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Morphometric analysis for characterizing landforms study on Sarabanga Sub-basin, Cauvery River, Tamil Nadu, India

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Abstract

GIS and image processing techniques have been adopted for the present investigation to identify the morphological features and analyzing their properties. The Sarabanga Sub-basin Cauvery River fall in Salem district, Tamil Nadu, India, have been taken in the present investigation .Morphometric analysis was carried out at sub basin level using Spatial Analysis System (ArcGIS ver. 9.3). The basin morphometric parameters such as linear and aerial aspects of the Sarabanga river basin were determined and computed. Sarabanga river is the one of the tributary of Cauvery river drained in the middle of the sub basin.It is 6^{th} order drainage basin and drainage pattern mainly in subdendritic to dendritic type. It is observed that the drainage density value is low which indicates the basin is highly permeable subsoil and thick vegetative cover. The circularity ratio value reveals that the basin is strongly elongated and highly permeable homogenous geologic formations. This study would help the local people to utilize the groundwater resources for sustainable development of the basin area. The morphometric analysis suggests that the comparison of all the fifteen micro watersheds shows that the nos 4, 8, 9, 10 and 13 micro watersheds have the lowest drainage density, and hence are better suited for construction of artificial groundwater recharge structures.

Keywords: Geographic Information System (GIS), Morphometric analysis; Artificial recharge; image processing techniques,

Introduction

The optimal and sustainable development of the groundwater 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. Accordingly, the importance of water has been recognized and greater emphasis is being laid on its economic use and better management. The basin morphomatric characteristics of the various basins have been studied by many scientists using conventional methods (Horton, 1945; Smith, 1950; Strahler, 1957) and remote sensing and GIS methods (Krishnamurthy and Srinivas, 1995; Srivastava and Mitra, 1995; Agarwal, 1998; Biswas et al., 1999; Keller et al., 1982; Mayer, 1990; Cox, 1994; Merritts, et al., 1994; Lupia Palmieri et al., 1995 and 2001; Currado and Fredi, 2000; Pike, 2002; Della Seta, 2004; Della Seta et al., 2004. The fastly emerging spatial information technology (SIT) viz. remote sensing, 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 study area, lies between the latitudes 11°46’ N to 12°09’39” N and longitudes 78°12’27” E to 78°36’65” E covering an area of 1178.56 km^2. Out of which plain land covers an area of 1015.79 km^2 (Fig.1). The study area falls in Salem district of Tamil Nadu. The major source for recharge of water in this area is rainfall, during monsoon season. The average annual rainfall is 852 mm (2000 to 2009). The study area is underlaid by the Archaean crystalline rocks surrounded by wavy hills and hillocks.

Methodology

The base map was prepared using toposheet nos. 57L/4, 8, 58 I/1, and 5 of 1:50,000 scale. In the present study base map showing drainage details have been prepared from toposheets (SOI). The Sarabanga Sub-Basin was further subdivided into 15 micro watersheds, the drainage channels were classified into different orders using Strahler’s (1964) classification. The primary basin parameters such as basin area, basin perimeter, basin length and stream length were obtained which were further used to obtain the derived parameters such as drainage density, Drainage Texture, Bifurcation Ratio, Stream length Ratio, Stream Frequency, Form Factor, Elongation Ratio and Circulatory Ratio. Were calculated and taken into the present investigation.

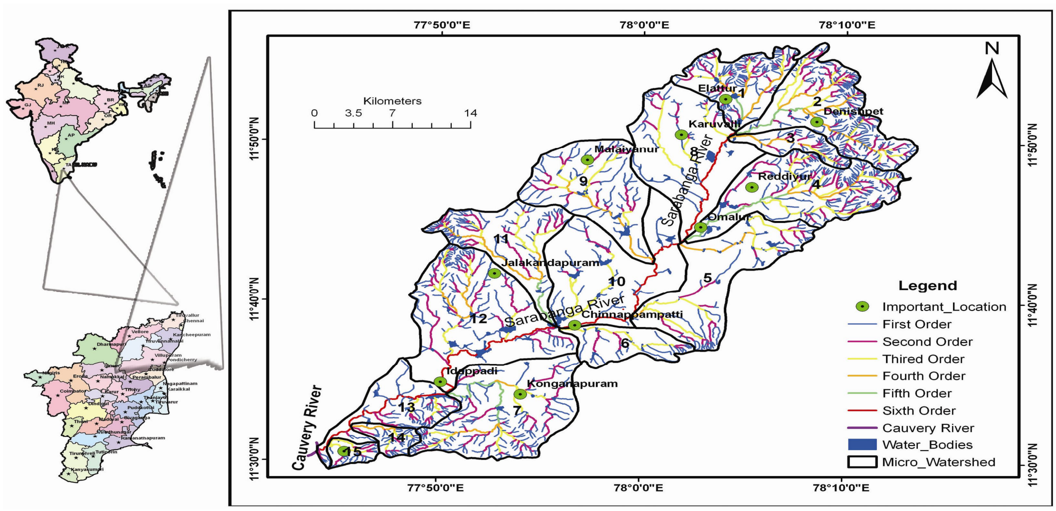

Fig.1 Study Area Map of Sarabanga Sub basin micro watersheds.

Results and Discussion

The development of drainage networks mainly depends on the underlying geology, precipitation, exogenic and endogenic processes of the area. The drainage pattern of the basin ranges from dentritic to sub dentritic at higher elevations and parallel to sub parallel in the lower elevations. A radial drainage pattern was also observed in the areas with isolated hillocks. Based on the drainage orders, the Sarabanga river basin has been classified as sixth order river basin.

Linear parameters

Stream order analysis shows that the main sub basin is fall under sixth order category. Based on the network pattern it has been further sub divided in to fifteen micro watersheds. The micro watershed no 13 were identified second order stream, three watersheds (5,6,15) under third order stream, three watersheds (3,9, and 14) under fourth order stream, five watersheds (1,2,7,11,13) under fifth order stream and three watersheds (8,10,12) under sixth order stream (Table 1). The sixth order stream is found in the unclassified area. Analysis of cumulative length of streams (L) shows that micro watersheds 2,4 and 11 have the highest L value, whereas, micro watersheds 6,13 and 15 have the lowest L value. The existence of high (L) value is due to structural complexity, high relief and impermeable bedrock. Analyses of bifurcation ratio (Rb) shows lower (Rb) values in the micro watersheds of 3, 6 and 9 are attributed to the characteristics of less structural disturbances which, in turn, has not distorted the drainage pattern (Strahler, 1964). Whereas, the higher (Rb) values in the micro watersheds of 5, 7 and 14 indicate high structural complexity and low permeability of the sub surface strata.

Table 1. Linear Morphometric Parameters of Sarabanga Sub basin micro watersheds.

micro watershed no	Basin Length Lb (km)	Perimeter P (km)	Drainage Order (in Number)						Total Number N	Cumulative Length L (km)	Bifurcation Ratio Rb
			N_1	N_2	N_3	N_4	N_5	N_6			
1	11.09	38.57	129	68	25	17	2	0	241	353.00	3.65
2	16.41	54.37	216	117	52	46	7	0	438	660.00	2.95
3	12.33	27.09	47	25	11	9	0	0	92	137.00	1.79
4	23.04	56.02	183	94	53	19	8	2	359	535.00	2.58
5	29.67	71.01	51	30	29.91	0	0	0	111.91	172.82	5.08
6	11.91	31.36	22	8	9	0	0	0	41	60.00	1.21
7	18.93	51.48	149	65	22	2	1	0	239	329.00	4.56
8	18.47	50.35	47	19	11	1	3	1	82	117.00	3.71
9	17.87	48.42	126	54	17	11	0	0	208	290.00	2.35
10	20.25	60.57	41	7	7	3	2	1	61	81.00	2.54
11	19.07	48.41	135	58	28	20	5	0	246	357.00	2.45
12	20.89	62.22	143	67	32	4	1	1	248	353.00	3.45
13	15.23	51.09	23	6	0	0	0	0	30	37.00	3.83
14	5.82	17.61	37	14	2	1	0	0	54	71.00	3.88
15	4.94	14.69	21	10	2	0	0	0	33	45.00	3.55

Areal parameters

Drainage density indicates that the low Dd exists in micro watersheds 4, 8, 9, 10 and 13 having high permeable sub surface material and are under dense vegetation cover and low relief (Table 2). In contrast, high Dd values are observed in micro watersheds 2, 14 and 15 may be due to the presence of impermeable sub surface material, sparse vegetation and high relief. The measurement of drainage density provides a numerical measurement of landscape dissection and runoff potential. Analysis of stream frequency (Fu) shows low values of Fu existing in micro watersheds 8 and 10, 13 which are having high permeable geology and low relief. Where high value of Fu is noticed in 1 and 2 micro watersheds, where impermeable sub-surface material, sparse vegetation and high relief conditions prevails. Texture ratio (T) indicates that highest T values are found in micro watersheds 1, 2 and 4 whereas the lowest T values are noticed in micro watersheds 6, 10 and 13. Thus it can infer that T values depend on the underlying geology, infiltration capacity of bedrock and relief aspects of the individual micro watersheds.

Analysis of form factor (Rf) reveals that micro watersheds having low Rf have less side flow for shorter duration and high main flow for longer duration and vice versa. This condition prevails in micro watersheds 3, 4 and 13. High Rf exists in micro watersheds 1, 5 and 15 with high side flow for longer duration and low main flow for shorter duration causing high peak flows in a shorter duration. Circulatory ratio (Rc) values approaching 1 indicates that the basin shapes are like circular and as a result, it gets scope for uniform infiltration and takes long time to reach excess water at micro watershed outlet, which further depend on the existing geology, slope and land cover. The micro watersheds 5 and 15 are having highest Rc value of 1.01 and 0.66 respectively, which support the above concept. Analysis of elongation ratio (Re) indicates that the areas with higher Re values have high infiltration capacity and low runoff. The micro watersheds 5 and 15 are characterized by high Re and 3, 4 and 11 micro watersheds have low Re respectively. The micro watersheds having low Re values are susceptible to high erosion and sedimentation load. Constant of channel maintenance (C) depends on the rock type, permeability, climatic regime, vegetation cover and relief as well as duration of erosion (Schumm, 1956). The micro watersheds 3 and 14 have low C values of 0.43 and 0.37 respectively. It indicates that these micro watersheds are under the influence of high structural disturbance, low permeability; steep to very steep slopes and high surface runoff. The micro watersheds of 5 and 13 have highest C values of 1.94 and 1.46 respectively and are under very less structural disturbances and less runoff conditions.

Table 2. Areal Morphometric parameters of micro watersheds

micro watershed no	Area A (km^2)	Stream Frequency Fu	Drainage density Dd	Texture Ratio T	Form factor Rf	Circulatory Ratio Rc	Elongation Ratio Re	Constant of channel Maintenance C
1	57.4	4.20	2.18	3.34	0.47	0.48	0.77	0.46
2	92.24	4.75	2.33	3.97	0.34	0.39	0.66	0.43
3	23.51	3.91	2.02	1.73	0.15	0.40	0.44	0.50
4	107.54	3.34	1.95	3.27	0.20	0.43	0.51	0.51
5	103.08	2.2	2.18	1.4	0.56	1.01	1.17	1.94
6	36.22	1.13	1.12	0.70	0.26	0.46	0.57	0.89
7	122.48	1.95	1.46	2.89	0.34	0.58	0.66	0.68
8	116.28	0.71	0.69	0.93	0.34	0.58	0.66	1.45
9	108.22	1.92	0.99	2.60	0.34	0.58	0.66	1.01
10	124.97	0.49	0.72	0.68	0.30	0.43	0.62	1.40
11	74.43	3.31	1.67	2.79	0.20	0.40	0.51	0.60
12	173.24	1.43	1.14	2.30	0.40	0.56	0.71	0.88
13	69.81	0.43	0.68	0.45	0.30	0.34	0.62	1.46
14	14.19	3.81	2.69	2.10	0.42	0.57	0.73	0.37
15	11.29	2.92	2.35	1.43	0.46	0.66	0.77	0.43

Drainage morphometry and its impact on landform characteristics

The underlying geology, exogenic and endogenic activities, drainage morphometry and considerable changes in climate during the Quaternary, influences the genesis and morphology of landforms (Subramanyan, 1981). In this study area, the denutation hills are located in the micro watersheds (4, 7, 11, 14, 15) pediplain covers nearly 60 percentage of the sub basin. The structural hills found in the following micro watersheds (1, 2, 3, 4, 7, 11) are identified and mapped as major landforms on the upper reaches. These landforms are associated with high drainage density, high bifurcation ratio and high cumulative length of first, second and third order streams. Rolling plains, foot slopes, narrow valleys and main valley floors are analyzed and mapped as landforms of the Sarabanga sub basin (Fig. 2). Which are formed by the influence of permeable geology, moderate to nearly level plains, medium to low drainage density (< 2.0), low cumulative length of streams having fourth and fifth order streams.

Landforms of upper reaches

The fluvio-denudational geomorphological processes are actively involved in landscape reduction processes at upper reaches. The physio-chemical weathering and multiple slope dissections under the influence of steep slopes, high drainage density and precipitation conditions lead to the development of ridge-valley land systems in the north eastern and north western part of the area. The occurrences of alluvium and colluvium deposits at places are dissected by incoming third and fourth order streams. They are noticed in the upper parts of micro watershed nos. (1, 2, 3, 4, 5, 8). Foot slopes are low in relief and consist of deposited sediments that are regularly carried out from upland catchments. The deposited sediments are admixed with sandy loam and clay. The majority of these landforms are occupied in the micro watershed nos. 7, 13, 14 and 15 of the study area.

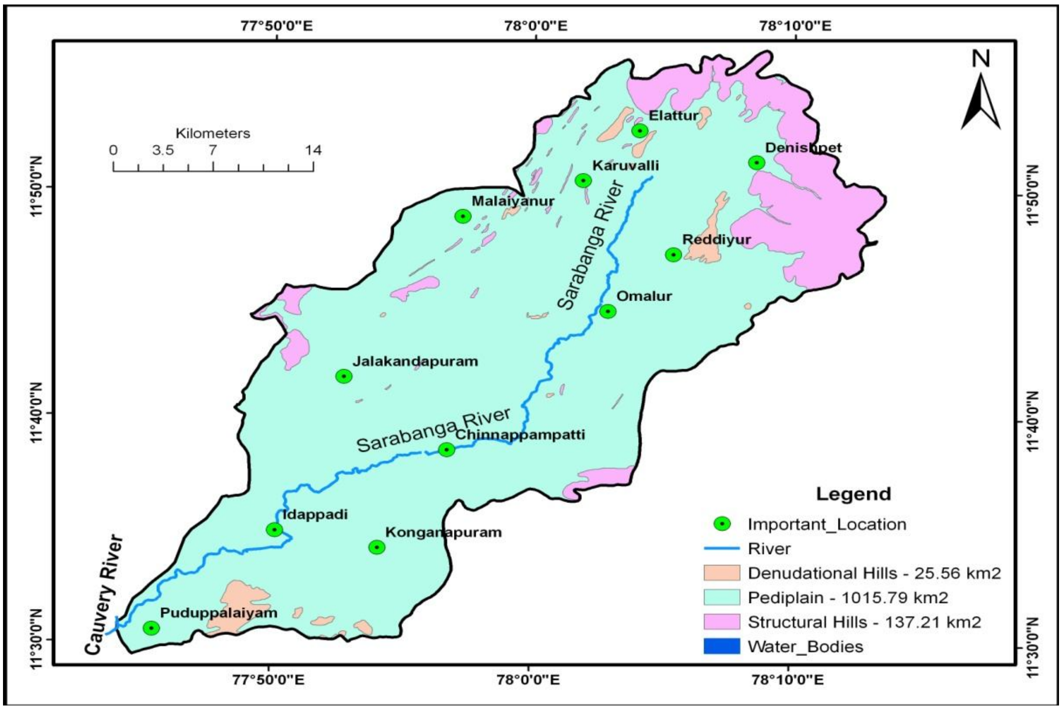

Fig. 2 Geomorphology with important location of Sarabanga Sub basin micro watersheds.

Conclusions

The study reveals that remotely sensed data and GIS based approach in evaluation of drainage morphometric parameters and their influence on landforms, geology at river basin level is more appropriate than the conventional methods. GIS based approach facilitates to analyze different morphometric parameters and to explore the relationship between the drainage morphometry on one hand and properties of landforms and geology on other hand. Geomorphology spatial variation in the upper parts of micro watershed nos. (1, 2, 3, 4, 5, 8). Foot slopes are low in relief and consist of deposited sediments that are regularly carried out from upland catchments. The majority of these landforms are occupied in the micro watershed nos.7, 13, 14 and 15 of the study area. The sixth order stream is found in the unclassified area. Analysis of cumulative length of streams (L) shows that micro watersheds 2,4 and 11 have the highest L value, whereas, micro watersheds 6,13 and 15 have the lowest L value. The existence of high (L) value is due to structural complexity, high relief and impermeable bedrock.

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