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Micro level geomorphic study in part of Udaipur, Rajasthan

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Abstract

Geomorphic study in micro level of a watershed has been studied in remote sensing and GIS environment. Delineation of drainage network and computation of various morphometric parameters were done using Arc GIS 10.2. The study area shows mostly of trellis drainage pattern with maximum stream order of 5. Length of all streams is 181.808 Km and stream length ratio is 2.155. High bifurcation ratio indicating the area is highly structural controlled. High drainage density with fine texture shows the area is covered with impermeable subsurface material. According to the values form factor and circularity ratio, the area is sub circular to elongated in shape. The main course the drainage shifted to NE direction with sinuous in nature.

Keywords: Geomorphic Character; Micro Watershed; Remote Sensing And GIS; Morphometric

1. Introduction

Most of the cases for understanding the hydrological study, we consider watershed as a basic unit. Horton first studied morphometric parameters in the field of hydrology to identify and measurement of shape [1]. Morphometric analysis of a watershed provides a quantitative description of the drainage system, which is an important aspect of the characterization of watersheds [2, 3]. It is a mathematical analysis to configure the dimension and shape of earth's landforms [4] and it can be achieved by study of linear, aerial and relief parameters along with slope contribution [5, 6]. Morphometric analysis provides quantitative description of basin geometry [7]. Morphometric analysis involves the evaluation of stream parameters through the measurements of different stream properties [8-10]. Traditional methods are difficult to work out drainage network. The study of drainage characteristic has been carried out in different part of the globe by using conventional method [11]. In recent years, GIS is very friendly tools for geomorphic study in India as well as abroad. The morphometric parameters of the micro watershed in the study area have taken in account by using Remote Sensing and GIS techniques.

1.1. Study area

The study area covers 52.91 square kilometres and located in the villages of Jhalon ka gura, Kundal ka gura, Borvaliya, Kailashpuri, Ghodach, Khatpal ka gura, Kunda of Udaipur district of Rajasthan and lies between latitude 24^{0}44'N to 24^{0}48.75'N and longitude 73^{0}38.125'E to 73^{0}45'E. The study area falls semi-arid region under tropical climatic condition.

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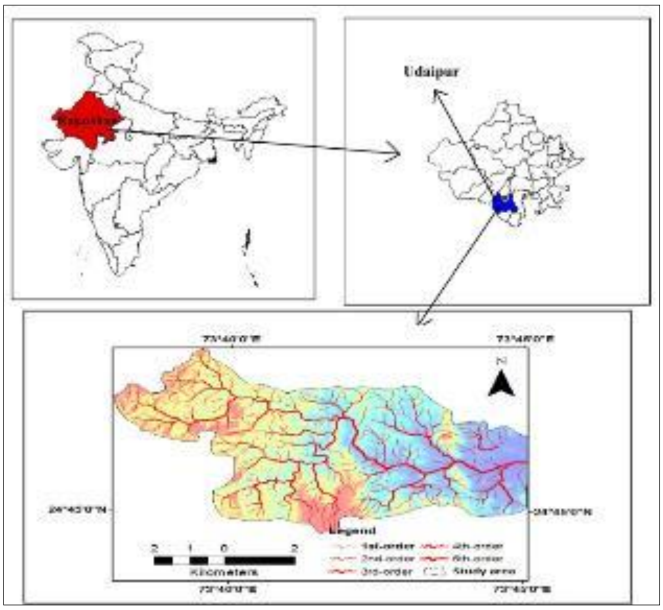

Figure 1 Location map

2. Methodology

In the present study the area, streams were digitized using SOI topographic map 45H/9 and 45H/10 on 1:50,000 scale and updation through SRTM DEM of 1arc resolution and google earth image. The ArcMap 10 software has been used to digitize the drainage network. Three aspects such as linear, areal and relief of morphometric parameter were calculated by using standard formulae. Elevation (fig 3a), Slope (fig 3b) and drainage density map (fig 3c) has prepared using SRTM data to understand about the behaviour of the study area. To understand the tectonic behaviour of the area, river sinuosity and Transverse Topographic Symmetry Factor (TTSF) was analysed.

3. Result and discussion

3.1. Linear aspect

The channel segments have been ranked according to Strahler's (1964) stream ordering system that is 1st order stream has no tributaries, 2nd order streams have tributaries only of 1st order streams and by joining two 2nd order, 3rd order stream is formed and so on [2]. In this study area the highest order is five (Fig 1).

"Laws of stream numbers" states that the number of stream segments of each order forms an inverse geometric sequence against plotted order [1]. The total number of streams are 312. Out of which 229 are 1st order, 58 are 2nd order, 19 are 3rd order, 5 are 4th order and 1 is 5th order. Most of the places the streams have been formed trellis pattern. The calculated number of streams with order shows that the number of streams decreases with increasing order (Fig.2a). With small deviation from straight line most of the drainage network shows linear relationship (Fig. 2b).

Table 1 Linear aspects of the drainage network of the study area

Stream Order (u)	Number Of Stream (Nu)	Stream Length (Lu)	Mean Stream Length (Lsm)
1	229	107.59	0.47
2	58	34.64	0.597
3	19	17.77	0.935
4	5	14	2.8
5	1	7.81	7.81
Total	312	181.81	12.612

The average length of streams of each order in a drainage basin tends closely to approximate a direct geometric ratio [1]. Generally, the total length of stream segments decreases with increasing stream order (Fig. 2c, Fig. 2d). The total length of all stream segments is 181.81 Km. The length of 1st order is 107.59 Km, 2nd order is 34.64 Km, 3rd order is 17.77 Km, 4th order is 14 Km and 5th order is 7.81 Km. The Mean Stream Length varies from 0.47 to 7.81 respectively 1st order to 5th order as shown in table 1. The mean stream length of a particular order is greater than that of next lower order and less than that next higher order (Fig. 2e). The mean length of a channel is a dimensional property and reveals the characteristic size of drainage network components and its contributing basin surface. Table 1 shows total Lsm value of the micro watershed is 12.612. The stream length ratio can be defined as the ratio of the total stream length of a given order to the total stream length of next lower order and having important relationship with surface flow and discharge. First three values of stream length ratio increase with increasing order but at higher order the value decreases (Table 2, Fig. 2f). The changes of stream length ratio from one order to another indicating their late youth stage of geomorphic development [12]. The variation may be due to changes in slope and topography [13]. Mean stream length ratio of the micro watershed is 2.155.

Table 2 Stream length ratio of the study area

Stream Length Ratio (Rl)	
2nd order/ 1st order	1.27
3rd order/ 2nd order	1.566
4th order/ 3rd order	2.994
5th order/ 4th order	2.788
Mean Stream length ratio (Rlm) = 2.155	

The bifurcation ratio (Rb) is the ratio between stream numbers of a particular order and next higher order [14]. Bifurcation ratio (Rb) is an index of relief and dissections. It is a dimensionless parameter. Bifurcation ratio shows only a small variation from region to region or different environments except where powerful geological control dominates [15]. If bifurcation ratio vary from one order to its next order, then these irregularities are attributed to geological and lithological development of a drainage basin. Generally, bifurcation ratios range between 2.0 to 5.0 for sub basins in which the geologic structure does not exercise a dominant influence on the drainage pattern and indicates that the basin is falling under normal basin category. Here the bifurcation ratio ranges from 3.05 to 5 indicates that this value falls under normal basin category (Table-3). The mean bifurcation ratio is 3.95 which indicates the area has suffered highly structural disturbance.

Table 3 Bifurcation ratio of the study area

Bifurcation Ratio (Rb)	
1st order/ 2nd order	3.95
2nd order/ 3rd order	3.05
3rd order/ 4th order	3.8
4th order/ 5th order	5
Mean Bifurcation Ratio (Rbm) = 3.95	

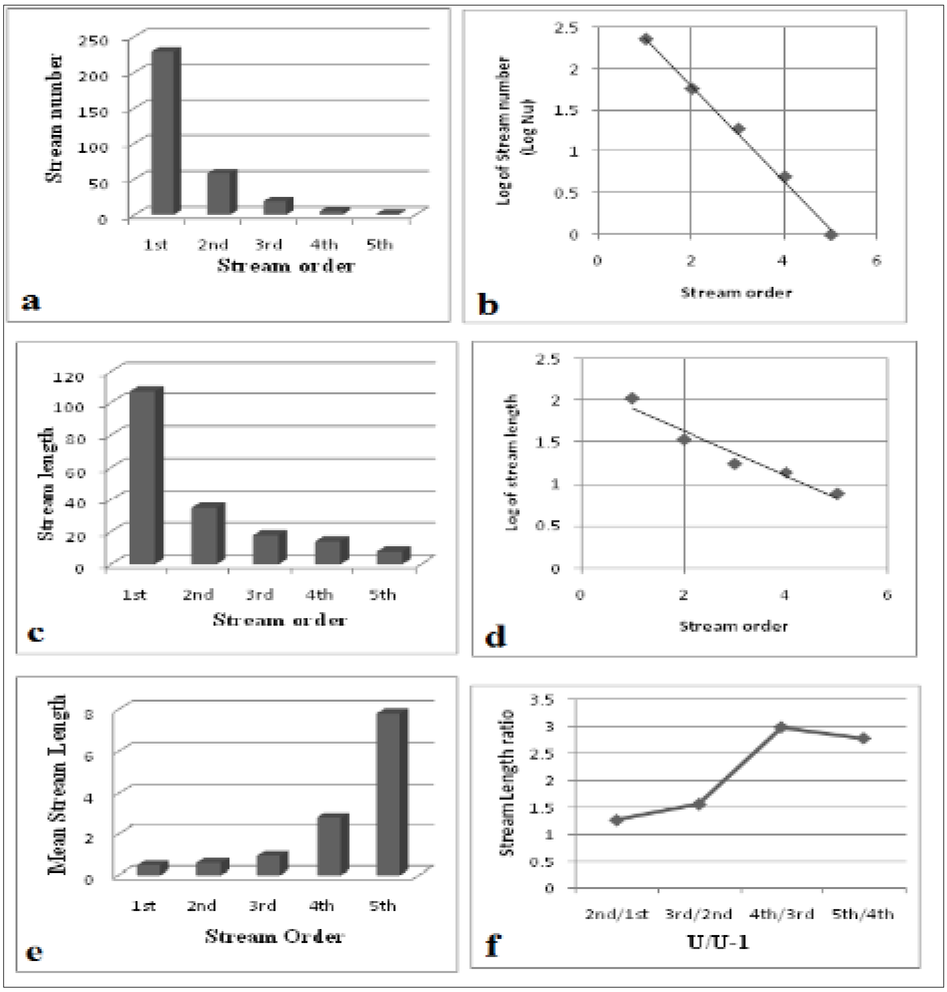

Figure 2 Linear aspect (a) Stream number vs. Stream order (b) Log of Stream number vs. stream order (c) Stream length vs. Stream order (d) Log of Stream length vs. Stream order (e) Mean Stream length vs. Stream order (f) Stream length ratio vs. U/U-1

3.2. Areal Aspect

Drainage density is defined as the total length of all streams in a basin divided by the area of the basin [16]. It describes the spacing of channel. Low value of drainage density Dd indicated that the region is having permeable subsoil material under vegetative cover and it also indicates the watershed has low relief, whereas high Dd is favored in regions of weak or impermeable subsurface materials, sparse vegetation and mountainous relief. Low drainage density leads to coarse drainage texture whereas high drainage density leads to fine drainage texture. Drainage density of the micro watershed is 3.436, suggests that streams network is closely spaced in the watershed (fig 3c). This high drainage density with fine texture indicates that the area is composed of impermeable subsurface material with mountainous relief and also basin falls late youth stage towards maturity.

Table 4 Aerial aspects of the study area

Area (A) in Km2	52.91
Perimeter (P) in Km	37.927
Length of Basin (L) in Km	13.10
Width of Basin (W) in Km	6.217
Drainage Density (Dd)	3.436
Drainage Texture (T)	8.226

Stream Frequency (Fs)	5.897
Form Factor (Ff)	0.308
Elongation Ratio (Re)	2.267
Circularity Ratio (Rc)	0.462
Constant of channel maintenance (C)	0.291
Length of overland flow (Lg)	0.146

Drainage texture is defined as the total number of stream segments of all orders divided by the perimeter of the watershed. It describes relative spacing of drainage lines, which are more prominent in impermeable material compared to the permeable ones. Drainage texture (T) depends upon a number of natural factors such as climate, rainfall, vegetation, lithology, soil type, infiltration capacity, relief and stage of development [17]. Soft or weak rocks unprotected by vegetation produce a fine texture, whereas massive and resistant rocks cause coarse texture. Sparse vegetation of arid climate causes finer textures than those developed on similar rocks in a humid climate. Smith (1954) classified drainage density into five different classes of drainage texture, i.e. less than 2, indicates very coarse, between 2 and 4 is coarse, between 4 and 6 is moderate, between 6 and 8 is fine and greater than 8 is very fine drainage texture. The study area has a value of 8.23 which falls very fine drainage texture. Stream frequency is the total number of stream segments of all order per unit basin area [1,18]. Flooding is commonly occurring in a basin with high drainage and stream frequency. A higher Fs reflects greater surface runoff and a steeper ground surface. lower Fs values indicate permeable sub-surface material and low relief [19]. The Fs value of the study area is 5.897, which indicate impermeable sub-surface material and moderate to high relief.

Form factor is measured dividing the basin area by the square of basin length [18]. For a perfectly circular basin the form factor would always be near about 0.7854. The basins with high form factors have high peak flows of shorter duration. The study area has form factor value of 0.308 which indicate elongated shape with medium peak of flow. 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 [20]. In the study area Rc value is 0.462 indicates the micro watershed is sub circular in nature. It is the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin [14]. Values near to 1.0 are the characteristics of the region of very low relief, while values in the range of 0.6 - 0.8 usually occur in the areas of high relief and steep ground slope. The Re value is 0.627 indicates the micro watershed is high relief and steep ground slope. Constant channel maintenance is inverse of drainage density. It depends on the lithology, permeability and infiltration capacity of surface material, climatic condition and vegetation [14]. In the study area the value of C is 0.291, means 0.291 Km^2 of area is required to sustain 1 km of the channel. Length of overland flow is the length of water over the ground before it gets concentrated into definite stream channels. It is like sheet flow of water over the ground. It approximately equals to half of reciprocal of drainage density. The calculated Lg value 0.146 indicates of high relief of the study area.

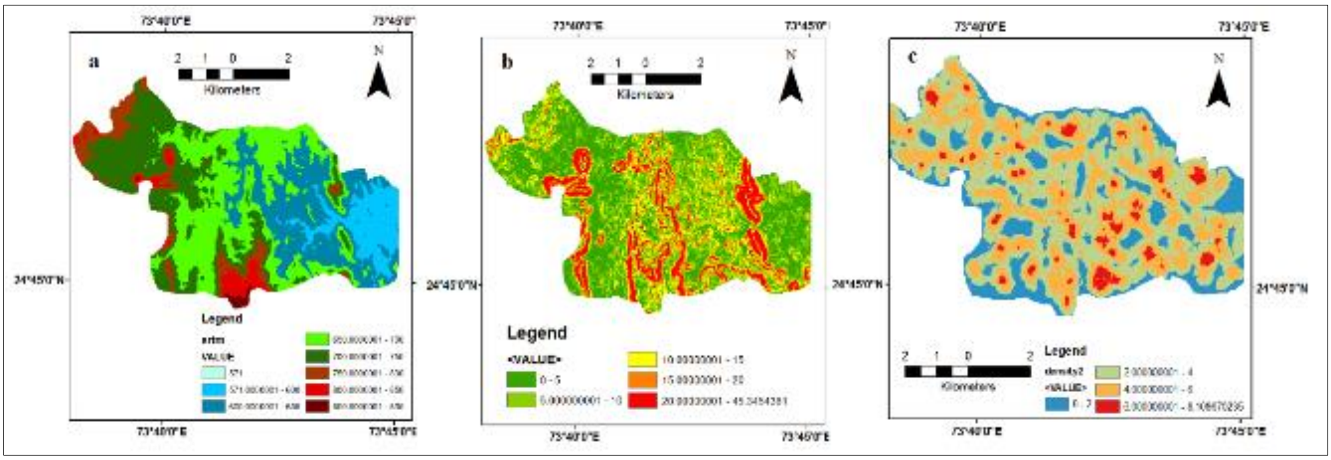

Figure 3 (a) Elevation map ((b) Slope map, (c) Drainage density map

3.3. Relief aspect

Basin relief is the difference in elevation between the highest and the lowest point of the basin. The maximum elevation of the study area is 866 meter and minimum elevation is 560 meters so the basin relief of the micro watershed is 306 meters (fig 3a). This high value of R indicates gravity of water flow, low infiltration and high runoff conditions of the study area. The relief ratio is the ratio between the basin relief and the length of the basin [14]. It is also an indicator of intensity of erosion processes and sediment delivery rate of the basin. The relief ratio of the study area is 0.023 which is the characteristic features of less resistant rocks of the area [21].

Table 5 Relief aspect of the study area

Basin relief (R)	306
Relief ratio (Rr)	0.023
Ruggedness number (Rn)	1.05

It 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. In the study area the value of Rn is 1.05, which indicates that the area is rugged with high relief and high stream density (Fig 3a).

3.4. River Sinuosity

Although Sinuosity of river channel put its imprint on geomorphic history it also depends on the geological control like active tectonics [22]. Channel gradient, sediment load of river manages channel sinuosity. The behaviour of channel sinuosity also depends on the structural characteristics of the area and stage of valley development through which it flows. Mathematically it can be computed through following formula: SI=CL/SL, where, SI is sinuosity index, CL is the actual length of the channel and SL is the straight-line length or the air length between the same point. According to Morisawa (1985) classification except segment 2 all are shows sinuous channel where segment 2 shows meandering in nature [23] (Fig 4a).

Table 6 River sinuosity

Segment	Lmax (Km)	Lr (Km)	P (Sinuosity)	Channel deflection (Maximum) from straight line (Km)
1	5.94	4.97	1.19	0.43
2	6.92	4.39	1.57	0.58
3	4.18	3.37	1.24	0.77
4	3.45	2.95	1.16	0.38

3.5. Transverse Topographic symmetry factor (TTSF)

TTSF is important tool to identifying the active tectonic nature in the area of poorly exposed active structure of quaternary rock [24]. TTSF can be evaluate by the following formula T=Da/Dd, where Da is the distance from the stream channel to the middle of its drainage basin and Dd is the distance from the basin margin to the middle of the basin. When main river channel flow in the middle of the watershed then the area may be considered as tectonically inactive and the value of TTSF will be zero. In the fig 4b, the red circle part has TTSF value is more than 4.5 and fall in class 1 [25], which indicate the channel has shifted to NE direction (Fig 4b).

Table 7 Transverse Topographic Symmetry Factor

Da (KM)	Dd (KM)	Da/Dd	Da (KM)	Dd (KM)	Da/Dd
0.76	1.67	0.455	0.25	2.33	0.107
1.02	1.66	0.614	0.36	1.70	0.211
1.22	2.24	0.544	0.22	1.85	0.118
1.74	3.06	0.568	0.42	1.60	0.262

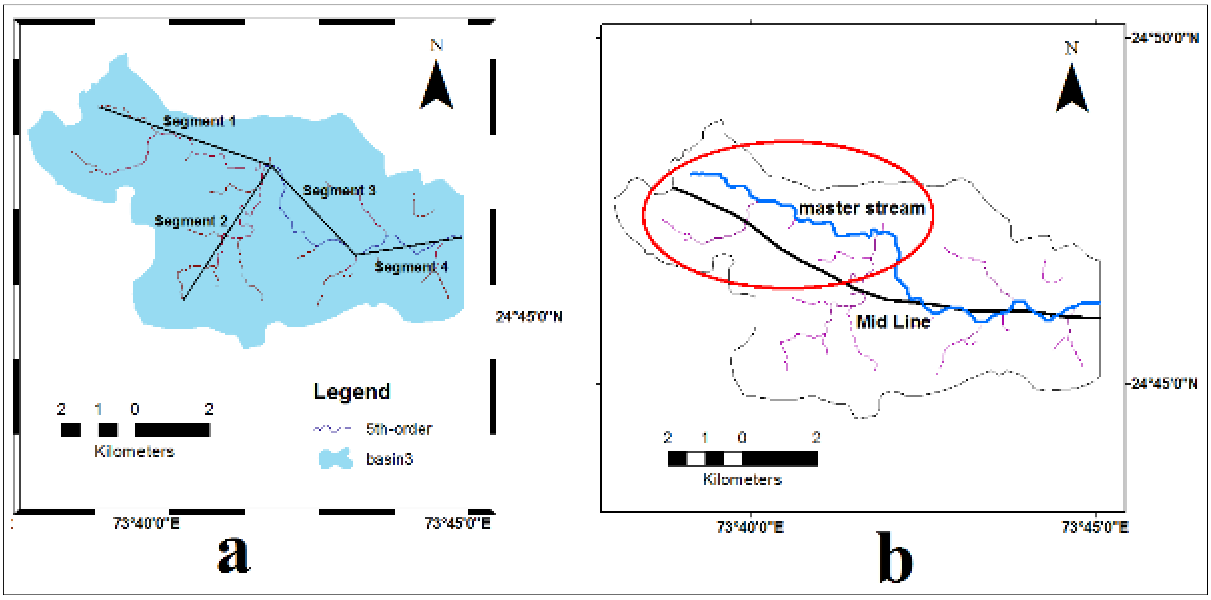

Figure 4 (a) River sinuosity map, (b) Transverse Topographic Symmetry Factor map

4. Conclusion

Morphometric analysis of Katla river basin has been done by the use of Remote sensing and GIS software. Three aspects of morphometric analysis tell us about the character of the micro watershed. The morphometric analysis reveals that the study area of high drainage density is highly structurally controlled and the area has developed late youth stage of geomorphic development. Drainage density, drainage texture and stream frequency shows that the area falls in impermeable sub surface material. The sub circular to elongated shaped micro watershed has high relief with undulating topography so that surface water can move with high velocity in monsoon season. TTSF map shows that in the red circled area the stream flows along northern margin of the watershed is due to north-east tilting of the watershed. High meandering nature of segment 2 in the river sinuosity map is also the reason of tilting.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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