

Significance of Morphometry Studies, Soil Characteristics, Erosion Phenomena and Landform Processes Using Remote Sensing and GIS for Kodaikanal Hills, A Global Biodiversity Hotspot in Western Ghats, Dindigul District, Tamil Nadu, South India

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Abstract: An attempt is made to study the significance of morphometry, integrating Remote Sensing data and techniques in addition to the conventional methods in a GIS platform. The Western Ghats are amongst the eighteen biodiversity hot-spots recognized globally (WCMC, 1992) and are known for their high levels of endemism. Kodaikkanal Hills are parts of Palani hills of Western Ghats. The study has demonstrated the potential use of remotely sensed data and Geographical Information Systems (GIS) in evaluation of linear, relief and areal morphometric parameters and to analyze their influence on the genesis and processes of landforms and characteristics of soil parameters like texture, drainage and land erosion conditions. Visual interpretation of satellite data in analysis of geological, landforms and land erosion characteristics in conjunction with drainage pattern facilitates effective delineation of distinct features to evaluate the influence of drainage morphometry. GIS is an effective tool to analyze spatial and non-spatial data on drainage, geology, landforms and soil parameters to understand their inter-relationships. Geo-coded resource database generated on drainage, landforms and soil parameters in the core of GIS provides an excellent means of storing, retrieving and analyzing data at river basin level to find out their association. It also provides a powerful mechanism not only to upgrade and monitor morphometric parameters but also to permit the spatial analysis of other associated resources database. An attempt has been made to utilize the interpretation capabilities of GIS to find out the relationships between the morphometric parameters at sub basin level.

Key words: Bio diversity hotspots, GIS, land form, morphometry, relief, remote sensing, slope

INTRODUCTION

Morphometric studies involve evaluation of streams through the measurement of various stream properties. analysis of various drainage parameters namely ordering of the various streams and measurement of area of basin, perimeter of basin, length of drainage channels, drainage density (Dd), drainage frequency, bifurcation ratio (Rb), texture ratio (T) and circulatory ratio (Rc) (Kumar *et al.*, 2000). GIS and image processing techniques have been adopted for the identification of morphological features and analyzing their properties of the Lower Gostani River Basin (LGRB) area in Andhra Pradesh state, India (Nageswarara Rao, 2010). River basins comprise a distinct morphologic region and have special relevance to drainage pattern and geomorphology (Doornkamp and Cuchlaine, 1971; Strahler, 1957). Horton's law of stream lengths suggests a geometric relationship between the number of stream segments in successive stream orders and landforms (Horton, 1945). Quantitative description of the basin morphometry also requires the characterization of linear and areal features,

gradient of channel network and contributing ground slopes of the drainage basin. Detailed analysis of drainage parameters is of great help in understanding the influence of drainage morphometry on landforms and their characteristics. The Western Ghats are amongst the eighteen biodiversity hot-spots recognized globally and are known for their high levels of endemism (Selvaraj, 2002). The study complements the efforts to understand the inter-relationship of various factors for planning, biodiversity management and disaster prone area zonation.

As compared to the conventional morphometry studies, using Remote Sensing enables extant ground reality inputs to assess changes in drainage patterns, density soil characteristics, Landuse changes and landforms present in real time.

In this context High Spatial Resolution Indian Remote Sensing Satellite (IRS)-P6 Linear Image Self Scanning (LISS)-4 sensor data of 7 July 2002, Survey of India (SOI) topographical sheets (1:50,000 scale) and field verification data were used for systematic analysis of

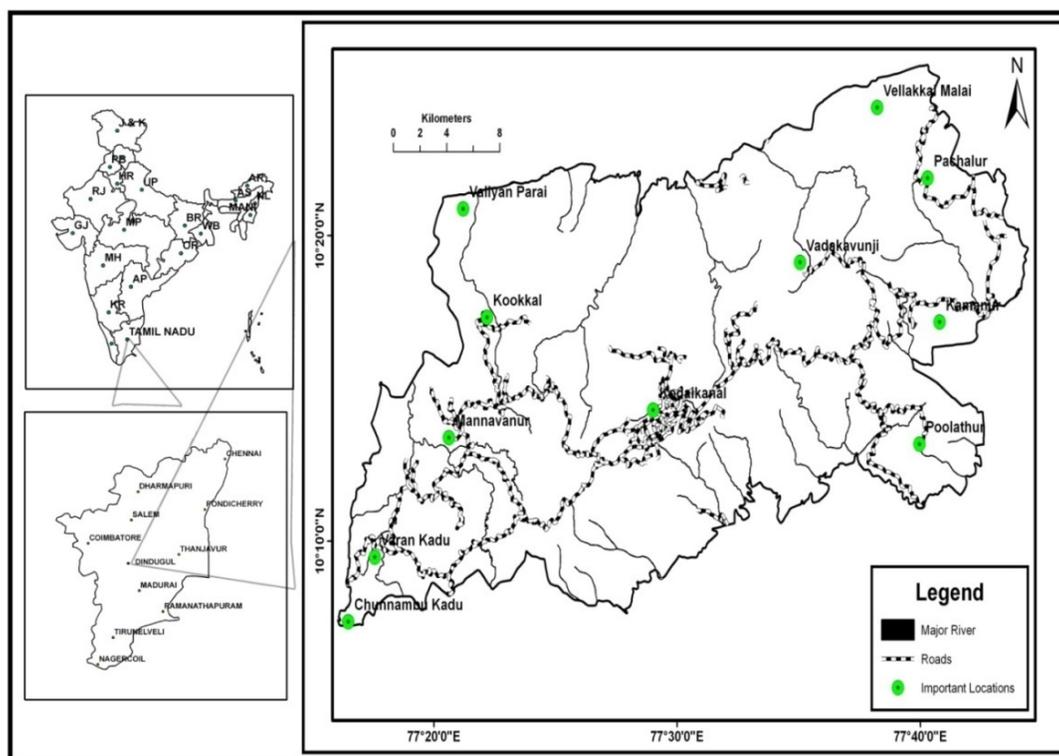


Fig. 1: Study area

various Geomorphic processes, hydrological and landform characteristics of the study area. Drainage Network analysis was carried out at basin level using Spatial Analysis GIS System (ArcGIS. 9.3) to identify the influence of drainage morphometry on landforms, drainage, and land erosion characteristics. The study demonstrates the fact that integrated Remote Sensing and GIS based approach is more appropriate and useful than conventional methods. The study seeks to utilize the interpretation capabilities of GIS to find out the relationships between the morphometric parameters at sub basin level on one hand and landforms, soil physical and eroded land characteristics on the other hand. The study complements the efforts to understand the inter-relationship of various interacting factors for planning, biodiversity management and disaster prone area zonation.

Study area (Fig. 1) Kodaikanal hills is located in the Dindigul district of Tamil Nadu with an area of 1039.46 km². It is geographically located between 77°14'26" and 77°45'28" E longitudes and 10°6'25" and 10°26'54" N latitudes. In the survey of India toposheet, it forms part of 58 F/7, 8, 11 and 12 on 1:50,000 scale. It is a part of the Western Ghats which is designated as one of the eighteen Biodiversity hotspots of the world. As a biodiversity hotspot it has variety of endemic flora and fauna. Its

richness of epiphytes, orchids and thirteen different varieties of Shola forests are unique. Species accorded highly endangered status such as Nigligi Tahr (a mountain goat and the state animal are endemic to the region), Also the Shola forests serve as traditional Aniaml corridors for Bison, deer, elephants and the tiger. By virtue of sheer antiquity and virtual non regeneration they are termed as 'living fossils'. Sunlight can not sufficiently penetrate the canopy and the accumulated litter and high alleochemical presence seeds can not let seeds to germinate. Loss of these unique systems is permanent and irreplaceable. They also remain as the watershed region of Vaigai, Manjalar Rivers catering to southern districts of Tamil Nadu. Destruction of these forests will amount to extinction of a vast array of plants and animals. Conservation efforts have to be interdisciplinary in nature and this study is one such attempt. The study area is anthropologically significant in that it is inhabited from prehistoric period and still there are tribals living in their ancient way.

On a tourism perspective the region is widely hailed as the 'Princess of Hill Stations' owing to the popularity it gained during British Raj. The climatic condition of the study area is characterized by humid conditions. Relative humidity is high during retreating NE monsoon season (October to mid December). The mean temperature of

Kodaikanal taluk is 15.93°C with a mean summer temperature of 17.29°C (June, July and August) and mean winter (December, January and February) temperature of 14.10°C. The average annual rainfall is 1436.87mm. The study area is fully covered by hills. The plain area forms a small part. The hilly area is in the form of undulating terrain and slope towards south-southeast and east. The maximum elevation is 2517 m, located in the south west portion. Labour intensive tea and coffee plantations and extensive vegetable cultivation mark the place. The settlements are created on the man made terraces and are densely populated in isolated pockets. Hence drainage patterns are intensely modified increasing the risk of landslide hazards.

Surface drainage characteristics of many river basins and sub basins in different parts of the globe have been studied using conventional methods (Horton, 1945; Strahler, 1952, 1957, 1964; Morisawa, 1959; Leopold and Miller, 1956; Krishnamurthy *et al.*, 1996).

The aim of the study was to demonstrate the potential use of remotely sensed data and Geographical Information Systems (GIS) in evaluation of linear, relief and areal morphometric parameters and to analyze their influence on the genesis and processes of landforms and characteristics of soil parameters like texture, drainage and land erosion conditions. Visual interpretation of satellite data in analysis of geological, landforms and land erosion characteristics in conjunction with drainage pattern facilitates effective delineation of distinct features to evaluate the influence of drainage morphometry on landform characteristics and their processes. The high spatial resolution remotely sensed data coupled with topographical data analysis procedures have made satellite sensor data based morphometric analysis is a highly effective tool to understand and manage the natural resources (Srinivasan, 1988). It provides the real time and accurate information related to distinct geological formations, landforms and helps in identification of drainage channels, which are altered by natural forces or anthropogenic activities. Multispectral satellite sensor data provides a convenient means to analyze drainage and distinct landform characteristics at various scales. GIS is an effective tool to analyze spatial and non-spatial data on drainage, geology, landforms and soil parameters to understand their inter-relationships. Geo-coded resource database generated on drainage, landforms and soil parameters in the core of GIS provides an excellent means of storing, retrieving and analyzing data at river basin level to find out their association. It also provides a powerful mechanism not only to upgrade and monitor morphometric parameters but also to permit the spatial analysis of other associated resources database (Jain *et al.*, 1995). Integration of remotely sensed data and GIS thereby provides an efficient way in analysis of morphometric parameters and landform characteristics for

resource evaluation, analysis and management. An attempt has been made to utilize the interpretative techniques of GIS to find out the relationships between the morphometric parameters at sub basin level on the one hand and landforms, soil physical and eroded lands characteristics on the other hand.

METHODOLOGY

The Indian Remote Sensing (IRS)-P6 Satellite Linear Image Self Scanning (LISS) - 4 sensor data of 7 March 2002 were collected and registered to Survey of India (SOI) topographical sheets at 1:50,000 scale in the ERDAS image analysis system version. 9.3. The Kodai hills of Dindigul district was delineated based on the water divide line concept. The drainage network of the basin was traced on transparency and digitized as available on toposheets (1:50,000) and some of the first order streams were updated with the help of satellite sensor data. The elevation model was generated based on the contour values of 500 m interval to generate height and slope maps. The basin was divided into 48 sub basins and morphometric analysis was carried out at sub basin level in the Spatial Analysis GIS System (ArcGIS version. 9.3) methodology flow chart (Fig. 2). Some areas have been left out in the process of delineation of sub basins and were considered as unclassified. Based on the drainage order, the drainage channels were classified into different orders (Strahler, 1964). In GIS, drainage channel segments were ordered numerically as order number 1 from a stream's headwaters to a point down stream. The stream segment that results from the joining of two first order streams was assigned order 2. Two second order streams formed a third order stream and so on. The sub basin area, perimeter, cumulative length of streams and basin length were measured in GIS and are expressed as A, P, L and Lb respectively. Parameters such as ruggedness number (Rn), drainage density, bifurcation ratio, stream frequency (Fu), texture ratio, form factor (Rf), circulatory ratio (Rc), elongation ratio (Re) and constant of channel maintenance (C) were evaluated with established mathematical equations (Strahler, 1964) (Table 1). The Study was conducted for parts of Kodai hills of Dindigul district. Base information is extracted from toposheets. Satellite data (2002) was used to extract landform characteristics. The study carried out in the year 2010.

The evaluated morphometric parameters were grouped as linear, relief and areal parameters. Visual interpretation techniques were followed for delineation of geology, landforms, and soil boundaries and degraded lands based on the tone, texture, shape, drainage pattern, color and differential erosion characteristics of the satellite imagery in conjunction with drainage morphometry and collateral data. Subsequently detailed

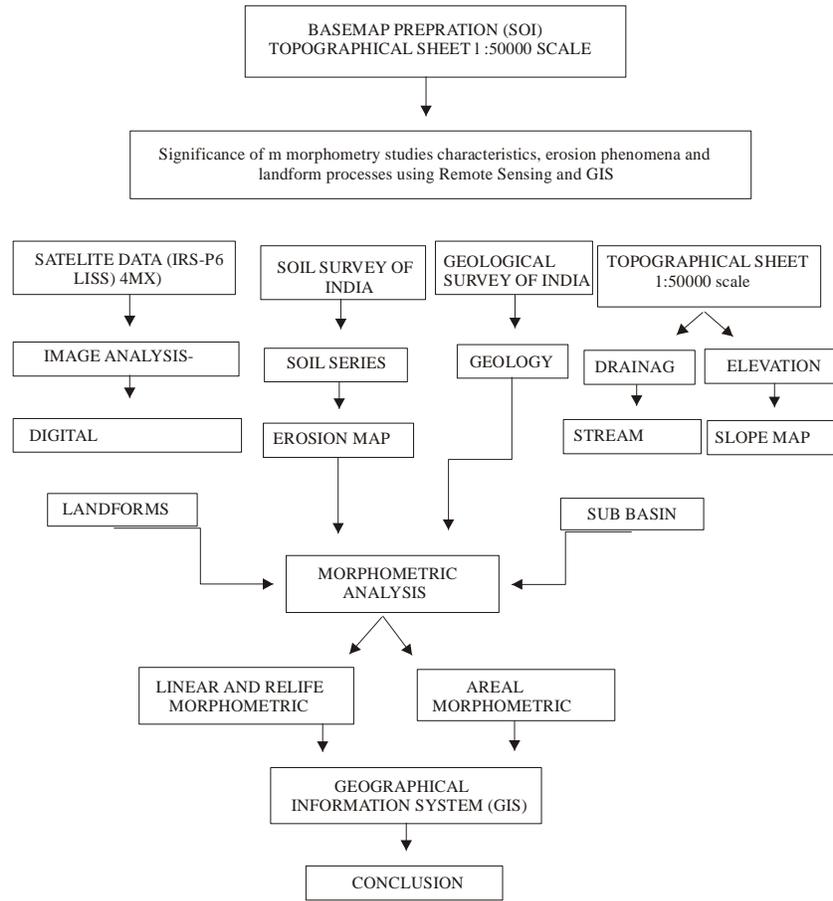


Fig. 2: Methodology flow chart

Table 1: Morphometric parameters and their mathematical expressions

S.No.	Morphometric parameter	Formula	Description
1	Cumulative length of streams (L)	$L = \sum Nu$	L was calculated as the number of streams in each order and total length of each order was computed at sub basin level
2	Bifurcation ratio (Rb)	$Rb = Nu/(Nu + 1)$	Rb was computed as the ratio between the number of streams of any given order to the number of streams in the next higher order
3	Basin relief (Bh)	$Bh = h_{max} - h_{min}$	Bh was defined as the maximum vertical distance between the lowest and the highest points of a sub basin
4	Ruggedness number (Rn)	$Rn = Bh \times Dd$	Rn was calculated as the product of the basin relief and its drainage density
5	Drainage density (Dd)	$Dd = L/A$	Dd was measured as the length of stream channel per unit area of drainage basin
6	Stream frequency (Fu)	$Fu = N/A$	Fu was computed as the ratio between the total number of streams and area of the basin
7	Texture ratio (T)	$T = N(1/P)$	T was estimated as the ratio between the first order streams and perimeter of the basin
8	Form factor (Rf)	$Rf = A/(Lb)^2$	Rf was computed as the ratio between the basin area and square of the basin length
9	Elongation ratio (Re)	$Re = (2/Lb) \times A/\sqrt{A/P\pi}$	Re was computed as the ratio between the diameter of the circle having the same area as that of basin) and the maximum length of the basin
10	Constant of channel maintenance (C)	$C = km^2/km$	C is expressed as the inverse of drainage density

landform analysis has been carried out based on their genesis, relief and their morphometric characteristics.

RESULTS AND DISCUSSION

Elevation: The elevation of the study area reveals that higher elevation of 2517 m above mean sea level is

associated with dissected hills and escarpments in the south west portion of the study area (Fig. 3).

The elevation ranging from 2000-2500 m above MSL is mainly confined to Hill top plains/Dissected plateau and structural hill. The elevation ranging from 0 to 500 m above MSL is mainly associated with lower parts of foot slopes, structural hill and pediments.

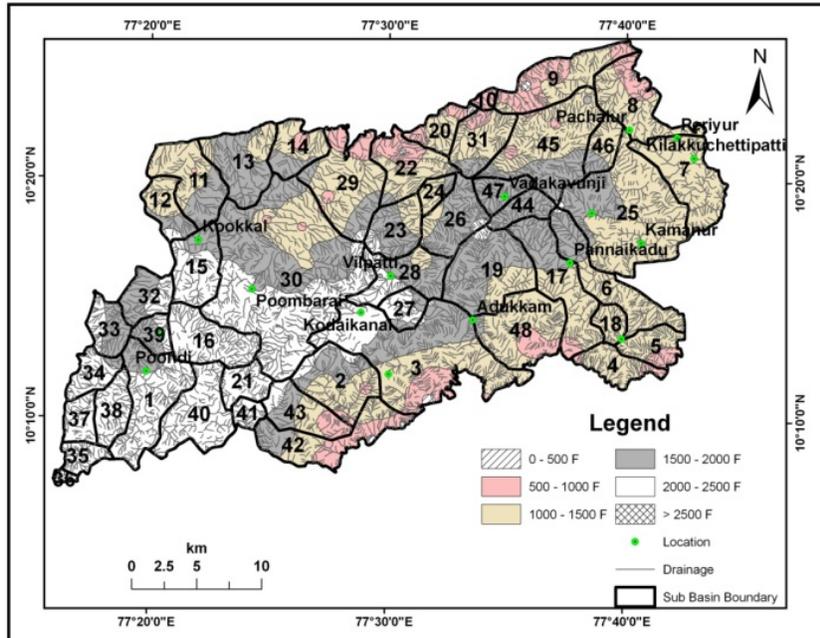


Fig. 3. Elevation map of Kodai hills

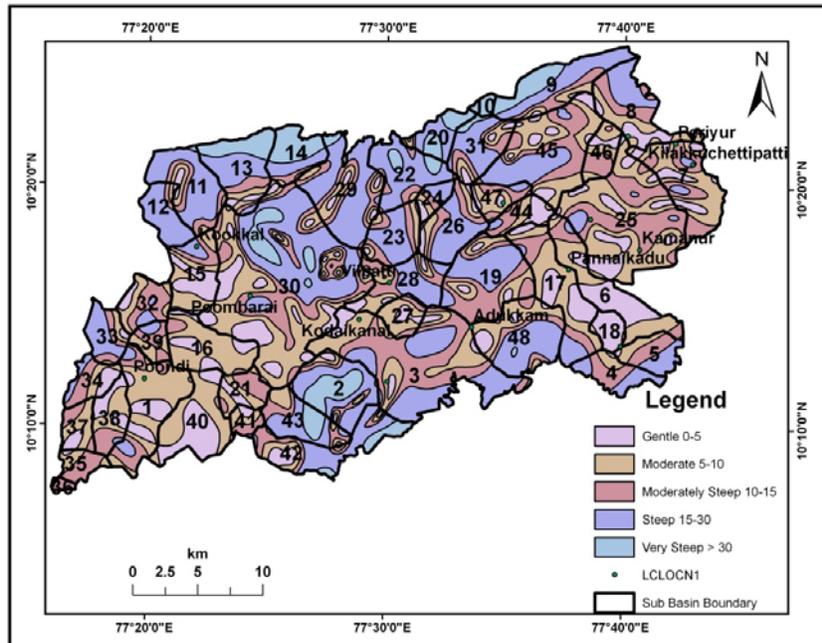


Fig. 4: Slope map of Kodai hills

Slope: In the study area, the slope values vary from 0 to 60°. The slope values have been categorized in to five groups namely 0-5, 5-10, 10-15, 15-30, and above 30°, (Fig. 4). Gentle slopes (0-5°) are observed in hill top plain/dissected plateau and valley fill zones covering 13.73% of the total area. These slopes are found in all the

sub basins except in sub basins 10, 14, 22 and 36. The moderately sloping areas (5-10°) are in association with Structural hill, Pediment and Structural valley zones and occupy about 28% of area in the lower parts of all the sub basins except in sub basin n. 10. Moderately steep slopes (10-15°) are found all the sub basins except in sub basin

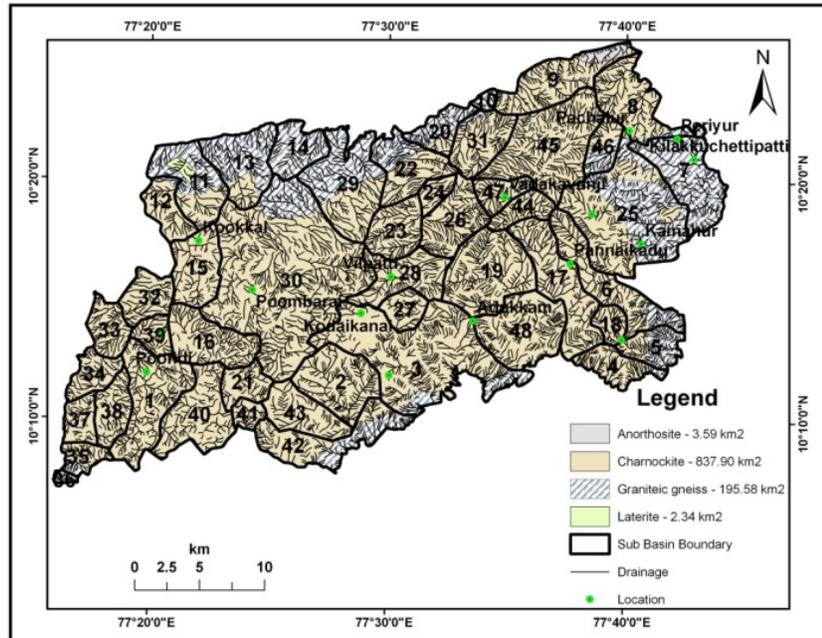


Fig. 5. Geology map of Kodai hills

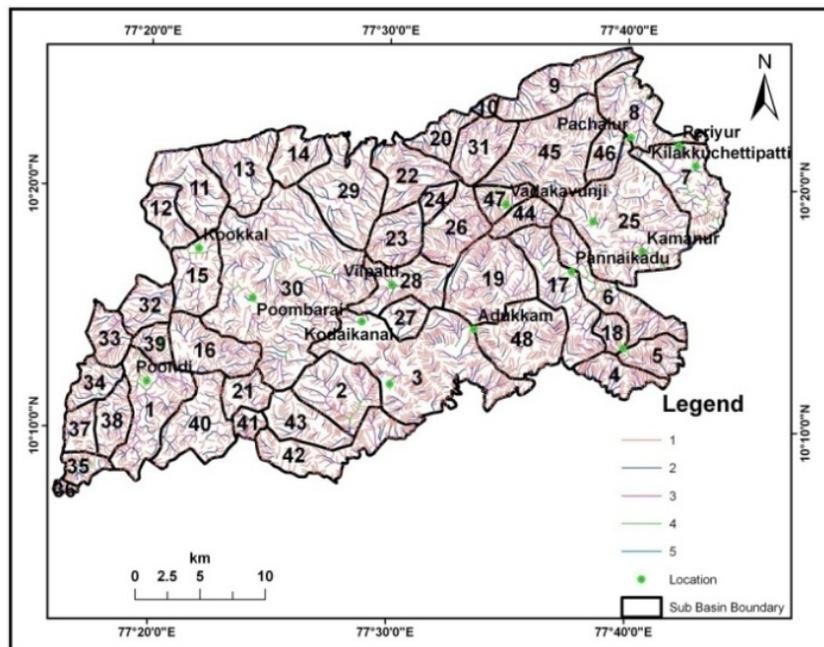


Fig. 6. Stream order map of Kodai hills

nos. 10, 18 and 20 located in the western and eastern parts of the study area. These slopes are in association with Hill top plains, Pediment and Structural hills with an area of about 22.99%. Steep slopes (15-30°) are associated with dissected plateau, Pediment, structural hill; structural valley and valley fill are found in all the sub basins except

in sub basin 10, 16, 18, 31, 35, 36, 37, 40 and 46 covering 29.55% of the study areas. These slopes exist mainly in the north-western, central and north-eastern parts of the study area. Steep slopes are characterized with high drainage density and high stream frequency. Very steep slopes (>30°) mainly cover the upper parts of sub basins

Table 2: Linear and relief morphometric parameters at sub basin level

Sub basin	Basin length (Km)	Perimeter, P (Km)	Drainage Order in (no)					Total no. N	Cumulative length, L (Km)	Bifurcation ratio, Rb	Basin height Bh (m)	Ruggedness no., Rn
			N1	N2	N3	N4	N5					
1	8.65	29.11	174	34	49	15		272	109.57	4.97	980	0.64
2	6.03	20.73	133	65	34	22	4	258	97.76	2.02	1640	1.10
3	7.46	57.74	276	103	32	2		413	228.94	2.65	1880	1.04
4	2.10	19.21	75	32	7			114	55.20	2.27	3040	2.51
5	3.20	15.62	93	40				133	49.14	2.27	780	0.61
6	4.41	34.71	151	67	29	14		261	100.05	2.22	1280	0.91
7	7.86	27.13	111	57	20	19		207	81.24	1.91	400	0.21
8	3.97	30.45	113	56	27	10		206	78.88	1.98	800	0.48
9	3.19	28.04	132	65	30			227	93.91	2.00	1120	0.77
10	1.23	6.23	11	6				17	7.37	1.57	380	0.23
11	5.00	22.16	96	40	22	4		162	68.46	2.34	1300	0.77
12	2.79	16.15	45	16	20	1		82	34.09	2.65	1020	0.55
13	5.42	21.41	80	38	25			143	75.17	2.05	1500	0.93
14	3.57	16.19	45	19				64	37.85	2.25	1340	0.71
15	5.88	18.55	69	21	14	10		114	50.34	3.14	180	0.09
16	4.75	20.78	110	59	17			186	81.24	1.83	380	0.26
17	5.04	31.64	118	59	38	3		218	98.11	1.97	1049	0.64
18	1.96	10.05	35	15	7			57	22.12	2.19	280	0.19
19	5.49	23.19	186	85	61	7		339	129.03	2.16	480	0.34
20	2.45	16.30	54	25	10			89	35.78	2.08	880	0.58
21	3.41	16.81	90	36	30			156	28.44	2.43	1320	0.92
22	5.88	23.05	92	35	17			144	78.08	2.56	920	0.63
23	4.59	15.61	90	56	24			170	63.58	1.58	720	0.53
24	3.55	10.06	24	9	4			37	15.84	2.40	700	0.40
25	9.11	36.11	290	121	39	7		457	190.08	2.38	1400	0.80
26	4.15	18.94	120	40	40	6		206	80.40	2.93	760	0.58
27	2.97	11.21	34	17	12			63	23.41	1.89	340	0.18
28	6.27	26.19	97	41	16	9		163	73.29	2.31	880	0.60
29	5.49	31.91	90	45	19			154	96.72	1.96	1820	0.97
30	11.89	52.32	438	237	83	30		788	381.42	1.84	1480	0.91
31	4.66	14.38	90	35	30			155	64.72	2.50	220	0.27
32	3.48	15.03	55	17	10	1		83	40.81	3.06	1000	0.62
33	3.20	14.08	59	32	13			104	43.37	1.79	880	0.64
34	3.07	14.95	47	21	6	1		75	33.63	2.14	460	0.29
35	2.93	11.94	42	24	6	1		73	27.78	1.68	360	0.34
36	0.97	5.30	12	3	2			17	4.71	3.00	860	0.55
37	2.69	12.92	39	19	3			61	23.43	1.95	260	0.13
38	3.33	15.84	65	32	7			104	40.33	1.97	340	0.21
39	2.76	10.95	40	10	7	1		58	25.25	3.64	500	0.35
40	5.31	25.48	99	51	11			161	70.83	1.90	160	0.08
41	2.23	9.13	21	10	3			34	15.13	1.91	320	0.19
42	2.93	34.55	125	38	11			174	79.07	3.21	1200	0.70
43	4.45	18.69	68	21	1			91	44.59	3.09	1520	0.73
44	2.96	13.78	55	23	12			90	33.78	2.29	180	0.13
45	6.79	32.24	225	102	30	12		369	158.63	2.18	1400	0.97
46	2.78	12.69	34	19	6			59	27.53	1.70	400	0.23
47	2.56	12.88	48	19	8	6		81	32.86	2.40	800	0.06
48	4.64	23.14	156	61	5			222	99.95	2.52	940	0.58

2, 3, 9, 10, 11, 13, 14, 20, 21, 22, 29, 30, 42, 43 and 48 and are in association with neck of Hill top, dissected plateau, pediment and structural hill covering an area of about 5.73% of the Study area.

Geology: The study area has the following rock types. They are Charnockite, Granitic gneiss, Laterite and Anorthosite (Fig. 5). Among these rock types, the Charnockites are found over large area in 837.90 km². The granitic gneisses cover less area in 195.58 km² and are observed in the southeastern portion. The other rock types namely Anorthosites 3.59 km² and Laterite 2.34 km² are distributed over very small areas and are observed in the northeastern portion of the study area.

Charnockite: Charnockite forms the bulk of the units of the study area. Charnockite is a coarse granular rock consisting mainly of quartz, feldspar, and hypersthene. The charnockite habitually occurs in terrains of high grade

regional metamorphism dominated by rocks of the granulite facies. The origin of charnockite is a matter of controversy. The Charnockite rocks occupy most of the total geographical area of the basin area (nearly 80.61%)

Granitic gneiss: The important mineral constituents present in granitic gneisses are quartz, feldspar, and mica. This rock type is distributed along the east and southeastern part of the study area. These formations occupy nearly 18.81% of total geographical area of the basin.

Anorthosite: The anorthosite is present in the north east portion of the study area. The anorthosite is present over a very small area occupies nearly 0.35%.

Laterite: The laterite is present in the North West portion of the study area. The laterite formation covers a very small area of nearly 0.23%.

Table 3: Areal morphometric parameters of sub basins

Sub basin	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	31.72	8.58	3.45	5.98	0.42	0.47	0.69	0.29
2	26.22	9.84	3.73	6.42	0.72	0.77	0.81	0.27
3	72.1	5.73	3.18	4.78	1.30	0.27	0.80	0.31
4	11.91	9.57	4.63	3.90	2.69	0.41	0.39	0.22
5	11.37	11.70	4.32	5.95	1.11	0.59	0.46	0.23
6	26.25	9.94	3.81	4.35	1.35	0.27	0.48	0.26
7	28.14	7.36	2.89	4.09	0.46	0.48	0.66	0.35
8	24.37	8.45	3.24	3.71	1.55	0.33	0.51	0.31
9	26.02	8.72	3.61	4.71	2.56	0.42	0.59	0.28
10	2.24	7.59	3.29	1.77	1.47	0.72	0.23	0.30
11	23.91	6.78	2.86	4.33	0.96	0.61	0.69	0.35
12	11.91	6.88	2.86	2.79	1.53	0.57	0.47	0.35
13	23.76	6.02	3.16	3.74	0.81	0.65	0.71	0.32
14	14.21	4.50	2.66	2.78	1.11	0.68	0.56	0.38
15	19.47	5.86	2.59	3.72	0.56	0.71	0.67	0.39
16	22.80	8.16	3.56	5.29	1.01	0.66	0.70	0.28
17	30.40	7.17	3.23	3.73	1.20	0.38	0.61	0.31
18	6.13	9.30	3.61	3.48	1.60	0.76	0.39	0.28
19	34.49	9.83	3.74	8.02	1.14	0.81	0.95	0.27
20	10.37	8.58	3.45	3.31	1.73	0.49	0.41	0.29
21	17.7	8.81	1.61	5.35	1.52	0.79	0.67	0.62
22	20.87	6.90	3.74	3.99	0.60	0.49	0.58	0.27
23	16.12	10.55	3.94	5.77	0.77	0.83	0.66	0.25
24	5.35	6.92	2.96	2.39	0.42	0.66	0.34	0.34
25	63.23	7.23	3.01	8.03	0.76	0.61	1.12	0.33
26	19.71	10.45	4.08	6.34	1.14	0.69	0.66	0.25
27	8.39	7.51	2.79	3.03	0.95	0.84	0.48	0.36
28	20.55	7.93	3.57	3.70	0.52	0.38	0.50	0.28
29	35.28	4.37	2.74	2.82	1.17	0.44	0.70	0.36
30	119.72	6.58	3.19	8.37	0.85	0.55	1.46	0.31
31	9.95	15.58	6.50	6.26	0.46	0.60	0.44	0.15
32	12.57	6.60	3.25	3.66	1.04	0.70	0.53	0.31
33	11.28	9.22	3.85	4.19	1.10	0.71	0.51	0.26
34	10.13	7.40	3.32	3.14	1.08	0.57	0.43	0.30
35	6.74	10.83	4.12	3.52	0.78	0.59	0.36	0.24
36	1.37	12.41	3.44	2.26	1.45	0.61	0.16	0.29
37	8.48	7.19	2.76	3.02	1.17	0.64	0.42	0.36
38	12.38	8.40	3.26	4.10	1.11	0.62	0.50	0.31
39	7.11	8.16	3.55	3.65	0.94	0.74	0.41	0.28
40	26.19	6.15	2.70	3.89	0.93	0.51	0.65	0.37
41	4.75	7.16	3.18	2.30	0.96	0.72	0.33	0.31
42	25.72	6.77	3.07	3.62	3.00	0.27	0.47	0.33
43	17.69	5.14	2.52	3.64	0.89	0.64	0.60	0.40
44	8.84	10.18	3.82	3.99	1.01	0.58	0.41	0.26
45	43.75	8.43	3.63	6.98	0.95	0.53	0.86	0.28
46	9.11	6.48	3.02	2.68	1.18	0.71	0.46	0.33
47	85.32	0.95	0.39	3.73	13.02	6.46	4.22	2.60
48	30.16	7.36	3.31	6.74	1.40	0.71	0.83	0.30

Evaluation of morphometric parameters: The evaluation of development of drainage networks of the study area can provide some clues to understanding the geomorphic processes and hydrological characteristics of the study area. For the purpose, the study area was divided into 48 sub-basins based on the water divide (Fig. 6). The parameters considered for assessing the linear aspects include stream order, stream number, bifurcation ratio, basin length, and perimeter.

Linear parameters: Stream order analysis shows that the main basin is of Fifth order. Three sub basins (4, 9 and 14) were identified under third order, eighteen sub basins (1, 3, 6, 7, 8, 11, 12, 15, 17, 19, 25, 26, 28, 30, 32, 34, 35 and 39) were under fourth order and two sub basins (2 and 43) were under fifth order (Table 2). Analysis of cumulative length of streams (L) shows that sub basins 3, and 30 have the highest L value, whereas, sub basins 10 and 36 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 sub basins of 7, 10, 16, 17, 23, 27, 29, 30, 33, 35, 37, 38, 40, 41 and 46 and 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 sub basins of 1, 15, 32, 36 and 39 indicate high structural complexity and low permeability of the sub surface strata.

Relief parameters: Basin relief (Bh) aspects of the sub basins play an important role in drainage development, surface and sub surface water flow, permeability, landforms development and erosion properties of the terrain. The analysis reveals that the all sub basins have relief more than 150 m (Table 2). The high Bh value indicates the gravity of water flow, low infiltration and high runoff conditions. Ruggedness number (Rn) indicates the structural complexity of the terrain. The analysis shows that the sub basins 2, 3 and 4 are having

Rn value more than 0.5 and the same is less than 0.10 in the sub basins 15, 40 and 47. The basins having high Rn values are highly susceptible to erosion.

Areal parameters: The parameters considered for the present study to understand the areal aspects include sub-basin area, drainage density, stream frequency, circularity ratio, texture ratio, and constant of channel maintenance. The data obtained are given in (Table 3). Drainage density (Dd) indicates that the low Dd exists in 21 and 47 sub basins, having high permeable sub surface material and are under dense vegetation cover and low relief. In contrast, high Dd values are observed in sub basins 4, 5, 26, 31 and 35 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 only one range from 0.95 (sub basins 47), in this basin having high permeable geology and low relief. The all other sub basins where stream frequencies are high range (>5) impermeable sub-surface material, sparse vegetation and high relief conditions prevail. Texture ratio (T) indicates that highest T values are found in range from (>3) all the sub basins without 10, 12, 14, 24, 36, 41, and 46 the lowest T values are noticed in above the sub basins. Thus it can infer that T values depend on the underlying geology, infiltration capacity of bedrock and relief aspects of the sub basins. Analysis of form factor (Rf) reveals that sub basins having low Rf have less side flow for shorter duration and high main flow for longer duration. This condition prevails in sub basins 1 and 24. High Rf exists in sub basin no 47 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 basin outlet, which further depend on the existing geology, slope and land cover. The sub basin nos. 23, 27 and 47 are having highest Rc value of 6.46 and 0.84 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 sub basin nos. 25 and 30 are characterized by high Re and 36 and 41 sub basins have low Re respectively. The sub basins 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 all the sub basins have low C values of 0.15 and 0.40 respectively. It indicates that these sub basins are under the influence of high structural disturbance, low permeability, steep to very steep slopes and high surface

runoff. The sub basin no 47 have highest C values 2.60, respectively and are under very less structural disturbances and less runoff conditions.

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 Hill top plains/dissected plateau landforms are associated with high drainage density, bifurcation ratio and high cumulative length of first, second and third order streams. Structural hill, Pediment, structural valley and valley fill (Fig. 7). 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. These are in the form of plateau composed of charnockite rocks. Dissected Plateau are found in following sub basin 1, 7, 17, 23, 25, 26, 30 and 31 represent a typical stream carved morphology comprising crested radiating eroded ridges along the down slopes. The cluster of hills is characterized by rill and gully erosion, smooth and rounded hilltop. The height of the ridges was found to decrease progressively on the eastern side of the study area, signifying intense linear headward stream erosion and slope retreat under high hydraulic gradients of streams. These plateaus occupying nearly 24.84% of total geographical area are highly susceptible to severe erosion hazards. Pediments are broad gently sloping erosion surface and of plain or low relief, in an arid or semiarid region at the base of an abrupt and receding mountain front; it is underlain by bedrock this pediment and are mainly noticed in sub basin 3, 4, 5, 42 and 48, occupying nearly 8.41% of total geographical area. Structural hills have been identified in almost all the sub basins and are delineated based on the image characteristics viz. valley fills are delineated with the help of satellite image. It is having more vegetation. The valley fills cover small areas. The composite slopes are also identified.

Soil drainage characteristics of different landforms: Soil drainage pattern reflects a local condition such as surface drainage conditions, sub surface geology, type of landform, slope, erosion, landuse and soil development. The analysis reveals that soil drainage is excessive in the higher elevations and poor in the low land areas of the basin (NBSS&LUP, 1990). Selected soil profiles were studied on different geomorphic units as per the procedure laid down by All India Soil and Land Use Survey organization (AISLUS, 1970) considering the

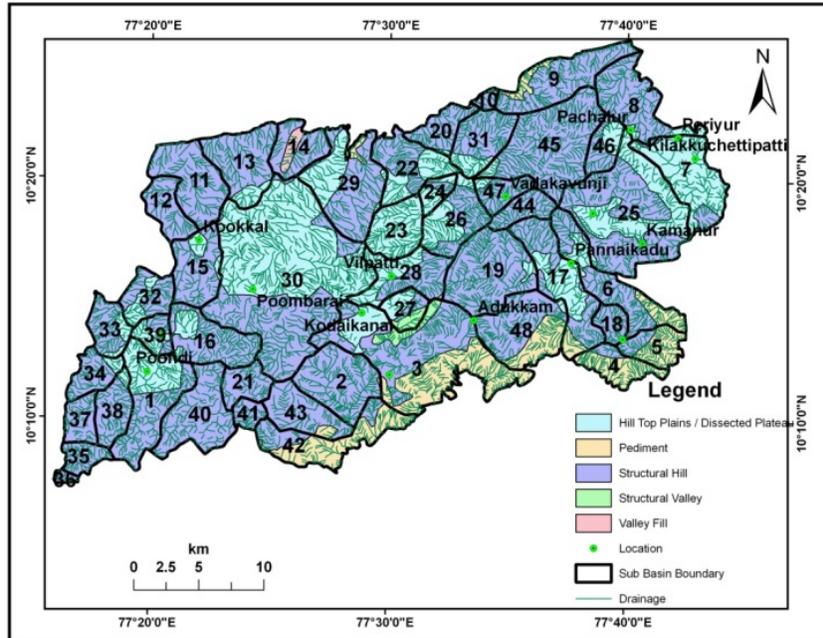


Fig. 7. Landform map of Kodai hills

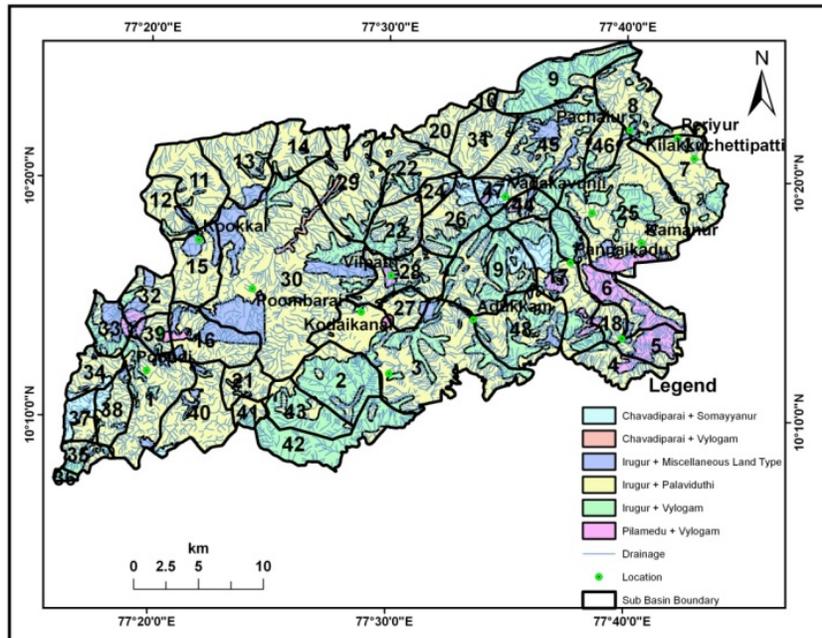


Fig. 8: Soil drainage map of Kodai hills

heterogeneity of topography, geology and vegetation conditions. The soils were classified following the USDA Handbook (USDA, 1990). The study area having six types of soil series (SOIL SURVEY OF INDIA Nomenclature) Chavadiparai-Samayanure, Chavadiparai-Vylogam, Irugur-miscellaneous, Irugur-Palaviduthi,

Irugur-Vyogam and Pilamedu-Vylogam. The Chavadiparai-Samayanure soil series covered in sub basin 17, 37, 38 and 47. In this soil very high drainage density, high bifurcation ratio and moderate steep slopes are the main causative factors for these soils. The Chavadiparai-Vylogam soil series covered in small area (0.30% basin

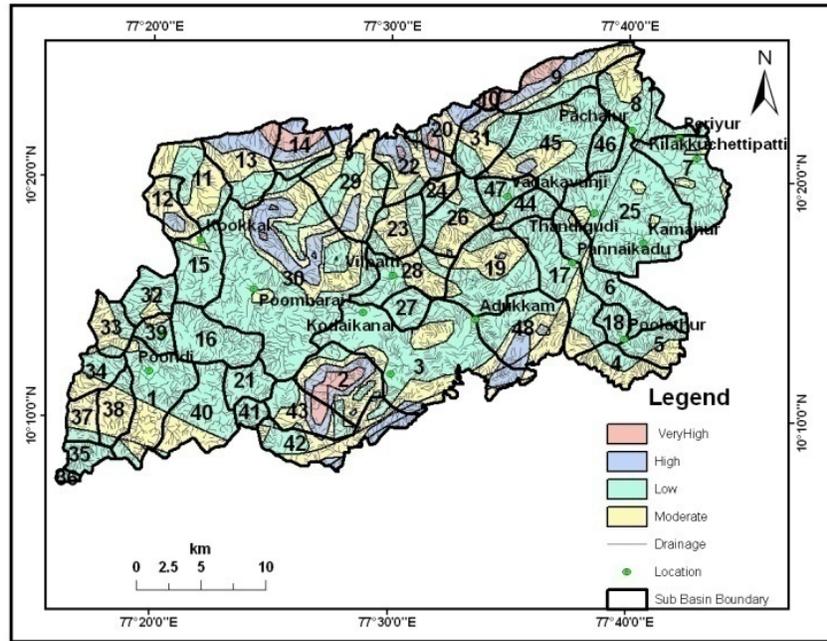


Fig. 9: Eroded lands of Kodai hills

no 29, 30 and 33 are steep slope, drainage density and stream frequency are the influencing factors for the genesis of these soil Irugur-miscellaneous soil series having moderate slope, high drainage density, are the main causative factors for these soils.

These soil occupied in 5% of the study area. Irugur-Palaviduthi covers majority of the study area of 65.82% (Fig. 8). The high drainage density, high bifurcation ratio and steep slopes are the main causative factors for these soils. These soils are in association with Structural hill areas. The Irugur-Vylogam soils occupied in sub basin 2, 9, 13 and 42. These soils having steep to very steep slopes, very high drainage density and stream frequency are the main contributing factors for the development of Irugur-Vylogam soils. The Pilamedu-Vylogam soil series cover 3.41% of the total geographical area. These soil series occupied sub basin 5 and 6 having moderately steep slopes, high drainage density, and high bifurcation ratio.

Erosion characteristics of different landforms: The analysis of (IRS-P6 LISS-4 MX) satellite data in conjunction with slope gradient, drainage morphometry, annual rainfalls, vegetation cover and ground truth information enable to delineate and characterize four categories of eroded lands i.e., very high, high, moderate, and low. Very high eroded lands are found in very steep sloping lands having moderate drainage density, low form factor and double cropped area. These lands are existed in the lower parts of sub basin nos. 2, 9, 10, and 43 in main

valley floor and foot slopes covering with an area of 0.93% of total geographical area (Fig. 9).

The high eroded lands are found on structural valley, dissected plateau and structural hill in the sub basins 2, 9, 13, 14, 22, 30 and 48 unclassified areas. These are in association with steep slopes to gentle slopes with moderate vegetation cover and high drainage density and occupy nearly 8.80% of total geographical area. Moderate eroded lands are in association with gently to moderately sloping lands these lands cover an area of 26.15% of total geographical area. The low eroded lands are in associated with gently sloping areas. These lands are characterized by high drainage density (>1.75), high bifurcation ratio (>3.5), high form factor (>0.4) and high texture ratio (>2.5). These factors are the manifestation of the underlying geology, moderate to high runoff and sparse vegetation cover. Very severely eroded lands are found in areas of dissected to undulating topography in the sub basins of 1, 3, 6, 7, 8, 15, 16, 17, 18 and 21 and occupy nearly an area of 64.10% of total geographical area. These eroded lands are in association with steep to very steep slopes, very high drainage density (>2.5), very high stream frequency (>3.0) and less circulatory ratio (<0.5).

CONCLUSION

The study reveals that remotely sensed data and GIS based approach in evaluation of drainage morphometric

parameters and their influence on landforms, soils and eroded land characteristics at river basin level is more appropriate than the conventional methods. Interpretation of multi-spectral satellite sensor data is of great help in analysis of drainage parameters and delineation of distinct geological and landform units and eroded lands. GIS based approach facilitates analysis of different morphometric parameters and to explore the relationship between the drainage morphometry and properties of landforms, soils and eroded lands. Different landforms were identified in the basin based on visual interpretation of satellite sensor data. These are dissected plateau, structural hill, structural valley and valley fill. The sub basin 4, 5, 26, 31 and 35 and are associated with high Drainage density (Dd), impermeable geology and high runoff conditions. High drainage density, high bifurcation ratio (Rb) and steep slopes are the main causative factors for the development of well drained soils. The soil drainage of the basin is associated with drainage morphometry and the majority of the area is under well-drained condition. Low and moderate eroded lands are noticed in the sub basins of 1, 2, 5, 15 and 16, which are in association with high drainage density, stream frequency and texture ratio. The detailed quantitative morphometric analysis at the sub basin level enables to understand the relationships among the different aspects of the drainage patterns and their influence on landform processes, drainage, and land erosion properties. The results reveal that the types of morphometry, underlying geology and slope factors have great influence on the gneiss and processes of the landforms. The derived morphometric parameters of the study area are closely following with the values obtained in similar terrain conditions (Subramanian and Subramanyan, 1978). The morphometric parameters evaluated using GIS helped to understand various terrain parameters such as nature of the bedrock, infiltration capacity, runoff, etc. Similar studies in conjunction with high resolution satellite data help in better understanding the landforms and their processes and drainage pattern demarcations for basin area planning and management.

Conservation efforts should take into account the importance of a Biodiversity hot spot and an interdisciplinary approach can pave way for sustainable development and ecological preservation. This study is one such attempt.

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