IMPACT: International Journal of Research in Applied, Natural and Social Sciences (IMPACT: IJRANSS)
ISSN (P): 2347-4580; ISSN (E): 2321-8851
Vol. 5, Issue 9, Sep 2017, 1-8

GEOMORPHOLOGICAL ANALYSIS OF GADELA WATERSHED USING REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEM

CHERAKU RADHA SRIVALLI[1] & MANJEET SINGH[2]

[1]Research Scholar, Student, Software Engineering, Department, College of Technology & Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

[2]Research Scholar, Assistant Professor, Software Engineering, Department, College of Technology & Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

ABSTRACT

In this study, the morphometric parameters of selected watershed have been calculated. The study area was classified in to 10 sub basins and linear, aerial and relief aspects, for each sub basin were found to understand the hydrology of the watershed. Satellite imagery from Cartosat, along with survey of India toposheet was used to delineate watershed boundary, with Arc GIS 10.3. The results revealed that, the study area is a sixth order drainage basin with total stream length of 1422.05 km. The mean bifurcation ratio varies between 3.06 and 5.50, which shows that the region is subjected to less structural control, by which there is no distortion of drainage pattern. Drainage density value of 3.38 Km/Km^2 shows that, there is a mountainous relief with fine drainage texture in the study area. The shape parameters such as form factor, elongation ratio and circulatory ratio calculated indicates that, the basin is elongated in shape in which, flow can be managed efficiently.

KEYWORDS: Remote Sensing, GIS, Drainage, Morphometric analysis, Prioritization

INTRODUCTION

Water is one of the most important natural resource, for every sector whether in agriculture industry or for daily activities. As the population is growing day by day, demand for water is also in increasing rate which shows alarming need to conserve the maximum amount, before reaching to the sea. Morphometric analysis provides a quantitative description of the basin geometry to understand its slope, structural controls, geological and geomorphic history of drainage basin (Strahler, 1964). It gives idea about the geo-hydrological behaviour of the basin and expresses the prevailing climate, geology, geomorphology and structure.

The knowledge of topography, stream network and its pattern, geological and geomorphologic setup, in the watershed is requisite for its management and implementation plan for conservation measures (Sreedevi et al. 2013). Remote sensing along with GIS application aid to collect, analyze and interpret the data rapidly on large scale intermittently and is very much helpful for watershed planning (Sharma et al. 2014; Gajbhiye 2014). The main aim of the study is to understand morphometric parameters of the watershed and their behaviour.

STUDY AREA

The Gadela watershed is located in the Udaipur district, which falls under Agro-climatic zone IVA, sub humid region of Rajasthan. The study area is bounded by $73^0$30' to $74^0$15' E, longitude and $24^0$30' to $25^0$0' N, latitude covering survey of India (SOI) toposheets of 45H-13, 14 and 45L-1, 2, 9, of 1:50,000 scale. The total catchment of Gadela watershed is 418.33 km^2, with highest elevation of 692m and the lowest elevation is about 420m, above mean sea level. The climate of the study area is sub humid, characterized with dry hot in summer and extremely cold in winter season. The rainfall during south-west monsoon constitutes 80% of rainfall, which is about 535 mm in the study area. On an average, the numbers of rainy days are 31.

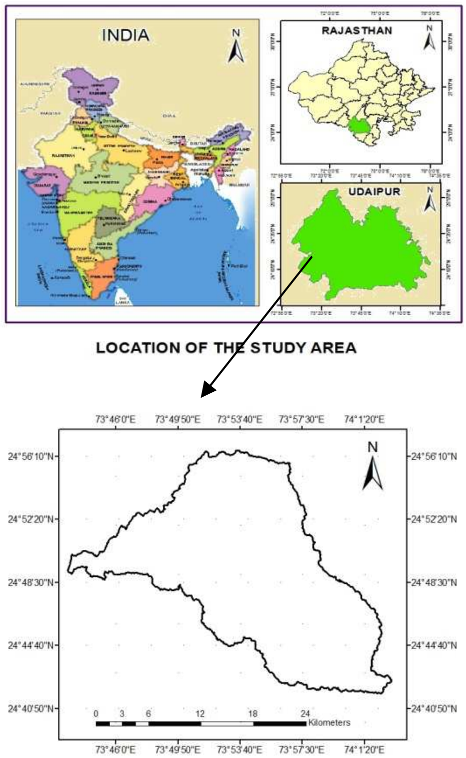

Figure 1: Location Map of the Gadela Watershed

MATERIALS AND METHODS

The Cartosat image obtained from Bhuvan.nrsc.in, was used to derive DEM and subsequent delineation of watershed with the help of Arc GIS, was performed. Toposheets obtained from survey of India, was used as reference for the study. The watershed was divided into ten sub basins and morphometric parameters were calculated for each basin, by using the formulas presented in table1. The drainage map of Gadela watershed was shown in Fig 1.The data used for deriving the parameters are

- Metrological data- Rainfall data (Water Resource department, Rajasthan)
- Remote Sensing data- DEM, Land use/ Land cover map, Geomorphology map (bhuvan.nrsc.in)
- NBSSLUP- Soil map
- Software used- Arc GIS, ILWIS

Table 1: Formulas for Calculating Linear Aspects

S.No.	Parameter	Formula	Reference
1	Stream order	Hierarchical order	Strahler(1964)
2	Stream length	Length of stream	Horton(1945)
3	Average stream length	L_u / N_u	Strahler(1964)
4	Stream length ratio	$R_L = L_u / L_{u-1}$; Where, L_u = stream length of order u, L_{u-1} = stream length of its next lower order	Horton(1954)
5	Bifurcation ratio	$R_b = N_u / N_{u+1}$; Where, N_u = total number of streams of order u, N_{u+1} = total number of streams of next higher order	Schumm(1956)
6	Length of overland flow	$Lg = 1/2D_d$; Where, D_d = Drainage density	Horton(1945)

Table 2: Formulas for Calculating Aerial Aspects

S.No.	Parameter	Formula	Reference
1	Drainage density	$D_d = \varepsilon L_u / A$; where, Lu = Total stream length of all orders, A = Area of the basin (Km2)	Horton(1932)
2	Constant of channel maintenance	$C = 1/D_d$; Where, D_d = drainage density	Schumm(1956)
3	Stream frequency	$F_s = N_u/A$; Where, N_u = Total number of streams of all orders, A = Area of the basin	Horton(1932)
4	Circulatory ratio	$Rc = 12.57A/P^2$; where, Rc = Circularity ratio, A = Area of the basin (Km^2), P = Perimeter (Km)	Miller(1953)
5	Elongation ratio	$Re = \sqrt{A} / \pi / Lb$; Where, A= Area of the basin (Km^2) Lb=Maximum Basin length (Km)	Schumm(1956)
6	Form factor	$R_f = A/L_b^2$; Where, A= area of basin(km^2), L_b= Basin length(km)	Horton(1945)
7	Compactness coefficient	$C_c = 0.2841*P/A^{0.5}$; Where, P=Perimeter of the basin(km), A= Area of the basin(km^2)	Gravelius(1914)

RESULTS AND DISCUSSIONS

Morphometric Analysis

Morphometric analysis of watershed involves finding of linear, aerial and relief aspects, of the watershed. The drainage map prepared in Arc GIS environment was imported in ILWIS, to calculate the morphometric parameters of the sub basins for the study area, and the results are presented as below

Linear Aspects

The linear aspects of the watershed such as stream number, stream length ratio, bifurcation ratio and length of overland flow was calculated, from the formulas suggested by different scientists. The results found were that, the study area is the 6^{th} order drainage basin, with area of 418.33 km^2 and the total number of streams are 1477. The linear aspects calculated were presented in Table 3(a) and 3(b).

Stream Number

Stream number gives the number of streams of different orders, in a given drainage basin. The plotting of logarithm of number of streams, against stream order is given in Fig 3. The graph shows a straight line satisfying the Horton's law, which defines that the number of stream segments in the drainage network shows linear relationship with small deviation. It means that, the number of streams usually decreases in geometric progression, as the stream order increases.

Stream Length

The total stream length in the study area was 1422.05 km. The total length of stream segments was maximum in first order and decreased as the stream order increased. A graph drawn between logarithm of the cumulative stream length as ordinate and stream order, as abscissa gives almost a straight line to fit, as shown in Fig 3.

Stream Length Ratio

Stream length ratio, defined as the stream length of order u to the stream length of next lower order (Horton, 1945). The values of stream length ratio are varying, from 2.97 to 1.37. The average stream length ratio is 2.54 and the value of R_L, decreased as the stream order is increased.

Bifurcation Ratio

Bifurcation ratio expresses the number of streams, in a given order to the number of streams in next higher order. The minimum bifurcation for Gadela watershed is 3.06 for sub basin 9 which reveal that, it was less affected by structural disturbance and there will be less distortion of drainage pattern. The maximum Rb value found in sub basin 7, as 5.50 indicates strong structural control.

Length of Overland Flow

Length of overland flow defined as, the length of water over the ground; before it gets concentrated into definite stream channels (Horton, 1945). The length of overland flow is 0.123 km^2/km, for basin5 indicating the water is travelling relatively, lesser distance before reaching the stream and there will be more runoff, as compared to basin 1 which was having high value 0.169 km^2/km.

Aerial Aspects

The aerial aspects of the watershed include drainage density, stream frequency, drainage texture, compactness coefficient, form factor, and circulatory ratio and elongation ratio. The aerial aspects calculated were shown in Fig 4(a) and 4(b)

Drainage Density

The drainage density values of Gadela watershed ranging from 2.96 to 4.08 km/km^2 for basin1 and basin5 respectively, which indicates the basin 1 has a permeable sub surface material, with sparse vegetation and mountainous relief. The basin 5, showing high drainage density was having more impermeable formation, compared to other basins.

Stream Frequency

Stream frequency is related to permeability, infiltration capacity and relief of watershed. The lowest stream frequency value found as 3.29 streams/ km^2, for sub basin 1 and higher stream frequency 3.89 streams/km^2, for sub basin 7. This shows that, sub basin 7 was having a moderately resistant sub-surface material and there will be low infiltration and moderate runoff.

Drainage Texture

The drainage texture of Gadela watershed ranges from 2.02 and 3.34, for basin 9 and basin 3, respectively. The drainage texture in-between 2 and 4 indicates, there was a presence of coarse drainage texture in all the sub basins.

Form Factor

Form factor is defined as the ratio of the area of the basin, to the square of the length of the basin (Horton, 1932). The value of form factor, approaching 1.0 indicates circular basin. Smaller the value of form factor, more elongated is the basin. The calculated form factor for Gadela watershed is varying between 1.523, for basin 1 and lowest 0.153, for basin 9. The results indicate an elongated shape of the basin, with low form factor and thus, a flatter peak flow for longer duration can be obtained for basin 9 compared to basin1, which is circular shaped.

Compactness Coefficient

It expresses the relationship of a hydrologic basin, with that of a circular basin having the same area as the hydrologic basin. The compactness coefficient for the Gadela watershed was calculated as 1.517 to 2.070.

Circulatory Ratio

Gadela watershed has highest value of circulatory ratio 0.441, for basin 8 and lowest value 0.188, for basin 7. The low circulatory ratio for basin 7 indicates, a slow discharge from the basin will be obtained and so possibility of erosion will be less.

Elongation Ratio

Elongation ratio is an important index, for the analysis of basin shape. The higher elongation ratio values indicate that, the areas with have high infiltration capacity and low runoff. The elongation ratio is classified as circular (0.9-1.0), oval (0.8-0.9), less elongated (0.5-0.7) and more elongated (<0.5) by Strahler, 1964. Elongation ratio of Gadela watershed was 0.696, for basin 1 and 0.221, for basin 9 indicates the basin 9 is more elongated and basin1 is less elongated.

Relief Aspects

The relief aspects of watershed such as basin relief, relief ratio and ruggedness number are calculated, and the results were presented in Table 5.

Basin Relief

Basin relief is an important factor, in understanding the geomorphic processes and landform characteristics. The total basin relief of the watershed observed as 271m, with lowest basin relief as 25m and highest of 193m.

Relief Ratio (Rr)

Relief ratio measures the overall steepness of a drainage basin and is an indicator of the intensity of erosion, operating on the slope of basin. The relief ratio of the basin varies from 0.02 to 0.35 and the higher relief ratio for basin 1 shows that, it has hilly slope with less infiltration and more runoff, and basin 9 was having lowest slope.

Ruggedness Number

It is a measure of surface unevenness. The average R_N value was 0.22, for Gadela watershed.

Prioritization of Sub Basins

Prioritization of sub basins was assigning the rank based on the average value, of compound parameter. The sub basin having the lowest compound parameter was given higher priority, for taking up the conservation measures. It was found that, the Sub basin 4, sub basin 6 and sub basin 10 had the lowest compound parameter, so given the priority 1, 2 and 3, respectively.

The sub basin having highest compound parameter was assigned the last priority. It was observed that, the sub basin 8 was having the highest compound parameter, so given the less priority 10 followed by sub basin 1. Hence, on the basis of priority, the water conservation measures most suitable for the watershed in the order of sub basin 4, sub basin 6, sub basin 10, sub basin 5, sub basin 2 and sub basin 3. The prioritization of sub basins was presented in Table 6.

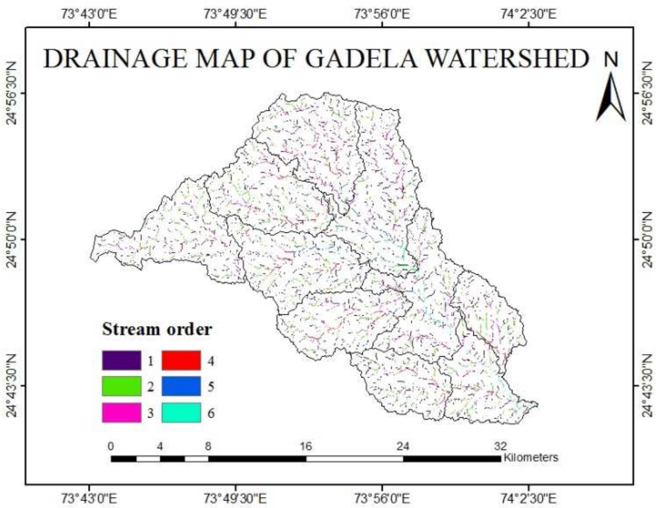

Figure 2: Drainage Map of Gadela Watershed

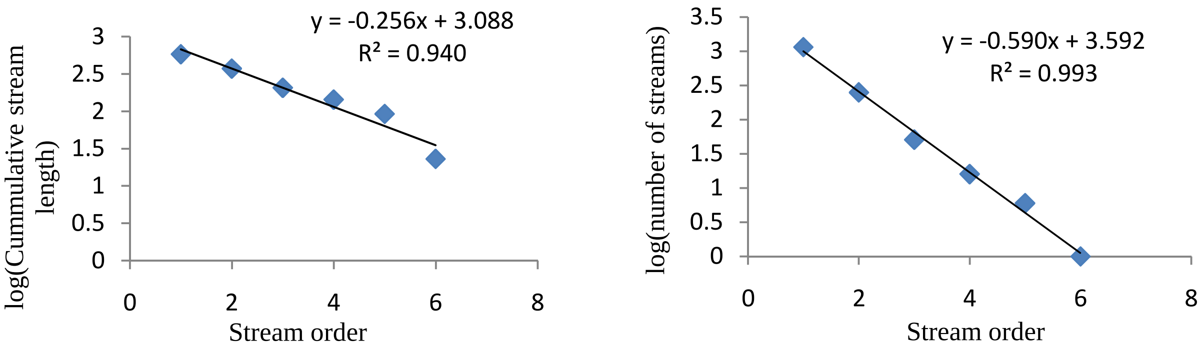

Figure 3: Showing Relation Between Number of Streams and Stream Length Againest Stream Order

Table 3: Linear Aspects of Gadela Watershed

Stream Order	1	2	3	4	5	6	Total
Stream length	582.2	373.74	206.92	143.69	92.38	23.12	**1422.05**
Stream length ratio	2.97	2.84	2.54	1.48	1.37	-	**2.54**

Table 4: Linear Aspects of Gadela Watershed

Basin	Area, Km	Perimeter, Km	Number Of Streams	Total Stream Length, Km	Average Stream Length	Stream Length Ratio	Bifurcation Ratio
1	47.16	46.29	155	139.44	5.47	3.3	5
2	45.88	39.27	157	159.2	5.65	2.5	3.48
3	48.94	41.03	171	170.53	6.19	2.4	3.65
4	47.07	41.29	176	163.69	5.84	2.5	3.63
5	59.39	56.15	216	242.1	10.4	2.5	4.7
6	38.89	35.93	137	122.72	4.81	3	4.8
7	47.61	56.37	185	143.09	3.76	2.8	5.5
8	22.26	28.88	97	98.89	3.36	2.3	4.21
9	31.6	39.07	107	100.39	2.18	2.9	3.06
10	22.52	28.14	76	82	4.25	2.9	3.85
Total	**418.3**	**412.455**	**1477**	**1422.05**	**5.19**	**2.24**	**3.64**

Table 5: Aerial Aspects of the Gadela Watershed

Compactness Constant	Drainage Density (Km/Km^2)	Stream Frequency	Constant Of Channel Maintenance	Length Of Overland Flow (Km^2/Km)
1.915	2.96	3.29	0.338	0.169
1.647	3.47	3.42	0.288	0.144
1.666	3.485	3.49	0.287	0.143
1.71	3.478	3.74	0.288	0.144
2.07	4.08	3.64	0.245	0.123
1.637	3.16	3.52	0.317	0.158
2.321	3.01	3.89	0.333	0.166
1.517	3.38	3.32	0.296	0.148
1.975	3.18	3.39	0.315	0.157
1.685	3.64	3.37	0.275	0.137
1.814	**3.38**	**3.506**	**0.298**	**0.149**

Table 6: Aerial Aspects of the Gadela Watershed

Sub-Basin	Form Factor	Shape Factor	Circulatory Ratio	Elongation Ratio	Texture Ratio
1	1.523	0.66	0.277	0.696	2.7
2	0.303	3.3	0.374	0.311	3.06
3	0.638	1.57	0.365	0.451	3.34
4	0.38	2.63	0.347	0.348	3.27
5	1.233	0.81	0.237	0.627	3.03
6	0.245	4.08	0.378	0.28	2.95
7	0.585	1.71	0.188	0.432	2.66
8	0.451	2.22	0.441	0.379	2.53
9	0.154	6.51	0.26	0.221	2.02
10	0.185	5.42	0.357	0.242	2.03
Average	**0.525**	**2.89**	**0.322**	**0.399**	**2.76**

Table 7: Relief Aspects of the Gadela Watershed

Sub-Basin	Elevation (M)		Relief (M)	Relief Ratio	Ruggedness Number
	Max.	Min.			
1	692	499	193	0.35	0.57
2	567	472	95	0.08	0.33
3	573	470	103	0.12	0.359
4	517	461	56	0.05	0.195
5	512	451	61	0.09	0.249
6	501	451	50	0.04	0.158
7	472	438	34	0.04	0.102
8	481	438	43	0.05	0.145
9	446	421	25	0.02	0.079
10	458	430	28	0.03	0.102
Gadela watershed	**692**	**421**	**271**	**0.09**	**0.22**

Table 8: Prioritization Results of Gadela Watershed

Sub Basin No.	Bifurcation Ratio	Drainage Density	Stream Frequency	Texture Ratio	Circulatory Ratio	Form Factor	Elongation Ratio	Compactness Constant	Compound Parameter	Final Priority
1	2	10	10	6	4	10	10	7	7.375	**10**
2	9	5	5	3	8	4	4	3	5.125	**5**
3	7	3	4	1	7	8	8	4	5.25	**6**
4	8	4	2	2	5	5	5	6	4.625	**1**
5	4	1	3	4	2	9	9	9	5.125	**4**
6	3	8	6	5	9	3	3	2	4.875	**2**
7	1	9	1	7	1	7	7	10	5.375	**7**
8	5	6	9	8	10	6	6	1	6.375	**9**
9	10	7	7	10	3	1	1	8	5.875	**8**
10	6	2	8	9	6	2	2	5	5	**3**

CONCLUSIONS

From the study it was found that, remote sensing coupled with GIS was best tool, in arriving the morphometric parameters of the watershed, which will be helpful in knowing the hydro-geological characteristics of watershed**.**

REFERENCES

1. Sreedevi PD, Sreekanth PD, Khan HH, Ahmed S (2013) Drainage morphometry and its influence on hydrology in an semi arid region: using SRTM data and GIS. Environ Earth Sci, 70(2):839–848
2. S. Gajbhiye, S. K. Sharma and C. Meshram, 2014. Prioritization of Watershed through Sediment Yield Index Using RS and GIS Approach. International Journal of u- and e- Service, Science and Technology, 7(6):47-60.
3. Strahler AN (1957) Quantitative analysis of watershed geomorphology. American Geophysical Union Transactions 38: 912-920.
4. Strahler, A. N. 1964. Quantitative gcomorphology of drainage and channel networks. Handbook of Applied Hydrology. (Ed. By Ven Te Chow) Mc Graw Hill Book Company, New York, 4:39-76.
5. Horton, R. E., 1945, Erosional development of streams and their drainage basins; Hydrophysical approach to quantitative morphology. Geol. Soc. Am. Bull., 56:275– 370.
6. Praveen Dahiphale, P. K. Singh and K. K. Yadav (2014) Morphometric analysis of Sub basins in Jaismand Catchment using Geographical Information System. International Journal of research in Engineering and Technology.2 (6): 189-202.