Drainage Morphometric Analysis of Kanchi River Sub-Basin, Khunti and Ranchi Districts, Jharkhand Using Remote Sensing and GIS.

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Abstract: Satellite based remote sensing techniques and GIS have demonstrated their efficacy in quantitative and qualitative assessment of drainage basin. The drainage system's quantitative analysis is a crucial component of watershed characterization. Morphometry deals with mathematical quantifying of various aspects of basin. The present study focuses on the morphometric analysis of Kanchi River watershed using remote sensing and GIS approach for optimal management and planning of the basin's groundwater resources. The Kanchi River is one of the major tributaries of Subarnarekha River in eastern India. In this study SRTM (date of acquisition- 2nd January 2015)) is used to extract the crucial hydrological parameters of Kanchi River in ARC GIS 10v. For microlevel morphometric analysis the study area has been divided into 21sub watershed based on 4th stream order and above. The linear, aerial and relief parameters have been calculated and their hydrological inferences were discussed. The drainage area of Kanchi watershed is 1023.68 sq km and the main stream of the basin is of 6th order with dendritic to sub- dendritic and parallel drainage pattern. Most of the morphometric parameters such as bifurcation ratio, drainage density, drainage texture, stream frequency, form factor, basin relief conclude that the basin is elongated in nature with high overland flow due to some structural control. The database generated by the study can provide scientific information for site selection of water recharge structures in the basin.

Keywords: Kanchi river, Morphometry, Remote Sensing and GIS, Watershed.

1. Introduction

The study of drainage basins provides important insight into the region's geological and evolutionary past. A systematic study of the drainage patterns and quantitative studies like morphometric, hypsometric analysis and their statistical details play a major role in understanding the hydrolological conditions of an area and further helps in water resource management and valuation in a river basin. Morphometric analysis of river basin deals with the quantitative assessment of the topographic pattern of the Earth's surface, the shape and dimensions of its landforms, and it is also an imperative technique to assess and comprehend the role of watershed dynamics (Clark 1966). In order to conduct a thorough and organized analysis, the river basin is divided into sub basins. Detailed drainage analysis of sub basin helps in understanding the influence of drainage morphometry on landform and its characteristics (Jasmin et.al 2013). Several researchers in India have worked on morphometric analysis of different river basins using conventional methods (Horton 1945, Smith et al 1945, Smith K.G. 1950) and using Geographic information system (GIS) Platform. (Krishnamurty et.al. 1995, Prasad et.al.1997, Obi reddy et al. 2004). GIS have been successfully used for evaluation of various basin parameters, providing flexible environment and powerful tool for determination, interpretation and analysis of spatial information related to river basins.

The Kanchi River drains through the hard rock terrain of Chotanagpur Granite Gneissic Complex (CGGC). The terrain is mainly comprised of gneisses, varied type of granites and some other metamorphics which does not permit sufficient groundwater recharge owing to low porosity and permeability. Though receiving sufficient rainfall but due to lithological constraints and over exploitation of groundwater resources, the region is recharge deficit. The present study attempts to analyse the morphometric and hypsometric development, with the help of remote sensing and GIS techniques for understanding the hydrological behaviour of the Kanchi River sub-basin.

Study Area

The Kanchi River sub basin having an area of about 1023.68 sq km forms the part of Subernrekha basin. It is geographically bounded by latitude 23° 11' 30" N - 23° 13' 50" N and longitude 85°13'15" E - 85°50'20" E and covers the area within SOI toposheet No 73E/4, 73E/8, 73E/12 & 73E/16 housing Khunti and Ranchi districts. Kanchi river is main river in study area with its other important tributaries such as Raisa River and Arra river. It originates near Murhu (Khunti) and confluences with Subernrekha at the east of Sonahatu (Ranchi). The drainage pattern is dendritic to sub dendritic and parallel passing through dissected hills and valleys. About 90 % of annual rainfall of Kanchi River sub-basin occurs during the southwest and northeast monsoon season spanning over June to December. Without much variance tropical climate dominates and the annual average rainfall is about 1300 mm.

Geology of the study area

Kanchi river sub basin is an important tributary of Subarnarekha River basin and occupies a vast area within CGGC. The CGGC is an east-west trending subarcuate crustal segment of East Indian Shield expaning about 100000 Km^2 having length of 500km in E-W direction and width of 200km (Mahadevan 2002, Acharyya 2006, Sharma 2009). This unit is primarily made up of gneisses with patches of amphibolite and granulites, bands of high-grade metasediments, and a small amount of gabbroic and anorthosite rocks. An east-west to ENE-WSW-trending crustal scale brittle-ductile shear zone, variously known as the south Purulia shear zone (SPSZ)(Mazumdar 1988), the northern shear zone (NSZ)(Kumar et.al. 1978), or the Tamar- Porapahar- Khatra fault zone (TPKF)(Mahadevan 2002), marks the tectonic southern boundary of the CGGC.

The oldest rocks exposed in the study area are the unclassified metamorphics dominated by mica schists, hornblende schists and amphibolites. Pelitic metasediments, interlayered quartzite, isolated minor exposures of calcareous metasediments, metabasics, and different types of granite constitute the main lithounits. The rock units present in the area includes granite gneisses, granites, pegmatites, migmatites, and related quartzo-felspathic veins, biotite schist, biotite-muscovite schist, talc-chlorite schist, phyllites, calc silicates, crystalline limestones, quartzites, and amphibolites.

The study area is structurally disturbed and has undergone multiple phases of tectonism (Sinha et. al 1998). As a result, primary structures are rarely preserved, and foliation, which is present in all rock types except newer intrusive, is the most prevalent secondary structure.

Methodology

The Shuttle Radar Topography Mission (SRTM) near-global high-resolution digital elevation model (DEM) (date of acquisition- 2nd January 2015) having spatial resolution of 30mts and vertical accuracy of about 0.25mts. was used for delineation of drainage map. SRTM DEM was obtained from the opensource Earth Explorer (https://earthexplorer.usgs.gov). The delineated drainage was further updated using satellite data IRS- P6 LISS III (Date of acquisition- 17th January 2017) data of study area and the SOI toposheets number 73E/4, 73E/8, 73E/12 and 73E/16.

Horton's (Horton 1945) approach was used to assess the basin and drainage network, and Strahler (Strahler 1964) methods were used for ordering of streams. The following basic watershed metrics such as basin area (A), basin perimeter (P), basin length (Lb), stream length (L), and stream order (N) were extracted from ArcGIS -10 geodatabase and further contributing elements, such as the length of the overland flow, stream frequency, drainage density, texture ratio, basin relief, elongation ratio, and circulation ratio, were calculated using these parameters. Table 1 lists the key parameters with their description and the formulas used to calculate them.

Table 1: Morphometric parameters with their formulae used for analysis.

Sl. no	Parameters	Definition	units	References
Linear aspects				
1.	Perimeter (P)	Length of the boundary of watershed	Km	
2.	Basin length (Lb)	Maximum length of the watershed measured parallel along the main drainage network	Km	

3.	Stream order (Nu)	Hierarchical ordering	Dimensionless	Strahler (1957)
4.	Stream length (Lu)	Length of the main stream	Km	Horton (1945)
5.	Bifurcation ratio (Rb)	Rb = Nu/N(u+1), where Nu is the total number of streams of any given order and N(u+1) is the total number of streams of next higher order	Dimensionless	Horton (1945)
6.	Stream Length ratio (Rl)	Rl = Lu/L(u-1), where Lu is stream length order u and L(u-1) is the stream length segment of the next lower order	Dimensionless	Horton (1945)
Areal aspects				
7.	Area (A)	Area of watershed	Km^2	-
8.	Drainage density (Dd)	$Dd = \Sigma Lt/A$, where ΣLt is the total length of all the ordered streams	Km/km^2	Horton (1945)
9.	Stream frequency (Fs)	$Fs = \Sigma Nt/A$, where Nt is total number of stream segments of all order	Km^{-2}	Horton (1945)
11.	Drainage texture (T)	T= Dd x Fs	Km^2/Km^4	Smith (1950)
12.	Length of overland flow (Lg)	Lg = 1/2Dd	Km	Horton (1945)
13.	Constant of channel maintenance (c)	C= 1/Dd	Km	Schumm (1956)
14.	Form factor (Ff)	$Ff = A/Lb^2$	Dimensionless	Horton (1945)
15.	Circulatory ratio	$Rc = 4\pi A/P^2$	Dimensionless	Miller (1953)
Relief aspects				
17.	Basin relief (R)	R = H-h, where H is maximum elevation and h is minimum elevation within the basin	Km	Schumm (1956)
18.	Relief ratio (Rr)	Rr = R/Lb	Dimensionless	Schumm (1956)
19.	Dissection index (DI)	DI =R/Ra, where Ra is absolute relief	Dimensionless	Singh and Dubey (1994)
20.	Ruggedness number (Rn)	Rn= R x Dd	Dimensionless	Strahler (1958)

Results and Discussion

The morphometric investigation incorporates measurement and mathematical analysis of the area, altitude, volume, slope, profiles of the land, and drainage basin characteristics of the catchment area concerned (Clarke 1966). In the present study microlevel analysis of watershed has been done. The catchment area of Kanchi river with stream network and 4^{th} and higher order sub watershed is shown in figure. 1. In the following section, the highlights of the drainage, linear, areal, relief, and tectonic characteristics have been analysed and described.

A. Drainage pattern

The Kanchi watershed's drainage orientations exhibit poly-modal distribution (NE-SW, NW-SE, N-S, and E-W). However, the main river trends E-W. The drainage pattern is dendritic in general; while rectangular, trellis, parallel, sub-dendritic are also observed (Fig.1). The dendritic to sub-dendritic pattern is formed by network of tributaries which follows the slope and are well adjusted to lithology and structure. The dendritic to sub dendritic drainage pattern is typical in regions representing almost uniform lithologies and strata that are horizontal or gently dipping.

A parallel, trellised and rectangular pattern in the central part of study area indicates that the region is structurally influenced at least to a moderate scale.

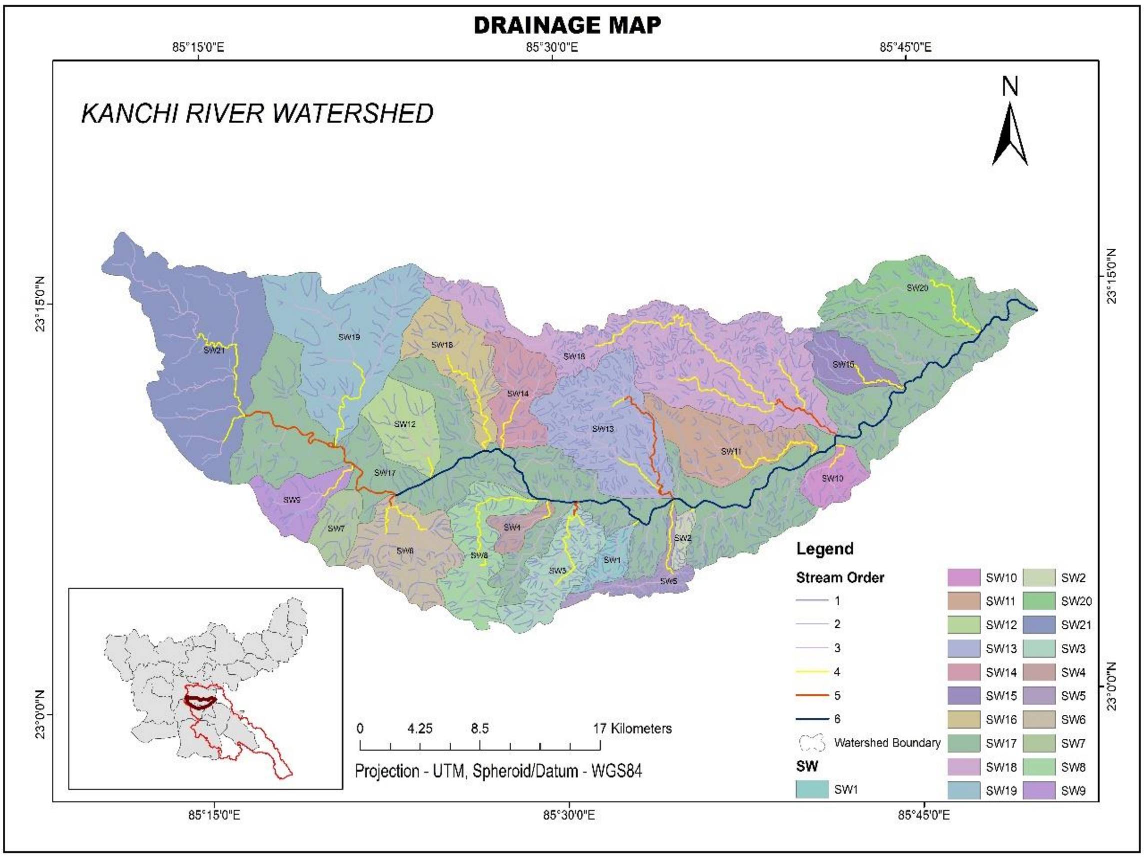


Fig: 1 Drainage map of study area

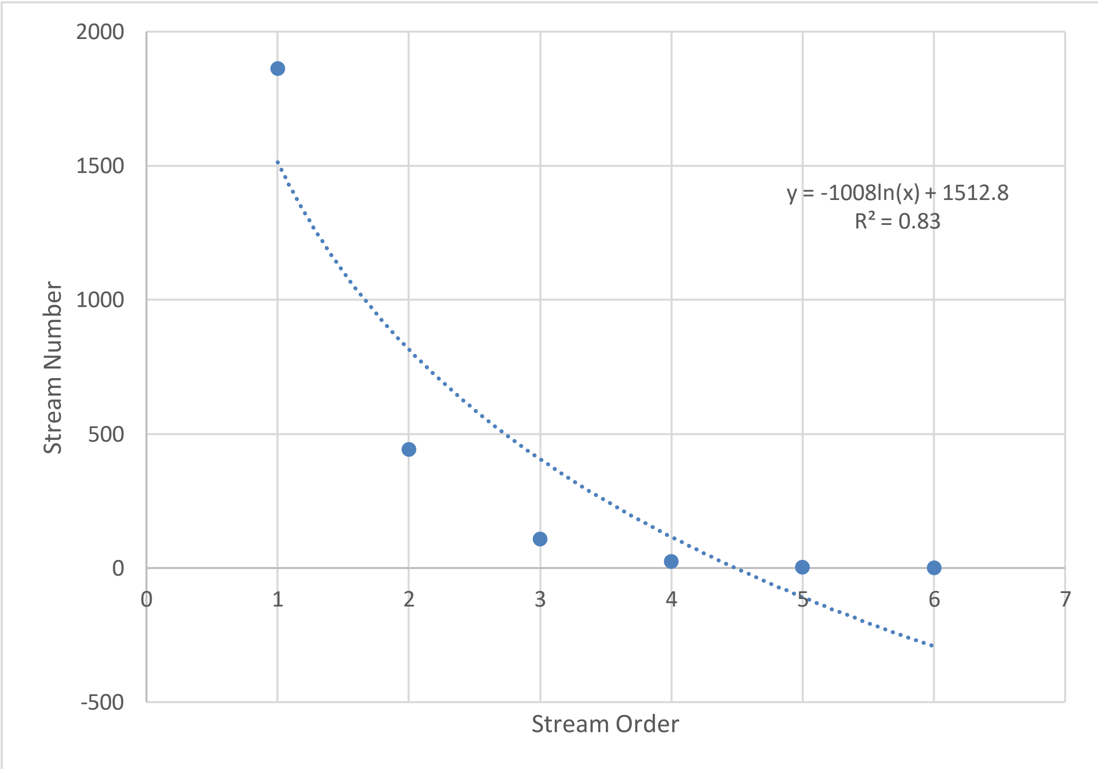
B. Linear aspects

Perimeter (P)

The main watershed (MW) with perimeter 850.77 km and that of 21 fourth order subwatersheds (SW) are shown in table 2. Among the sub watersheds, SW18 has the largest perimeter (258.84 km), while the perimeter of SW2 (10.26 km) is the smallest of all.

Stream order (Nu)

The classification of streams based on the number and type of tributary junctions, has proven to be a useful indicator of stream size, discharge, and drainage area. In Kanchi watershed the highest order is 6th order stream. The sub watershed are divided on the basis of 4th and higher order stream. There is an inverse geometric sequence with stream order and number of stream segments, as per Horton's laws of stream numbers. This signifies that as the stream order increases the number of stream decreases in accordance with geometric progression. To validate Horton's law of stream number a logarithmic regression line between stream order and stream number was drawn



(Fig 2.) The coefficient of determination obtained was 0.83. An R^2 of 1 indicated that the regression line perfectly fits the data. The stream order for MW and SW are listed in Table 2.

Fig 2: Logarithmic regression of number of streams and stream order

Bifurcation ratio (Rb)

According to Strahler (1957,1964) the bifurcation ratio (Rb) is defined as a ratio of the number of streams of a given order (Nu) to the number of streams of the next higher order (Nu+1). The Rb values reflect basin shape (Verstappen et. al. 1893). Elongated basins have low Rb values while circular basins have high Rb values (Morisawa 1985). The mean Rb of main watershed is 3.77. The bifurcation ratio in the 21 watershed varies between 2.42- 4.34, suggesting elongated shape of the basin and shows high overland flow and discharge due to hilly nature of the terrain. The Rb of MW and SW is given in table 2.

Stream Length (Lu)

The total length of all streams in the drainage basin, regardless of order, is known as the stream length (Lu). The mean length of channel segments of a given order is more than that of the next lower order, but less than the next higher order, indicating that the watershed evolution follows erosion laws acting on geologic material with homogeneous weathering and erosion characteristics (Nag et.al. 2003). Following the Horton's (1945) law of stream length, the overall length of a stream segment is greater in first order streams and decreases as the stream order increases. The combined length of streams in first order is longest and for highest order, the 6^{th} order is smallest. A regression line was plotted to validate the Hortons law of stream length. The coefficient of determination obtained was 0.9363 (Fig 3). An R^2 approaching value of 1suggest the fit of data for used method. The mean and total stream length of each stream order in SW and MW is given in table 2.

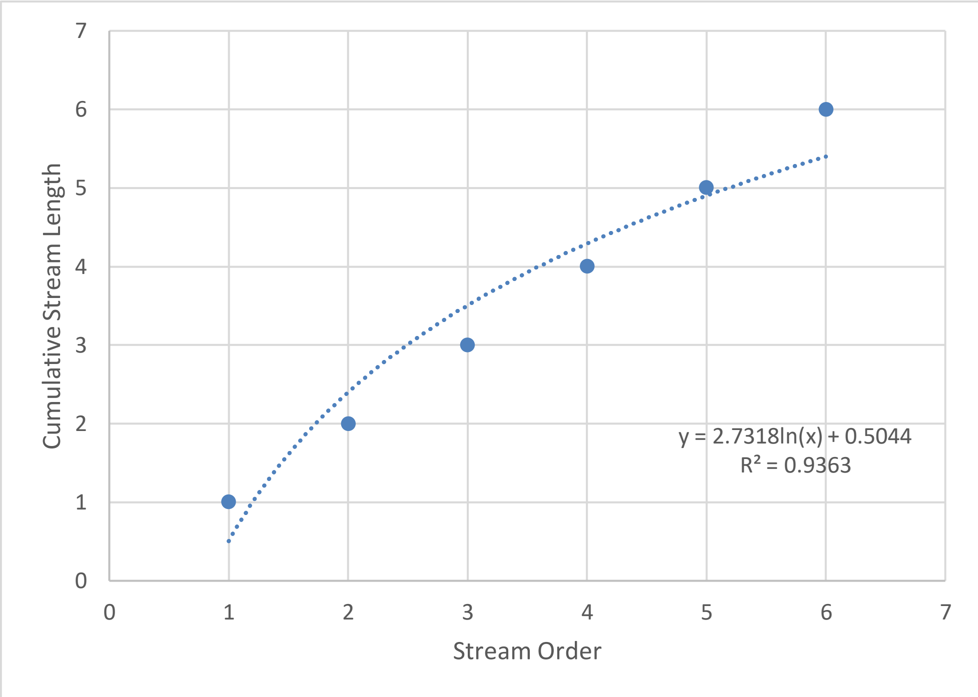


Fig 3: Logarithmic regression of cumulative stream length and stream order

Mean Stream Length (L_{sm})

The mean stream length (L_{sm}) of a channel reveals the characteristics size of drainage network components and its contributing basin surfaces (Strahler 1964). It is computed by dividing the cumulative stream length of order 'u' by the number of segments of that order (Table 2). The L_{sm} values for the Kanchi River sub basin varies from 0.54 to 60.01 with a mean Lsm of 12.41. According to Strahler the mean stream length is a characteristic property related to the drainage components and its associated basin surfaces. It is observed that mean stream length of any given order is greater than that of the lower order and lesser than that of its next higher order in the basin. In the study area inverse relation exist between stream length and stream order which could result from topographical and slope changes.

Stream length ratio (Rl)

The stream length ratio (Rl) of the 21 watershed varies between 0.17 to 1.94 (Table 2). Stream length ratio represents ratio between mean length of one order to the next lower order of the stream segment which tends to be constant throughout the basin. The irregularity in Rl suggests variation in slope and topography and hence it has an important control on discharge and different erosion stages of the watershed (Sreedevi et.al. 2004). Higher stream length ratio indicated higher degree of erosion. The increase of Rl from lower order to higher order indicates achievement of geomorphic maturity (Thomas et.al. 2010).

Table 2: Linear aspects of Kanchi River sub-basin

Parameter		SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	SW9	SW10	SW11	SW12	SW13	SW14	SW15	SW16	SW17	SW18	SW19	SW20	SW21	MW
P (Km)		16.68	10.26	28.58	14.45	32.24	28.56	14.75	35.74	21.63	14.71	32.36	19.74	36.18	26.72	20.36	32.08	258.84	82.13	42.88	30.45	51.54	850.77
Nu	N1	37	16	101	13	57	67	14	63	23	24	49	17	193	45	32	41	464	350	65	58	135	1,864
	N2	8	5	23	4	13	12	3	18	5	6	14	5	48	11	8	8	105	86	17	13	32	444
	N3	2	1	5	2	2	5	1	3	2	2	5	2	12	3	2	2	22	19	4	4	8	108
	N4	1	-	2	1	1	2	-	1	1	1	1	1	3	1	1	1	-	4	1	1	2	26
	N5	-	-	1	-	-	1	-	-	-	-	-	-	1	-	-	-	1	1	-	-	-	5
	N6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
	Nt	48	22	132	20	73	87	18	85	31	33	69	25	257	60	43	52	593	460	87	76	177	2,448
Rb	N1/N2	4.63	3.20	4.39	3.25	4.38	5.58	4.67	3.50	4.60	4.00	3.50	3.40	4.02	4.09	4.00	5.13	4.42	4.07	3.82	4.46	4.22	4.20
	N2/N3	4.00	5.00	4.60	2.00	6.50	2.40	3.00	6.00	2.50	3.00	2.80	2.50	4.00	3.67	4.00	4.0	4.77	4.53	4.25	3.25	4.00	4.11
	N3/N4	2.00	-	2.50	2.00	2.00	2.50	-	3.00	2.00	2.00	5.00	2.00	4.00	3.00	2.00	2.00	-	4.75	4.00	4.00	4.00	4.15
	N4/N5	-	-	2.00	-	-	2.00	-	-	-	-	-	-	3.00	-	-	-	-	4.00	-	-	-	5.2
	N5/N6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	-	-	-	5.00
	Sum Rb	10.63	8.20	13.49	7.25	12.88	12.48	7.67	12.50	9.10	9.00	11.30	7.90	15.02	10.76	10.00	11.13	10.19	17.35	12.07	11.71	12.22	22.66
	Mean Rb	3.54	4.10	3.37	2.42	4.29	3.12	3.83	4.17	3.03	3.00	3.77	2.63	3.76	3.59	3.33	3.71	2.55	4.34	4.02	3.90	4.07	3.78
Lu	N1	19.96	8.82	56.57	11.71	29.47	50.41	13.03	45.41	15.71	13.61	36.29	16.85	116.04	33.87	22.53	33.79	326.31	199.16	61.28	34.69	94.68	1240.18
	N2	3.92	3.36	16.49	5.32	8.07	11.65	5.49	17.52	4.71	5.49	14.67	7.63	41.79	8.44	13.05	11.82	113.09	68.12	15.97	16.95	36.72	430.26
	N3	9.02	2.33	5.90	3.20	4.51	9.10	1.20	3.94	5.53	3.97	9.91	6.01	29.38	7.71	2.93	1.84	55.10	37.42	17.09	9.26	27.69	252.95
	N4	0.57	-	7.94	1.55	5.76	6.05	-	9.91	3.47	2.57	8.62	1.52	4.92	4.19	5.88	9.46	-	32.44	8.33	6.79	12.30	132.10
	N5	-	-	1.37		-	-	1.02	-	-	-	-	-	10.25	-	-	-	8.48	5.89	-	-	-	27.00
	N6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60.10	-	-	-	-	60.01
	Total	33.47	14.51	88.26	21.78	47.81	78.22	19.71	76.78	29.42	25.65	69.49	32.02	202.37	54.21	44.19	56.91	563.08	343.04	102.67	67.70	171.40	2,142.50
Lsm	N1	0.54	0.55	0.56	0.90	0.52	0.75	0.93	0.72	0.68	0.57	0.74	0.99	0.60	0.75	0.70	0.82	0.70	0.57	0.94	0.60	0.70	.66
	N2	0.49	0.67	0.72	1.33	0.62	0.97	1.83	0.97	0.94	0.92	1.05	1.53	0.87	0.77	1.63	1.48	1.08	0.79	0.94	1.3	1.15	0.97
	N3	4.51	2.33	1.18	1.6	2.25	1.82	1.2	1.31	2.77	1.99	1.98	3.01	2.45	2.57	1.47	0.92	2.5	1.97	4.27	2.32	3.46	2.34
	N4	0.57	-	3.97	1.55	5.76	3.03	-	9.91	3.47	2.57	8.62	1.52	1.64	4.19	5.68	9.46	-	8.11	8.33	6.79	6.15	5.08
	N5	-	-	1.37	-	-	1.02	-	-	-	-	-	-	10.02	-	-	-	8.48	5.89	-	-	-	5.4
	N6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60.10	-	-	-	-	60.01
Rl	2/1	0.20	0.38	0.29	0.45	0.27	0.23	0.42	0.39	0.30	0.40	0.40	0.45	0.36	0.25	0.58	0.35	0.35	0.34	0.26	0.49	0.39	1.47
	3/2	2.30	0.69	0.36	0.60	0.56	0.78	0.22	0.22	1.18	0.72	0.68	0.79	0.70	0.91	0.22	0.16	0.49	0.55	1.07	0.55	0.75	2.41
	4/3	0.06	0.00	1.35	0.49	1.28	0.67	0.00	2.52	0.63	0.65	0.87	0.25	0.17	0.54	1.94	5.16	0.00	0.87	0.49	0.73	0.44	2.17
	5/4	-	-	0.17	-	-	0.17	-	-	-	-	-	-	2.09	-	-	-	-	0.18	-	-	-	1.06
	6/5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.09	-	-	-	-	11.11

Note: P -Perimeter, Nu- stream order, Rb- bifurcation ratio, Lu- stream length, Lsm- Mean stream length, Rl- stream length ratio

C. Areal aspects

Area (A)

The Kanchi River watershed occupies an area of 1023.26 Km^2 in eastern India. It has been divided into 21 sub-watersheds. The area of the sub-watersheds are tabulated in Table 3.

Drainage density (Dd)

Drainage density (Dd) can be defined as the ratio of the total channel segment lengths to the basin area. It is a quantitative measure of the closeness of channel spacing (Strahler 1964). The annual rainfall, rock infiltration capacity, vegetation cover, roughness of the surface, and strength of runoff all affect drainage density. A low drainage density is preferred in areas with high permeability and high resistance lithology under dense vegetation while high drainage density is preferred, in areas with impermeable bedrock with sparse vegetation. Dd of whole basin is 1.45km/km^2 suggesting uniform lithology and highly permeable subsurface with some little structural disturbance within the watershed. However, it has been noticed that within the middle reaches of watershed the density is high indicating impermeable formations and high runoff. Dd for the SW and MW is given in Table 3.

Stream frequency (Fs)

Stream frequency (Fs) represents the total number of stream segments of all orders per unit area (Horton 1945). In the watershed, stream frequency shows a positive association with drainage density, indicating a rise in stream number in relation to an increase in drainage density (Sharma 2014). Fs is greatly affected by lithology and climate and affects the drainage texture. The stream frequency of the entire basin is 2.33 km^{-2} indicating a moderate relief and permeable sub surface material. The Fs of SW and MW is given in table 3.

Drainage texture (T)

According to Smith (1950), drainage texture (T), is largely impacted by lithology, vegetation, soil type, relief, and the stage of development of a watershed and is a measure of relative channel spacing in a fluvial-dissected terrain. According to classification given by Smith the study area is falling under very coarse drainage (< 2) (Table 3) texture because of low drainage density.

Length of overland flow (Lg)

Length of overland flow (Lg) is a length of water over the ground before it gets concentrated into certain stream channels. Horton defined Lg as the length of flow path, projected to the horizontal of non-channel flow from a point on the drainage divide to a point on the adjacent stream channel. The important factors which affect Lg includes rainfall intensity, infiltration rate, soil type, vegetation cover etc. The Lg in study area varies from 0.13 to 0.38 (Table 3). The moderate value of Lg is suggestive of moderate paths, gentle slope and mature stage. Maximum length of overland flow demarcate youth stage and old stages are characterized by reduced value of Lg.

Form factor (Ff)

Form factor (Ff) is a ratio of watershed area to the square of the length of the watershed. Flow intensity of watershed can be estimated by form factor (Horton 1945, Gregory and Walling 1973). The index of Ff also illustrates the inverse relationship with the square of the axial length and a direct relationship with peak discharge (Maghesh et.al. 2012). The Ff values greater than 0.78 indicate perfect circular basin and value lower than 0.78 indicate an elongated basin. Basins with Ff indicate high peak flows for shorter duration whereas elongated basins have low peak flows for longer duration. The Ff for Kanchi watershed is 0.22 suggesting an elongated shape of the basin having low peak flows for longer duration. The Ff values for SW and MW in mentioned in table 3.

Circulatory ratio (Rc)

Circulatory ratio (Rc) is a dimensionless property and is defined as the ratio of basin area to the area of a circle having the same perimeter as the basin (Miller 1958). Values of Rc approaching 1 indicates circular shape of the basin. In Kanchi watershed the Rc values range from 0.15 to 0.76, which shows elongated nature of basin with little structural disturbances and youth and mature stages of watershed development.

Constant of channel maintenance (C)

According to Schumm 1956, constant of channel maintenance (C) is the inverse of the drainage density. Its value increases with the size of watershed and is influenced by factors such as lithology, vegetation cover, soil infiltration and permeability. The C of Kanchi River sub-basin is 0.69 (Table 3). Higher value of C signifies resistant rock with moderate to high infiltration, good vegetation and mature stages of watershed development.

Table 3: Aerial aspects of Kanchi River sub-basin

Parameter	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	SW9	SW10	SW11	SW12	SW13	SW14	SW15	SW16	SW17	SW18	SW19	SW20	SW21	MW
A	21.65	14.24	28.18	18.50	14.64	37.23	12.21	32.98	18.77	17.25	35.13	23.51	60.57	25.36	17.82	38.15	275.23	118.10	77.36	34.53	101.84	1023.26
Dd	1.44	1.54	1.32	1.42	1.19	1.32	1.61	1.58	1.57	1.43	1.33	1.36	1.34	1.42	1.56	1.65	1.62	1.45	1.33	1.34	1.61	1.45
Fs	2.22	1.54	4.68	1.08	4.99	2.34	1.47	2.58	1.65	1.91	1.96	1.06	4.24	2.37	2.41	1.36	2.15	3.90	1.12	2.20	1.74	2.33
T	2.34	2.14	1.99	1.38	2.26	2.05	1.22	2.38	1.43	2.24	2.13	1.27	2.15	2.25	2.11	1.62	2.29	1.21	2.03	2.50	2.31	1.97
Lg	0.13	0.15	0.16	0.17	0.13	0.24	0.33	0.21	0.32	0.24	0.25	0.37	0.15	0.23	0.19	0.28	0.24	0.17	0.38	0.26	0.30	0.23
Ff	0.13	0.07	0.15	0.20	0.07	0.29	0.28	0.15	0.20	0.39	0.09	0.40	0.22	0.27	0.18	0.16	0.06	0.07	0.24	0.13	0.23	0.22
Rc	0.98	1.70	0.43	1.11	0.18	0.57	0.70	0.32	0.50	1.00	0.42	0.76	0.58	0.45	0.54	0.47	0.05	0.22	0.53	0.47	0.48	0.59
C	0.69	0.65	0.76	0.70	0.84	0.76	0.62	0.63	0.64	0.70	0.75	0.73	0.75	0.70	0.64	0.61	0.62	0.69	0.75	0.75	0.62	0.69

D. Relief aspects

Basin relief (R)

Basin relief (R) controls the stream gradient, flood pattern and volume of sediment that can be transported (Hadley and Schumn 1961). R is an important factor in understanding denudational characteristics of the basin (Sreedevi et.al. 2009). R plays an important role in landform and drainage development and in deciphering erosive nature of terrain. The basin relief parameters are tabulate in table 4. The MW has a relief of 560.

Relief Ratio (Rr)

Relief ratio (Rr) is a dimensionless ratio between basin relief and basin length and widely accepted as an effective measure of gradient aspects of the watershed (Vittala et.al 2004). The high values of Rr are indicative of hilly regions while low values indicate pediplanation of the terrain. The Rr values range from 0.007 to 0.83 in the watershed (Table 4). The Rr value signifies the presence of low to moderate slope in form of ridges, residual hills and mounds underlain by resistant rocks. The low to moderate relief ratios are suggestive of strong groundwater prospects and limited watershed discharge capabilities.

Dissection Index (DI)

Dissection Index (DI) of a basin infers to the degree of dissection or vertical erosion and expounds the stages of terrain or landform development in any given physiographic region or watershed (Singh and Dubey 1994). The value of DI for the region ranges between 0 (complete absence of vertical dissection/erosion suggesting dominance of flat surface) and 1 (vertical cliffs, be at hill escarpment or at sea shore). DI of the MW is 0.58 and ranges from 0.22 (SW 12) to 0.80 (SW21) (Table 4), indicating that the watershed is moderately dissected.

Ruggedness Number (Rn)

The ruggedness number (Rn) is a dimensionless property and is expressed as the product of basin relief and drainage density (Strahler 1957). The Rn of Mw is 0.44 and that of 21 watershed is tabulated in table 4. The Rn values for the sub-watersheds range between 0.16 (SW 12) and 0.67 (SW 21). The low to moderate Rn suggest that the watershed is moderately prone to soil erosion and possess inherent structural complexity related to drainage density and relief (Vijith et.al. 2006).

Table 4: Relief aspects of Kanchi River sub-basin

Parameter	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	SW9	SW10	SW11	SW12	SW13	SW14	SW15	SW16	SW17	SW18	SW19	SW20	SW21	MW
R	300	180	380	300	380	360	380	310	360	120	160	120	360	240	220	300	400	400	340	280	420	560
Rr	0.023	0.041	0.039	0.061	0.037	0.047	0.083	0.042	0.049	0.028	0.013	0.018	0.032	0.031	0.029	0.030	0.007	0.027	0.007	0.023	0.028	0.033
DI	0.56	0.43	0.63	0.56	0.70	0.60	0.70	0.49	0.62	0.67	0.46	0.22	0.60	0.36	0.64	0.43	0.65	0.61	0.57	0.60	0.80	0.58
Rn	0.43	0.28	0.50	0.43	0.45	0.47	0.61	0.48	0.56	0.17	0.22	0.16	0.48	0.34	0.34	0.50	0.64	0.58	0.45	0.38	0.67	0.44

Conclusion

Morphometric analysis of watershed has a direct bearing on the complexity of denudational processes and the rate of morphological changes. The quantitative study of above parameter is important for river basin evaluation, water prioritization for soil and water conservation and natural resource management.

Geologically the study area belongs to CGGC showing multiple phases of tectonism affecting the drainage behaviour of the area. The drainage pattern varies from dendritic to sub dendritic to parallel with 6^{th} order drainage and the variation in mean stream length reflects the changes in slope and topography.

Various linear, areal and relief parameters of morphometric evolution were studied and discussed in relation to the hydrological process. The R_b of the studied basin suggest high overland flow and discharge due to hilly nature of the terrain and is under some structural control. The computed values of basin shape reveals that it is of elongated nature. The Dd of whole basin is 1.45km/km^2 suggesting uniform lithology and highly permeable subsurface with little structural disturbance. This is in conveyance with the low values of FS as 2.33Km^{-1}. The Kanchi River sub-basin has coarse drainage texture. The computed values of C for the SW suggest resistant rock with moderate to high infiltration, good vegetation and mature stages of watershed development. The relief parameters reveal the presence of low to moderate slope in form of ridges, residual hills and mounds underlain by resistant rocks. The low to moderate relief ratios are suggestive of strong groundwater prospects and limited watershed discharge capabilities. DI of the MW is 0.58, indicating that the watershed is moderately dissected. The low to moderate Rn suggest that the watershed is moderately prone to soil erosion.

The findings of morphometric study suggest that though the area is permeable with good vegetation cover it still requires some measure to check the sediment loss but may need more artificial recharge and water harvesting structures to conserve water for conjunctive used of water. The results of this study suggest that remote sensing and GIS techniques The findings of this study suggest that remote sensing and GIS techniques can be a useful resource for retrieving the morphometric parameters that define the geometry, shape, relief, and stream network analysis of a basin.

Conflict of Interest

There is no conflict of interest between the authors.

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