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MORPHOMETRIC ANALYSIS OF SHALMALA RIVER SUB-BASIN DHARWAD DISTRICT, KARNATAKA, USING RS AND GIS TECHNIQUES

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***Abstract*— In the present study an attempt has been made to evaluate the morphometric analysis of the Shalmala river sub-basin by using Remote Sensing (RS) and Geographic Information System (GIS) techniques. The study area is delineated by Arc GIS v10.4 software as per ASTER-DEM. Morphometric parameters like linear, areal and relief aspects of the basin have been evaluated. The study revealed that, the drainage pattern of the study area is sub-dendritic to dendritic. The highest stream order is fifth order. The drainage density (Dd) of the area is 1.583 Km^{-1} indicates the area comprises of highly permeable subsurface material. The mean bifurcation ratio of the present area is 4.69, suggests that the area is not affected by structural disturbances. The relief ratio of the study area is 0.00786 which indicates gentle slope and comparatively higher infiltration. The Shalmala river sub-basin comprises sufficient number of lineaments for the groundwater recharge.**

***Keywords*— Dharwad, Digital Elevation Model, GIS, Karnataka, Morphometric analysis, Remote sensing, Shalmala River**

1. INTRODUCTION

Morphometry is the operation of measurement and mathematical analysis of the configuration of the earth's surface, shape and dimensions of the landforms [1], [2], [3], [4] and [5]. The study helps to understand channel network, ground slope, structural control, geologic and geomorphic of a drainage basin [6]. Remote sensing and geographical information system (RS-GIS) techniques are in trend for assessing various morphometric and hypsometric parameters of the drainage basin/watershed [7], [8], [9], [10], [11], [12] and [13]. Recently, researchers carried out morphometric analysis using RS and GIS techniques [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26]. Hence, the present study is carried out on morphometric characteristics of the Shalmala river sub-basin, Karnataka, which is located between latitudes 15º 06' 21.6" to 15º 24' 50.4" and longitudes 75º 00' 3.6" to 75º 11' 49.2" and fall in parts of Survey of India toposheet numbers 48M/3 and 48M/4 (1:50,000 scale). The sub-basin covers an area of 363.39Km² (Figure 1). The elevation ranges from 498m to 772m above mean sea level (MSL) and receives 772mm of an average annual rainfall and annual average temperature is around 24.3ºC.

Geologically, the Shalmala river sub-basin is covered by Sedimentary rocks such as greywacke, argillites and banded ferruginous quartzite. The present study constitutes metamorphic formation like Quartz mica-schist of Chitradurga group of Archean age. At some places, dolerite dyke cuts across the bedding planes.

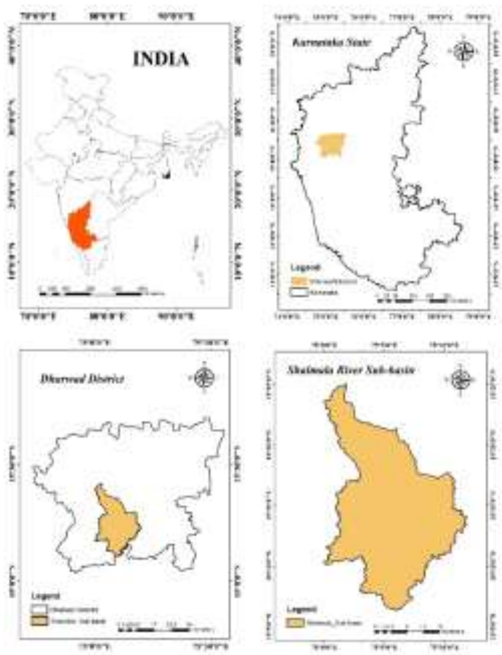

Fig. 1 Location map of the Shalmala river sub-basin

2. METHODOLOGY

The morphometry analysis of Shalmala river sub-basin has been carried out by using Arc-GIS software v10.4. Georeferencing, digitization and delineating the entire study area has been done with NRSC standards. The drainage system is extracted by using Advanced Spaceborne Thermal Emission and Reflection Radiometer-Digital Elevation Model (ASTER-DEM) data (30m resolution) (Figure 2).

The morphometric parameters like linear aspects, areal aspects and relief aspects were calculated using the formulas (Table 1) given by the Strahler, Horton and Schumm [6], [27] and [28].

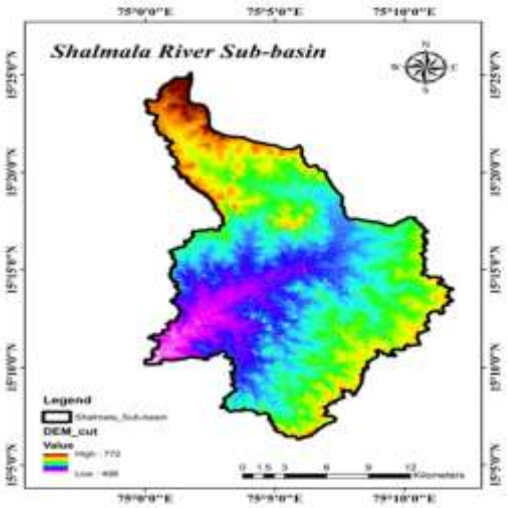

Fig. 2 Digital Elevation Model (DEM) of the study area

Table I. Formulae adopted for computation of morphometric parameters.

Sl. No.	Morphometric parameters	Formulae
01	Steam Order (U)	Hierarchical rank
02	Steam Length (Lu)	Length of the steam
03	Mean Steam Length (Lsm)	Lsm = Lu/Nu Where, Lsm=Mean stream length Lu=Total steam length of order ‘u’ Nu=Total number of stream segments of order ‘u’
04	Steam Length Ratio (Rl)	Rl = Lu/Lu-1 Where, Rl=Stream length ratio Lu=Total steam length of order ‘u’ Lu-1=Total steam length of its lower order
05	Bifurcation Ratio (Rb)	Rb = Nu/Nu+1 Where, Rb=Bifurcation ratio Nu=Total number of stream segments of order ‘u’ Nu+1=Total number of segments of the next higher order
06	Drainage Density (Dd)	Dd=Lu/A Where, Dd=Drainage density Lu=Total length of streams A=Area of the basin
07	Drainage texture (Rt)	Rt = Nu/P Where, Rt=Drainage texture Nu=Total no. of streams of all orders P=Perimeter of the basin
08	Elongation Ratio (Re)	Re= $(2\sqrt{(A/\pi)})/Lb$ Where, Re=Elongation ratio A=Area of watershed Lb=Basin Length π =3.14
09	Circulatory Ratio (Rc)	$Rc = (4 * \pi * A)/P^2$ Where, Rc=Circulatory ratio A=Area of sub-basin

		P=Perimeter of sub-basin π=3.14
10	Stream Frequency (Fs)	Fs=Nu/A Where, Fs=Stream frequency Nu=Total number of all streams A=Area of sub-basin
11	Form Factor (Ff)	$Ff=A/Lb^2$ Where, Ff=Form factor A=Area of a sub-basin Lb=Basin Length
12	Length of Overland Flow (Lo)	Lo=1/Dd*2 Where, Lo=Length of overland flow Dd=Drainage density
13	Constant Channel Maintenance (Cm)	Cm=1/Dd Where, Cm=Constant channel maintenance Dd=Drainage density
14	Basin relief (Bh)	Bh = H – h Where, Bh=Basin relief Vertical distance between the highest & lowest points
15	Relief ratio (Rh)	Rh = Bh/Lb Where, Rh=Relief ratio Bh=Basin relief Lb=Basin length
16	Relative relief (Rr)	Rr = Bh/P Where, Rr=Relative relief Bh=Basin relief P=Perimeter of basin
17	Ruggedness number (Rn)	Rn = Dd*Bh Where, Rn=Ruggedness number Dd=Drainage density Bh=Basin relief

3. RESULTS AND DISCUSSIONS

3.1. LINEAR ASPECTS

A linear aspect of morphometric studies includes following parameters (Table 2).

Stream order is a hierarchy of tributaries as proposed by Strahler [6]. The current area is the fifth order drainage basin (Figure 3).

The number of stream segments in each order is known as stream number (Nu). Horton [27] stated, the number of stream segments forms an inverse geometric relationship against the order. It is calculated that, the total stream numbers of different orders from the study area is 586. The stream numbers of the first stream order in the present study area is 457, for second stream order is 100, for third stream order is 22, for fourth order is 6 and for fifth order is 1 respectively (Table 2). Hence, the large number of streams in the basin indicates that the topography is still rugged and streams are rapidly cutting their channels.

The stream length has been carried out as per the law proposed by Horton [27]. The maximum steam length (Lu) of the study area is 287.575 Km and average stream length is 115.065 Km. The stream length of various orders is presented in the Table 2.

The mean stream length (Lsm) is a characteristic property associated with basin surface [6], [27]. It can be determined by dividing the total stream length of all orders by the total number of stream segments. The mean stream length of the study area is varying from 0.629 Km to 20.768 Km with an average 06.714 Km (Table 2). Topography and slope cause the variation of its value.

The stream length ratio (Rl) of the study area ranges between 0.483 to 0.610 (Table 2). Change in stream length indicates late youth stage of geomorphic development [29], [30], [31].

Bifurcation ratio (Rb) is a dimensionless property and shows the degree of integration prevailing between streams of various orders in a drainage basin. Bifurcation ratio of the Shalmala river sub-basin varies from 3.666 to 6 with a mean

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of 4.69 (Table 2), which indicates that the area is not much affected by structural disturbances.

Fig. 3 Stream orders of the Shalmala river sub-basin.

Table II. Results of linear aspects of Shalmala river sub-basin.

Stream Order (U)	Stream Number (Nu)	Stream Length (Lu) Km	Mean stream length (Lsm) Km	Stream length ratio (Rl)	Bifurcation ratio (Rb)
1	457	287.575	0.629	-	-
2	100	140.084	1.400	0.487	4.57
3	22	085.524	3.88	0.610	4.545
4	06	041.374	6.895	0.483	3.666
5	01	020.768	20.768	0.501	6
Total	586	575.325	33.572	2.081	18.781

3.2. AREAL ASPECTS

Areal aspects of morphometric analysis of a study area include following parameters discussed below and presented in table 3.

Drainage density is directly related to climate, rock types, relief, infiltration capacity, vegetation cover, surface roughness and run off intensity index. The low drainage density indicates that the area is composed of highly resistant and highly permeable sub-soil material under the dense vegetative cover and low relief. Drainage density of the present study area is 1.583 Km^{-1} (Table 3), suggesting low drainage density (Figure 4).

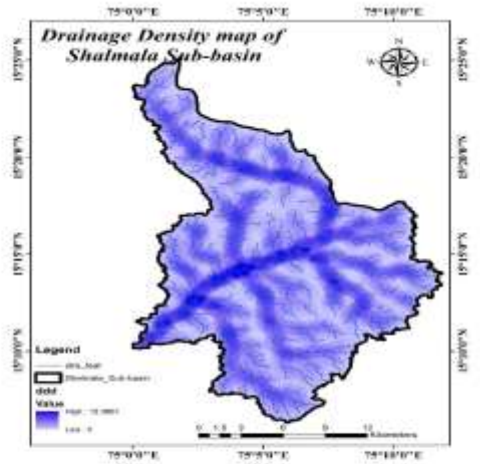

Fig. 4 Drainage density of the Shalmala river sub-basin.

Drainage texture is the ratio of total number of stream segments to the perimeter area. It depends upon the meteorological, geological and climate aspects [32], [33]. According to Smith [32] classification, the drainage texture of the study area is 4.327 Km^{-1} (Table 3), indicates moderate drainage texture.

Horton [8] stated that the basin elongation ratio is varies between 0.6 to 1.0 associated with a wide variety of climate and geology. A circular basin is more effective in discharge than elongated basin [31]. In the study area the elongation ratio is 0.61 (Table 3), represents elongated shape.

Circulatory ratio is influenced by the length of the streams, frequency of streams and slope of the basin. The circulatory ratio of the study area is 0.2490 (Table 3). It indicates that the Shalmala river sub-basin is elongated in nature.

Stream frequency mostly controlled by the lithology of the basin and specifies the texture of the stream network. The stream frequency is 1.612 Km^{-2} (Table 3), indicates increase in stream frequency as increase in drainage density.

The form factor should be always less than 0.7854 to be a perfect circular basin and greater the value of form factor higher the peak flow of shorter duration, lesser will be the elongated drainage basin. The study area comprises 0.299 (Table 3), represents elongated drainage basin.

Length of overland flow is used to describe the length of flow of water over the ground before it becomes concentrated in definite stream channels. The high value of length overland flow indicates that the rainwater had to travel relatively longer distance before getting concentrated into stream channels [34]. The value of length of overland flow is 0.315 Km (Table 3), indicates that rainwater will join streams quickly.

The constant channel maintenance of this area is 0.6317Km^2, suggests impermeable nature of sub-surface formations (Table 3).

Table III. Results of areal aspects of Shalmala river sub-basin.

Areal Aspects	**Results**
Drainage density (Dd)	1.583 Km^{-1}
Drainage texture (Rt)	4.327 Km^{-1}
Elongation ratio (Re)	0.617
Circulatory ratio (Rc)	0.249
Stream frequency (Fs)	1.612 Km^{-2}
Form factor (Rf)	0.299
Length of overland flow (Lo)	0.315 Km
Constant channel maintenance (Cm)	0.631 Km^2

3.3. RELIEF ASPECTS

Relief aspects of the study area include following characteristics (Table 4).

The highest elevation of the sub-basin is 772m and lowest is 498m above Mean Sea Level (MSL). The basin relief of the study area is 0.274Km (Table 4).

The Shalmala river sub-basin shows relief ratio 0.00786 (Table 4), indicates gentle slope and comparatively higher infiltration.

The relative relief of Shalmala river sub-basin is 0.00202 (Table 4).

The ruggedness number of the present sub-basin is 0.433 (Table 4). The low ruggedness number (Rn) value of the sub-basin implies that area is less prone to soil erosion and have intrinsic structural complexity in association with relief and drainage density.

Table IV. Results of relief aspects of Shalmala river sub-basin.

Relief aspects	**Results**
Basin relief (Bh)	0.274 Km
Relief ratio (Rh)	0.00786
Relative relief (Rr)	0.00202
Ruggedness number (Rn)	0.433

4. SLOPE

The study of slope is an essential parameter in morphometric studies. Steeper the slope may cause less recharge of groundwater because of rapid run-off during rainy season and hence, takes minimum duration to infiltrate the surface water to recharge the zone of saturation [35], [36], [37], [38]. In the present study area, it is measured that the slope is varies from 0% to 77% (Figure 5). Greater the percentage of slopes leads to rapid runoff and high erosion. The larger part of the sub-basin varies between 0% to 19%, suggesting less prone to surface runoff and erosion of water. Hence, the rate of infiltration is maximum.

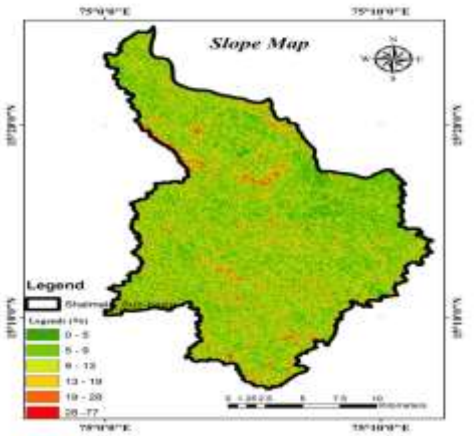

Fig. 5 Slope map of the Shalmala river sub-basin.

5. LINEAMENTS

The lineaments are the weaknesses of the topography such as joints, cracks, faults etc. In hard rock lithology, due to less porosity of terrain the groundwater potentiality depends on other structural features [39], [40], [41] [42] [26]. The area having high lineament density are good for groundwater recharge [43].

From the figure 6, illustrated that the present sub-basin consists of total 26 lineaments in that 08 are major and 18 are minor lineaments. The longest lineaments trends in the north-west to south-east direction. The majority of minor lineaments are noted in the NNW-SSE direction and majority of major lineaments are observed in the NW-SE direction as shown in Table 5. In the study area the seepage of water will be maximum due to the presence of joints, fractures and cracks sufficiently.

Table V. Results of relief aspects of Shalmala river sub-basin.

Direction	Lineaments	
	Minor	Major
NW-SE	4	3
NE-SW	2	1
N-S	1	0
NNE-SSW	1	2
NNW-SSE	5	1
NWW-SEE	4	1
NEE-SWW	1	0
Total	18	08

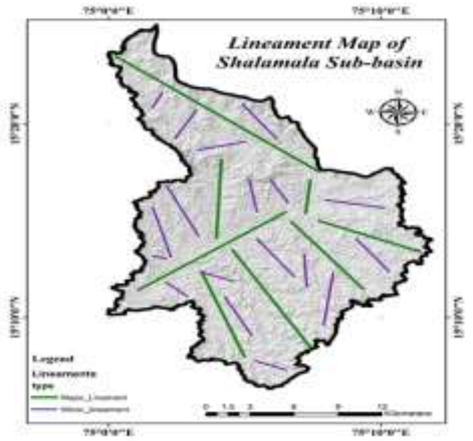

Fig. 6 Lineaments map of the Shalmala river sub-basin.

6. CONCLUSION

The morphometric analysis is based on the measurement of linear, areal and relief aspects using GIS techniques. The drainage system of the Shalmala river sub-basin showing dendritic to sub-dendritic patterns with moderate drainage texture. The changes in stream length ratio might be due to the variation in slope and topography of the area. The drainage density is low in the present sub-basin which indicates that the area comprises of highly resistant and highly permeable sub-soil material under the dense vegetative cover and low relief. The present study reveals that the elongation ratio and circulatory ratio of the present area is 0.617 and 0.2490 respectively which represents the sub-basin is in elongated shape. The length of overland flow of the Shalmala river sub-basin is 0.315 indicates that rainwater will join streams quickly. The basin relief is 274m. The relief ratio of the study area is 0.00786 shows that slope of the sub-basin is gentle and also indicates maximum infiltration. The ruggedness number of Shalmala river sub-basin is 0.433, suggests that the particular area is less prone to soil erosion. The slope is almost moderate which implies that the rate of infiltration will be maximum. The lineaments are sufficient in the study area which constitute enough groundwater recharge. Hence, the present study concludes to implement groundwater recharge structures for amended water management.

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