Morphometric Analysis of Sina Basin using GIS and Remote Sensing Techniques

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Abstract: Geographical Information system (GIS) and Remote Sensing has become an efficient tool in this present era for the delineation of drainage pattern and water resource management. Sina river basin up to Sina dam of Nimgaon Gangurda in Ahmednagar district of Maharastra is considered for the present study. The basin has about 1484 km^2 catchment area. The Cartosat DEM (Digital Elevation Model) with 32 m x 32 m resolution is used for the morphometric analysis of the basin to derive linear, areal and relief aspects by using the ArcGIS 10.3. Survey Of India (SOI) toposheet number E43I13 having 1: 50,000 scale is used for the study. Strahler's stream order was followed for the further analysis. The drainage pattern of Sina river basin is dendritic type with 6^{th} order trunk stream having mean bifurcation ratio 5.798, main channel length 77.9 km and Channel index is 1.42. The areal aspect such as Elongation ratio, Circulatory ratio, Stream frequency, Drainage density and Length of overland flow (Km) is found to be 0.69, 0.4, 4.283, 2.49 and 0.2, respectively. The relief aspect such as Ruggedness number, Total contour length (Km) and average slope (%) is 0.986, 9305.842, and 1.422, respectively. Sina basin has very fine texture, elongated in shape, dendric drainage nature and eroded watershed which need protection.

***Keywords**: GIS, Remote Sensing, Morphometric analysis, Cartosat DEM*

INTRODUCTION

Morphometry is nothing but the mathematical analysis and measurement of configurations of earths shape, surface and dimension of landforms. Morphometric properties gives important information's related with the formation & development of hydrologic & geographic properties of watershed. Morphometric analysis also gives a quantitative description of drainage system, as drainage system is important for characterisation of watershed. Morphometric analysis is also important in order to investigate the pedology, environmental assessment, groundwater management & groundwater potential. It also checks the relief, areal aspect, geometric and linear aspect gives hierarchial order of streams along with number and length of stream segment etc. The areal aspect gives the analysis of basin shape, basin parameter both geometrical and topological (Stream frequency, Drainage density). The relief aspects include dissection index, absolute and relative relief and average slope. Morphometric parameter generally depends upon bed rock, lithology, pedology and geological structures. Hence, the information related with the geomorphology, hydrology, geology, and land use pattern is highly important for doing trusted study of drainage pattern of the watershed. For quantitative analysis of the watershed involving various components such as stream segments, stream order , basin perimeter & area, elevation difference, slope and profile of land has majorly responsible for the natural development of basin (Horton, 1945). As the first and majorly important work on basin morphometry analysis was carried out by Horton (1932, 1945). Then, Horton's study in various ways modified and developed by several Geomorphologist and Geohydrologist, which was mainly Strahler (1953), Schumm (1956), Melton (1957), Morisawa (1957), Strahler (1957), Gregory and Walling (1973), Chorley *et al.* (1984). In recent decades, the morphometric analysis of the various River basins, have been done by many researchers and scientist (Esper, 2008; Magesh *et al.*, 2011; Bhagwat *et al.*, 2011; Wilson *et al.*, 2012; Singh *et al.*, 2014; Sujatha *et al.*, 2014; Gaikwad and Bhagat (2017) have studied morphometric parameters for watershed prioritization . In this study an attempt has made to understand the morphometric characteristics of Sina river basin which helps to understand the basin area, topographic relation, agriculture, forestation and regional planning.

STUDY AREA

Sina River makes the boundary between Ahmednagar district on one side and other side Ashti Tahsil of Beed district. Sina river is the major left tributary of Bhima river. Sina dam is an earthfill dam on Sina river at Nimgaon Gangurda in Karjat taluka of Ahmednagar district of Maharashtra is considered as an outlet for this study. The latitude and longitudinal coordinates of Sina dam are $18^0 49'39.15''$N, $74^0 56'52.17''$E and corresponding elevation is 579 m above mean sea level. Sina river is starting near Ahmednagar city as it has two main sources one near Jeur about 16 km to its north-east and one near Jamgaon about 20 km west of Ahmednagar city. The study area of Sina river basin is taken about 1484 km^2. The latitudinal and longitudinal extent of the Sina river basin under study lies between 18.736 to 19.26 N and 74.482 to 74.948 E. The study area lies in scarcity areas as the annual average rainfall is about 546 mm (Musande, et al, 2003). The soil type of this area is medium to fine textured and available water content was 205 mm/m depth and depth 85% soils in category of moderate deep to very deep. Average rainfall occurs in month of June and highest rainfall occurs in July and September (Musande et al 2003). Crops cultivated in this area are pearl millet, black gram, red gram, green gram, sorghum, pigeon pea, sunflower etc.

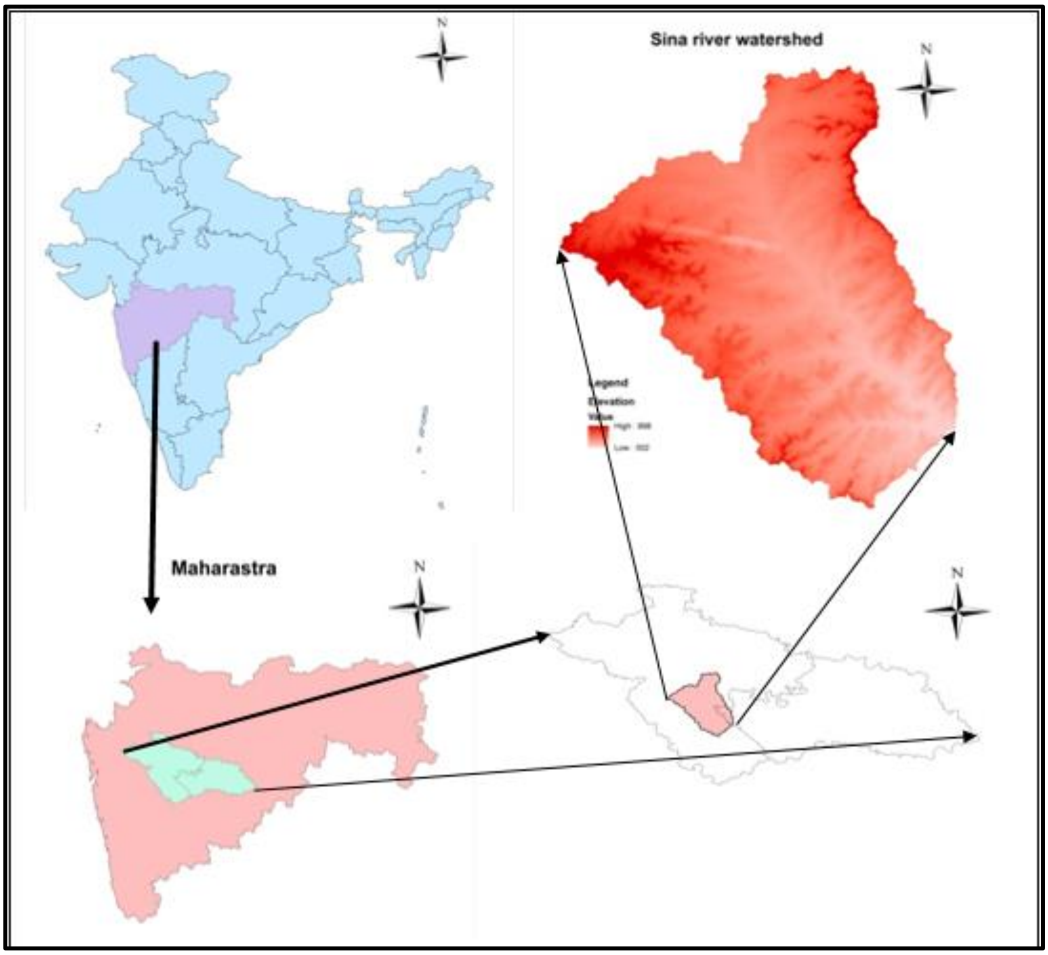

Figure 1. Location map of study area

Data Used and Methodology

In this study of morphometric analysis of Sina river basin remote sensing and GIS (Geographic Information System) technique was used. The remotely sensed data rectified by using the Survey of India (SOI) topographical maps of about 1: 50,000 and analysed by using ArcGIS 10.3 by using DEM (Digital Elevation Model) and toposheet. Topographical map: SOI (Scale 1: 50,000) Number E43I13; Cartosat (DEM) with 32 m x 32 m spatial resolution. SOI topographic map is georeferenced using WGS-1984 datum, Universal Transverse Mercator (UTM) zone 43N projection in ArcGIS 10.3. In this study the Strahlers law is used for giving the stream order to the branch by considering first unbranched stream as first order stream then next when two first order streams join together then it is designated as second order. When second order stream joins together to form third order and so on then number of streams are counted and recorded.

RESULT AND DISCUSSION

Linear aspect

The liner aspects of drainage network such as Stream Orders (Sμ), Stream Number (Nμ), bifurcation ratio (R_b), Stream Length (Lu), Mean Stream Length (Lum) and Stream Length Ratio (Lur)

Stream order (Su)

Stream order designation is the first step in morphometric analysis of drainage basin depending on hierarchy (Strahler, 1952). It was found that the Sina river basin is a 6th order trunk stream. It is found that the maximum stream order frequency of the Sina river is observed in case of first-order streams and then for second order and then decreses upto last highest order stream.

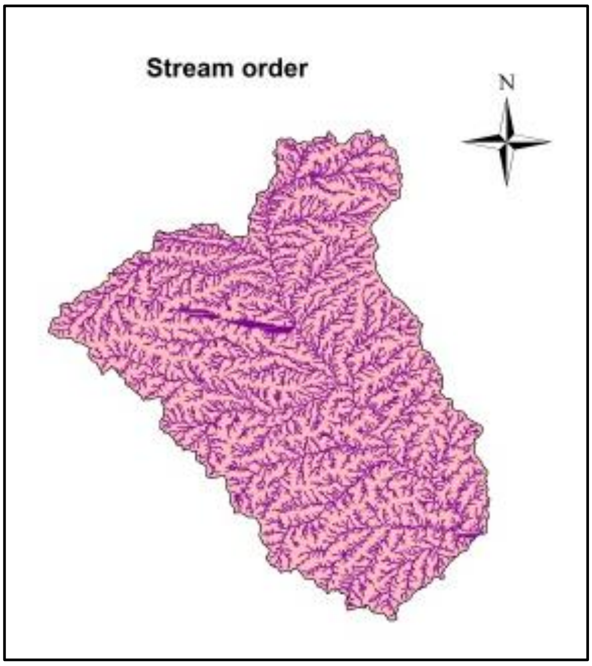

Figure 2. Stream Order of Sina Basin

Stream Number (Nu)

The summation of order wise stream segments is known as stream number. Stream number is an inverse of stream order. Stream numbers of 1st, 2nd, 3rd, 4th, 5th, 6th streams are 5001, 1098, 204, 42, 10 and 1 respectively. As the basin has 1st order stream has more number of stream number so it is responsible for sudden removal of water after heavy rainfall.

Stream length (Lu)

Total stream lengths calculated by using SOI topographical sheets and ArcGIS software. In Hortons law the Geometric similarity preserved in watershed of increasing order (Strahler, 1964).

Mean Stream Length (Lum)

Mean stream length (Lum) is related to drainage network components and contributing watershed surface (Strahler, 1964). It is calculated by dividing the total length of stream of an order by total number of segments in the order.

Stream Length Ratio (Lurm)

Horton (1945) calculated the length ratio by dividing the man length of segment (Lu) of order to mean length of segments of next lower order (Lu-1) which is constant throughout the successive orders of basin. When stream length ratio increase from lower order to higher order indicates mature geographic stage of basin.

Bifurcation ratio (Rb)

Bifurcation ratio is calculated by dividing the number of stream segments of given order (Nu) to the number of streams in the next higher order (Nu+1). Bifurcation ratio is an index of relief and dissertation. Bifurcation ratio is a dimensionless property. Lower values (<5) of bifurcation ratio indicate that watershed has less structural disturbances (Strahler, 1964) and drainage pattern has been not distorting (Nag 1998). A higher value (>5) of bifurcation ratio indicates that strong structural control on the drainage pattern and the lower values indicates that watershed is not affected by structural disturbance. The results shows that bifurcation ratio is found 5.798 shows drainage pattern is controlled by geological structure.

Weighted mean Bifurcation ratio (Rbwm)

Strahler (1953) used a weighted mean bifurcation ratio in order to arrive at a more representative bifurcation ratio by multiplying the bifurcation ratio of each successive pair of orders by toatal number of streams in this ratio and then calculated the mean of sum of these values. The obtained value of Rbwm for this is 4.71.

Length of main channel (Cl)

Length of main channel (Cl) is the length along the longest watercourse from outflow point of watershed to the uppermost watershed boundary. The length of main channel (Cl) is computed by using ArcGIS 10.3 software, which is 77.9 km.

Channel Index (Ci) & Valley Index (Vi)

For the measurement of valley length, channel length and shortest distance between the mouth and source of river (Adm). Adm is used for the computation of Channel index and valley index. The calculated Channel Index (Ci) & Valley Index (Vi) is found to be 1.42 and 1.35 respectively.

RHO coefficient

RHO coefficient is calculated by dividing the stream length ratio to the bifurcation ratio. The relation between the drainage density and physiographic development of basin is determined by RHO coefficient (Horton, 1945). RHO coefficient is influenced by factors like climatic, biologic, anthropogenic and geomorphologic factors. The calculated value of RHO coefficient for this study area is 0.58.

Table 1: Stream Order, Streams Number, and Bifurcation Ratios in Sina river basin

Su	Nu	Rb	Nu-r	Rb*Nu-r	Rbwm
I	5001	-	-	-	4.71
II	1098	4.55	6099	27750.45	
III	204	5.38	1302	7004.76	
IV	42	4.86	246	1195.56	
V	10	4.2	52	218.4	
VI	1	10	11	121	
Total	6353	28.99	7710	36290.17	
Mean		Rbm= 5.798			

Su: Stream order, Nu: Number of streams, Rb: Bifurcation ratios, Rbm: Mean bifurcation Ratio*, Nu-r: Number of stream used in the ratio, Rbwm: Weighted mean bifurcation ratios

Table 2: Stream Length and Stream Length Ratio in Sina river basin

Su	Lu	Lu/Su	Lur	Lur-r	Lur*Lur-r	Luwm
I	2035	0.41	-	-	-	2.199
II	837	0.76	1.85	2872	5313.2	
III	405	0.5	0.66	1242	819.72	
IV	254	1.99	3.98	659	2622.82	
V	117	11.7	5.88	371	2181.48	
VI	52	52	4.44	169	750.36	
Total	3700	67.36	16.81	5313	11687.58	
Mean			Lurm=3.362			

Su: Stream order, Lu: Stream length, Lur: Stream length ratio, Lurm: Mean stream length ratio*, Lur-r: Stream length used in the ratio, Luwm: Weighted mean stream length ratio

Table 3: Linear aspect of Sina river basin

Sr. No	Morphometric parameter	Formula	Reference	Result
1	Stream Order (Su)	Hierarchical Rank	Strahler (1952)	1 to 6
2	1st Order Stream (Suf)	Suf = N1	Strahler (1952)	5001
3	Stream Number	(Nu = N1+N2+ ...Nn	Horton (1945)	6356
4	Stream Length (Lu) Kms	Lu = L1+L2 ...... Ln	Strahler (1964)	3700
5	Stream Length Ratio (Lur)	see Table 2	Strahler (1964)	0.66-5.88
6	Mean Stream Length Ratio (Lurm)	see Table 2	Horton (1945)	3.362

7	Weighted Mean Stream Length Ratio (Luwm)	see Table 2	Horton (1945)	2.199
8	Bifurcation Ratio (Rb)	see Table1	Strahler (1964)	4.2-10
9	Mean Bifurcation Ratio (Rbm)	see Table1	Strahler (1964)	5.798
10	Weighted Mean Bifurcation Ratio (Rbwm)	see Table1	Strahler (1953)	4.71
11	Main Channel Length (Cl) Kms	GIS Software Analysis	-	77.9
12	Valley Length (Vl) Kms	GIS Software Analysis	-	74.31
13	Minimum Aerial Distance (Adm) Kms	GIS Software Analysis	-	54.92
14	Channel Index (Ci)	Ci = Cl / Adm (H & TS)	Miller (1968)	1.42
15	Valley Index (Vi)	Vi = Vl / Adm (TS)	Miller (1968)	1.35
16	Rho Coefficient (ρ)	ρ = Lur / Rb	Horton (1945)	0.58

Areal aspect

The areal aspect of the drainage basin (watershed) such as Drainage density (Dd), Stream frequency (Fs), Drainage Texture (Rt), Form Factor (RF), Elongation ratio (Re), Circularity ratio (Rc), Length of overland flow (Lg), Constant of channel maintenance (C), Lemniscate (k), Infiltration Number (If), Basin perimeter (P) were calculated and result shown in Table 4.

Length of basin (Lb)

Basin length is the longest dimension of basin parallel to principal drainage line (Schumm, 1956). It is calculated according to Schumm (1956) as it is found to be 62.8 km.

Basin area (A)

Area has the same importance like other parameter that is the total stream length. The basin area is computed by using the ArcGIS 10.3 software, which is 1484 km^2.

Basin Perimeter (P)

The outermost boundary of basin that enclosed the area called the basin perimeter. Basin perimeter is an indicator of watershed size and shape. The basin perimeter is computed by using the ArcGIS 10.3 software, which is found to be 222m.

Length area relation (Lar)

Lar = 1.4* $A^{0.6}$ formula proposed by Hack (1957) gives the relation between the stream length and basin area.

Lemniscate's (k)

For the determination of the slope of basin Chorely (1967) gives a Lemniscate's value. It is determined by using the formula $k= Lb^2/4*A$ where Lb is basin length in km and A is the area of basin in km^2. The computed value of k is found to be 2.66.

Form factor (Ff)

Form factor is also known as an index as it is dimensionless form used to represent the different basin shapes (Horton, 1932). Form factor varies between 0.1 to 0.8. Higher value of form factor indicates basin is circular type while the smaller value indicates enlongated basin. The range of form factor for elongated basin is <0.78 and for circular is >0.78. In case of Sina river basin the form factor value is 0.38 which indicates basin is elongated.

Elongation ratio (Re)

Elongation ratio is defined as the ratio of diameter of a circle of the same area as the basin to maximum basin length (Schumm, 1956). According to Strahler states that elongation ratio varies between 0.6 to 1.0 over a wide variety of climatic and geologic types. The slope of watershed is classified with the help of elongation ratio, i.e elongated (0.5-0.7), less elongated (0.7-0.8), oval (0.8-0.9), circular (0.9-0.10). The elongated ratio of Sina river basin is 0.69, which represents that the basin is elongated.

Texture ratio (Rt)

Texture ratio is ratio between the first order streams and perimeter of basin (Rt= NI/P) and its depends on lithology, relief aspects of terrain and infiltration capacity. Texture ratio is an important parameter in order to morphometric analysis as it depends on infiltration capacity, relief aspects of terrain and lithology. The texture ratio of this basin was found to be 22.527.

Circulatory ratio (Rc)

Circularity ratio is dimensionless property and express as the degree of circulatory of the entire basin. Circularity value varies between 0 to 1 but value closes to 1. Circulatory ratio is calculated by dividing the watershed area to the area of a circle having the same perimeter as that the watershed. According to Miller (1953) the circulatory ratio of basin varies from 0.4 to 0.6 which indicates the basin is elongated and highly permeable geological materials. The circulatory ratio of basin is found to be 0.4 which indicates that the basin is elongated type.

Drainage texture (Dt)

Drainage texture is calculated by dividing the stream segments of all orders to the perimeter of that area (Horton, 1945). The five drainage texture classification given by the Smith (1950) i.e., very fine (>8), fine (6 to 8), moderate (4 to 6), coarse (2 to 4), very coarse (<2). The drainage texture of basin is calculated to be 28.63 indicates that the texture is very fine.

Compactness coefficient (Cc)

Compactness coefficient (Cc) is calculated by dividing the perimeter of watershed to circumference of circular area, which is equal to the area of watershed (Gravelius 1994). Compactness coefficient depends only on the slope but not on the size of watershed. The Cc of given basin was found to be 1.21.

Fitness ratio (Rf)

Fitness ratio is the ratio of the main channel length to the length of watershed perimeter. Fitness ratio is a measure of topographic fitness (Melton 1957). The fitness ratio for Sina basin is 0.35.

Wandering ratio (Rw)

The ratio of main stream length to the valley length is known as wandering ratio (Rw) (Smart & Surkan 1967). The straight line distance between outlet of basin and remost point on the ridge is called the valley length. In this study wandering ratio is found to be 1.24.

Watershed Eccentricity (τ)

The expression for watershed eccentricity, which is: τ = [(|Lcm2 -Wcm2|)] 0.5 / Wcm Where: τ = Watershed eccentricity, Lcm = Straight length from the watershed mouth to the centre of mass of the watershed, and Wcm = Width of the watershed at the centre of mass and perpendicular to Lcm. The watershed eccentricity is a dimensionless property. For the given watershed the watershed eccentricity, is computed to be 0.42.

Centre of Gravity of watershed (Gc)

Centre of Gravity of watershed (Gc) is calculated by measuring the length from the outlet of watershed to a point on stream nearest to the center of of watershed. The centre of gravity of watershed calculated by using the ArcGIS-10.3 software, which is latitude 18.99N and longitudes 74.75E.

Sinuosity Index (Si)

The pattern of channel of a drainage basin is equal to sinusity. The ratio of channel length to down valley distance is sinuosity. Sinusity value varies between 1 to 4 and more. Sinuosity index is generally used for the Geomorphologists, Hydrologists and Geologists. The computed hydraulic, topographic and standard sinuosity index which are 16.66%, 83.33%, and 1.05 respectively.

Stream frequency (Fs)

The number of stream segment per unit area is called stream frequency. Stream frequency also known as channel frequency (Horton 1932). The stream frequency of watershed found to be 4.283.

Drainage Density (Dd)

The stream length per unit area in region of watershed is called drainage density (Horton, 1952). The drainage density calculated by using spatial analyst tool in ArcGIS-10.3. The range for Dd are vary as very coarse (<2), coarse (2-4), moderate (4-6), fine (6-8) and very fine (>8). The basin has Dd found to be 2.49 which indicates coarse drainage basin.

Infiltration Number (If)

Infiltration number is the product of drainage density (Dd) and stream frequency (Fs) i.e. If= Dd*Fs. Higher value of infiltration number means lower the infiltration capacity and higher runoff (Horton1964). The infiltration number (If) is found to be 10.66 for the basin which indicates basin has lower value of infiltration capacity and higher runoff.

Drainage pattern (Dp)

Drainage pattern (Dp) helps in identifying the stage of erosion. In drainage pattern influence of slope, lithology and structure reflects. The study area has dendritic and radial pattern. Howard (1967) related drainage patterns to geological information's.

Length of Overland flow (Lg)

Length of Overland flow (Lg) is equal to the half the reciprocal of drainage density. Higher the value of length of overland flow indicates lower relief and vice versa. The range for the values of length of overland flow are in three classes as low value (<0.2), moderate value (0.2-0.3) and high value (>0.3). Lower value indicates high relief, more runoff and less infiltration where as higher value of Lg gives gentle slope, more infiltration and reduced runoff. Length of Overland flow (Lg) is computed to be 0.2 means it has moderate to high relief, runoff and less infiltration.

Constant of Channel Maintenance (C)

Constant of Channel Maintenance (C=1/Dd) is the inverse of drainage density. Constant channel maintenance of watershed is computed to be 0.4.

Table 4: Areal aspect of Sina river basin

Sr.No	Morphometric parameter	Formula	Reference	Result
1.	Length from W's Center to Mouth of W's (Lcm) Kms	GIS Software Analysis	Black (1972)	27.74
2.	Width of W's at the Center of Mass (Wcm) Kms	GIS Software Analysis	Black (1972)	30.53
3.	Basin Length (Lb) Kms	GIS Software Analysis	Black (1972)	62.8
4.	Mean Basin Width (Wb)	Wb = A / Lb	Horton (1932)	23.63
5.	Basin Area (A) Sq Kms	GIS Software Analysis	Schumm(1956)	1484
6.	Basin Perimeter (P) Kms	GIS Software Analysis	Schumm(1956)	222
7.	Relative Perimeter (Pr)	Pr = A / P	Schumm(1956)	6.68
8.	Length Area Relation (Lar)	$Lar = 1.4 * A^{0.6}$	Hack (1957)	111.94
9.	Lemniscate's (k)	$k = Lb^2 / A$	Chorley (1957)	2.66
10.	Form Factor Ratio (Rf)	$Ff = A / Lb^2$	Horton (1932)	0.38
11.	Shape Factor Ratio (Rs)	$Sf = Lb^2 / A$	Horton (1956)	2.66
12.	Elongation Ratio (Re)	$Re = 2 / Lb * (A / \pi)^{0.5}$	Schumm(1956)	0.69
13.	Elipticity Index (Ie)	$Ie = \pi * Vl^2 / 4 A$		2.92
14.	Texture Ratio (Rt)	Rt = N1 / P	Schumm(1965)	22.527
15.	Circularity Ratio (Rc)	$Rc = 12.57 * (A / P^2)$	Miller (1953)	0.4
16.	Circularity Ration (Rcn)	Rcn = A / P	Strahler (1964)	6.68
17.	Drainage Texture (Dt)	Dt = Nu / P	Horton (1945)	28.63
18.	Compactness Coefficient (Cc)	$Cc = 0.2841 * P / A^{0.5}$	Gravelius (1914)	1.64
19.	Fitness Ratio (Rf)	Rf = Cl / P	Melton (1957)	0.35
20.	Wandering Ratio (Rw)	Rw = Cl / Lb	Smart & Surkan (1967)	1.24
21.	Watershed Eccentricity (τ)	$\tau = [(\lvert Lcm^2 Wcm^2 \rvert)]^{0.5} / Wcm$	Black (1972)	0.42
22.	Centre of Gravity of	GIS Software Analysis	Rao (1998)	74.75E &

	the Watershed (Gc)			18.99N
23.	Hydraulic Sinuosity Index (Hsi) %	Hsi = ((Ci - Vi)/(Ci - 1))*100	Mueller (1968)	16.66
24.	Topographic Sinuosity Index (Tsi) %	Tsi = ((Vi - 1)/(Ci- 1))*100	Mueller (1968)	83.33
25.	Standard Sinuosity Index (Ssi)	Ssi = Ci / Vi	Mueller (1968)	1.05
26.	Longest Dimension Parallel to the Principal Drainage Line (Clp) Kms	GIS Software Analysis	-	74.707
27.	Stream Frequency (Fs)	Fs = Nu / A	Horton (1932)	4.283
28.	Drainage Density (Dd) Km / Kms^2	Dd = Lu / A	Horton (1932)	2.49
29.	Constant of Channel Maintenance (Kms^2 / Km)	C = 1 / Dd	Schumm(1956)	0.4
30.	Drainage Intensity (Di)	Di = Fs / Dd	Faniran (1968)	1.72
31.	Infiltration Number (If)	If = Fs * Dd	Faniran (1968)	10.66
32.	Drainage Pattern (Dp)		Horton (1932)	Dn & Ra
33.	Length of Overland Flow (Lg) Kms	Lg = A / 2 * Lu	Horton (1945)	0.2

Relief aspect

Relief refers to the relative height of points on surface and lines with respect to the horizontal base of reference. Relief expresses the magnitude of the vertical dimension of the landform.

Maximum basin relief (H)

Maximum basin relief (H) is the elevation difference between the highest Point in the catchment and the catchment outlet. The basin relief is found to be 396m reveals that basin has undulating terrain having high kinetic energy of water results in severe soil erosion.

Relief ratio (Rhl)

The elevation difference between the highest point and lowest point of watershed on the valley floor is the total relief of river basin. The ratio between the total relief of basin and the longest dimension of basin parallel to main drainage line is relief ratio (Schumm, 1956). In this study area of river basin relief ratio found to be 0.0063.

Relative relief (Rhp)

Relative relief is calculated by using the formula given by the Melton (1957) is Rhp= H*100/P, where P is perimeter in meter & H is total basin relief.

4.3.4 Absolute relief (Ra)

Absolute relief is the difference between the given location and the sea level. The absolute relief is calculated by using ArcGIS-10.3 and which is found to be 898 m.

Channel gradient (Cg)

Channel Gradient (Cg) m / Kms is calculated by using the formula given by the Broscoe (1959) is Cg = H / {(π/2) * Clp} where H is total basin relief an Clp is the longest dimension parallel to the Principal drainage line (Clp) Kms. The channel gradient for the study area is found to be 3.37.

Ruggedness Number (Rn)

The surface unevenness or roughness is measured by the ruggedness number (Rn). The product of basin relief and drainage density is the ruggedness number (Strahler, 1968). Ruggedness number is usually combines the slope steepness along with the length. The ruggedness number for the study area is 0.986.

Melton Ruggedness number (MRn)

The slope index that gives special representation of the relief ruggedness within the watershed is called the Melton Ruggedness number (MRn).The study area has the MRn is 10.28.

Gradient ratio (Rg)

The indicator of the channel slope wich enables the assessment of of runoff volume (Sreedevi, 2004). The Rg for the study area is 0.0061.

Gradient & channel slope (Sgc)

The steepness of slope is the gradient expressed as a variation between its vertical intervals (Vei) reduced to unity and its horizontal equivalent (Hoe). Gradient is calculated by using the formula Sgc= Vei/Hoe.

Slope analysis (Sa)

Slope analysis (Sa) is calculated by using ArcGIS-10.3. It is the average slope in the degree. It is found to be 0.01422 for the study area.

Average slope of overall basin (S)

Erodibility of watershed studied by using the average slope (Wenthworth 1930). When slope percentage is more then erosion is more. The slope of watershed computed by using the formula S = (Z * (Ctl/H)) / (10 * A) and is found to be 1.422%.

Mean slope of overall basin (Θs)

Mean slope of basin computed by using the formula Ɵs = (Ctl * Cin) /A where Ɵs = Mean slope of oveall basin, Ctl= Total length of contour in watershed, A= area of the watershed, Cin=Contour interval. The computed value of mean slope of Sina river basin is 0.063.

Hypsometric analysis (Hs)

The value of integral and the form of hypsometric curve both are important elements in the topographic form. It shows the variation in regions differ in geologic structure and the stage of development. The starting of hypsometric curve is large and it decreases at the stage of maturity and old age (Strahler, 1952).

Table 5: Hypsometric data of Sina river basin

Sr.No.	Altitude Range(m)	Height(m)h	Area(kms^2)a	h/H^1	a/A^2
1	>800	298	9	1	0.0098
2	800-700	198	104	0.66	0.114
3	700-600	98	799	0.32	0.88
4	600-502	0	912	0	1

A^2= 912 km^2

Table 6: Relief aspect of Sina river basin

Sr.No	Morphometric parameter	Formula	Reference	Result
1.	Height of Basin Mouth (z) m	GIS Analysis / DEM	-	502
2.	Maximum Height of the Basin (Z) m	GIS Analysis / DEM	-	898
3.	Total Basin Relief (H) m	H = Z - z	Strahler (1952)	396
4.	Relief Ratio (Rhl)	Rhl = H / Lb	Schumm(1956)	0.0063
5.	Absolute Relief (Ra) m	GIS Software Analysis		898
6.	Relative Relief Ratio (Rhp)	Rhp = H * 100 / P	Melton (1957)	0.178
7.	Dissection Index (Dis)	Dis = H / Ra	Singh & Dubey (1994)	0.44
8.	Channel Gradient (Cg) m / Kms	Cg = H / {(π/2) * Clp}	Broscoe (1959)	3.37
9.	Gradient Ratio (Rg)	Rg = (Z - z) / Lb	Sreedevi (2004)	0.0061
10.	Watershed Slope (Sw)	Sw = H / Lb		0.0063
11.	Ruggedness Number (Rn)	Rn = Dd * (H / 1000)	Patton & Baker (1976)	0.986

12.	Melton Ruggedness Number (MRn)	MRn = H / $A^{0.5}$	Melton (1965)	10.28
13.	Total Contour Length (Ctl) Kms	GIS Software Analysis	-	9305.842
14.	Contour Interval (Cin) m	GIS Software Analysis		10m
15.	Slope Analysis (Sa)	GIS Analysis / DEM	Rich (1916)	0.01422
16.	Average Slope (S) %	S = (Z * (Ctl/H)) / (10 * A)	Wenthworth's (1930)	1.422
17.	Mean Slope of Overall Basin (Ѳs)	Ѳs = (Ctl * Cin) /A	Chorley (1979)	0.063
18.	Relative Height (h/H)	see Table 5 (h/H)	Strahler (1952)	1 to 0
19.	Relative Area (a/A)	see Table 5 (a/A)	Strahler (1952)	0 to 1
20.	Surface Area of Relief (Rsa) Sq Kms	Composite Profile	Brown (1952)	1484
21.	Composite Profile area (Acp) sq.km.	Area between the Composite curve and horizontal line	Pareta (2004)	1484

Conclusion

The present study conclude that Cartosat -DEM and GIS based evaluation of drainage morphometric parameters and their influence on landforms, soils and eroded land characteristics. The prioritization of watershed based on the linear aspect (La), Areal aspect (Aa), Relief aspect (Ra). Length ratio, bifurcation ratio and stream order of basin indicates that the basin is sixth order basin with dendritic type of drainage pattern. Higher first order stream results in easily disposal of water hence the groundwater recharge is less. Form factor, Elongation ratio and Circulatory ratio shows the basin type is elongated. Drainage texture shows that the basin texture is very fine that implies it has more risk of soil erosion and infiltration ratio indicates basin has lower infiltration capacity and higher runoff. From the maximum basin relief the terrain is undulating type having kinetic energy of water is high results higher runoff.

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