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RESEARCH ARTICLE

GEOGRAPHICAL INFORMATION SYSTEM BASED MORPHOMETRIC ANALYSIS OF TAKOLI GAD WATERSHED, TEHRI GARHWAL, UTTARAKHAND, INDIA

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ABSTRACT

The quantitative analysis of drainage system is an important aspect of characterization of watersheds. Using watershed as a basic unit in morphometric analysis is the most logical choice because all hydrologic and geomorphic processes occur within the watershed. The geographical position of watershed is 30^0 14' to 30^0 23' N latitude and 78^0 37' to 78^0 46' E longitudes. The elevation of the watershed ranges from 605 m to 2278 m. The study was carried out using the method of Horton and Strahler, to rank the stream segments using ERDAS IMAGINE 9.1. The relevant numbers of the streams were entered into the attribute table and all other analyses based on the mathematical formulas. The results indicated that the watershed area is 131.43 km^2, The drainage Density ranges from 2.55 to 5.91, Stream frequency ranges from 3.65 to 13.13, Relief ratio ranges from 0.18 to 0.70, Ruggedness number ranges from 0.88 to 4.00 and Drainage texture ranges from 9.30 to 71.68. The results of this analysis would be useful in determining the effect of watershed characteristics such as size, shape, slope of the watershed & distribution of stream net work within the watershed.

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INTRODUCTION

Morphometry is the quantitative study of the characters of a drainage basin. A drainage basin is the area which contributes water to a particular channel or a set of channels. It is the source area of precipitation eventually provided to the stream channels through various paths. As such, it forms a unit for the consideration of the process determining the formation of specific landscapes (Leopold et al., 1964). Morphometry aims collecting data of the measurable factors of drainage basins which are subjected to statistical analysis and used in comparing precisely the characters of various individual basins. The main objective of this study, using advanced remote sensing and GIS technology is to compute basin morphometric characteristics for various parameters.

Study area

Geographically the catchment (Takoli Gad) is lying between the 30^0 14' to 30^0 23' N latitude and 78^0 37' to 78^0 46' E longitudes in the Survey of India toposheet No. 53 J/11, 53 J/12 and 53 J/15 with an area of about 131.43 Km^2. It comes under jurisdiction of district Tehri Garhwal, Uttarakhand. The area is approached by Kirtinagar-Tehri and Kirtinagar- Chauki all weather roads.

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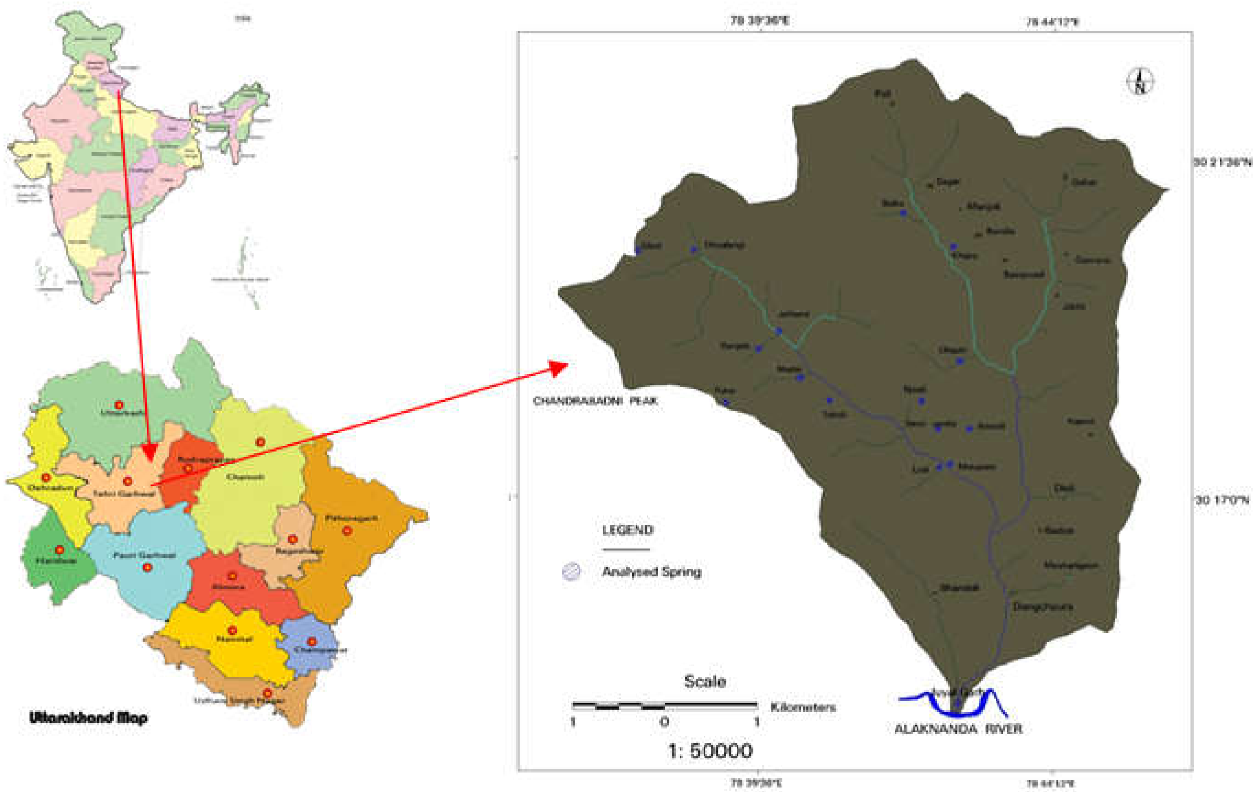
The area falls in inner Garhwal lesser Himalaya and is characterized by gentle and mature topography. The Takoli Gad originates from the Eastern slope of the Chandrabadni Peak (2278 meter) and join the Alaknanda at Juyal Garh (605 meter). Jakhand and Dagar Gad are the two main sub streams / tributaries of the Takoli Gad watershed.

MATERIALS AND METHOD

The Morphometric analysis of Takoli Gad watershed have been carried out on the basis of a topographic map of study area, followed by relevant field checks supported by satellite data. Based on topographical map on 1:50,000 scales (Survey of India, toposheet No.- 53 J/11, 53 J/12, 53 J/15) the drainage map of Takoli Gad watershed has been prepared. Digitization work has been carried out for entire analysis of basin morphometry using GIS software (ERDAS IMAGINE 9.1). The streams of various orders (I^{st} to 6^{th}) were marked on the basis of Strahler's method (1952). Following parameters as suggested by Doornkamp and King (1971) were used for statistical analysis. The attributes were assigned to create the digital data base for drainage layer of the watershed. Various morphometric parameters such as linear aspects of the drainage network: stream order (Nu), bifurcation ratio (Rb), stream length (Lu) and areal aspects of the drainage basin: drainage density (Du), stream frequency (Fu), Drainage texture (Tu) of the basin were computed.



RESULTS AND DISCUSSION

The morphometric analysis of drainage network of the basin was carried out on the basis of the technique proposed by Doornkamp and King (1971). For this purpose the 3rd order basins were marked on the topographic map. Various morphometric parameters were calculated (Table 1) These parameters are divisible into three groups.

- Linear aspects (attitude of various drains)
- Areal aspects (geometry of basins)
- Relief aspects (relative heights within the basin)

Linear Aspects (order, number, length of streams)

In the map of drainage network of the basin, various order of streams were identified. Each fingertip channel, which has no tributary is designated as a segment of first order. Different methods of stream ordering have been proposed by different geomorphologists like Horton (1945) and Strahler (1952). In the present study, the method proposed by Horton (1945) and modified by Strahler (1952) has been adopted for stream ordering. The length of the streams was measured with the help of Erdas imagine 9.1 GIS software and stream orders were directly recorded from the topographic map. In the linear aspect of stream channel system, various geometric attributes of streams viz. order, number, length, bifurcation ration and sinuosity index of the streams were computed.

Stream Order

The stream order is defined as the measurement of the position of stream in the hierarchy of the tributaries. It offers quantitative basis for the comparison of the degree of development of different size streams in the drainage nets. This method was introduced by Horton (1945) and modified by Strahler (1958).

Stream Number

The number of streams of different order in a Takoli Gad watershed decreased with increasing order in a regular way. The relation between stream order and number suggests that the stream of lower orders are in agreement with stream net work.

Bifurcation Ratio

From the stream order data, the bifurcation ratio is calculated. The data reveals that bifurcation ratio does not remain constant from one order to the next order. To arrive a more accurate bifurcation ratio, Strahler (1968) used a weighted mean bifurcation ratio. The weighted mean bifurcation ratio of the stream under study suggests the following-

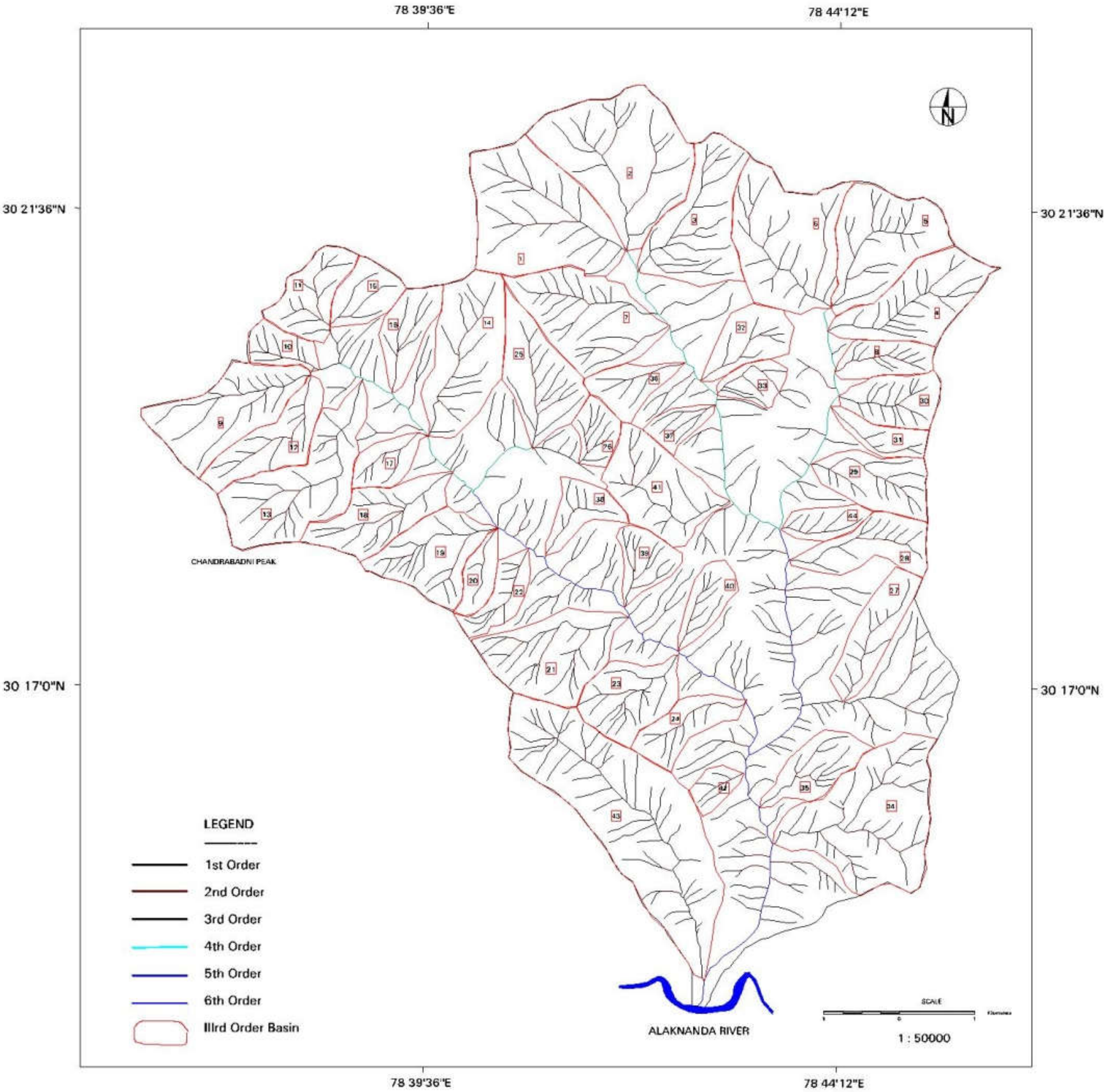
The bifurcation ratio of streams ranges from 2.0 to 7.0 in showing a great variation, which reflects that the drainage pattern may be highly disturbed due to heterogeneous bed rock characters, complex structural features and changes in watershed geometry. The basins are structurally controlled and high to moderately dissect.

Stream Length

From the stream length data, the length ratio of each order of stream was calculated.

Sinuosity Index

The main stream as well as the tributaries may not follow a straight coarse, rathter they have characteristic features of lateral migration of shift, which is known as meandering.



Thus stream coarse is controlled by so many factors like topography, geomorphic threshold, stream gradient, channel area, sediment load, volume of water discharge and lithological and structural characters of bed rocks. Meandering is defined as the sinuous (curve or bend) channel. According Muller (1968), stream having a sinuosity 1.0 is straight, between 1.0 to 1.30 is sinuous and more than 1.3 is meandering. It is observed that the Takoli Gad of present study area is sinuous because it has less than 1.3 sinuosity index.

Areal Aspect (Basin Geometry)

The area of the basin is defined as the total area of the surfaces contributing to all the channels in the basin along with all interbasinal areas. The area of the basin is delimited from the adjoining one by a drainage divide. The drainage divide is a ridge like that can be identified on the basis of contour patterns. The area of drainage basin was computed with the help of erdas imagine 9.1 GIS software. The length of the basin is measured as the distance from the mouth of the stream to the most distant point on the basin perimeter with the help of also erdas imagine 9.1 software. Stream frequency, drainage density, drainage texture and basin shape were determined by the methods as suggested by Doornkamp and King (1971). The areal characteristics of a basin are related to its planer to curviplaner features. The areal aspects may be described into two ways viz. morphometric parameters and morphometric characteristics.

Morphometric Parameters

The basin size and basin shape are important parameters of the areal aspects. They are defined as

Basin Size

The total basin area of Takoli Gad is 131.43 sq. km.

Basin Shape

The basin shape is an important parameter which controls the morphometry of the stream network and largely depends on the geology and structure present in the area. Almost all the basins of Takoli Gad are elongated. Therefore, the impact of lithology and structure feature are quite apparent in the study area and the shape of the basin is an important morphometric parameter, affecting the discharge characteristics of the stream.

Morphometric Characteristics

The drainage density and stream frequency are the main parameters to determine the morphometric characteristics of watershed basin.

Table 1. Morphometric Parameters of Third Order basins of the Catchment

Basin No.	N_1	N_2	N_3	∑N	L_1 (Km)	L_2 (Km)	L_3 (Km)	∑L (Km)	Au (Km^2)	Lb	Wb
1	17	2	1	20	9.58	2.71	0.99	13.28	4.85	3.30	2.39
2	14	3	1	18	8.21	2.56	1.82	12.59	4.92	3.04	2.95
3	14	4	1	19	8.33	2.08	2.20	12.61	3.08	2.81	1.02
4	17	2	1	20	7.82	0.86	2.07	10.75	2.70	2.74	1.05
5	16	5	1	22	6.49	1.43	2.08	10.00	3.10	1.89	1.41
6	17	4	1	22	7.39	2.76	1.69	11.84	4.04	2.23	1.76
7	15	2	1	18	7.35	1.33	1.28	9.96	2.42	1.91	1.01
8	9	1	-	10	3.09	1.44	-	4.53	1.00	1.65	0.60
9	14	3	1	18	7.39	0.93	1.28	9.60	2.93	2.52	0.95
10	7	1	-	8	2.80	0.89	-	3.69	0.72	0.96	0.64
11	10	2	1	13	3.87	1.60	0.26	5.73	1.50	1.78	0.89
12	9	1	-	10	4.02	2.24	-	6.26	1.81	2.02	0.68
13	17	3	1	21	8.27	1.48	2.65	12.4	3.63	2.81	0.96
14	12	2	1	15	6.79	2.16	0.68	9.63	3.19	2.55	1.13
15	3	1	-	4	2.72	.42	-	3.14	1.06	1.15	0.76
16	5	1	-	6	3.17	1.30	-	4.47	1.22	1.57	0.67
17	5	1	-	6	1.70	1.31	-	3.01	0.83	1.04	0.61
18	12	3	1	16	5.18	2.32	1.13	8.63	2.10	2.01	0.80
19	14	3	1	18	6.23	1.51	1.73	9.47	2.23	1.53	1.06
20	2	1	-	3	1.02	.77	-	1.79	0.69	1.08	0.42
21	16	4	-	20	7.88	2.23	2.16	12.27	2.93	2.03	1.23
22	8	1	-	9	3.12	1.35	-	4.47	0.93	1.25	0.55
23	13	3	1	17	6.20	0.88	1.42	8.5	1.94	1.48	1.00
24	7	1	-	8	2.87	1.76	-	4.63	1.25	1.56	0.60
25	11	3	1	15	6.52	1.77	0.72	9.01	2.28	1.92	0.92
26	7	2	1	10	3.32	0.66	0.24	4.22	0.77	0.94	0.62
27	9	1	-	10	3.60	1.82	-	5.42	1.59	2.49	0.67
28	9	2	1	12	3.74	1.01	1.34	6.09	1.70	1.93	0.74
29	12	2	1	15	4.90	2.10	0.34	7.34	1.76	1.77	0.91
30	14	2	1	17	4.84	.56	1.05	6.45	1.41	1.49	0.86
31	4	1	-	5	1.13	1.67	-	2.80	0.79	1.43	0.46
32	6	1	-	7	2.38	1.55	-	3.93	1.32	1.34	0.82
33	4	1	-	5	2.37	1.50	-	3.87	0.73	0.87	0.63
34	30	5	1	36	10.29	4.18	2.66	17.13	4.98	2.45	1.43
35	8	2	1	11	3.76	1.05	0.89	5.70	1.40	1.41	0.60
36	4	1	-	5	2.22	1.09	-	3.31	0.98	1.17	0.61
37	4	2	1	7	2.61	0.54	0.16	3.31	0.56	0.91	0.46
38	5	1	-	6	2.17	1.23	-	3.50	0.93	0.93	0.77
39	8	4	1	13	3.19	1.56	0.66	5.41	0.99	0.92	0.76
40	6	1	-	7	2.85	1.19	-	4.04	0.90	1.55	0.60
41	15	4	1	20	5.69	1.16	2.15	9.00	2.61	2.04	1.30
42	4	1	-	5	1.75	0.54	-	2.39	0.49	0.86	0.55
43	41	7	1	49	20.18	1.62	5.58	27.38	7.85	4.87	1.54
44	5	1	-	6	2.35	0.78	-	3.13	0.74	1.28	0.50

Basin No.	Rb	H (Km)	RI	Rn	Fu	Tu	Du	Rh	Z	z	h
1	8.50	1.000	3.49	2.73	4.12	11.24	2.73	0.30	2.28	1.28	1.78
2	4.66	0.840	5.82	2.14	3.65	9.30	2.55	0.27	2.12	1.28	1.70
3	3.50	0.980	8.80	4.00	6.16	25.19	4.09	0.34	2.22	1.24	1.73
4	8.50	0.820	18.81	3.26	7.40	29.45	3.98	0.29	2.04	1.22	1.63
5	3.20	0.760	9.42	2.44	7.09	22.82	3.22	0.40	2.06	1.30	1.68
6	4.25	0.800	4.51	2.34	5.44	15.93	2.93	0.35	2.12	1.32	1.72
7	7.50	0.920	7.06	3.78	7.43	30.53	4.11	0.48	2.10	1.18	1.64
8	9.00	0.640	2.14	2.89	10.00	45.30	4.53	0.38	1.80	1.16	1.48
9	4.66	0.960	10.16	3.13	6.14	20.07	3.27	0.38	2.10	1.16	1.64
10	7.00	0.440	3.14	2.25	11.11	56.88	5.12	0.45	1.58	1.14	1.36
11	5.00	0.540	0.62	2.06	8.66	33.08	3.82	0.30	1.72	1.18	1.45
12	9.00	0.880	1.79	3.03	5.52	19.04	3.45	0.43	2.20	1.14	1.58
13	5.66	0.960	14.78	3.27	5.78	19.70	3.41	0.34	2.20	1.06	1.54
14	6.00	0.640	2.13	1.92	4.70	14.14	3.01	0.25	2.10	1.46	1.78
15	3.00	0.740	6.47	2.19	3.77	11.15	2.96	0.64	1.92	1.18	1.55
16	5.00	0.980	2.43	3.58	4.91	17.97	3.66	0.62	2.02	1.04	1.55
17	5.00	0.420	1.29	1.52	7.22	26.13	3.62	0.40	1.38	0.96	1.53
18	4.00	0.760	2.51	3.11	7.61	31.20	4.10	0.37	1.72	0.96	1.17
19	4.66	0.580	7.12	2.45	8.07	34.21	4.24	0.37	1.46	0.88	1.34
20	2.00	0.340	1.32	0.88	4.34	11.24	2.59	0.31	1.22	0.88	1.17

Continue……………………

21	4.50	0.700	7.62	2.92	7.16	29.92	4.18	0.34	1.48	0.78	1.05
22	8.00	0.580	2.31	2.78	9.67	46.41	4.80	0.46	1.42	0.84	1.13
23	4.33	0.620	9.99	2.71	8.76	38.36	4.38	0.41	1.36	0.74	1.13
24	7.00	0.560	1.63	2.07	6.40	23.68	3.70	0.35	1.22	0.66	1.05
25	3.66	0.760	2.64	3.00	6.57	25.95	3.95	0.39	1.90	1.14	0.94
26	3.50	0.540	1.20	2.95	12.98	71.13	5.48	0.57	1.80	1.26	1.52
27	9.00	0.790	1.97	2.68	6.28	21.35	3.40	0.31	1.61	0.82	1.53
28	4.50	0.860	4.95	3.07	7.05	25.23	3.58	0.44	1.72	0.86	1.215
29	6.00	0.740	0.79	3.08	8.52	35.52	4.17	0.41	1.74	1.00	1.29
30	7.00	0.600	9.07	2.74	12.05	55.06	4.57	0.40	1.72	1.12	1.37
31	4.00	0.520	0.67	1.84	6.32	22.37	3.54	0.36	1.66	1.14	1.40
32	6.00	0.520	1.53	1.54	5.30	15.74	2.97	0.38	1.62	1.10	1.36
33	4.00	0.440	1.58	2.33	6.84	36.25	5.30	0.50	1.50	1.06	1.28
34	6.00	0.680	6.54	2.33	7.22	24.76	3.43	0.27	1.32	0.64	0.98
35	4.00	0.460	3.18	1.87	7.85	31.94	4.07	0.32	1.10	0.64	0.87
36	4.00	0.720	2.03	2.42	5.10	17.18	3.37	0.61	1.80	1.08	1.44
37	2.00	0.640	0.77	3.78	12.5	73.87	5.91	0.70	1.68	1.04	1.36
38	5.00	0.520	1.76	1.95	6.45	24.25	3.76	0.55	1.38	0.86	1.12
39	2.00	0.520	1.34	2.83	13.13	71.68	5.46	0.56	1.30	0.78	1.04
40	6.00	0.600	2.39	2.68	7.77	34.80	4.48	0.38	1.32	0.72	1.02
41	3.75	0.860	10.53	2.95	7.66	26.35	3.44	0.42	1.76	0.90	1.33
42	4.00	0.400	3.24	1.94	10.20	49.67	4.87	0.46	1.06	0.66	0.86
43	5.85	0.880	69.47	3.06	6.24	21.71	3.48	0.18	1.42	0.54	0.98
44	5.00	0.560	3.01	2.36	8.10	34.18	4.22	0.43	1.42	0.86	1.14

Drainage Density (Du)

The drainage density is a measure of the degree of dissection of the basin and has a relationship with permeability of the exposed rocks and the extent of geological control on the drainage pattern (Schumm, 1972). The drainage density of Takoli Gad catchment ranges between 2.55 to 5.91 (Table 1)

Stream Frequency (Fu)

The stream frequency is referred to as the total number of streams of all orders present in a basin, divided by the surface area of the basin. The stream frequency of Takoli Gad ranges from 3.65 to 13.13 (Table 1).

Relief Aspects (on the basis of heights measurement)

The channel slope/gradient expresses the rate of the denudation and height of stream channel per unit of length. The total basin relief is the difference of altitude between the lowest and the highest points within the basin. Both of these parameters are measured from the contours or spot heights given on the topographic maps. The ratio between basin relief and basin length has been expressed as the relief ratio. The multiple of basin relief with drainage density divided by basin area is expressed as ruggedness number. For the measurement of all the parameters of relief, the parameters suggested by Doornkamp and King (1971) are followed in the present observation. The relief aspect is interrelated with slope and where the relief is maximum, the slope angle and sediment loss is highest. Relief may be explained as the range in altitude (Smith, 1935) or it may be defined as the elevation difference between reference points (Durry, 1951). Strahler (1968) stated the maximum relief is the elevation difference between basin mouth and the highest point on the basin perimeter. The relief measures indicate the potential energy of a drainage system, intensity of rate of erosion and transmissibility of rock debris. According to Brusden (1980), relief and slope steepness together have a marked effect on the rate of surface run-off, infiltration and flow through the channel.

Basin Relief (H)

Basin relief is the elevation difference within a basin. It is measure of driving forces due to gravity acting on all the streams flowing into the basin. The highest basin relief of Takoli Gad is 1.00 Km.(Table 1).

Relief Ratio (Rh)

It is the ratio between the basin relief to basin length. The relief ratio of different third order basins in Takoli Gad ranges from 0.70 to 0.18 (Table 1).

Ruggedness Number

It is the product of basin relief and drainage density. According to Strahler (1958), it indicates the qualities of slope steepness and stream length. The ruggedness number of Takoli Gad ranges from 0.88 to 4.00 (Table 1). This shows the remarkable difference in different controlling factors from basin to basin.

Conclusion

It is easy to analyze the Morphometric features of the basin using GIS and Remote Sensing. Size, shape, slope of the watershed basin& distribution of stream network within the watershed indicated the watershed characteristics (Rasool et.al. 2011). The morphometric parameters evaluated using GIS helped us to understand various terrain parameters such as nature of the bedrock, infiltration capacity, runoff, etc.

The drainage basin is being frequently selected as an ideal geomorphological unit. Watershed as a basic unit of morphometric analysis has gained importance because of its topographic and hydrological unity. GIS techniques characterized by very high accuracy of mapping and measurement prove to be a competent tool in morphometric analysis. Drainage density and stream frequency are the most useful criterion for the morphometric classification of drainage basins which certainly control the runoff pattern, sediment yield and other hydrological parameters of the drainage basin. It is observed that there is a decrease in stream frequency as the stream order increases. The law of lower the order higher the number of streams is implied throughout the catchment. The total length of stream segments is maximum in first order streams and decreases as the stream order increases (Malik etal., 2011).

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