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Morphometric Analysis of Wazure and Lasina Watersheds of Godavari River Basin, Parbhani District (Maharashtra) using Geographical Information System

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Abstract
The morphometric characteristics of streams are very important factors in watershed hydrology. Present paper deals with morphometric analysis of watershed of Godavari river drainage basin in Parbhani district with the help of geographical information system (GIS). The morphometric parameters of watershed determined include linear, areal and relief features. The present study mainly focuses on the geometry, more importance being given on the evaluation of morphometric parameters such as stream order (Nu), stream length (Lu), bifurcation ratio (Rb), drainage density (D), stream frequency (Fs), texture ratio (T), elongation ratio (Re), circularity ratio (Rc), and form factor ratio (Rf) etc. The GIS based Morphometric analysis of the two watersheds revealed that the Wazur is of 4th order and Lasina is of 3th order stream and drainage pattern mainly in dendritic type thereby indicates homogeneity in texture and lack of structural control. In Wazur watershed total number of streams are 326, in which 253 are first order, 60 are second order, 12 are third order and 1 is of fourth order streams. In Lasina watershed total number of streams are 70, in which 58 are first order, 11 are second order, and 01 is third order stream. Geographical information system (GIS) is a professional tool in differentiating drainage pattern and groundwater potential. SRTM DEM and SOI toposheets have been used to calculate various parameters using Arc GIS 10.3 software. Comparative study of two watersheds has been carried out to find out relation between geology and morphometric characteristics of watersheds. The entire Parbhani District is covered up by the Basaltic rocks of Deccan Trap origin. Deccan Basalt in this area is corresponding to Ajanta formations, which are stratigraphic equivalents of Upper Ratangad formations of Western Maharashtra comprising compound flows

Keywords: *GIS , Morphometric analysis, Remote sensing, Watershed*

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I. Introduction

The morphometric characteristics of any watershed scale may have important information regarding its formation development and spatiotemporal variations because all hydrologic and geomorphic processes occur within the watershed (Pareta and Pareta, 2011). The watershed analysis is important in any hydrological investigation like assessment of groundwater potential and groundwater management. Various important hydrologic phenomena can be correlated with the characteristics of watershed such as size, shape, slope of drainage area, drainage density, size and length of the tributaries etc (Rastogi and Sharma, 1976). The present paper describes the drainage characteristics of Wazur-Lasina watershed area in Parbhani district obtained through RS GIS based morphometric analysis. The study will be useful to understand hydrological behavior of the watershed.

II. Study Area

The study area (Fig. 1) belongs to Godavari river drainage in Parbhani District, Maharashtra. Parbhani district is bounded on the North by Hingoli district,on the East by Nanded district, on the South by Latur The study area belongs to Pathri and Manwat Taluka of Parbhani District. The Pathri taluka consists of the cluster of seven villages. The Manwat taluka with another seven villages are studied in the present research. The Pathri taluka extend from latitudes 19°15'00"N to 19°22'00"N and longitudes 76°12'30"E to 76°20'00"E. The altitude of the area was ranges from 400 to 440 amsl. Manwat is the second taluka with seven villages belongs to this research. The Manwat taluka extending from latitude 19°07'20"N to 19°12'10"N and longitude 76°26'40"E to 76° 32'40"E. The altitude of the area ranges from 380 to 430 amsl Wazur (kh), Wazur (bk), Thar, Wagalgaon, Sarola (bk), Kekarjawala and Chate Pimpalgaon are the part of Wazur watershed.

III. Methodology

For the present study we selected 2 watersheds along the Godavari river for morphometric analysis. The morphometric analysis is based on GIS techniques. GIS software demonstrated that it has a great significance in the morphometric analysis of the drainage basins (Tribhuvan and Sonar, 2016). In present study remote sensing and GIS methods are used in support with the field survey for delineation of watershed and preparation of various maps.

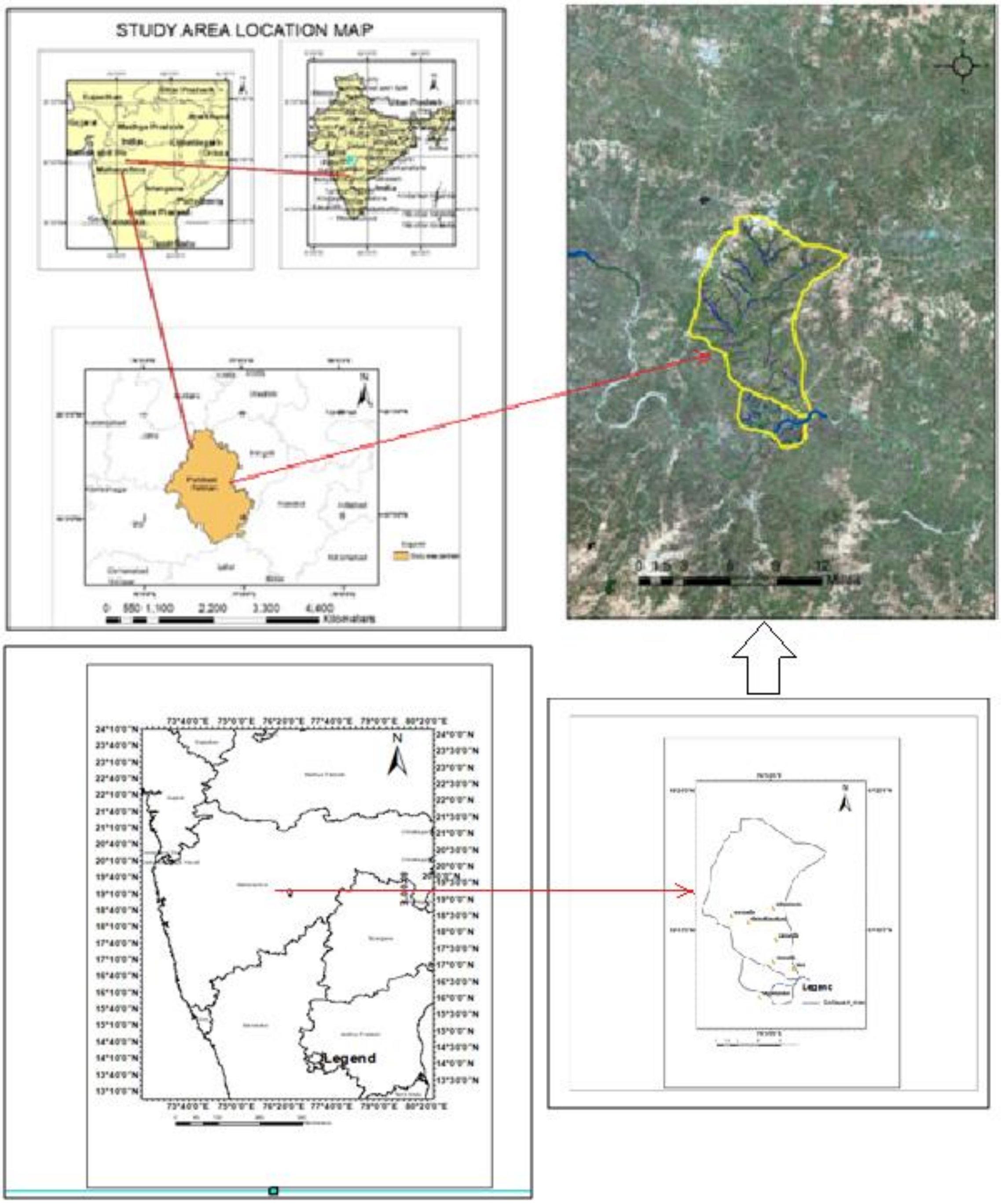

Fig. 1. Location map of study area represented in Google earth image

Morphometric parameters under linear and shape are determined using standard methods and formulae (Horton 1932, 1945; Smith 1954; Strahler, 1964). The fundamental parameter namely; stream length, area, perimeter, number of streams and basin length are derived from drainage layer. The values of morphometric parameters namely; stream length ratio, bifurcation ratio, drainage density, stream frequency, form factor, texture ratio, elongation ratio, circularity ratio and compactness constant are calculated based on the formulae suggested by Horton (1945), Miller (1953), Schumm (1956), Strahler(1964), Nooka Ratnam et al.(2005).

Digital elevation model was used for preparation of slope and Contour map. Digital elevation model representing a surface is presently used in many applications such as hydrology, geomorphology, geology and disaster risk mitigation (Tran et al., 2014). The base map has been prepared in ArcMap application of the ArcGIS software using geocoded toposheets (56A/11,56A/7.56A/12,56A/8,56A/3,56A/4). The Survey of India toposheet maps were geometrically rectified for next work then digitization of drainage pattern is carried out in Arc GIS 10.3 software. GIS and Remote sensing techniques have proved to be accurate and efficient tool in drainage delineation and updation (Waikar et al., 2014 and Tribhuvan and Sonar 2016).

Geology

The study area primarily consists of basaltic rocks of Deccan Volcanic province. The Deccan trap basalts are formed by fissure type of volcanic eruption. The lava outpoured is of basic type. The lava eruption forms the horizontal flows of basaltic rocks. The Deccan volcanic outbreak took place in late Cretaceous to early Eocene period. Deccan Basalts in this area are corresponding to Ajanta formations, whichare stratigraphic equivalents of Upper Ratangad formations of Western Maharashtra comprising compound flows (Godbole et al, 1996). The outpoured lava pile is thinnest in the east, while thickening westward to more than 2 km along parts of the Western Ghats range (Mahoney,1988).

The traps are quite massive, fine-grained bluish-greyto brown in colour. Both "aa" and "Pahoehoe" types of basalts are seen. The Pahoehoe type, which is dominant in the region, is characterised by predominantly vesicular amygdaloidal basalt with very thin massive portions. The vesicles are highly irregular. The pipe amygdales and the ropy structure mark the basal portions of these flows. The amygdales are filled with chlorite, calcite, zeolites and devitrified glass. The vesicular amygdaloidal basalt also shows the formation of sheet jointing due to weathering (Fig.2b).

The "aa" flow is characterised by lower thick massive basalt showing columnar jointing and spheroidal weathering and upper vesicular portions show brecciation, along with otherassociated intrusions of red and greenish coloured Tachylitic basalts.

In some regions this red coloured tachylite behaves like red coloured dusty soil called redbole. Some researchers called it as ancient buried soil (Singhal, 1997). The red bole which generallyoccurs in the upper part of pink zeolitic basalt at Kekarjawala in Wazur (Fig.2a) and in some region it occurs at the base of amygdaloidal basalt underlain by compact basalt. The red bole varies in thickness from few cm. to about 1 m. In some dug wells it occurs as small veins in vesicular amygdaloidal basalt.

Fig. 2: a) Redbole bed occurring between compact basalt and the amygdaloidal basalt flow at Sarola in Wazur watershed b) amygdaloidal basalt flow at Kekarjawal in Wazur watershed.

Morphometric analysis of watersheds

Morphometry of drainages involved evaluation of streams and it play an important role in order to understand the hydrogeological behavior of watersheds and expresses the prevailing climate, geology, and geomorphology. In general, the relationship between various drainage parameters was studied in the beginning by Morisawa, 1959; Strahler, 1952, 1957 and 1964. Babar and Kaplay (1998) carried out the geomorphometric analysis of Purna River basin Parbhani District (Maharashtra). Similarly, Babar (2002) undertaken the hydrogeomorphological mapping for groundwater resource development in the northern part of Parbhani District (Maharashtra) using IRS 1B, LISS II Geocoded data. The drainage map of two watersheds and the SRTM DEM map of present study are represented in Fig. 3.

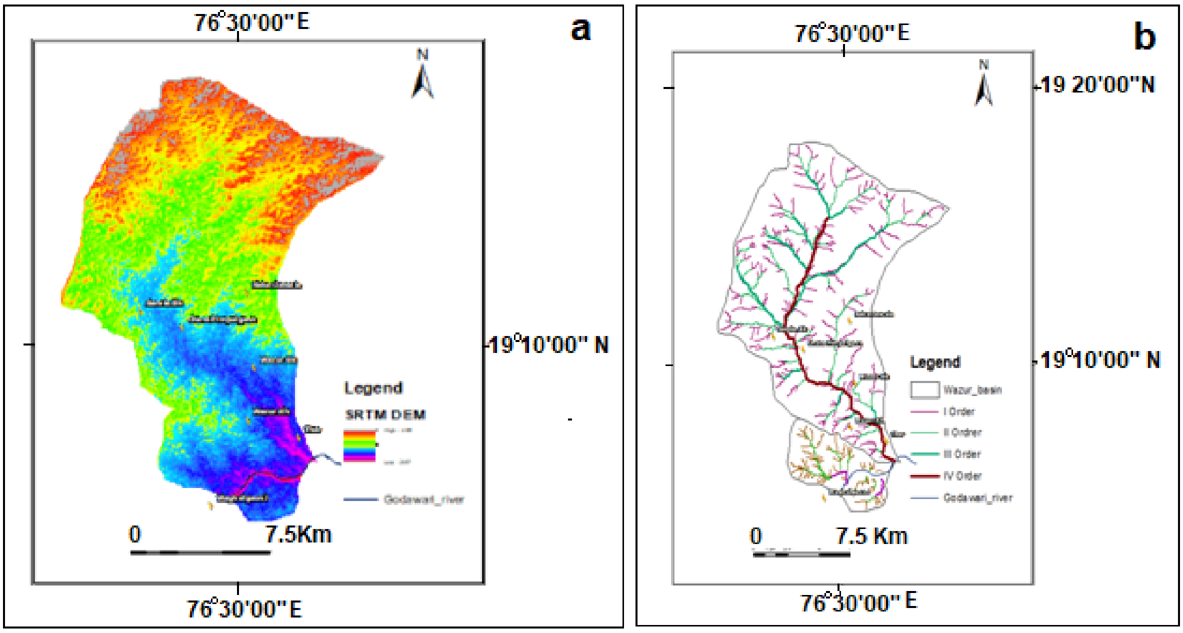

Fig. 3: (a) SRTM DEM map (b) Drainage pattern and Stream Network of Wazur and Lasina Watersheds.

IV. Results and Discussion

1. Linear Aspects

i) Stream Order (U) : Strahler (1952) system, which is a slightly modified of Horton's (1945) system, has been followed because of its simplicity, where the smallest, unbranched fingertip streams are designated as 1st order, the confluence of two 1st order channels give a channels segments of 2nd order, two 2nd order streams join to form a segment of 3rd order and so on. It is found that Wazur Watershed is of 4th order stream while Lasina watershed is of 3rd order. The semilog graph is plotted for number of stream vs stream order, which indicate number of streams are maximum at first order and decreases as order of stream increases (Fig. 4 and 5).

ii) Stream Length (Lu)

Stream length is one of the most significant hydrological features of the watershed as it reveals surface runoff characteristics. The stream of relatively smaller length is characteristics of areas with larger slopes longer lengths of streams are generally indicative of flatter gradient. The semilog graph is plotted for stream length vs stream order, which indicate stream length is maximum at first order and decreases as order of stream increases (Fig. 4 and 5). The length of first order stream is 143.77 Km, second order stream is 65.38 Km, third order stream is 33.72 Km, and fourth order stream is 22.63 Km. The change may indicate flowing of streams from high altitude, lithological variation and moderately steep slopes (Singh, 1997).

iii) Mean Stream Length (Lsm)

The mean stream length is a characteristic property related to the drainage network and is associated surfaces (Strahler, 1964, Horton, 1945). The mean stream length (Lsm) has been calculated by dividing the total stream length of order by the number of streams of the same order as given (Table 1 and 3).

Lsm=Lu/Nu where, 'Nu' means number of streams of given order and 'Lu' is the length of streams of given order.

iv) Stream Length Ratio (RL)

The stream length ratio can be defined as the ratio of the mean stream length of a given order to the mean stream length of next lower order and has an important relationship with surface flow and discharge (Horton, 1945). The values are given Table 1 and 3.

v) Bifurcation Ratio (Rb)

Bifurcation ratio (Rb) is defined as the ratio of the number of stream segments of given order to the number of stream segments of the next higher order (Schumn, 1956) The values of bifurcation ratio for both the watershed are between 3.97 and 5.5 indicating that the geological structures do not distort the drainage system (Table 1,3) (Strahler, 1964).

2. Watershed Geometry

i) Watershed Area (A)

The area of the watershed is important parameter which gives idea about drainage density, stream frequency and other related parameters basin area is calculated by using Arc GIS 10.3 software, for Wazur watershed the area is 184.90 km^2 and for Lasina watershed it is 26.42 km^2 (Table 2,4).

ii) Watershed Perimeter (P)

Watershed perimeter is the outer boundary of the watershed that enclosed its area. It is measured along the divides between watersheds and is used as an indicator of watershed size and shape. Basin perimeter is calculated by using Arc GIS 10.3 software for Wazur watershed 64.21 km and for Lasina watershed is 22.55 km (Table 2, 4).

3. Aerial Aspects

i) Drainage density (Dd)

Drainage density is the stream length per unit area in region of watershed Drainage density is a better quantitative expression for analysis of landform in present study area Dd calculated by using Spatial Analyst Tool in Arc-GIS10.3. The drainage density obtained for Wazur watershed is 1.44 km/km^2 and for Lasina watershed is 1.96 km/km^2 moderate drainage densities indicating the basin is with moderately permeable sub-soil and thick vegetative cover (Nag, 1998).

ii) Stream Frequency (Fs)

Stream frequency, is expressed as the total number of stream segments of all orders per unit area. The stream frequency value obtained is 1.379 $streams/km^2$. Horton (1945) used this term to refer the length of the run of the rainwater on the ground surface before it is localized into definite channels.

iii) Form Factor (Ff)

According to Horton (1932), form factor is defined as the ratio of basin area to square of the basin length. The form factor obtained for Wazur is 0.428 and for Lasina is 0.404. The smaller value of the form factor implies both watersheds are elongated.

iv) Circulatory Ratio (Rc)

Circularity Ratio is the ratio of the area of a watershed to the area of circle having the same circumference as the perimeter of the watershed (Miller, 1953). Circularity ratio for Wazur watershed is 0.56 and for Lasina watershed is 0.652. The values of circularity ratio indicate that the watershed is moderately circular and somewhat elongated.

v) Elongation Ratio (Re)

According to Schumm (1965 elongation ratio is defined as the ratio of diameter of a circle of the same area as the watershed to the maximum basin length. Strahler (1952) stated that this ratio runs between 0.6 and 1.0 over a wide variety of climatic and geologic types. The varying slopes of watershed can be classified with the help of the index of elongation ratio, i.e. circular (0.9-0.10), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7), and more elongated (<0.5) value of elongation ratio for Wazur watershed is 0.73 and for Lasina watershed is 0.35. The values of elongation ratio indicate that the basin is moderately circular and somewhat elongated (Schumm 1965).

vi) Constant channel maintenance (C)

Schumm (1956) used the inverse of drainage density as a property termed constant of stream maintenance C. The value of Constant of stream maintenance obtained is 0.696.

4. Relief Aspects

i) **Relief Ratio (Rh)**

Difference in the elevation between the highest point of a watershed and the lowest point on the valley floor is known as the total relief of the watershed. The relief ratio may be defined as the ratio between the total relief of the watershed and the longest dimension of the watershed parallel to the main drainage line (Schumm, 1956). The Rh normally increases with decreasing drainage area and size of watersheds of a given watershed (Gottschalk, 1964). The relief ratio obtained for Wazur watershed is 3.22 and for Lasina watershed is 4.08 (Table 2, 4).

ii) **Ruggedness Number (Rn)**

Strahler (1968) ruggedness number is the product of the basin relief and the drainage density of the watershed and usefully combines slope steepness with its length. Calculated accordingly, the Wazur watershed has a ruggedness number of 0.092 and for Lasina watershed 0.064.

Table 1 Representing Linear Aspects of Wazur Watershed

Order	Total number of streams(Nu)	Bifurcation Ratio (Rb)	Stream Length (Lu)	Mean Stream Ratio (Lu/Nu)	Length Ratio
1	195		143.77	0.73	
		3.297			0.55
2	49		65.38	1.33	
		4.9			0.395
3	10		33.72	3.37	
		10			0.149
4	1		22.63	22.63	
Total	255	18.87	265.52	28.07	
Mean		4.71	66.38		

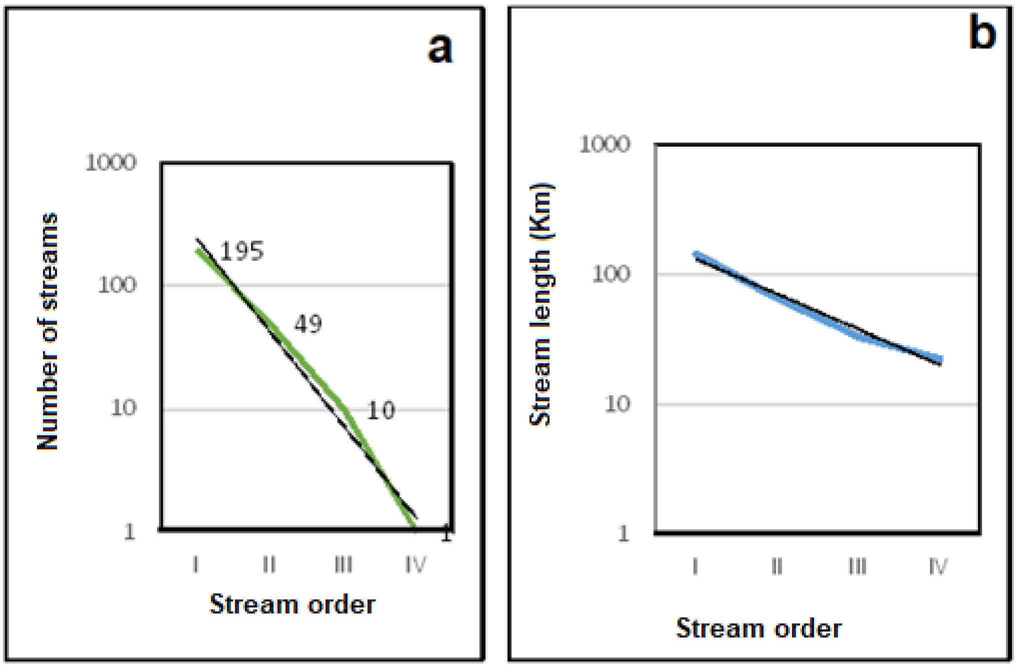

Fig-4 (a) Stream Number vs stream order semilog graph of Wazur watershed (b) Stream Length vs Stream order graph Wazur watershed

Table 2 Areal parameters Wazur Watershed

Parameter	values
Basin area in Sq.km.	184.90
Drainage density (Dd) Lu/A Km/km^2	1.435
Stream frequency(Fs) Nu/A streams/km^2	1.379
Drainage texture(Rt) Nu/p streams/km	3.970
Circulatory ratio (Rc) Rc=4πA/P2	0.563
Perimeter Km	64.216
Length of overland flow (Lg) Km	0.348
Constant channel maintenance (C)	0.696
Form factor (Rf) A/(Lb)2	0.428
Length of Basin(Lb)Km	20.77
Elongation ratio (Re)	0.738
Basin relief(Bh)m	67
Relief ratio(Rh)	3.224

Ruggedness Number(Rn)	0.092

Table 3 Representing Linear Aspects of Lasina Watershed

Order	Total number of treams(Nu)	Bifurcation Ratio (Rb)	Stream Length(Lu) Km	Mean Stream Ratio (Lu/Nu) Km	Length Ratio
1	58		34.80	0.60	
		5.272			0.494
2	11		13.36	1.214	
		11.0			0.325
3	1		3.73	3.73	
Total	70	10.772	51.96	3.713	
Mean		2.633	12.99		

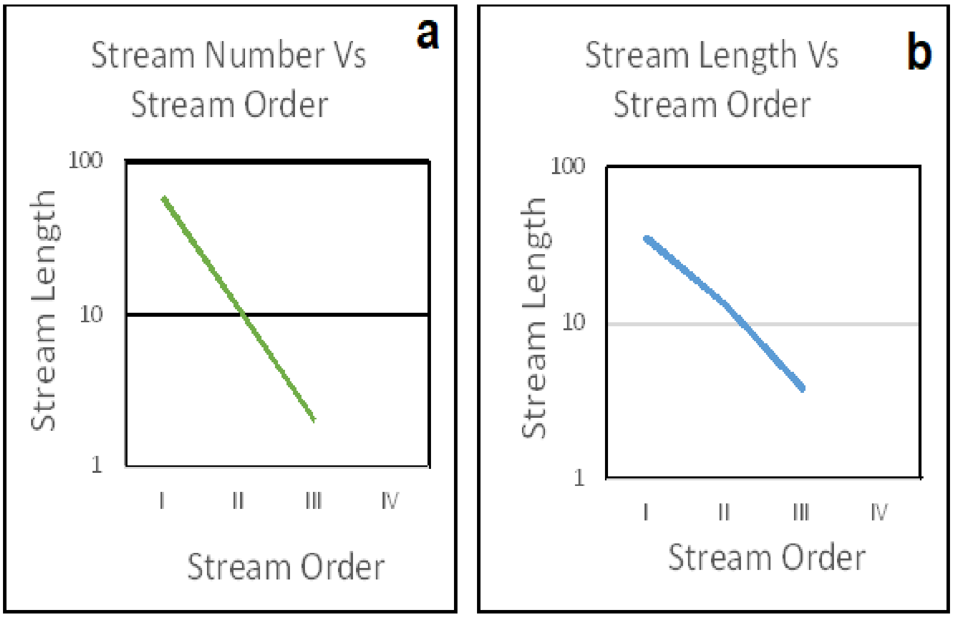

Fig-5 (a) Stream Number vs stream order semilog graph Lasina watershed (b) Stream Length (Km) vs Stream order semilog graph Lasina watershed

Table 4 Areal parameters Lasina Watershed

Parameter	values
Basin area in Sq.km	26.42
Drainage density (Dd) Lu/A (Km/km^2)	1.966
Stream frequency(Fs) Nu/A (streams/km^2)	2.686
Drainage texture(Rt) Nu/p (streams/km)	3.147
Circulatory ratio (Rc) Rc=4πA/P2	0.652
Perimeter Km	22.55
Length of overland flow (Lg) Km	0.254
Constant channel maintenance (C)	0.508
Form factor (Rf) A/(Lb)2	0.404
Length of Basin(Lb)Km	8.078
Elongation ratio (Re)	0.359
Basin relief(Bh)m	33

Relief ratio(Rh)	4.085
Ruggedness Number(Rn)	0.064

Table 5 List and description of the used geomorphometric parameters

Parameters	Formula	References	Characteristics of Value	Values obtained in study area
Area	GIS Analysis in km^2	--		184.90-26.42
Drainage density	Dd=Lu/A (Km/km^2)	Horton (1932)	>1 is impermeable layer and <1 permeable layer	1.435-1.966
Stream frequency	Fs=Nu/A (Streams/ km^2)	Smith (1950)	>1 is impermeable layer and <1 permeable layer	1.379-2.686
Drainage texture	Rt=Nu/p (Streams/ km)	Miller (1953)	Very course (<2), course (2-4), moderate (4-6), fine (6-8) very fine (>8	3.97-3.14
Form factor	$Rf=A/Lb^2$	Horton (1932)	Nearer to 0 indicates elongated basin,>0.78 circular basin	0.428-0.404
Circulatory ratio	$Rc=4\pi A/P2$	Schumm (1956)	--	0.563-0.652
Elongation ratio	Re = (2 A:)/Lb	Schumm (1956)	circular (> 0.9), oval (0.9 - 0.8) and elongated <0.7	0.73-0.35

V. Conclusion

GIS and Remote sensing techniques have proved to be accurate and efficient tool in drainage delineation. Bifurcation ratio, length ratio and stream order of watershed indicates that the Wazur watershed is fourth order, while Lasina watershed is of third order with dendritic type of drainage pattern indicating that the geological structures do not distort the drainage system The values of circularity ratio and elongation ratio indicate that the watershed is moderately circular and somewhat elongated.

The drainage density values obtained are moderate drainage densities indicating the watershed is moderately permeable sub-soil and thick vegetative cover-Drainage density (Dd) and stream frequency (Fs) are the most important criterion for the morphometric categorization of watersheds which unquestionably control the runoff pattern, sediment yield and other hydrological parameters of the watershed The Drainage density (Dd) and Drainage texture (Rt) of the watershed reveal that the nature of subsurface strata differs from moderately permeable to permeable.

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