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CHARACTERISTICS OF DRAINAGE MORPHOLOGICAL STUDIES USING GIS IN KOLLI HILLS, CENTRAL OF TAMIL NADU, INDIA

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Abstract

GIS techniques have been adopted for the present investigation to identify the drainage morphological features and analyzing their properties. The Kolli hills fall in Namakkal district, Tamil Nadu, India, have been taken up in the present investigation. The drainage morphometric analysis of the study area indicates that the micro-watersheds show dendritic, sub-dendritic and radial drainage pattern. The parameters worked out includes Drainage density, Drainage texture, Bifurcation ratio, Stream order, Stream length, Stream length ratio, Stream frequency, Basin length, Form factor, Elongation ratio and Circulatory ratio. The morphometric analysis suggests that the comparison of all the fourteen micro-watershed shows that the morphometric parameters evaluated using GIS helped us to understand various terrain parameters such as nature of the bedrock, infiltration capacity and runoff, etc,. In the present scenario where water resources are becoming scarce, this exercise of calculating the various attributes of drainages plays a significant role in locating sites for groundwater potential and artificial recharge structures. However, a comparison of the entire 14 watershed shows that the 2nd, 3rd and 7th micro watersheds have lowest drainage density, and hence are better suited for construction of recharge structures.

Key words: Morphometric analysis; Artificial recharge; Micro-watershed; groundwater potential; Bedrock; Infiltration.

Introduction

Drainage of the micro watershed is the study for the better understanding of the morphological characteristics. The optimal and sustainable development of the resource is prerequisite, so that, it is assessed rationally to avoid any future problems regarding its qualitative and quantitative availability. About 70% of population in India is dependent on agriculture, directly or indirectly. India has diverse geographical features and varied climates. It has 14 major basins through which drain numerous rivers, while rivers in the southern India are rain fed, with little perennial water. The morphometric characteristics of the various watersheds have been studied by many scientists using conventional (Horton, 1945; Smith, 1950; Strahler, 1957) and GIS methods (Krishnamurthy and Srinivas, 1995; Srivastava and Mitra, 1995; Agarwal, 1998; Biswas et al., 1999; Narendra and Nageswara Rao, 2006). The quickly emerging spatial information technology (SIT) viz. GIS, and GPS has effective tools to overcome most of the problems of land and water resources planning and management on the account of usage of conventional methods of data process. An attempt is made here to find out holistic stream properties from the measurements of various stream attributes and identifying zones for artificial recharge.

Study Area

The proposed study is taken up in Kolli hills, the area chosen for the present lies almost wholly in the Namakkal District of Tamil Nadu State (Fig.1), except a small pocket on the eastern part of the hills, which lies in Tiruchirappalli District. The study area is geographically situated between the north latitudes 11°11' N to 11°30'N and east longitudes 78°16'E to 78°29'E covering an area of 485 km2. On the northern side, it is bounded by Salem District and in the eastern and the south eastern sides it is bounded by Tituchirappalli District.

Methodology

The base map was prepared using toposheet nos. 58I/7, 8 of 1:50,000 scale. In the present study base map showing drainage details have been prepared from toposheets (SOI). The Kolli Hills was further subdivided into 14 micro watersheds, the drainage channels were classified into different orders using Strahler's 1964 classification. Other morphometric parameters such as basin area, basin perimeter, basin length and stream length were obtained which were further used to obtain the different ratios such as drainage density, Bifurcation Ratio, Stream length Ratio, Stream Frequency, Form Factor, Elongation Ratio, Circulatory Ratio and Constant of channel maintenance.

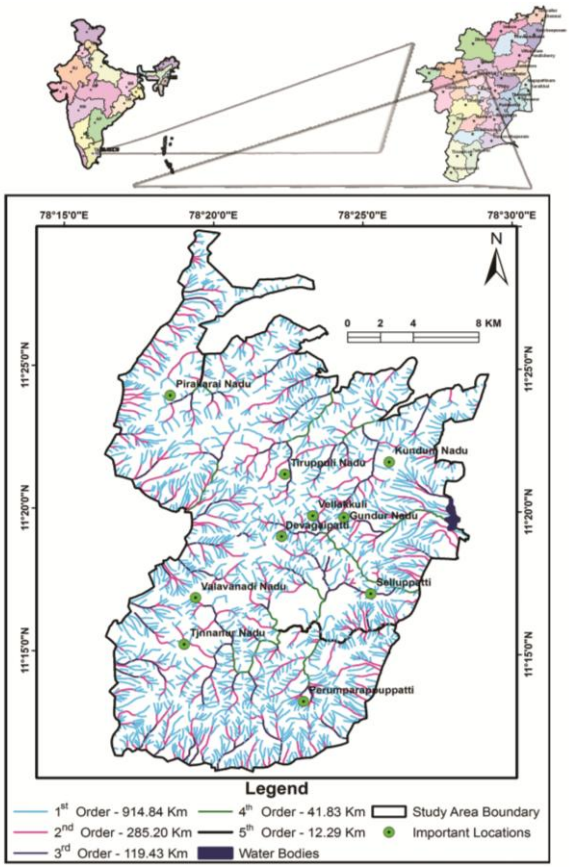

Fig.1. Study Area

Results and Discussion

Stream Order (Nu)

In the present study, the channel segment of the drainage basin has been ranked according to Strahler's stream ordering system. According to Strahler (1964), the smallest fingertip tributaries are designated as order 1. Where two first order channels join, a channel segment of order 2 is formed; where two of order 2 join, a segment of order 3 is formed and so forth. The trunk stream through which all discharge of water and sediment passes is therefore the stream segment of highest order. The study area is a 5th order drainage basin (Figure 2). The total number of 3130 streams were identified of which 1765 are 1st order streams, 809 are 2nd order, 367 are 3rd order, 138 in 4th order and 51 in fifth order streams (Table 1). Drainage patterns of stream network from the basin have been observed as mainly dendritic type which indicates the homogeneity in texture and lack of structural control. This pattern is characterized by a tree like or fern-like pattern with branches that intersect primarily at acute angles. While in some parts of the basin represent sub-dentritic and radial pattern types indicating that the topographical features are dipping, folded and highly jointed in the hilly terrains. A parallel drainage pattern consists of tributaries that flow nearly parallel to one another and all the tributaries join the main channel at approximately the same angle. Parallel drainage suggest that the area has a gentle, uniform slopes and with less resistant bed rock. A radial drainage pattern forms when water flows downward or outward from a hill or dome. The radial drainage pattern of channels produced can be linked to a wheel consisting of a circular network of parallel channels flowing away from a central high point (Jensen, 2006). The properties of the stream networks are very important to study the landform making process (Strahler and Strahler, 2002).

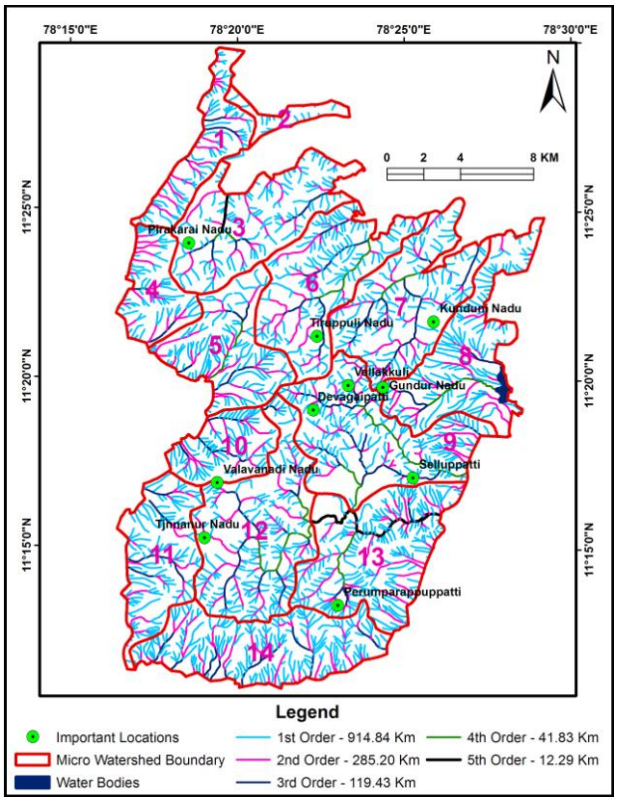

Fig.2. Micro watershed boundary with drainage order

Table 1. Stream order and number of stream for the Kolli Hills

Basin	I Order	II Order	III Order	IV Order	V Order	Total
1	80	38	4	-	-	122
2	20	1	-	-	-	21
3	122	52	22	5	8	209
4	65	30	8	-	-	103
5	102	53	10	12	-	177
6	144	55	46	18	-	263
7	144	52	46	10	-	252

8	122	54	9	11	-	196
9	194	98	60	38	-	390
10	78	35	31	-	-	144
11	117	54	22	-	-	193
12	192	99	62	25	-	378
13	205	97	9	19	43	373
14	180	91	38	-	-	309

Stream Length (Lu)

Stream length is one of the most significant hydrological features of the hilly portion as it reveals surface runoff characteristics streams of relatively smaller lengths are characteristics of areas with larger slopes and finer textures. Longer lengths of streams are generally indicative of flatter gradients. Generally, the total length of stream segments is maximum first order streams and decreases as the stream order increases. The numbers of streams of various orders in the hilly terrain are counted and their lengths from mouth to drainage divide are measured with the help of ArcGIS version 9.3.1 software. The length of the first order stream is maximum in all the 14 micro watersheds (Table 2).

Table 2. Stream length (in kilometers) for the different orders for Kolli Hills

Basin	I Order	II Order	III Order	IV Order	V Order	Total
1	37.13	14.91	3.51	-	-	55.55
2	6.75	0.22	-	-	-	6.97
3	60.7	17.72	6.98	1.58	2.06	89.04
4	34.88	14.59	2.93	-	-	52.40
5	63.1	21.95	6.11	3.99	-	95.15
6	72.42	20.6	11.24	4.93	-	109.19
7	72.83	19.51	13.26	2.25	-	107.85
8	77.44	22.68	5.94	4.56	-	110.62
9	86.83	27.25	17.94	11.63	-	143.65
10	41.1	11.72	6.45	-	-	59.27
11	63.95	15.72	9.3	-	-	88.97
12	89.77	28.68	14.98	8.79	-	142.22
13	106.02	36.94	3.68	3.61	10.26	160.51
14	102.65	33.1	16.12	-	-	151.87

Drainage Density

Drainage Density is defined as the total stream length in a given basin to the total area of the basin, (Strahler. 1932, 1945). It is related to various features of landscape dissection such as valley density, (Montgomery and Dietrrich, 1994; Tucker and Bras, 1998), channel head source area, (Montgomery and Dietrich, 1989), climate and vegetation, (Moglen et al. 1998), soil and rock properties, (Smith, 1958; Kelson and Wells, 1989), relief (Montgomery and Dietrich, 1988) and landscape evolution processes. Strahler (1964) noted that low drainage density is favored when basin relief is low and vice-versa. The drainage density varies from 1.25 to 3.50 for the various micro watersheds in the Kolli hills, (Table 3). The drainage density for the entire study area is 2.77. A low drainage density indicates permeable subsurface strata and is a characteristic feature of coarse drainage which generally shows values less than 5.0.

Table-3. Area, Length, Drainage density, Bifurcation Ratio of Kolli Hills and the Micro watershed

Basin	Area (km2)	Length (km)	Length Ratio	Drainage Density (km/km2)	Bifurcation Ratio
1	19.75	55.55	3.37	2.81	5.80
2	5.58	6.97	30.68	1.25	20.00
3	41.46	89.04	2.79	2.15	2.43
4	17.97	52.40	3.69	2.92	2.96
5	31.77	95.15	2.67	2.99	2.69
6	41.70	109.19	2.54	2.62	2.12
7	43.55	107.85	3.70	2.48	2.83
8	39.59	110.62	2.85	2.79	3.03
9	49.09	143.65	2.08	2.93	1.73
10	18.44	59.27	2.66	3.21	1.68
11	29.89	88.97	2.88	2.98	2.31
12	51.27	142.22	2.25	2.77	2.01
13	47.79	160.51	3.57	3.36	3.45
14	43.39	151.87	2.58	3.50	2.19
Total	481.25	1373.26	68.30	38.76	55.23

Bifurcation Ratio (Rb)

Bifurcation Ratio is defined as the ratio of the number of streams of any given order to the number of streams in the next lower order. The average of all these ratios gives the bifurcation ratio. The term was introduced by Horton in 1932. Bifurcation ratios characteristically range between 3 and 5 for watershed in which the geologic structures do not distort the drainage pattern (Strahler, 1964). However, the 2ed micro watershed shows an average bifurcation ratio of 20. This is mainly due to the fact that the basin area is very small and consists only of 1st and 2nd order streams and there is a big difference in the frequencies between the successive orders.

Stream Length Ratio

The stream length ratio is the ratio between the lengths of streams in a given order to the total length of streams in the next order. The stream length ratios for the Kolli hills (Table 4) and other sub-basins very widely and are strongly dependant on the topography and the slope. The stream length ratio has an important relationship with the surface flow discharge and the erosional stage of the basin.

Table-4. Stream length ratio for the different order for Kolli Hills

Basin	1/2	2/3	3/4	4/5
1	2.49	4.25	-	-
2	30.68	-	-	-
3	3.43	2.54	4.42	0.77
4	2.39	4.98	-	-
5	2.87	3.59	1.53	-
6	3.52	1.83	2.28	-
7	3.73	1.47	5.89	-
8	3.41	3.82	1.30	-
9	3.19	1.52	1.54	-
10	3.51	1.82	-	-
11	4.07	1.69	-	-
12	3.13	1.91	1.70	-
13	2.87	10.04	1.02	0.35
14	3.10	2.05	-	-
Total	**72.39**	**41.51**	**19.69**	**1.12**

Stream Frequency (Fs)

Stream frequency or channel frequency is the total number of stream segments of all orders per unit area (Horton, 1932). The average stream frequency value of the study area is 6.27 Km2 (Table 5). The value of stream frequency (Fs) for the basin exhibit positive correlation with the drainage density value of the area indicating the increase in stream population with respect to increase in drainage density. The stream frequency is dependant more or less on the rainfall and the temperature of the region.

Table 5. Stream frequency, length, form factor, elongation ratio, circulatory ratio and Constant of channel Maintenance for the Kolli hills

Basin	Stream Frequency	Length (km)	Form Factor	Elongation Ratio	Circulatory Ratio	Constant of channel Maintenance (C)
1	6.18	11.48	1.72	1.10	1.88	1.72
2	3.76	7.32	0.76	0.49	1.31	0.76
3	5.04	11.85	3.50	2.23	3.71	3.50
4	5.73	6.77	2.66	1.69	4.93	2.66
5	5.57	9.09	3.50	2.23	4.84	3.50
6	6.31	13.01	3.21	2.04	3.10	3.21
7	5.79	11.74	3.71	2.36	3.97	3.71
8	4.95	13.83	2.86	1.82	2.60	2.86
9	7.94	11.44	4.29	2.73	4.71	4.29
10	7.81	6.26	2.95	1.88	5.92	2.95
11	6.46	11.22	2.66	1.70	2.98	2.66
12	7.37	13.07	3.92	2.50	3.77	3.92
13	7.80	11.79	4.05	2.58	4.32	4.05
14	7.12	13.98	3.10	1.98	2.79	3.10
Total	**87.84**	**152.84**	**42.90**	**27.32**	**50.82**	**42.90**

Basin Length

According to Gregory and wailing (1973) basin length is the longest length of the basin from the head water to the point of confluence. The total length of the Kolli hills is 152.84 km, (Table 5). The length of the other microwatershed has been given in Table 5.

Elongation Ratio (Re)

Schumm (1956) used an elongation ratio (Re) defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. It is a very significant index in the analysis of watershed shape which helps to give an idea about the hydrological character of a drainage basin. Values near to 1.0 are typical of regions of very low relief (Strahler, 1964). The value Re of the study area is 1.95 indicates that the high relief of the terrain and elongated in shape.

Circularity Ratio (Rc)

It is defined as the ratio of the study area to the area of the circle having the same perimeter as the basin. This factor is influenced more by the lithological characteristics of the watershed rather than anything else. The low, medoum and high values of the circulatory ratio are indications of the youth mature and old stages of the life cycle of the tributary basins. Kolli hills shows a circulatory ratio of 3.63 (Table 5), whereas 1st and 2ed micro watersheds was appears to be the most mature micro watershed with a circulatory ratio of 1.31 and this watersheds is in the youth stage of its development with a circulatory ratio of 1.88. This anomaly is mainly due to the diversity of slope and relief present in the watershed.

Conclusions

The quantitative analysis of morphometric parameters is found to be of immense utility in kolli hills area are evaluation, watershed prioritization for soil and water conservation, and natural resources management at micro level. The morphometric analysis carried out in the Kolli hills area shows that the micro watersheds are having high relief of the terrain and elongated in shape. Drainage network of the study area exhibits as mainly sub-dendritic and radial type which indicates the dipping and jointing of the topographical land form. The morphometric parameters evaluated using GIS helped us to understand various terrain parameters such as nature of the bedrock, infiltration capacity, runoff, etc.

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References

[1] AGARWAL, C.S., (1998) "Study of drainage pattern through aerial data in Naugarh area of Varanasi district, U.P.", Jour. Indian Soc. Remote Sensing, v.26, pp.169-175.

[2] BISWAS, S., SUDHAKAR, S., and DESAI, V.R. (1999) "Prioritisation of sub-watersheds based on morphometric analysis of drainage basin - a remote sensing and GIS approach", Jour. Indian Soc. Remote Sensing, v.27, pp.155-166.

[3] GREGORY, K.J. and WALLING, D.E. (1973) Drainage Basin Form and Process. A Geomorphological Approch, Edward Arnold, London.

[4] HONRON, R.E. (1932) Drainage basin characteristics. Trans. Amer. Geophys. Union, v.13, pp.350-361.

[5] HORTON, R.E. (1945) Erosional development of streams and their drainage density: hydrophysical approach to quantitative geomorphology. Geol. Soc. Amer. Bull., v.56, pp.275-370.

[6] JENSEN, J.R. (2006) Remote Sensing of the Environment, Dorling Kindersley (India) Pvt. Ltd., New Delhi, 1st edition.

[7] KELSON, K.I. and WELLS, S.G. (1989) Geologic influences on fluvial hydrology and bedload transport in small rnountainous watersheds, northern New Mexico, USA. Earth Surf. Processes Landforms, v.14, pp.671-690.

[8] KRISHNAMURTHY, J., and SRINIVAS,G. (1995) "Role of geological and geo-morphological factors in groundwater exploration: a study using IRS LISS data", Int. Jour. Remote Sensing, v.16, pp.2595-2618.

[9] MOGLEN, G.E., Eltahir, E.A. and BRas, R.L. (1998) On the sensitivity of drainage density to climate change. Water Rsour. Res., v.34, pp.855-862.

[10] MONTGOMERY D.R. and DIETRICH, W.E. (1988) Where do channels begin? Nature, v.336, pp.232-234.

[11] MONTGOMERY, D.R. and Dietrich, W.E. (1989) Source areas, drainage density and channel initiation. Water Resour. Res., v.25, pp.1907-1918.

[12] NARENDRA, K., and NAGESWARA Rao, K. (2006) "Morphometry of the Mehadrigedda watershed, Visakhapatnam district, Andhra Pradesh using GIS and Resourcesat data", Jour. Indian Soc. Remote Sensing, v.34, pp.101-110.

[13] SCHUMM, S.A. (1963) Sinuosity of alluvial rivers on the great plains. Geol. Soc. Amer. Bull. v.74, pp.1089- 1100.

[14] SMITH K.G (1950) Standards for grading texture of erosional topography. Amer. Jour. Sci., v.248, pp.655-668.

[15] SMITH K.G. (1958) Erosional processes and landforms in Badlanda National Monument, South Dakota. Grol, Soc. Arner. Bull., v.69, pp.975-l008.

[16] SRIVASTAVA, V.K., and MITRA,D. (1995) "Study of drainage pattern of Raniganj Coalfield (Burdwan District) as observed on Landsat-TM/IRS LISS II imagery, Jour. Indian Soc. Remote Sensing, v.23, pp.225-235.

[17] STRAHLER, A.N. (1964) Quantitative geomorphology of drainage basins and channel networks. In: VT. Chow (Ed.), Handbook of Applied Hydrology. McGraw-Hill, New York, pp.439-476.

[18] STRAHLER, A.N., and STRAHLER, A.H. (2002) A Text Book of Physical Geography, John Wiley & Sons, New York.

[19] TUCKER, G.E. and BRAS, R.L. (1998) Hillslope processes drainage density and landscape morphology. water Resour. Res., v.34, pp.275l-2764.

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