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Remote sensing, DEM and GIS based morphometric analysis in some part of Wainganga River sub-basin

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Abstract
Geologically, the study area is mainly constituted by the rocks of Paleoproterozoic age in the central part, the northern part is covered by Archean, Paleoproterozoic-Mesoproterozoic, Paleoproterozoic with some patches of Late Permian-Early Triassic and Quaternary age while the southern part is covered by Archean age. Geomorphologically study area covered by denudational hills and plateau on northern to eastern part, pediment and pediplain on central part, alluvial plain western part. The bifurcation ratio ranges from 3 to 5.45. Lower Rb values are the characteristics of structurally less disturbed basins without any distortion in drainage pattern. A low drainage density is more likely to occur highly resistant region of highly permeable subsoil material under dense vegetative cover and where relief is low. The study area further divided into four Sub-watersheds: SW-1, SW-2, SW-3 and SW-4. The comprehensive use of GIS resulted in the development of an efficient and effective methodology of spatial data management and manipulation. The integration and analyses of various thematic maps and image data proved useful for the delineation of zones of groundwater potential. This present study has helped in understanding the geomorphological characteristics of the study area with proper understanding of the landforms and their role in water resource management. Over all this study will help in improving the hydrogeological conditions of the area for the sustainable development of the region.

Keywords: watershed, Wainganga River, remote sensing and GIS

Introduction

Remote sensing technology deals the requirements of reliability and speed, and is an ideal tool for generating spatial information which is pre-requisite for planned and balanced development at watershed level (Ravindran *et al*., 1992) [36]. The geographical information system (GIS) technology provides suitable alternatives for efficient management of large databases. Integration of remote sensing data and GIS technologies has proved to be an efficient tool for water resources development and management projects as well as for watershed characterization and prioritization (Kumar *et al*. 2001; Ali and Singh, 2002; Singh *et al*., 2003, Pandey *et al*., 2009, Pandey *et al*., 2010, Manjare,2020) [15, 34]. Digital elevation model based terrain imaging, processing of topographic aspects in morphometric studies made GIS a dominant tool (Patel *et al*., 2016) [7] in understanding basin structure (Thomas *et al*., 2011, Bali *et al*., 2012, Manjare B.S. and Jagtap Suyog, 2013, Yadav *et al*., 2014, Das S, Patel PP, Sengupta, 2016. Choudhari *et al*., 2018; Yadav *et al*., Manjare *et al* 2017, 2018; Kumar *et al*., 2018; Yadav *et al*., 2020, Manjare, 2020) [50, 2, 24, 13, 7, 53]. Thus, DEM is the principal dataset for various purposes in hydrology, morphometry, etc. (Kumar *et al*., 2017, Kumar *et al*., 2018, Manjare B. S and Pophare A. M, 2019 Manjare, 2020, Manjare *et al* 2021) [12, 13, 20, 26].

Morphometry may be defined as the mathematical analysis of the earth's surface that describes its topographic reliefs (Clarke 1966; Pakhmode *et al*. 2003) [5]. Rastogi and Sharma (1976) mentioned that several phenomena related to hydrology can be correlated with the physiographic characteristics of watersheds. Morphometric analysis gives a comprehensive interpretation about the hydrologic response such as surface runoff generation, infiltration capacity and even groundwater potential. Other basin characteristics such as travel time, time to peak and intensity of erosional processes can be predicted with better insight and accuracy through morphometric analysis (Altaf *et al*. 2013) [1], and it could be a good alternative in ungauged watersheds where information on hydrology, geology, geomorphology and soil are scarce (Lindsay JB, Evans MG, 2008, Rudraiah M, Govindaiah S, Srinivas, 2008, Sreedevi *et al*., 2009, Romshoo *et al*. 2012; Magesh *et al*., 2013, Manjare *et al*., 2014b,, Senthamizhan *et al*., 2016 Ready, 2018, Puno and Puno 2019, Jena and Dandabat, 2019, Manjare, 2020, Tukura, *et al*., 2021) [16, 41, 47, 40, 17, 23, 43, 10, 27, 51]. The other factors like Slope, Drainage, structure and Land use/cover and incorporated in characteristic expressions of lithological and geomorphologic (Manjare, 2014a) [22].

Study Area

The study area falls in Gadchiroli district of Maharashtra which is bounded by latitude and longitude 20^{0}15'00" to 20^{0}45'00"N and 79°30'00"E to 80^{0}30'0"E is in the Desaiganj taluka in Gadchiroli district, Maharashtra. The

Wainganga River originates from Mahadeo hills in Mundara, Seoni district in Madhya Pradesh and it flows 580 km south to join Wardha River, northeast of Kagaznagar in Maharashtra state. (Fig. 1). The climate of study area is tropical. Most precipitation falls in July with an average of 233mm and May is the warmest month with an average temperature of 36°C and January is the coldest month with a lowest average temperature of 21°C. The average rainfall in the study area is about 700 to 800 mm (Fig.1). The study area has been divided in to four sub watersheds namely SW1, SW2, SW3 and SW4 watersheds.

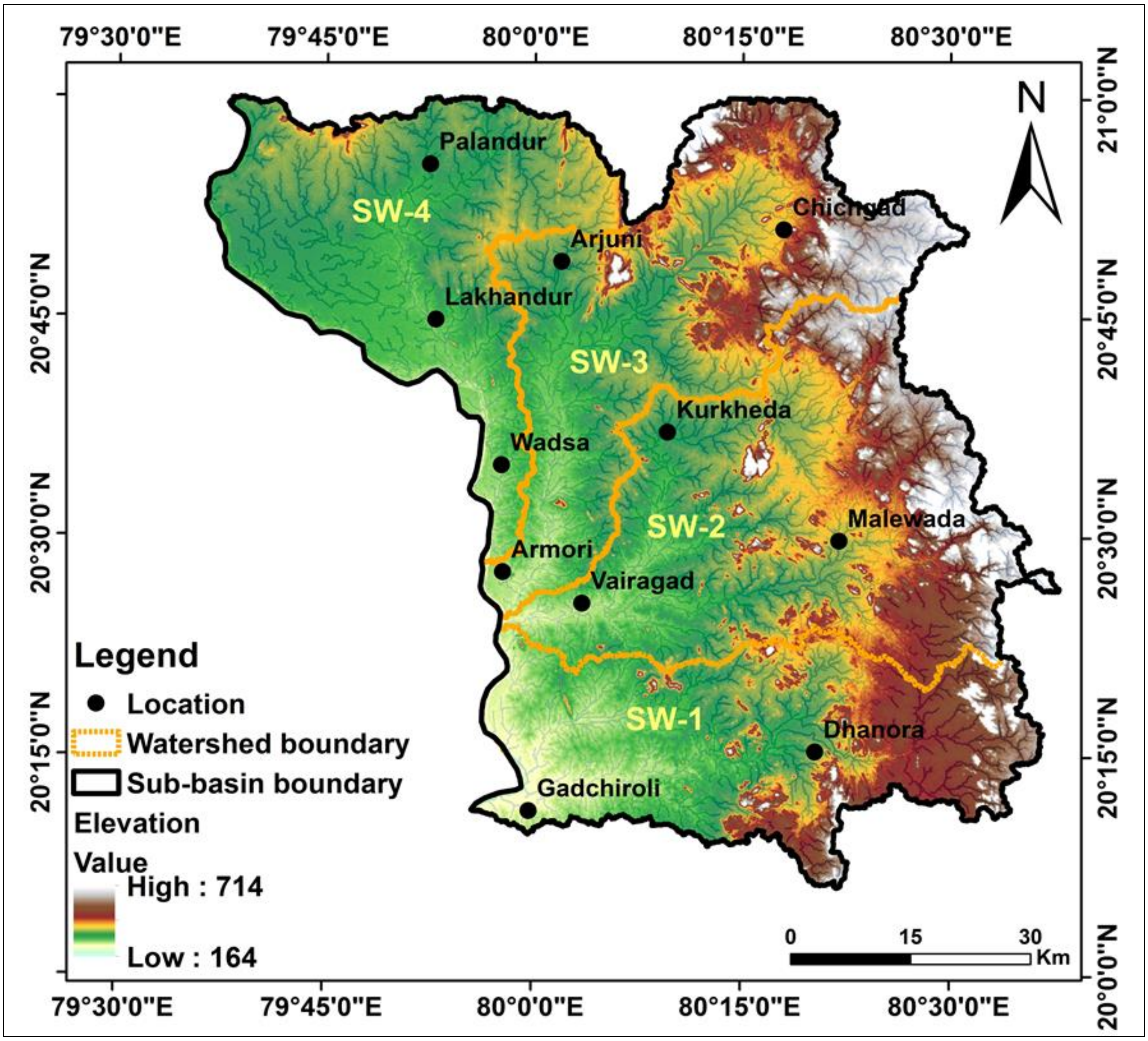

Fig 1: Location map of the study area

Geomorphology

The geomorphology map has been prepared by visual interpretation and field studies. In the study area, five major geomorphic unit are present *viz*., denudational hills, plateau, pediments, pediplain, and alluvial plain. Denudational landforms are formed as a result of active process of weathering, mass wasting and erosion deu to the action of exogenic agent upon the exposed rocks. During these process, the rock on the land surface area worn away and the result is an overall lowering of the land surface. the study area it covers northern and western part of watershed. It cover the area near Chichgad and Malewada village (Fig.2). A plateau is a flat, elevated landform that rises sharply above the surrounding area on the one side. Plateaus occur on every continent and take up a third of the Earth land. They are one of the four major landforms, along with mountains, plains and hills. It the study area it covers northern and southern part of watershed. It is located in the area near Chichgad, Malewada, and dhanora village (Fig. 2.2). A pediment is a gently sloping erosion surface or plain of low relief formed by running water in arid or semiarid region at the base of a receding mountain fornt. A pediment is underlain by bedrock that is typically covered by a thin, discontinuous veneer of soil and alluvium derived from upland areas. In the study area it situated between hilly terrain/plateau and plain. It is located in the area near Chichgad, Malewada, and Dhanora village (Fig. 2). Pediplain is the broad, relatively flat rock surface formed by the joining of several pediments. Pediplains are usually formed in arid or semi-arid climates and may have a thin veneer of sediments. It is postulated that the pediplain may be the last stage of landform evolution, the final result of the processes of erosion. It covers central part of watershed and it is located in the near Palandur, Arjuni, Kurkheda, Malewada, Dhanora village (Fig.2). An alluvial plain is a largely flat landform created by the deposition of sediment over a long period of time by one or more rivers coming from highland regions, from which alluvial soil forms. As the highlands erode due to weathering and water flow, the sediment from the hills is transported to the lower plain. In the study area it covers western part of watershed. It is located in the area near Palandur,Lakhandur, Wadsa, Armori,Vairagad, and Gadchiroli village (Fig. 2).

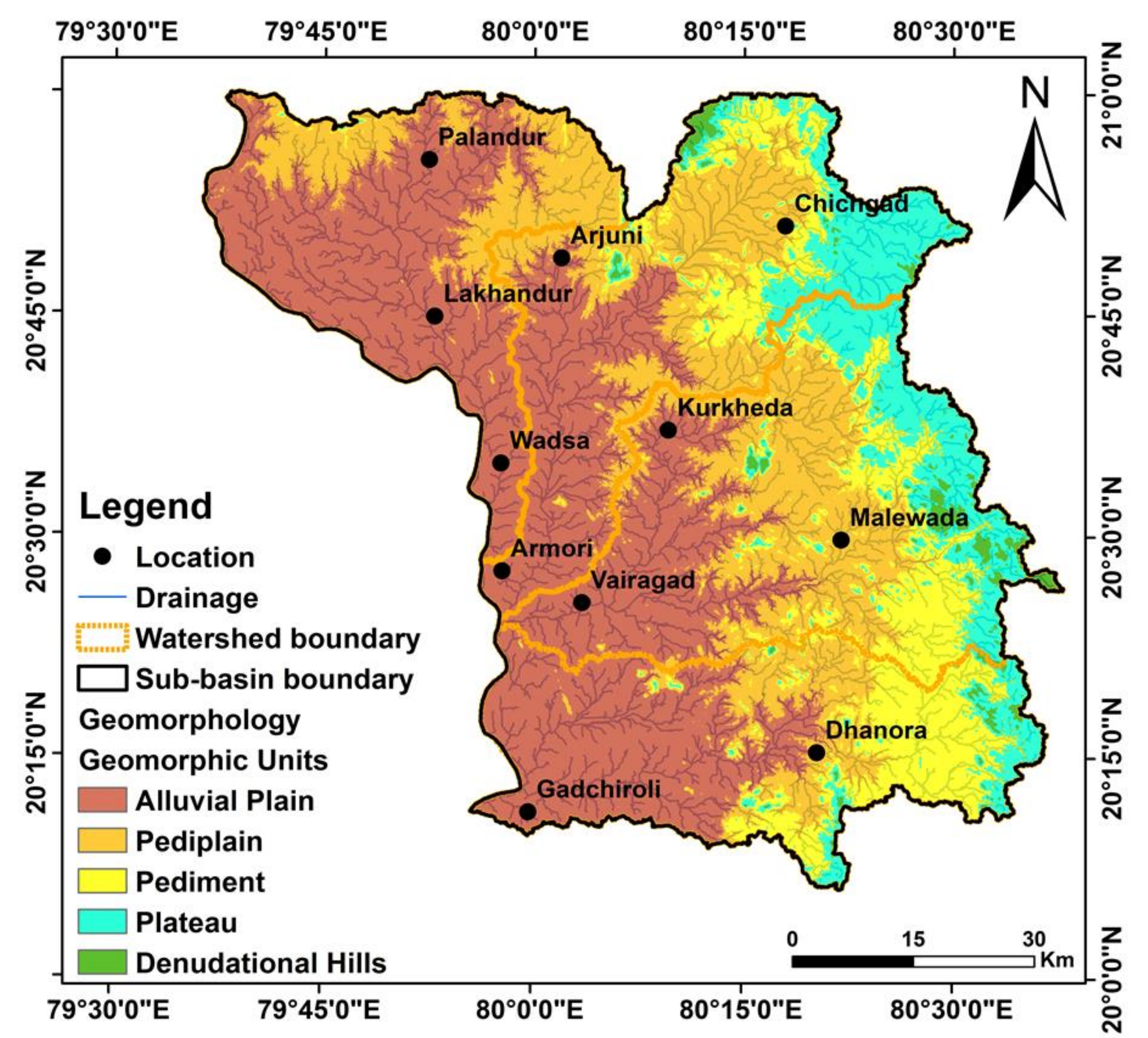

Fig 2: Geomorphology of the study area

Data Used and methodology

In the present study, various types of data have been used (table 3.1 and 3.2). Both satellite borne remote sensing data and other published maps and reports constitute the database necessary for the interpretation and delineation of various thematic layers and information. Multidate IRS 1D/P6(March 2007) LISS III data in digital format, geocoded at the scale of 1:500000 were used in conjunction with secondary or collateral data. Survey of India toposheet on scale 1:50,000, District resources map and SRTM-DEM 90m (USGS/NASA SRTM DEM data) were used.

The values of morphometric parameters namely; stream length, bifurcation ratio, drainage density, stream frequency, form factor, texture ratio, elongation ratio, circularity ratio are calculated based on the formulae suggested by Horton (1945, Miller 1953, Schumn,1956, Strahler,1964, Nookaratm,2005). The study area has been divided in to four sub watersheds namely SW1, SW2, SW3 and SW4 watersheds.

Morphometric Analysis

The morphometric analysis is carried out through measurement of linear, areal and relief aspects of the basin (Nag and Chakraborty, 2003). Morphometric analysis is used in watershed prioritization and conservation of natural resources at watershed level. The landform processes, soil physical properties and erosional characteristics can be studied using drainage morphometry (Horton, 1945; Strahler, 1957). Remote sensing and GIS techniques play an important role in providing spatial information needed for computation of morphometric parameters of drainage basins. Morphometric parameters provide information on various terrain factors such as denudation characteristics, nature of bedrock, etc. The morphometric analysis is carried out by three aspects, namely linear, aerial and relief (Table 1).

Table 1: Formulae adopted for computations of morphometric parameters

Sr. No	Parameter	Symbol	Formula	Reference
1.	Stream Order	S_u	Hierarchical rank	Strahler (1952)
2.	Stream number	N_u	N_u=S1+S2+S3…Ln	Horton (1945)
3.	Stream Length	L_u	Length of the stream (kilometres)	Strahler (1964)
4.	Mean stream length	L_{sm}	$L_{sm}= L_u/N_u$ where, L_u= Total stream length of order 'u' N_u= Total no. of stream segments of order 'u'	Strahler (1964)
5.	Stream length Ratio	R_L	R_L= Lsm/L_{sm}-1 L_{sm}= Mean stream length of a given order and L_{sm}- 1 = Mean stream length of next lower order	Strahler (1964)
6.	Bifurcation Ratio	R_b	$R_b=N_u/N_u+1$ where, N_u=Total no. of stream segments of order 'u' N_u+1=Number of stream segments of the next higher order	Schumm (1956)
7.	Mean bifurcation ratio	R_{bm}	R_{bm}= Average of bifurcation ratio of all orders	Strahler (1964)
9.	Basin perimeter (km)	P	P= Outer boundary of drainage basin measured in kilometres	Schumm (1956)
10.	Basin length (km)	L_b	$L_b = 1.312 \times A^{0.568}$ where, A = Area of the basin	Schumm (1956)
11.	Basin area (km2)	A	Area from which water drains to a common stream and boundary is determined by opposite ridges	Schumm (1956)
12.	Form factor (R_f< 1)	R_f	$R_f = A/L_b^2$ where, A= area of the basin (km^2) and L_b= basin length, km	Horton (1932)
14.	Drainage density	D_d	$D_d= L_u/A$ measured in (km/ km2) where, L_u = Total length of the stream (km) and A = Area of the basin in (km^2)	Horton (1932)
15.	Stream frequency	F_s	$F_s = N_u/A$ where, N_u = Total no. of stream segments of all orders and A = area of the basin (km^2)	Horton (1945)
16.	Drainage texture	D_t	$D_t= N_u/P$ where, N_u= Total no. of stream of all orders and P= basin perimeter measured in km	Horton (1945)
17.	Circulatory ratio ($R_c \leq 1$)	R_c	$R_C= 4\pi A/P^2$ where, A = area of the basin (km^2) and P= basin perimeter measured in km	Miller (1953)
18.	Elongation ratio	R_e	$R_e=2\sqrt{(A/\pi)}/Lb$, Where, A= Basin area, L= Basin length	Bull & Mc Fadden (1977)
19.	Constant of channel maintenance	CCM (km2/km)	CCM=1/D_d Where, D_d= drainage density	Schumm (1956)

Linear aspects

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

Stream Order (Nu)

Based on the hierarchic making of streams, the designation of stream order is the first step in morphometric analysis of a drainage basin (Strahler, 1957). Wainganga River is allocated as 6th order stream. The stream order and stream number is presented in (Table 1). Out of four sub watershed, SW-2 and SW-4 has 6th order stream while SW-1 and SW-3 has 5th order stream. (Fig.3).

Table 2: Calculation of different linear morphometric parameters of all four sub watersheds from the study area

Sr. No.	Sub Watershed Code	Basin Area (km^2)	Stream Order (S_u)	Stream Number (N_u)	Stream Length (L_u) (km)	Log N_u	Log L_u
1.	SW1	1414.31	I	409	504.93	2.61	2.70
			II	194	277.40	2.28	2.44
			III	24	158.02	1.38	2.19
			IV	5	43.81	0.69	1.64
			V	1	63.61	-	1.80
			VI	-	-	-	-
2.	SW2	1832.81	I	566	688.92	2.75	2.83
			II	279	396.85	2.44	2.59
			III	27	154.11	1.43	2.18
			IV	8	100.81	0.90	2.00
			V	2	84.02	0.30	1.92
			VI	1	15.55	-	1.19

3.	SW3	1556.00	I II III IV V VI	481 223 23 5 1 -	650.86 334.75 165.55 72.16 77.44 -	2.68 2.34 1.36 0.69 - -	2.81 2.52 2.21 1.85 1.88 -
4.	SW4	1366.06	I II III IV V VI	393 188 17 3 2 1	509.30 244.79 151.52 21.03 93.42 28.93	2.59 2.27 1.23 0.47 0.30 -	2.70 2.38 2.18 1.32 1.97 1.46

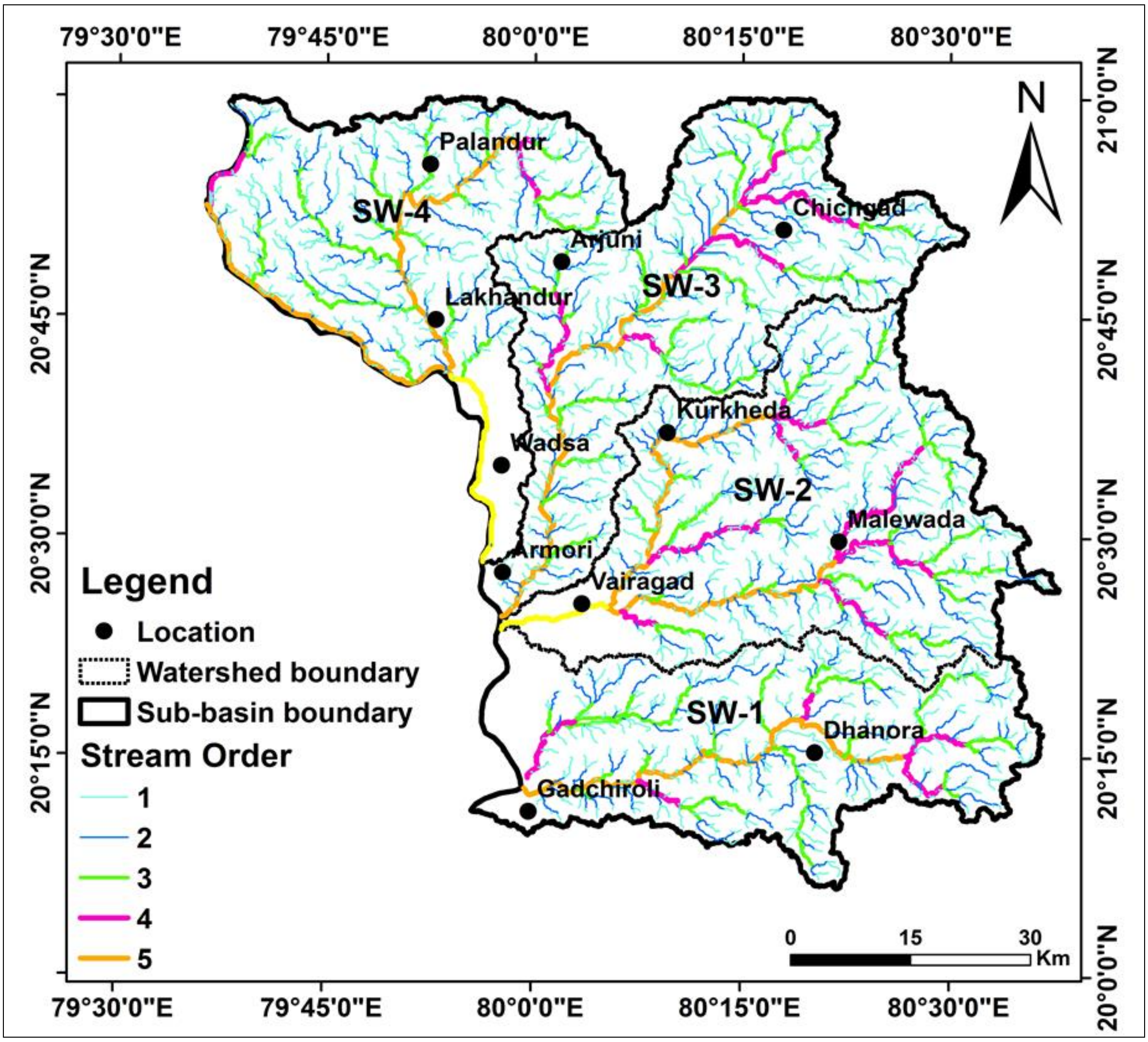

Fig 3: Stream ordering of the study area

Stream length (Lu) and mean stream length (Lsm)

The total length of individual stream segments of each order is the stream length (Lu) of that order. Stream length measures the average (or mean) length of a stream in each orders, and is calculated by dividing the total length of all streams in a particular order by the number of streams in that order. The stream length in each order increases exponentially with increasing stream order. Generally, the total length of stream segments is high in first order streams and decreases as the stream order increases. In case of SW-1, SW-3 and SW-4 the stream segments of various orders show variation from general observation. The length of 5th order in SW-1, SW-3 and SW-4 is greater than 4th order. This change may indicate again the morphology of the terrain and the slope accuracy obtained from the satellite data.

Mean stream length of a stream channel segment of order 'u' is a dimensional property revealing the characteristic size of components of a drainage network and its contributing basin surface (Strahler, 1964). Low values in the upper reaches of sub watershed indicate young morphological development and high erosion potentiality. Except SW-4, all the remaining sub watersheds have low values in the upper reach but in SW-4 the low value of Lsm for high order stream i.e., 7.01 km for 4th and 28.93 km for 6th order in is due to the fact that the streams fall within this order has stopped their channel lengthening much before than the lower order streams. (Table 3)

Stream length ratio (RL)

Stream length ratio is the ratio between mean stream lengths of one order to next lower order of the stream (Horton, 1945). Areas having mountain–plain front river basin have irregular tendency of stream-length ratio than regular plateau fringe river basin (Magesh and Chandrasekhar, 2014). The RL value is calculated for all four sub watersheds. The RL in the study area for SW-1 starts with 1.13 for 1st to 2nd, 4.63 for 2nd to 3rd order, 1.33 for 3rd to 4th order and 7.26 for 4th to 5th order, for SW-2 starts with 1.17 for 1st to 2nd order, 4.01 for 2nd to 3rd order, 2.21 for 3rd to 4th order, 3.33 for 4th to 5th order and 0.37 for 5th to 6th order, for SW-3 starts with 1.11 for 1st to 2nd order, 4.79 for 2nd to 3rd order and 2.00 for 3rd to 4th order and 5.36 for 4th to 5th order, SW-4 starts with 1.00 for 1st to 2nd order, 6.85 for 2nd to 3rd order, 0.78 for 3rd to 4th order, 6.94 for 4th to 5th order and 0.61 for 5th to 6th order (Table 3). The changes in the RL between successive stream orders of the basin vary due to the differences in slope and topographic conditions (Adhikari S, 2020).

Table 3: Calculations of mean stream length (L_{sm}) and stream length ratio (R_L) for all four sub watersheds from the study area

Sr. No.	Sub Watershed Code	Mean Stream Length (L_{sm}) (km)						Stream Length Ratio (R_L)				
		I	II	III	IV	V	VI	II/I	III/II	IV/III	V/IV	VI/V
1.	SW1	1.23	1.42	6.58	8.76	63.61	-	1.13	4.63	1.33	7.26	-
2.	SW2	1.21	1.42	5.70	12.60	42.01	15.55	1.17	4.01	2.21	3.33	0.37
3.	SW3	1.35	1.50	7.19	14.43	77.44	-	1.11	4.79	2.00	5.36	-
4.	SW4	1.29	1.30	8.91	7.01	46.71	28.93	1.00	6.85	0.78	6.94	0.61

Bifurcation ratio (Rb)

Bifurcation ratio is the ratio between total numbers of streams in a given order (Nu) to the number of next higher order (Nu+1) (Horton, 1945). The lower value of Rb show structurally less disturbed watersheds without any distortion in drainage pattern (Suji *et al*., 2015). The bifurcation ratio is calculated for all four sub watersheds (Table 4). The Rb value for SW-1 is 2.10 for 1st to 2nd order, 8.08 for 2nd to 3rd order, 4.8 for 3rd to 4th order 0.2 for 4th to 5th order, for SW-2 is 2.05 for 1st to 2nd order, 10.33 for 2nd to 3rd order, 3.37 for 3rd to 4th order and 4 for 4th to 5th order,2 to 5th to 6th order, for SW-3 is 2.15 for 1st to 2nd order, 9.69 for 2nd to 3rd order and 4.6 for 3rd to 4th order,5 for 4th to 5th order, for SW-4 is 2.09 for 1st to 2nd order, 11.05 for 2nd to 3rd order, 5.66 for 3rd to 4th order and 3 for 4th to 5th order, Based on Rb values, SW-2 and SW-4 have high values whereas remaining SW-1, and SW-3 have low values. This implied that SW-2 and SW-4 are relatively more disturbed sub watersheds whereas SW-1 and SW-3 are relatively sustainable sub watersheds (Table 4).

Table 4: Calculations of bifurcation ratio (R_b) and mean bifurcation ratio (Rb_m) for all four sub watersheds from the study area

Sr. No.	Sub	Bifurcation Ratio (R_b)					Mean Bifurcation Ratio (Rbm)
	Watershed Code	I/II	II/III	III/IV	IV/V	V/VI	
1.	SW1	2.10	8.08	4.8	0.2	-	3.03
2.	SW2	2.05	10.33	3.37	4.0	2.0	4.35
3.	SW3	2.15	9.69	4.6	5.0	-	4.26
4.	SW4	2.09	11.05	5.66	3.0	-	5.45

Aerial Aspect

Drainage Density (Dd)

Drainage density (Dd) is the total stream length in a given basin to the total area of the basin (Strahler, 1964). Over a wide range of geologic and climatic types, the low drainage density is more likely to occur in regions of highly permeable sub soil material under dense vegetative cover and where relief is low. In contrast high Dd is favoured in regions of weak or impermeable subsurface materials, sparse vegetation and mountainous relief (Iqbal M, Sajjad H, 2014). The Dd is calculated for all four sub watersheds and it varies between 0.74 km/km2 to 0.83 km/km^2. For SW-1 the Dd is 0.74 km/km2, for SW-2 the Dd is 0.78 km/km^2, for SW-3 the Dd is 0.83km/km^2, for SW-4 the Dd is 0.76 km/km^2 (Table 5). Based on the Dd values, the study area mostly falls under low drainage density zone (<2 km/km^2) which indicates low relief, low slope, high infiltration capacity and low water regimes throughout the basin.

Stream frequency (Fs)

Drainage frequency is directly related to the lithological characteristics. The number of stream segments per unit area is termed stream frequency or drainage frequency (Horton, 1945). The Fs value is calculated for all the four sub-watershed and it ranges from 0.44 to 0.48. For SW-1, the Fs value is 0.44, SW-2 has Fs value 0.48, SW-3 has Fs value 0.47 and SW-4 has Fs value 0.44 (Table 5). Based on Fs value, SW-1 and SW-4 show low value which indicate the basin has low relief whereas remaining and SW-2 and SW-3 show high value which indicate the basin has high relief.

Drainage texture (Rt)

Drainage texture is the total number of stream segments of all order in a basin per perimeter of the basin (Horton, 1945). Smith (1950) has classified drainage texture into 5 different texture i.e., very coarse (<2), coarse (2 to 4), moderate (4 to 6), fine (6 to 8) and very fine (>8). SW-01and SW-03 show coarse drainage texture. The Rt value is calculated for all four sub-watersheds which range from 2.16 to 2.80 which indicate that all the four sub-watersheds have coarse drainage texture (Table 5).

Circulatory ratio (Rc)

The circulatory ratio is similar measure as elongation ratio, originally defined (Miller, 1953) as the ratio of the area of the basin to the circle having same circumference as the basin perimeter. The value of circulatory ratio varied from 0 (inline) to 1(in a circle). The circulatory ratio is mainly concerned with the length and frequency of streams, geological structures, land use/ land cover, climate, relief and slope of the watershed. In the study area, the Rc values are ranging from 0.18to 0.23. All the four sub-watersheds are found to be elongated to sub circular in shape (Table 5).

Elongation ratio (Re)

Elongation ratio (Re) is the ratio of diameter of a circle of same area as the basin to the maximum basin length (Schumm, 1956). Areas with higher elongation ratio values have high infiltration capacity and low runoff. A circular basin is more efficient in discharge to runoff than an elongated basin (Iqbal M, Sajjad H, 2014). The value of Re varies from 0 (in highly elongated shape) to unity i.e. 1.0(in the circular shape). The Re value of all the four sub-watersheds ranges from 0.59 to 0.76 which indicates that all the four sub-watersheds are elongated in nature (Table 5).

Constant of channel maintenance (Ccm)

Constant of channel maintenance is calculated as the reciprocal of drainage density (Schumm, 1956). Low value of CCM indicates the area is under the influence of high structural disturbance, low permeability, steep to very steep slopes and high surface runoff whereas high values of CCM indicates the area is under very less structural disturbances and less runoff conditions (G.P.O. Reddy *et al*, 2004). The CCM value is calculated for all four sub watersheds (Table 5) and it ranges from 1.20 to 1.35. For SW-1 the CCM value is 1.35, for SW-2 the value is 1.28, for SW-3 the value is 1.20 and for SW-4 the value is 1.31. CCM value of SW-1 and SW-4 has higher value while remaining SW-2 and SW-3 have lower value.

Table 5: Calculations of areal aspects for all the four sub watersheds from the study area

Sr. No.	Sub Watershed Code	A (sq.km)	P (km)	Lb (km)	Dd	Fs	Dt	Rf	Rc	Re	CCM
1.	SW1	1414.31	289.15	68.30	0.74	0.44	2.18	0.30	0.21	0.62	1.35
2.	SW2	1832.81	314.40	63.39	0.78	0.48	2.80	0.45	0.23	0.76	1.28
3.	SW3	1556.00	324.95	75.11	0.83	0.47	2.25	0.27	0.18	0.59	1.20
4.	SW4	1366.06	279.16	59.18	0.76	0.44	2.16	0.39	0.22	0.70	1.31

Conclusion

Remote sensing and GIS is a powerful tool in prioritization of sub watershed based on morphometric analysis which is helpful in management and planning at sub watershed level. Out of four sub watershed, SW-2 and SW-4 has 6^{th} order stream while SW-1 and SW-3 has 5^{th} order stream. The length of 5^{th} order in SW-1, SW-3 and SW-4 is greater than 4^{th} order. This change may indicate again the morphology of the terrain and the slope accuracy obtained from the satellite data. The changes in the RL between successive stream orders of the basin vary due to the differences in slope and topographic conditions. Based on Rb values, SW-2 and SW-4 have high values whereas remaining SW-1, and SW-3 have low values. This implied that SW-2 and SW-4 are relatively more disturbed sub watersheds whereas SW-1 and SW-3 are relatively sustainable sub watersheds. Dd values, the study area mostly falls under low drainage density zone (<2 km/km^2) which indicates low relief, low slope, high infiltration capacity and low water regimes throughout the basin on Fs value, SW-1 and SW-4 show low value which indicate the basin has low relief whereas remaining and SW-2 and SW-3 show high value which indicate the basin has high relief. The Rt value is calculated for all four sub-watersheds which range from 2.16 to 2.80 which indicate that all the four sub-watersheds have coarse drainage texture. In the study area, the Rc values are ranging from 0.18to 0.23. All the four sub-watersheds are found to be elongated to sub circular in shape. The Re value of all the four sub-watersheds ranges from 0.59 to 0.76 which indicates that all the four sub-watersheds are elongated in nature. For SW-1 the CCM value is 1.35, for SW-2 the value is 1.28, for SW-3 the value is 1.20 and for SW-4 the value is 1.31. CCM value of SW-1 and SW-4 has higher value while remaining SW-2 and SW-3 have lower value. The drainage density in sub-watershed of the study area shows variation from 0.74 to 0.83 per km2 suggesting low drainage density. Low drainage density indicate hard rock lithology. The values of stream frequency varies from 0.44 to 0.48. The value of drainage texture varies from 2.16 to 2.80. The values of circulatory ratio varies from 0.18 to 0.23. The values of elongation ratio vary from 0.59 to 0.76, which indicates that there is not much geologic variation in study area. Present study demonstrates the usefulness of GIS for morphometric analysis. The variation in length ratio, attributes to variation in slope of topography indicate youth stage of geomorphic development in the streams of the study area.

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