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Hydro-morphological appraisal of river sub basin using remote sensing and GIS tools

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Abstract
The present research work was carried out for hydro-morphological study of Subbasin of Kayadhu River in Hingoli District belonging to state of Maharashtra. The river basin under study is spread over 19°46'14.3" N to 19°53'36.9" N Latitudes and 76°58'57.4" E to 77°03'26.4" E Longitudes. Topographic maps (1:50000 scale) published by Survey of India (SOI) were used as base map for delineation of river streams and basin in the through GIS software. The ordering of the streams of the study basin was carried out by Strahler method. SRTM DEM data was used for estimation of elevation of river basin along with different relief parameters. Different morphometric parameters of the river basin were estimated using standard methods. The study revealed that the basin was spread over area of 64.92 sq. km with 38.52 km perimeter and 14.25 km of basin length. The basin was 4th order basin having 150 number of streams with dendritic to parallel pattern. The length of the streams in the basin increased with increasing order of the streams suggesting change in substrate type and steams flowing from high elevation. The estimates of stream length ratio infers that the basing has not achieved matured stage in the geographic development process. The bifurcation ratio varied between 3.58 and 7.00 suggesting dissected basin. The river basin under study has 1.9 km/sq. km drainage density with 2.86 texture ratio, 2.31 no./ sq. km stream frequency, and 0.26 Length of overland flow implying low surface runoff, permeable surface with higher infiltration & ground water prospectus, better vegetation cover, structural disturbance and steep slope. The values of elongation ratio, form factor and circulatory ratio estimated during present study imply that the basin is elongated with higher relief, low risk of erosion and low pick flows for longer duration whereas the estimated value of 0.53 sq.km/km for constant channel maintenance indicates that basin has higher infiltration and moderate runoff.

Keywords: Kayadhu, Morphometric analysis, GIS, River subbasin, Remote sensing,

Introduction
The study of different geomorphological factors of river basin including shape, size, relief, slope, drainage pattern, etc. is essential for deducing different hydrological processes pertaining to the river basin. Such studies can provide information appropriate water resource management, prediction of flood potential, erosion and sediment transport, assessing impact of land use changes, etc.

Morphometric analysis of river basin is a quantitative approach used for the study of physical parameters of a basin related to single dimension (Linear), two dimensional (Aerial) and three dimensional (Relief) aspects of the river basin. Morphometric study of river basins involves the collection of various data such as digital satellite imagery, digital elevation models, topographic maps, etc. along with field observations. These data are used for calculation of different parameters that can provide understandings about physical characteristics of basin. These physical parameters include drainage area, stream length, stream order, stream frequency, relief, slope, drainage density, shape factors and relief ratios. Such studies helps for identifying erosion potential, flooding possibilities, areas suitable for water storage and management projects, water availability, etc.

Geographic Information System (GIS) and remote sensing are tools with huge potential for morphometric analysis of river basins. It allows the integration and analysis of various spatial datasets, such as topographic maps, digital elevation models and satellite imagery data, to generate accurate and detailed maps of the river basin as well as its physical characteristics.

GIS-based morphometric analysis of river basins involves the different steps. Data collection and preparation involves collecting and preparing various spatial datasets, such as topographic maps and digital elevation models, for analysis in GIS.

Different terrain parameters, such as slope, relief, and drainage area are derived from digital elevation model using digital terrain analysis tools of GIS whereas stream network analysis tools of GIS are used for deriving morphometric parameters such as drainage density, stream order and stream frequency using the stream network. Visualization and interpretation involve use of GIS tools for generating maps and other visualizations that can help in interpreting the results of the morphometric analysis. Overall, GIS-based morphometric analysis of rivers can provide valuable insights into the physical characteristics of the river and its surrounding landscape. This information can be used to guide land use planning, water resources management and flood control efforts, among other applications.

Therefore, Geographic Information System (GIS) along with remote sensing forms important tool not only for morphometric analysis of basins but also interpretation and representation of the results. The study of Kundah subbasin from Nilgiri district in Tamil Nadu was carried out by Chitra *et al*. (2011) [2] through GIS and remote sensing for morphometric assessment. Singh *et al*., (2013) [15] assessed Morar River basin for morphometric parameters using GIS tools. Their study found that the river basin is elongated having high permeability of subsurface formation with homogenous texture and low relief. The study found that the GIS based approach for study of river basin was more appropriate than conventional techniques. Soni (2017) [17] carried out morphometric analysis of Chakrar watershed, Madhya Pradesh through the use of Remote sensing and GIS for study of geological variations, topographic information, structural setup and their interrelationships. Similarly, morphometric analysis of Kadvi basin located in Kolhapur district of Maharashtra was carried out by Chougale and Sapkale (2017) [3] using Cartosat data.

Kayadhu River is major river system in Hingoli district of Maharashtra state stretching 120.57 km within the district. Kayadhu River flows from central part of the district and provides water to majority parts of the district. Though river is seasonal, it delivers water for various purposes ranging from drinking to irrigation and industry activities. Thus, Kayadhu river along with its tributaries forms important source of water in Hingoli district. Therefore, subbasin belonging to Kayadhu River was studied using GIS tools and satellite data for assessment of various morphometric factors. This study will be advantageous for effective water management, understanding of hydrological processes, flood potential, erosion and sediment transport and other water related activities.

Study area

Current research work was carried out in one of the subbasin belonging to Kayadu River flowing through Hingoli district of Maharashtra. The basin under study extends from 19°46’14.3” N to 19°53’36.9” N Latitudes and 76°58’57.4” E to 77°03’26.4” E Longitudes (Map 01). The study area is spread over the Jawala BK, Umra, Changephal, Kadti, Kalkondi, Nandura, Amla, Goregaon and Babhulgaon villages of Hingoli District. The recorded average annual rainfall for study area was 939.30 mm with 41.7° C maximum reported atmospheric temperature and 12.7°C minimum temperature (District Census Handbook, 2011a) [5]. The basin had two water reservoirs.

Methodology

Morphometric analysis of the Subbasin of Kayadhu River was carried out by using different GIS tools on different dataset. Streams and drainage basin were delineated using SOI Topographic Maps (1:50000) through visual interpretation and manual tracing in GIS Software. Various parameters belonging to relief aspects of the basin were estimated by analysis of SRTM DEM data (~30 m spatial resolution). Different datasets used during the present study were processed, analysed and interpreted using ArcGIS and GRASS softwares.

The delineated streams from the study basin were ordered using Strahler Method (Strahler, 1964) [20]. Initial streams without any bifurcation were allotted first order whereas streams formed by unification of two first order streams were termed as second order stream and so on. The stream number were only increased if there was merger of streams with equal order, otherwise streams with higher order continued. Various morphometric parameters belonging different (linear, aerial and relief) aspects of the drainage basin were estimated using standard procedures and mathematical expression as given in Table 1.

Table 1: Mathematical expression fol. estimation of various morphometric parameters of river basin

Parameter	Formula
Linear Aspects	
1. Stream Order (N_u)	Hierarchical ordering
2. Stream Length (L_u)	Length of stream
3. Mean Stream Length (L_{sm})	Lsm=Lu/Nu
4. Stream length ratio (R_L)	Lu/Lu-1
5. Bifurcation ratio (R_b)	Nu/Nu+1
Aerial aspects	
1. Basin area (A)	
2. Basin Perimeter(P)	
3. Drainage density (D_d)	L/A
4. Stream Frequency (Fs)	Nu/A
5. Texture Ratio (T)	N1/P,
6. Length of overland flow (L_g)	1/2Dd
7. Form factor (Rf)	A/(Lb)2
8. Elongation ratio (R_e)	V(Au/nt)/Lb
9. Circulatory ratio (R_c)	4**A/P2
10. Constant channel Maintenance (C)	1/Dd

Relief aspects	
1. Basin Relief (Bh)	Vertical distance between lowest & highest point of basin
2. Relief Ratio (Rr)	Bh/Lb
3. Relative Relief (Rbh)	Bh/P
4. Ruggedness number (Rn)	Dd*(Bh/1000)

Results and Discussion

The rive subbasin assessed during current research work had semi parallel streams and semi-dendritic drainage pattern. The subbasin was found to be extended over the area of 64.92 sq. km enclosed in the perimeter of 38.52 km. The basin had relief of 91 m with estimated total length of 14.25 km. various morphometric parameters belonging to different three aspects of the basin are described below:

Linear aspects:

The parameters related to only one-dimensional measurement of basin were grouped under linear aspect (Table 2). The subbasin basin under study was 4th order basin (Strahler, 1957) [19] with total 150 streams. There were 111 streams with first order and 31 streams of second order whereas 7 streams were of third order and 1 stream of fourth order. The higher number of streams in lower order suggest that the basin is structurally weak (Thomas *et al*., 2012) [23] with possibility of flooding after heavy rain (Chougale and Sapkale, 2017) [3].

The total extent of streams of the basin was found to be 123.20 km and stream length was found to be decreasing with increasing order of the stream. This can be ascribed to the conditions wherein streams flows from higher altitudes and variations in basin substrate. (Horton, 1932; Singh and Singh, 1997 & Chougale and Sapkale, 2017) [6, 3, 16]. The study also revealed that the Mean Stream Lengths in the basin increased with respective increase in the stream order as described by Thomas *et al*., 2012 and Chougale and Sapkale, 2017 [3, 23] in their respective studies. The estimated stream length ratios among different orders showed increasing trend except for value assessed for third and fourth order streams. These estimates suggest that the basin area under study has not achieved matured stage of geographic development (Horton, 1945; Rai *et al*., 2017; Soni, 2017 & Sukristiyanti *et al*., 2017) [7, 11, 17, 21]. The bifurcation ratio calculated for the basin ranged between 3.58 to 7.00 which indicated that the basin is dissected (Horton, 1945) [7]. Comparable outcome were described by Thomas *et al*. (2012) [23]; Singh *et al*. (2013) [15]; Chougale and Sapkale (2017) [3] & Asfaw and Workineh (2019) [4] for their study areas.

Table 2: Different linear aspects for morphometric analysis

Sr.	Particulars	Unit	Stream Order				Total
			1	2	3	4	
1	Basin Length (L_b)	km					14.25
2	Stream Order (N_u)	no	111	31	7	1	150
3	Stream Length (L.)	km	71.73	23.50	18.17	9.79	123.20
4	Mean Stream Length (L.)	km	0.65	0.76	2.60	9.79	0.82
5	Stream length ratio (R_l)	-	0.00	0.33	0.77	0.54	
6	Bifurcation ratio (R_b)	-	3.58	4.43	7.00	0.00	

Aerial aspects

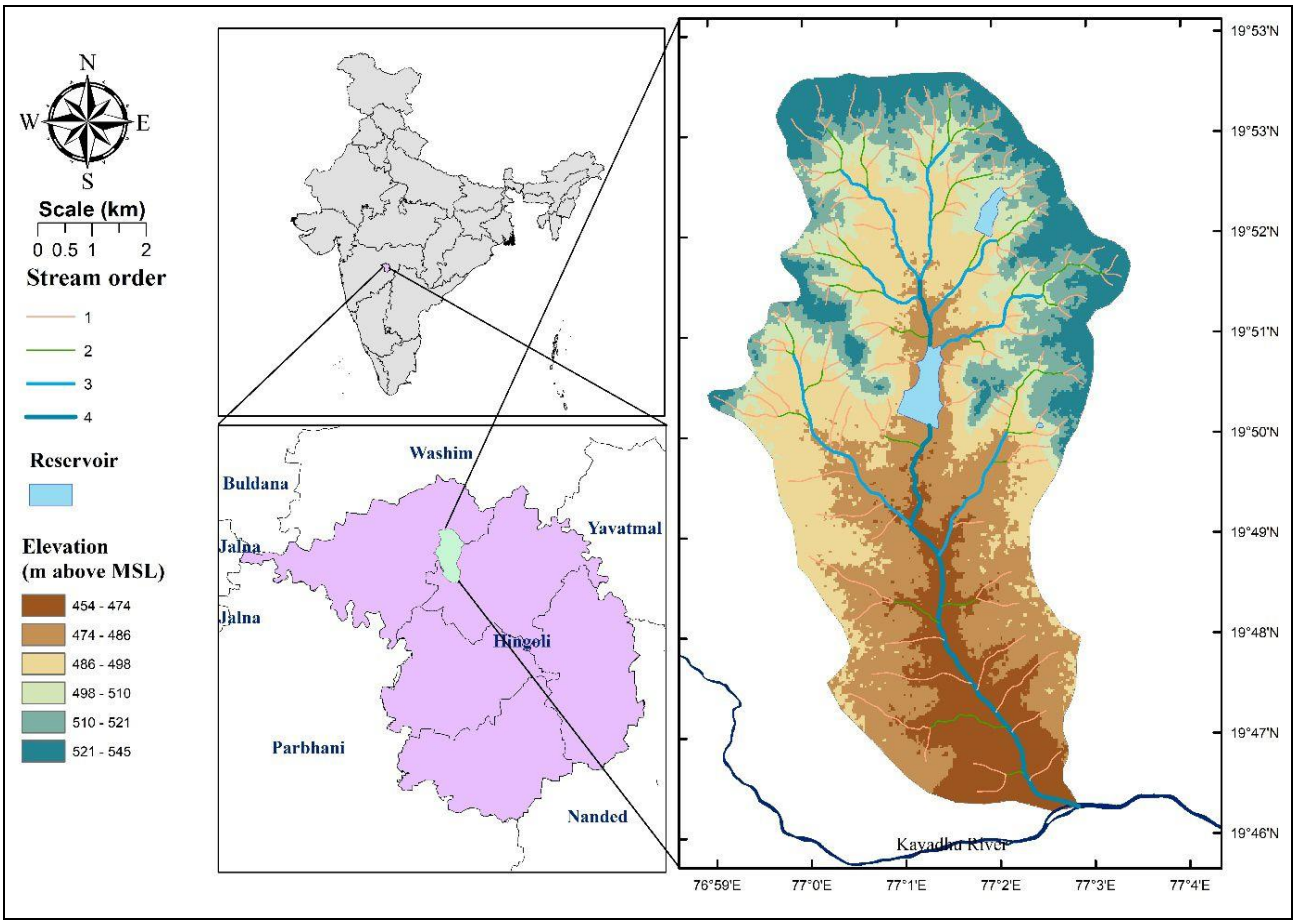
The parameters with two-dimensional measurements were covered under aerial aspects of basin (Table 3).

Table 3: Results of morphometric analysis of Aerial aspects of basin

Sr.	Parameter	Values
	Aerial aspects	
01	Basin area (A)	64.92 sq. km
02	Basin Perimeter (P)	38.82 km
03	Drainage density (D_a)	1.9 km/sq. km.
04	Stream Frequency (F_s)	2.31 no./ sq. km.
05	Texture Ratio (1')	2.86
06	Length of overland flow (L_g)	0.26 sq. km./km
07	Form factor (Rf)	0.32
08	Elongation ratio (R_e)	0.64
09	Circulatory ratio (R_c)	0.54
10	Constant channel Maintenance (C)	0.53 sq. km./km

The study basin was spread over the area of 64.92 sq. km and has the perimeter of around 38.52 km. The basin area was characterised by course drainage density of 1.9 km/sq. km indicating poor surface runoff, permeable surface with good ground water prospect and better vegetation cover (Sukristiyanti *et al*., 2017; Asfaw and Workineh, 2019) [4, 21]. The stream frequency of the basis was estimated to be 2.31 no. / Sq. km which suggest that the basin has permeable surface and low runoff with higher infiltration (Chitra *et al*., 2011; Thomas *et al*., 2012 & Soni, 2017) [2, 23, 17]. The estimated value of texture ratio was 2.86 which was moderate in nature as reported by Sukristiyanti *et al*. (2017) [21]. The Length of overland flow for the basin under study was found to be 0.26, which signify the influence of structural disturbance and steep slope as suggested by Soni (2017) [17].

The calculated value of form factor for the basin area was 0.32 implying elongated shape of the basin with lesser risk of erosion and lower peak currents over long period. The elongated shape with higher relief of the basin was also inferred from the estimated value of elongation ratio and circulatory ratio (Strahler, 1964; Waikar and Nilawar, 2014; Soni, 2017 and Sukristiyanti *et al*., 2018) [20, 17, 24, 21]. The estimated value of constant channel maintenance (0.53 sq.km/km) for the basin indicates higher infiltration and moderate runoff as reported by Chougale and Sapkale (2017) [3].



Relief aspects

The evaluation of relief parameters of the basin area under study are summarised in Table 4.

Table 4: Results of morphometric analysis of relief aspects of basin

Sr.	Parameter	Values
01	Basin Relief (Bb)	91 m
02	Relief Ratio (R_r)	6.39 m/km
03	Relative Relief (Rbh)	2.34 m/km
04	Ruggedness number (Rn)	0.17

The basin area of Kayadhu River studied during the present research work showed total relief of 91m with estimated relief ratio of 6.39m/km and relative relief of 2.34m/km. These higher values of relief ratio and relative relief confirms that the basin had steep slope (Miller, 1953; Sharma and Sharma, 2013; Singh *et al*., 2013 & Soni, 2017) [9, 14, 15]. The estimated value of Ruggedness number for the basis area was 0.17, indicating that the basin area is relatively smoother (Kumar *et al*. 2015; Chougale and Sapkale, 2017 & Asfaw and Workineh, 2019) [4, 3].

Conclusion

The basin area of the Kayadhu River studied during present work was of fourth order, spread over 64.92 sq. km area enclosed in 38.52 km perimeter. The basin was characterized by dendritic to parallel drainage pattern streams flowing from higher altitude to lower areas with changing substrate. The basin was found dissected with permeable surface, low runoff and higher infiltration showing better ground water prospect. The basin did not achieve structural maturity and was in geomorphic development phase. The basin was found to be elongated in shape with lower risk of erosion and low pick flows for longer duration.

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