order	Hicrarchial rank	Strahler (1964) [20]
Mean Steam Length(Lsm)	Lsm = Lu/Nu	Horton (1945) [6]
Stream Length Ratio (RL)	RL = Lu/Lu-l	
Length of Overland Flow (Lg)	Lg = 1/ Dd*2	
Bifurcation Ratio (Rb)	Rb = Nu/Nu+l	Schumn (1956) [17]
Relief Ratio (Rh)	Rh = H/Lb	
Elongation Ratio (Re)	$Re=(2/Lb)*(A/Pi)^{0.5}$	
Mean Bifurcation Ratio (Rbm)	Rbm = Average Rb of all orders	Strahler (1957) [19]
Drainage Density (Dd)	D = Lu/A	Horton (1932) [6]
Stream Frequency (Fs)	Fs = Nu/A	
Form Factor (Rf)	$Rf = A/Lb^2$	
Circulatory Ratio (Rc)	$Rc = 4*Pi*A/P^2$	Miller (1953) [10]
Textural Ratio (T)	T = N1/P	Nookaratnam *et al.* (2005) [12]

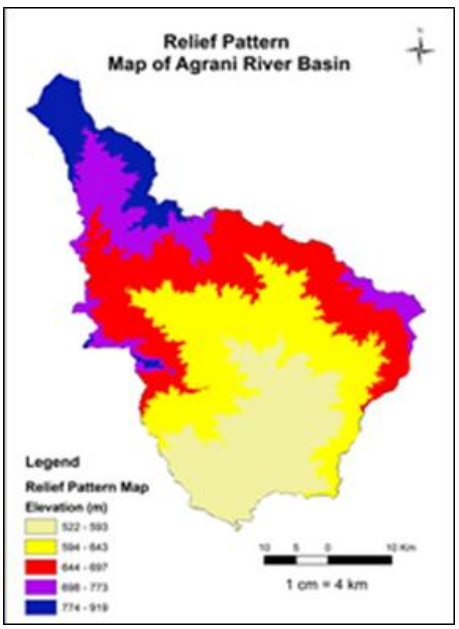
Where,

Lu = Total stream length of order u, Nu = Total no. of stream segments of order u, Lu-1= Total stream length of its next lower order, P = Perimeter (km), Nu+1 = Number of segments of the next higher order, H = Total relief (Relative relief) of the basin in kilometer, Lb = Basin length (km), A = Area of the Basin (km2), Pi = 'Pi' value i.e. 3.14, N1= Total no. of first order streams.

4. Result and Discussion

The drainage map of the study area was prepared from the toposheets. Agrani river basin was fern shape with well-developed drainage network up to 6th stream order in the total area 1918.05 km^2. Geomorphological characteristics of the Agrani river basin are shown in Table 2 and drainage network of the study area is shown in Fig. 1.





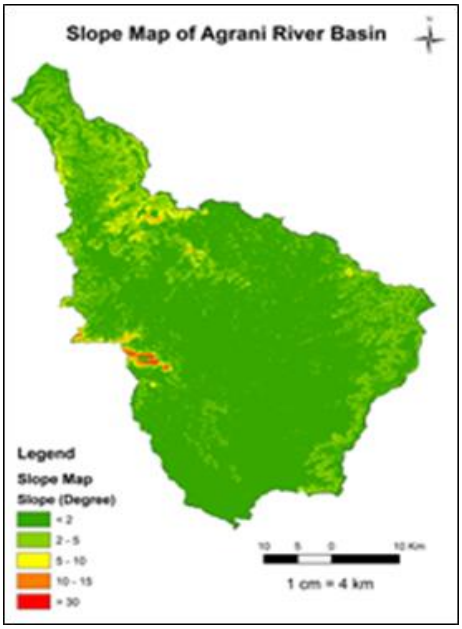


Fig 1: Stream Network Map of Agrani River Basin, **Fig 2:** Relief Pattern Map of Agrani River Basin **Fig 3:** Slope Map of Agrani River Basin

4.1 Linear Aspects of Drainage Networks

The linear aspects of morphometric analysis of drainage basin include stream order, stream number, stream length, mean stream length, stream length ratio and bifurcation ratio.

4.1.1 Stream order and stream number

The ranking of streams was carried out by adopting standard method proposed by Strahler, 1964 [20]. Total number of streams were 1595 of which 1187 were 1st order streams, 344

were 2nd order, 48 were 3rd order, 12 were 4th order, 3 were 5th order and one was 6th order. It is observed that the number of the stream segments decreases as the stream order increases. However, it was observed that the maximum frequency of number of streams was in case of first order streams i.e. 1187. It indicates that basin was subjected to erosion and some areas of the basin were characterized by variations in lithology and topography (Horton, 1945) [6].

4.1.2 Bifurcation ratio
Bifurcation ratio of Agrani river basin varied from 3 to 7.17. From Table 2, it is observed that initially up to the second order Bifurcation ratio was increases but from third order it decreases. The higher Bifurcation ratio indicate that the study area is largely controlled by structure in drainage development and lower indicate that it less affected by structure at end (Strahler, 1957) [19]. The mean bifurcation ratio of basin was 4.32.

4.1.3 Mean stream length
From Table it is observed that the total length of stream decreases with increase in order of stream. Similarly mean stream length increase with increase in order of stream i.e. from 0.94 to 31.38 km. This deviation is observed might be due the topographic elevation and slope of basin (Nongkynrh J. M. and Husain Z., 2011) [11].

4.1.4 Stream length ratio
Stream length ratio of VI/V order was 0.53 V/IV order was 0.49, IV/III order was 0.43, III/II order was 0.54 and II/I order was 0.46. The mean stream length ratio of study area was 0.49. These variations in stream length ratio in the study area were due to variations in slope and topography.

4.2 Areal aspects of drainage networks
The areal aspects of morphometric analysis of drainage basin include form factor, circulatory ratio, elongation ratio, drainage density and constant of channel maintenance.

4.2.1 Form factor
The form factor value of Agrani river basin was 0.32. The lower value of form factor represents elongated shape of watershed. The elongated basin with low form factor indicated that the basin may produce flatter peak of flood for longer duration. Flood flows in such elongated basins are easier to manage than of the circular basin (Kant *et al*. 2015) [7].

4.2.2 Circulatory ratio
The circulatory ratio of Agrani river basin was 0.35. Circulatory ratio less than 0.5 indicate that basin is elongated in shape and characterised by the high to moderate relief and the drainage system were structurally controlled (Miller, 1953) [10]. Flood flow in such areas are easily manageable as compare to circulatory areas is confirmed here.

4.2.3 Elongation ratio
Elongation ratio is very significant index in the analysis of the basin shape which helps to give idea about the hydrological character of a drainage basin. The elongation ratio of Agrani river basin was 0.64 which indicates high relief and steep slope in some portion of the Agrani river basin as shown in Fig. 2 and Fig. 3.

4.2.4 Drainage density
The drainage density of Agrani river basin was 1.10 km/km^2 is characterized by textural ratio 4.55. The low drainage density was due to the regions of highly resistant or permeable subsoil material, dense vegetation and low relief (Strahler, 1957) [19].

4.2.5 Constant of channel maintenance
The constant of channel maintenance was found 0.91 km for Agrani river basin. Constant of channel maintenance indicates that magnitude of surface area of watershed required to sustain unit length of stream segment.

4.3 Relief Aspects of Drainage Networks
Relief aspects of the watershed plays an important role in drainage development, surface and sub-surface water flow, permeability, landform development and associated features of the terrain. Relief morphometry is critical when studying the catchment erosional characteristics (Sreedevi *et al*. 2009; Magesh *et al*. 2011; Rai *et al*. 2014; Vieceli *et al*. 2015; Al-Saady *et al*. 2016) [18, 8, 16, 21, 2].

4.3.1 Relief
Total relief for Agrani river basin was 397 m. This indicates that Agrani river basin has high relief and steep slope. The high relief value indicates the high volume flow, low infiltration and high runoff conditions of the study area.

4.3.2 Relief ratio
The relief ratio was 0.0051 for Agrani river basin. The relief ratio normally increases with decreasing drainage area and the size of the watershed of a drainage basin. The low relief ratio of the basin indicates presence of less resistant rocks in the study area (Sreedevi, 2009) [18].

4.3.3 Relative relief
Relative relief of the Agrani river basin was 0.0015 m. It indicates that the presence of less resistant rocks in the drainage basin (Magesh *et al*. 2011) [8].

4.3.4 Ruggedness number
In the present study, ruggedness number was 0.36 which is moderate as stated by Prabhakaran A. and Jawahar Raj N., 2018 [15]. This indicates that the area is moderately rugged with moderate relief and moderate stream density.

4.3.5 Length of overland flow
The length of the overland flow is the length of water over the ground before it gets concentrated into definite stream channel. The length of overland flow of the Agrani river basin was 0.45 km^2/km.

Table 2: Geomorphological characteristics of Agrani river basin

A) Linear aspects of drainage networks			
Stream order	**Number of streams**	**Total stream length (km)**	**Mean stream length (km)**
1	1187	1110.79	0.94
2	344	514.26	1.49
3	48	279.50	5.82

4	12		120.18	10.01
5	3		59.47	19.82
6	1		31.38	31.38
Bifurcation ratio				
1^{st} order/2^{nd} order	2^{nd} order/3^{rd} order	3^{rd} order/4^{th} order	4^{rd} order/5^{th} order	5^{rd} order/6^{th} order
3.45	7.17	4	4	3
Mean bifurcation ratio			4.32	
Stream length ratio				
2^{nd} order/1^{st} order	3^{rd} order/2^{nd} order	4^{th} order/3^{rd} order	5^{th} order/4^{th} order	6^{th} order/5^{th} order
0.46	0.54	0.43	0.49	0.53
Stream Frequency			0.83	
Textural ratio			4.55	
Areal Aspects of drainage networks				
Area			1918.05 km^2	
Perimeter			260.94 km	
Length of Basin			77.39 km	
Form Factor			0.32	
Circulatory Ratio			0.35	
Elongation Ratio			0.64	
Drainage Density			1.10 km/km^2	
Constant of Channel Maintenance			0.91 km	
Relief aspects of drainage networks				
Relief			397 m	
Relief Ratio			0.0051	
Relative Relief			0.0015	
Ruggedness number			0.36	
Length of Overland Flow			0.45 km^2/km	

5. Conclusion

The morphometric analysis helps decision makers to understand several characteristics of a basin, such as underlying lithology, infiltration capacity, runoff, basin shape, and size. In this study, the RS and GIS technique with the help of DEM is used for accurate estimation of river basin parameters. Linear, areal, and relief aspects were the analyzed morphometric parameters for the Agrani river basin. Based on the current analysis, the highest stream order present in the catchment is of the sixth order. The most dominant order is the lowest order. The high number of low order streams indicates the adequacy of the basin to provide sufficient superficial draining. The analysis of the linear aspects suggests the presence of permeable rocks. The analysis of the areal aspects indicates that the catchment shape is approximately elongated, and the basin is characterized by high permeability of the underlying lithology, low relief and dense vegetation. Due to these characteristics, in this basin flood flow might be easily manageable. The relief aspects indicate the presence of less resistant rocks in the drainage basin. This study estimated the various parameters of Agrani river basin such as size, area, stream order, mean stream length, longest flow path, slope, elevation, and underlying lithology. This study is having great relevance or importance for decision makers, constituting an essential step towards a scientifically sound management of watershed.

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