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Research Article

MEASUREMENT OF WATERSHED GEOMETRY IN THE CENTRAL PART OF UDAIPUR SECTOR, RAJASTHAN USING REMOTE SENSING AND GIS

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ABSTRACT

Watershed is a naturally occurring hydrologic unit with similar physical, topographic and climatic conditions. Watershed behavior can be understood by the study of morphometric parameters which helps to make a various plan for sustainable development by using the natural resources. This analysis can be achieved through measurement of linear, aerial, and relief aspects of the watershed. The total of 11 subwatershed of the Ahar watershed of Udaipur district was individually analyzed. SOI toposheet map, ASTER DEM, SRTM DEM, and satellite imageries were used to delineate the stream network as well as making several maps under GIS environment. GIS is very powerful tool for regional as well as micro level watershed study.

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INTRODUCTION

A watershed is the area of land where all of the waterfalls in that area and drains off to a common outlet. Since the beginning of 20th century, morphometric methods have been applied for the analysis of area height relationship, slope, relative relief, and terrain characteristics but the application of statistical methods for the analysis of drainage basin characteristics to identify and measurement of shape started after the publication of classical research paper of R.E.Horton in 1945. Morphometric analysis of a watershed provides a quantitative description of the drainage system, which is an important aspect of the characterization of watersheds (Strahler 1964). Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Horton, 1945; Clarke, 1966; Agarwal, 1998; Iqbal *et al*., 2013). The morphometric study involves the evaluation of stream parameters through the measurements of various stream properties (Kumar *et al* 2000; Ali *et al* 2003; Ali & Pirasteh 2005). The study of landuse/ landcover change to determine the socio-environmental impact in Ethiopia highland with the help of remote sensing and GIS has been carried out (Ali a, 2010). Morphometric analysis of river basin of different area has been carried out using remote sensing and GIS techniques (Ali and Khan, 2013; Ali and Ali, 2014, Ali and Ikbal, 2015; Ali *et al*., 2016; Ikbal *et al*., 2017).

Study area

Udaipur district is located south-eastern part of Aravalli mountain range and the northern part of Udaipur district is considered for drainage analysis (Fig 1). The main Ahar river passes through the area from north-west to south-east direction. Geologically the area belongs to Paleoproterozoic Aravalli Supergroup. North-south trending Rakhavdeb lineament dissected the study area nearly equal halves where eastern half is considered as shallow water metasediment and a western jharol belt is considered for deep water metasediments. Geomorphologically western part is covered by undulating topography whereas eastern part is covered by plain area. Various types of rocks such as granite, quartzite, phyllite, schist, gneiss, metavolcanics and carbonaceous rocks (dolomite) found in the area. Ahar river granite similar to BGC is considered as basement rock in this area. Debari, Udaipur, Bari lake and Jharol group and their various formation are overlain by BGC (Fig 2).

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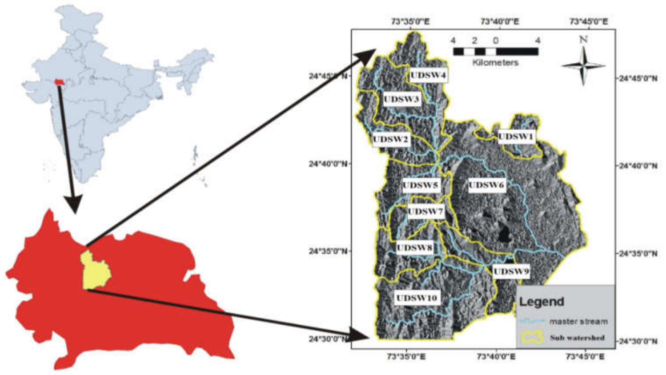

Fig 1 Location map of the astudy area

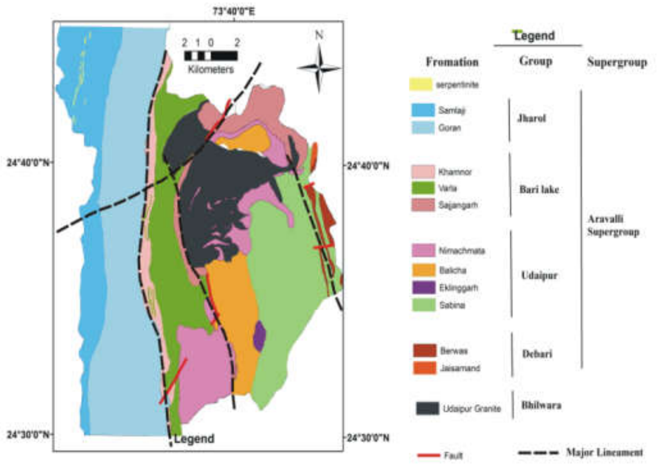

Fig 2 Geological map of the study area (After GSI)

METHODOLOGY

Digitization of drainage network was carried out using SOI topographic map. SRTM DEM (1 arc) and satellite data (Landsat 2008 and Google earth image) were used to delineate the watershed as well as subwatershed boundary under GIS environment. A variety of morphometric parameters such as linear, shape and relief parameter has computed for each sub-watershed using arc GIS 10.2 and assigned rank on the basis of the relationship with erodibility so as to arrive at a compound value for the final rankings of each sub-watershed. Lowest compound value is considered for high priority. The linear parameters have a direct relationship with erodibility where Shape parameters have an inverse relationship to the highest value of linear parameters and lowest value of shape parameters was rated as rank 1. Compound value has been calculated to make the priority for soil conservation which divides all the subwatersheds into three category such as high, medium and low with respect to soil conservation.

RESULT AND DISCUSSION

Linear aspect

Stream Order (U)

Strahler's (1957) stream ordering method based on a hierarchic ranking of stream has been followed because of its simplicity in the present study. Stream order of sub watershed shows that UDSW1, UDSW7 and UDSW8 are of fourth order, and remaining sub watersheds of the study area are of fifth order whereas the whole ahar watershed is of sixth order (Table 1).

Stream Number (Nu)

Ahar watershed has 1425 stream segments out of which 77.05% of segments (1098) comes under 1st order stream, 17.61% of segments (251) in 2nd order, 3.93% of segments (56) in 3rd order, 1.12% of segments (16) in 4th order, 0.21% or 3 segments are in 5th order and 0.07% or 1 stream segment fall under 6th order (Table 1). The number of streams decreases with increasing order in every subwarershed (Fig. 3) showing linear relationship (Fig. 4).

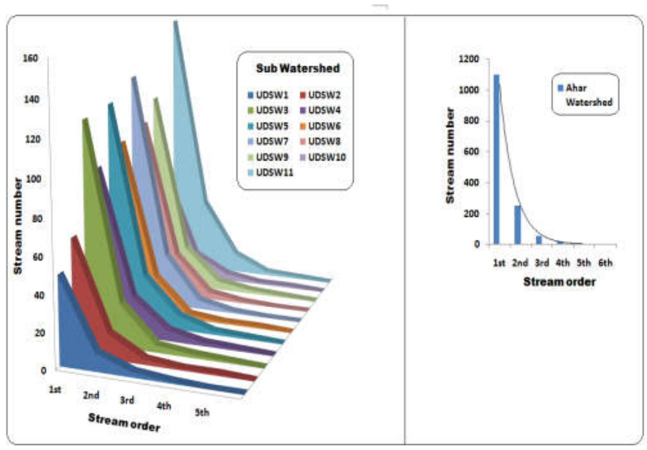

Fig 3 Stream number Stream order

Table 1 Linear aspect (subwatershed wise stream number and stream length with order)

Sub-Watershed	Number of Streams (Nu)							Stream Length in Km (Lu)						
	I	II	III	IV	V	VI	Total	I	II	III	IV	V	VI	Total
UDSW1	49	10	3	1			63	25.46	7.60	5.33	2.99			41.375
UDSW2	63	14	3	1	1		82	39.723	11.275	5.25	8.57	1.335		66.152
UDSW3	121	24	4	2	1		152	63.447	17.197	13.402	5.739	6.351		106.14
UDSW4	91	22	6	2	1		122	46.422	19.068	4.238	11.756	6.605		88.088
UDSW5	122	28	8	2	1		161	53.270	20.273	11.738	9.928	0.589		95.798
UDSW6	97	22	3	1	1		124	59.050	24.230	13.030	3.71	3.52		103.54
UDSW7	130	29	5	1			165	75.80	22.62	12.59	1.29			112.30
UDSW8	100	24	4	1			129	42.57	12.32	8.89	2.06			65.84
UDSW9	111	23	5	2	1		142	58.87	16.12	5.54	8.91	0.82		90.26
UDSW10	63	14	4	1	1		83	30.29	8.28	5.64	3.76	5.32		53.29
UDSW11	151	41	11	2	1		206	83.65	36.89	11.46	23.69	4.97		160.66
Ahad Watershed	1098	251	56	16	3	1	1425	579.85	195.89	97.12	82.41	24.03	20.67	999.97

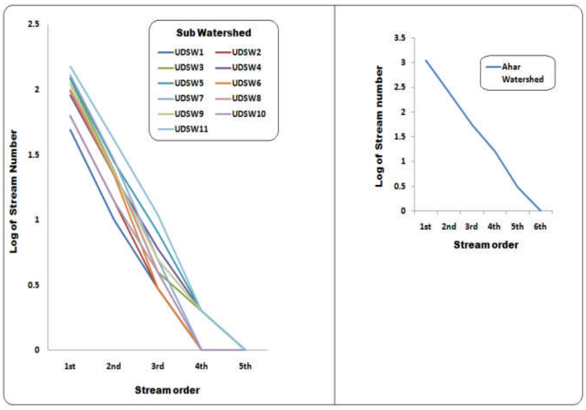

Fig 4 Log of stream number vs stream order

Stream Length (Lu)

The total length of stream segments decreases with increasing stream order (table 1) (Fig. 5 and Fig. 6). Deviation from its general behavior indicates that the terrain is characterized by high relief and/or moderately steep slope, underlain by varying lithology and probable uplift across the basin (Sing and Sing, 1997; Vittala *et al*, 2004). The whole area is followed the Horton's law but subwatershed wise consideration shows that except UDSW1, 6, 7 and 8 all the remaining sub watershed has drainage anomaly in just one particular order.

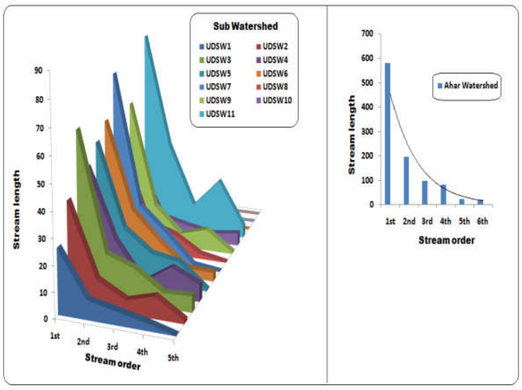

Fig 5 Stream length vs stream order

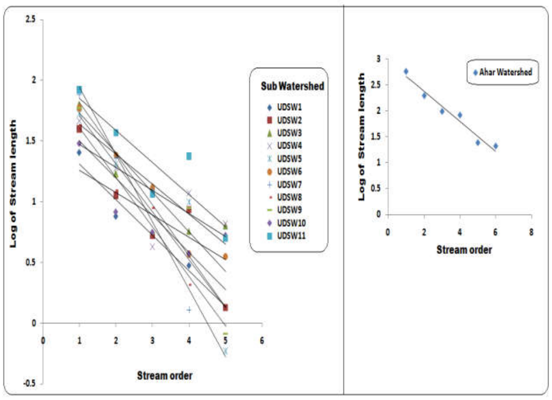

Fig 6 Log of stream length vs stream order

Mean Stream Length (Lsm)

The mean stream length is computed by dividing the total stream length of a particular order by the number of stream segments of that order. Generally, mean stream length of a particular order is greater than that of the next lower order but less than the next higher order (Table 2) (Fig 7). Deviation from this general behavior indicates variation in slope and topography.

Table 2 Linear aspect (sub watershed wise mean stream length)

Sub-Watershed	Mean stream length in Km (Lsm)						
	I	II	III	IV	V	VI	Total
UDSW1	0.52	0.76	1.78	2.99			6.04
UDSW2	0.63	0.81	1.75	8.57	1.34		13.09
UDSW3	0.52	0.72	3.35	2.87	6.35		13.81
UDSW4	0.51	0.87	0.71	5.88	6.61		14.57
UDSW5	0.43	0.72	1.47	4.96	0.59		8.18
UDSW6	0.61	1.10	4.34	3.71	3.52		13.28
UDSW7	0.58	0.78	2.52	1.29			5.17
UDSW8	0.43	0.51	2.22	2.06			5.22
UDSW9	0.53	0.70	1.11	4.45	0.82		7.61
UDSW10	0.48	0.59	1.41	3.76	5.32		11.56
UDSW11	0.55	0.90	1.04	11.84	4.97		19.31
Ahad Watershed	0.53	0.78	1.73	5.15	8.01	20.67	35.56

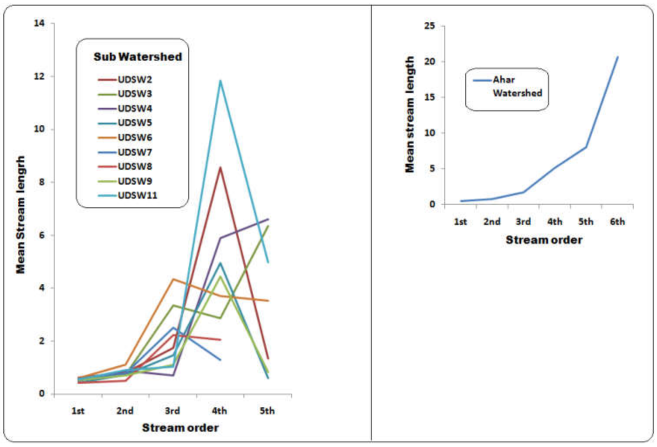

Fig 7 Mean stream length vs stream order

Stream Length Ratio (Rl)

The stream length ratio is the total stream length of a given order divided by the total stream length of next lower order. The stream length ratio Ahar watershed ranges from 0.29 to 0.86 respectively (Table 3) (Fig 8). All the sub watersheds as well as Ahar watershed shows variation of stream length ratio between different stream order. Changing value of stream length ratio from one order to another may be due to changes in slope and topography (Sreedevi *et al*., 2005)

Table 3 Linear aspect (Sub watershed wise stream length ratio)

Sub-Watershed	$2^{nd}/1^{st}$	$3^{rd}/2^{nd}$	$4^{th}/3^{rd}$	$5^{th}/4^{th}$	$6^{th}/5^{th}$	Mean stream length ratio
UDSW1	0.29	0.70	0.56			0.52
UDSW2	0.28	0.46	1.63	0.16		0.64
UDSW3	0.27	0.78	0.43	1.11		0.65
UDSW4	0.41	0.22	2.77	0.56		0.99
UDSW5	0.38	0.58	0.85	0.06		0.47
UDSW6	0.41	0.54	0.28	0.95		0.55
UDSW7	0.30	0.56	0.10			0.32
UDSW8	0.29	0.72	0.23			0.31
UDSW9	0.27	0.34	1.61	0.09		0.58
UDSW10	0.27	0.68	0.67	1.41		0.76
UDSW11	0.44	0.31	2.07	0.21		0.76
Ahad Watershed	0.34	0.49	0.85	0.29	0.86	0.57

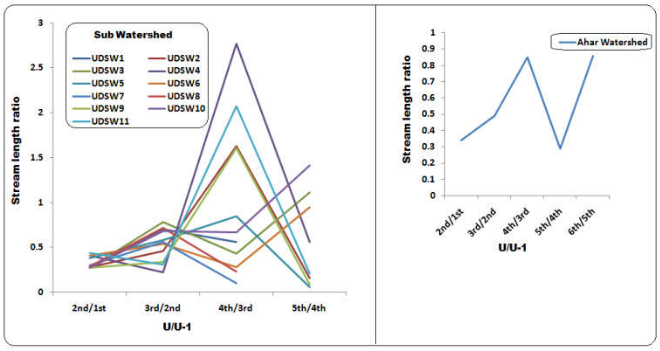

Fig 8 Stream length ratio vs U/U-1

Bifurcation Ratio (Rb)

The bifurcation ratio (Rb) is the ratio between stream numbers of a particular order and next higher order (Horton, 1945; Schumm, 1956). The mean Rb value of remaining subwatersheds Ahar watershed varies from 3.20 to 5.09 (Table 4) indicates the watershed has suffered highly structural disturbance.

Table 4 sub watershed wise bifurcation ratio

Sub-Watershed	1^{st} /2^{nd}	2^{nd} /3^{rd}	3^{rd} /4^{th}	4^{th} /5^{th}	5^{th} /6^{th}	Mean Bifurcation ratio (Rb)
UDSW1	4.9	3.33	3			3.74
UDSW2	4.5	4.67	3	1		3.29
UDSW3	5.04	6	2	2		3.76
UDSW4	4.14	3.67	3	2		3.20
UDSW5	4.36	3.5	4	2		3.46
UDSW6	4.41	7.33	3	1		3.94
UDSW7	4.48	5.8	5			5.09
UDSW8	4.17	6	4			4.72
UDSW9	4.82	4.6	2.5	2		3.48
UDSW10	4.5	3.5	4	1		3.25
UDSW11	3.71	3.73	5.5	2		3.73
Ahad Watershed	4.37	4.48	3.5	5.33	3	4.14

Length of Overland Flow (Lg)

It is the mean horizontal length of flow path from the water divide to the stream in a first order basin and indicates the amount of stream spacing and degree of dissection (Kedareswarudu *et al*., 2013). (Lg) values of subwatersheds ranges from a lowest of 0.14 (UDSW8) to a highest of 0.39 (UDSW6). The Lg value of Ahar watershed is 0.22. The sub watersheds having lower Lg value indicates that they are under the influence of structural disturbance, low permeability, moderate to steep slope and high surface run-off.

Aerial aspect

Drainage Density (Dd)

The drainage density values of sub watersheds vary between 1.29 km/km2 (UDSW6) and 3.46 km/km2 (UDSW8). Sub watershed UDSW4, 5, 8 and 9 have relatively high drainage density which indicates less permeable sub surface material and moderate to high relief and more prone to soil erosion

Drainage Texture (T)

Drainage texture is defined as the total number of stream segments of all orders divided by the perimeter of the watershed. On the basis of smith's classification UDSW1, 2, 4, 6, 7 and 10 have coarse drainage texture (table 5).

Stream Frequency (Fs)

Stream frequency is the total number of stream segments of all order per unit basin area (Horton, 1932). A higher value of stream frequency reflects greater surface runoff, resistance sub surface material, sparse vegetation and a steeper ground surface, whereas Lower stream frequency values indicate permeable sub-surface material and low relief (Reddy *et al*, 2004). Sub watershed wise values of stream frequency in the study area vary from 1.55 (UDSW6) to 6.77 (UDSW8).

Form Factor (Ff)

Form factor of a drainage basin can define as the ratio between the area of the basin and the square of the basin length. The value of form factor would always be less than 0.754 (for a perfectly circular watershed). Only sub-watershed USDW1, situated eastern side of the watershed, is nearly oval or circular in shape and the remaining sub-watersheds as well as Ahar watershed (0.41) are moderately circular to elongate in nature.

Elongation Ratio (Re)

Elongation ratio can be defined as the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin (Schumn, 1956). The value of Re in the study area lies between 0.46 (UDSW4) and 0.93 (UDSW1). Elongation ratio of the Ahar watershed is 0.73 reveals less elongated in shape, moderate to high relief.

Circularity Ratio (Rc)

Circularity ratio is the ratio of the basin area to the area of a circle having the same circumference perimeter as the basin, which is dimensionless and expresses the degree of circularity of the basin (Miller, 1953; Ali and Ikbal, 2015). The circulatory ratio of Ahar watershed is 0.45 and Sub watershed wise the value fluctuates from 0.25 (UDSW7) to 0.67 (UDSW11), indicating their elongated in nature.

Constant Channel Maintenance (C)

It is an inverse of drainage density. It depends on the lithology, permeability and infiltration capacity of a surface material, climatic condition and vegetation (Nag and Chakroborty, 2003. constant channel maintenance (C) of the study area varies from 0.29 (UDSW5 and UDSW8) to 0.71(UDSW6) which indicates that these sub-watersheds are under the influence of low permeability and high surface runoff (Table 5).

Relief Aspect

The maximum elevation in the study area is 1058 meters found at UDSW9 sub-watershed and the minimum height of 554 meters at the mouth of the watersheds at UDSW6 and UDSW7 sub-watershed (Table 6) (Fig 9). Relative relief for all the sub-watersheds ranges from 299 meters (UDSW4) to 444 meters (UDSW9) (Table 6). UDSW9, UDSW11 with a high value of R indicate gravity of water flow, low infiltration and high runoff conditions of the study area.

Table 5 Aerial aspect

Sub-watershed	UDSW 1	UDSW 2	UDSW 3	UDSW 4	UDSW 5	UDSW 6	UDSW 7	UDSW 8	UDSW 9	UDSW 10	UDSW 11	Ahad Watershed
Area (A) in Km2	15.72	25.69	36.94	27.34	27.95	80	74.9	19.04	27.19	27.77	76.43	437.92
Perimeter (P) in Km	23.07	28.82	32.47	36.43	29.07	52.56	60.73	22.94	26.77	31.56	37.85	110.24
Length of Basin (L) in Km	4.83	10.84	11.32	12.76	8.86	18.9	18.62	7.13	7.19	11.69	12.54	32.52
Drainage Density (Dd)	2.63	2.58	2.87	3.22	3.43	1.29	1.5	3.46	3.32	1.92	2.1	2.28
Drainage Texture (T)	2.73	2.85	4.68	3.35	5.54	2.36	2.72	5.62	5.30	2.63	5.47	12.93
Stream Frequency (Fs)	4.01	3.19	4.11	4.46	5.76	1.55	2.20	6.77	5.22	2.99	2.71	3.25
Form Factor (Ff)	0.67	0.22	0.29	0.17	0.35	0.22	0.21	0.37	0.53	0.20	0.48	0.41
Shape factor (Sb)	1.48	4.57	3.47	5.96	2.81	4.46	4.63	2.67	1.90	4.92	2.06	2.41
Elongation Ratio (Re)	0.93	0.53	0.61	0.46	0.67	0.53	0.52	0.69	0.82	0.51	0.79	0.73
Circularity Ratio (Rc)	0.37	0.39	0.44	0.26	0.41	0.36	0.25	0.45	0.47	0.35	0.67	0.45
Length of overland flow (Lg)	0.19	0.19	0.17	0.15	0.15	0.39	0.33	0.14	0.15	0.26	0.24	0.22
Constant of channel maintenance (C)	0.38	0.39	0.35	0.31	0.29	0.77	0.67	0.29	0.30	0.52	0.48	0.44
Compactness coefficient (Cc)	1.64	1.6	1.51	1.97	1.55	1.66	1.98	1.48	1.45	1.69	1.22	1.49

Table 6 Relief aspect

Sub-watershed	Maximum elevation in meter	Minimum elevation in meter	Relative relief (R)	Relief ratio (Rr)	Ruggedness number (Rn)
UDSW1	971	596	375	0.078	0.99
UDSW2	970	619	351	0.032	0.90
UDSW3	942	631	311	0.027	0.89
UDSW4	930	631	299	0.023	0.96
UDSW5	974	630	344	0.039	1.18
UDSW6	907	554	353	0.02	0.46
UDSW7	933	554	379	0.02	0.57
UDSW8	982	960	322	0.04	1.11
UDSW9	1058	614	444	0.06	1.47
UDSW10	917	591	326	0.03	0.63
UDSW11	1008	594	414	0.03	0.87
Ahad Watershed	1058	554	504	0.015	1.15

Ahar watershed as well as the whole study area too shows high relative relief. The Relief ratio ranges from 0.020 (UDSW6 and UDSW7) to 0.078 (UDSW1) (Table 6) indicates moderate relief and steep to moderate slope. Ruggedness number is the product of maximum basin relief and drainage density. It is a dimensionless number. It can describe the slope steepness and length of the basin. Table 6 shows that the value of Rn ranges from 0.46 (UDSW6) to 1.47 (UDSW9), which indicates that the area is rugged with high relief and high stream density.

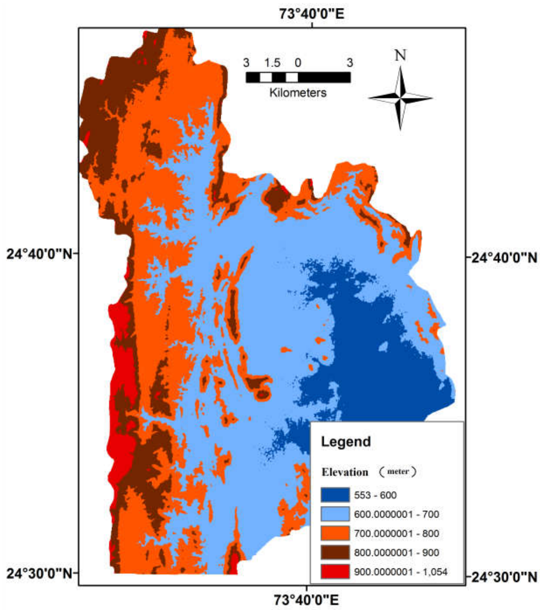

Fig 9 Elevation map

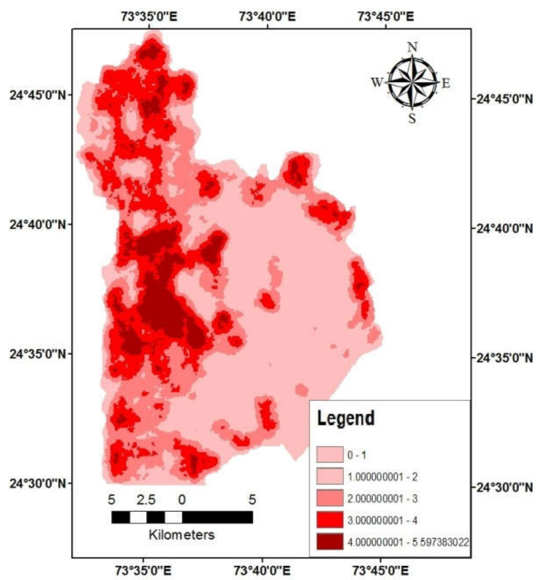

Fig 10 Drainage density map

CONCLUSION

All the three aspects (linear, aerial and relief) of the morphometric parameter has analyzed of all the 11 subwatershed as well as the whole area of Ahar watershed. The morphometric parameters evolved here would be of massive effectiveness in watershed prioritization for soil and water conservation, flood management and natural resources management at a micro level. High drainage density, high bifurcation ratio with high elevation found the watershed belongs to the western side. The geoprocessing techniques used in this study will help out the government in planning and decision making in basin development and management studies.

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