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Hypsometric Analysis of Sheonath River Basin, Chhatisgarh, India : A Remote Sensing and GIS Approach

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Abstract **- The present paper investigates the hypsometric properties i.e. area-altitude relationships of sub-watersheds of the Sheonath river basin. It is useful for understanding the geomorphic stages of a river basin. Hypsometric curve and hypsometric integrals are the important indicators of watershed conditions. The nature and shape of the hypsometric curve indicate the stage of watershed whether young or mature and can be used as an indicator of erosion susceptibility of the drainage basin. In the present paper, hypsometric analysis of 13 sub-watersheds of Sheonath river basin has been carried out and values of hypsometric integral have been computed. The values of the hypsometric integral in 11 watersheds has been found to be less than 0.3 indicating that these drainage basins have reached monadnock or stable stage with chances of low to moderate erosion, whereas two sub-watersheds have hypsometric integral value in the range 0.4-0.6 indicating equilibrium stage. The hypsometric integral value of Sheonath basin is 0.135 which indicates the basin has reached monadnock stage. There is a difference between the shape of the hypsometric curve of different watersheds which may be due to lithologic or structural differences. Remote sensing and Geographical information system provides an advanced and accurate tool to obtain hypsometric information and facilitates to compute the associated parameters of the landform.**

Keywords: Digital Elevation Model (DEM), Remote Sensing, Geographical Information System (GIS), Hypsometric Curve, Hypsometric Integral

I. INTRODUCTION

The hypsometric analysis is the study of the distribution of the ground surface area of a landmass with respect to elevation. The hypsometric analysis was introduced by Longbein (1947) to express overall slope and the forms of a drainage basin and further extended by Strahler (1952) to include percentage hypsometric curve and hypsometric integral. The hypsometric curve is a plot between percentage area to percentage elevation in a basin. The shape of the hypsometric curve explains the temporal changes in the slope of the original basin (Strahler,1952). The variation in the shape of the curve is frequent in the early geomorphic stage of development and becomes minimal when watershed attains a mature stage with the passage of time. Comparison of the shape of the hypsometric curve of different drainage basin under similar hydrologic condition provides a relative insight to the past movement of soil in the basin. Hypsometric curve and hypsometric integral are important morphological parameters indicating the health of a watershed. The hypsometric integral is an indicator of "cycle of erosion" which is the total time required for reduction of land area to the base level i.e. lowest level. The entire period of the cycle of erosion can be divided into three stages viz young stage (Hi >0.6) in which watershed is extremely susceptible to erosion; equilibrium or mature stage (Hi 0.3 to 0.6); and monadnock or old stage (Hi <0.3). Because hypsometric function combines the value of slope and surface area at any elevation of the basin, it might help to obtain more precise calculations of expected source of maximum sediment derived from surface runoff in a typical basin of a given order of magnitude (Strahler 1952). Besides erosional stage of landform evolution, the influence of tectonic activity, climatic and lithological factors controlling a landform evolution can be analyzed from hypsometric analysis (Lifton and Chase ,1992; Moglen and Bras, 1995; Willgoose and Hancock, 1998; Hurtrez and Lucazeau,1999; Chen et al,2003; Huang and Neimann, 2006). These surface elevations have been extensively used for topographic comparisons because of its revelation of three-dimensional information through two-dimensional approach (Harrison, 1983; Rosenblatt and Pinet,1994). Hypsometric analysis has been used by several researchers in India dealing with erosional topography (Pandey,2004; Singh,2008).

II. STUDY AREA

Sheonath river which is a tributary of Mahanadi river, originates from Panabaras hills, 624 m above mean sea level in Ambagarh chowky division of Rajnandgaon district of Chhatisgarh state. The river flows in north east direction for 380 km from its source and joins Mahanadi river near town Shivrinarayan. The drainage basin of Sheonath river is located between latitude 20^0 16' N to 22^0 41' N and Longitude 80^0 25' E to $82^0$35' E. The basin area of Sheonath river is 30,860 Sq Km and covers about 23 % area of Chhatisgarh state. The mean annual rainfall in the basin varies from 1005 mm to 1566 mm. The location map of the basin is shown in figure 1.

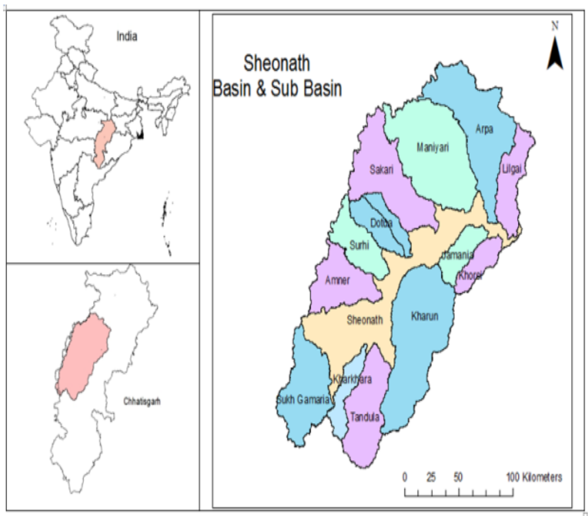

Figure-1: Location Map of Sheonath River Basin

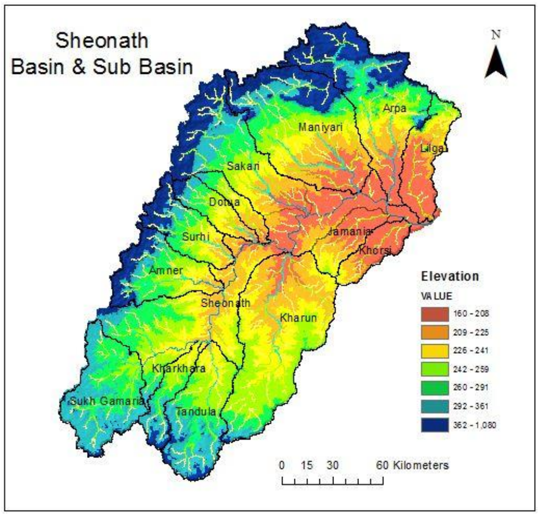

Figure-2: Elevation Map of Sheonath River Basin

The shape of the basin is elongated with higher elevation on western part of the basin whereas estern part is comparatively flatter. Sub watersheds Amner, Surhi, Dotua, Sakri, Maniyari and Arpa whish lie on the western side of main river has a relief more than 500 metre, whereas those situated on the eastern side have low relief range which continuously decreases as the we go towards mouth of river, for Jamania and Khorsi watershed it is even less than 100 metre.

III. MATERIAL AND METHODS

Data used for the Hypsometric analysis was Cartosat-I Digital Elevation Model (DEM), which were downloaded from Bhuvan, Indian Geo Platform of ISRO, bhuvan.nrsc.gov.in. Software ArcGIS 9, ArcMap version 9.3 was used for the analysis. The downloaded tiles of the area were mosaiced and modified by filling the sink. Flow direction and flow accumulation map of the basin was prepared using spatial analyst tool. The Digital Elevation Map of the Sheonath basin with stream network is given in Figure- 2. Sub-watersheds of the Sheonath basin were delineated and hypsometric analysis of each subwatershed was carried out. The elevation map of each watershed was reclassified into 20 equal intervals. Figure-3 shows the reclassified map of all 13 sub-watershed of Sheonath river basin and Figure-4 shows the reclass map of Sheonath river basin. Percentage area at each interval of 1/20th of total relief was computed by counting the number of pixel falling in that interval. The relative areas corresponding to relative relief at 0.05 interval were computed by dividing it by the total number of pixels. The relative elevation and corresponding relative area for sub-watersheds of the Sheonath basin have been computed and tabulated in Table-1.

The hypsometric curve can be represented by an equation x=f(y) also known as hypsometric function. When the hypsometric function is integrated between the limits of x=0 to x= 1, a measure of landmass volume with respect to total landmass volume above the horizontal plane passing through outlet is obtained. This integral is designated as hypsometric integral and denotes the area under the hypsometric curve. Hypsometric integral (Hi) which is equivalent to elevation relief-ratio (E) as proposed by Pike and Wilson (1971) is computed by the relationship

$$E = Hi = \frac{\text{Elevation (mean)} - \text{Elevation (min)}}{\text{Elevation (max)} - \text{Elevation (min)}}$$

Elevation (max) and Elevation (min) are the maximum and minimum elevations within the watershed and Elevation (mean) is the weighted mean elevation of the watershed. The Elevation (max) and Elevation (min) were found out from the DEM of the watershed and Elevation (mean) was obtained by the formula

$$Elevation\ (mean) = \frac{\sum \text{NiEi}}{\sum \text{Ni}}$$

Ni is the number of the pixel corresponding to elevation Ei in digital elevation model of a watershed which was obtained from the attribute table of respective DEM.

IV. RESULT AND CONCLUSION

A. Hypsometric Curve Coordinates

The coordinates of hypsometric curve i.e. relative area vs relative elevation for 13 sub-watersheds have been computed and tabulated in Table-1 and Table-2.

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TABLE-1 : HYPSOMETRIC CURVE CO-ORDINATES OF SUB WATERSHEDS LILAGAR, ARPA, MANIYARI, SAKARI, DOTUA, SURHI, AMNER SUB WATERSHEDS

elative elevation h/H	Relative area a/A						
	Lilagar	Arpa	Maniyari	Sakari	Dotua	Surhi	Amner
1.00	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.95	0.00011	0.00094	0.00160	0.00159	0.00060	0.00030	0.00058
0.90	0.00030	0.00487	0.00635	0.00748	0.00259	0.00160	0.00216
0.85	0.00082	0.00912	0.01064	0.01506	0.00438	0.00490	0.00532
0.80	0.00160	0.01132	0.01335	0.02234	0.00557	0.01659	0.01016
0.75	0.00223	0.01436	0.01620	0.03271	0.00724	0.03397	0.02065
0.70	0.00283	0.01787	0.01986	0.04593	0.00965	0.05907	0.04056
0.65	0.00366	0.02400	0.02451	0.06268	0.01318	0.08804	0.05799
0.60	0.00449	0.03567	0.03045	0.08509	0.01934	0.11160	0.07744
0.55	0.00558	0.05379	0.03839	0.10777	0.02864	0.12847	0.09938
0.50	0.00681	0.07733	0.04749	0.13029	0.04265	0.14360	0.12482
0.45	0.00815	0.12279	0.06327	0.15422	0.05821	0.16169	0.15563
0.40	0.00988	0.22353	0.09071	0.17951	0.07294	0.18695	0.18844
0.35	0.01256	0.30102	0.13219	0.20548	0.08709	0.22172	0.22687
0.30	0.01640	0.33733	0.17027	0.24999	0.10061	0.27222	0.27291
0.25	0.02283	0.36918	0.21857	0.29960	0.13227	0.32226	0.33032
0.20	0.06278	0.40256	0.28257	0.35861	0.23212	0.36969	0.38293
0.15	0.15846	0.47710	0.34896	0.47303	0.37927	0.44986	0.46839
0.10	0.41053	0.65268	0.52414	0.61905	0.57828	0.64487	0.67508
0.05	0.88325	0.90701	0.86043	0.83451	0.90909	0.90098	0.90472
0.00	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000

TABLE-2 : HYPSOMETRIC CURVE CO-ORDINATES OF SUKHGAMARIA, KHARKHARA, TANDULA, KHARUN, JAMANIA, KHORSI SUB WATERSHEDS AND SHEONATH BASIN

Relative elevation h/H	Relative area a/A						
	Sukhgamaria	Kharkhara	Tandula	Kharun	Jamania	Khorsi	Sheonath
1.00	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.95	0.00001	0.00007	0.00001	0.00035	0.00002	0.00004	0.00009
0.90	0.00005	0.00018	0.00011	0.00201	0.00265	0.00203	0.00050
0.85	0.00017	0.00045	0.00031	0.00509	0.01356	0.00996	0.00106
0.80	0.00035	0.00072	0.00062	0.00810	0.04144	0.02381	0.00199
0.75	0.00064	0.00097	0.00119	0.01172	0.08050	0.05147	0.00344
0.70	0.00122	0.00132	0.00209	0.01425	0.13269	0.09112	0.00504
0.65	0.00201	0.00286	0.00338	0.01778	0.18384	0.13151	0.00697
0.60	0.00363	0.00613	0.00509	0.02163	0.25467	0.18895	0.01038
0.55	0.00648	0.01248	0.00748	0.02707	0.33573	0.25625	0.01521
0.50	0.01122	0.02736	0.01124	0.03366	0.42682	0.33379	0.02310
0.45	0.02377	0.06095	0.01769	0.04381	0.53422	0.41211	0.03526
0.40	0.05620	0.11467	0.03442	0.07458	0.65539	0.52400	0.05500
0.35	0.14055	0.20036	0.09125	0.18637	0.76621	0.64470	0.07438
0.30	0.28906	0.29437	0.20162	0.37743	0.83982	0.73353	0.09300
0.25	0.47550	0.37906	0.32066	0.56198	0.91373	0.83802	0.11613
0.20	0.66830	0.45723	0.44837	0.76463	0.96188	0.92420	0.16174
0.15	0.85246	0.57302	0.56736	0.91213	0.98942	0.96609	0.26116
0.10	0.96317	0.78569	0.83365	0.99223	0.99850	0.99185	0.47664
0.05	0.99951	0.97459	0.99669	0.99990	0.99987	0.99939	0.87455
0.00	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000

B. Relative Area Map

The relative area map of sub-watersheds shows the distribution of area with respect to relative elevation. Total elevation of each watershed was divided into 20 equal parts and the DEM of each sub-watershed was reclassified corresponding to these elevation values. The map does not show the absolute elevation value but shows the distribution of horizontal area in percentage elevation range considering each sub-watershed as a separate unit. Thus it presents a clear picture for comparison of the distribution of horizontal area among different watersheds.

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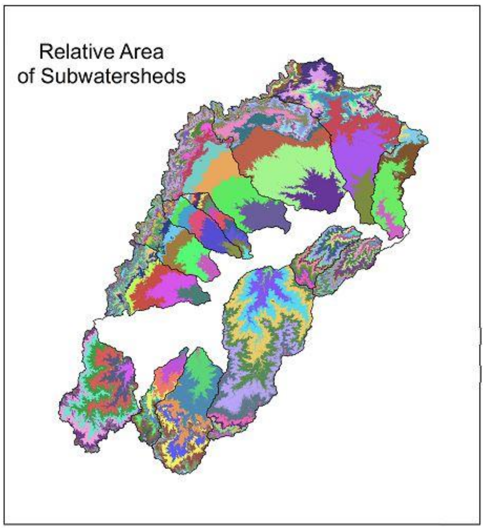


Figure-3 Relative Area Map of Sub watersheds of Sheonath River Basin

Figure-4 shows the distribution of horizontal area with respect to relative elevation of Sheonath river basin as a whole. It is clear from the observation that the distribution of area in lower relative elevation ranges is very high as compared to than that in higher elevation ranges indicating the larger landmass distribution in low lying areas resulting in a very low value of hypsometric integral.

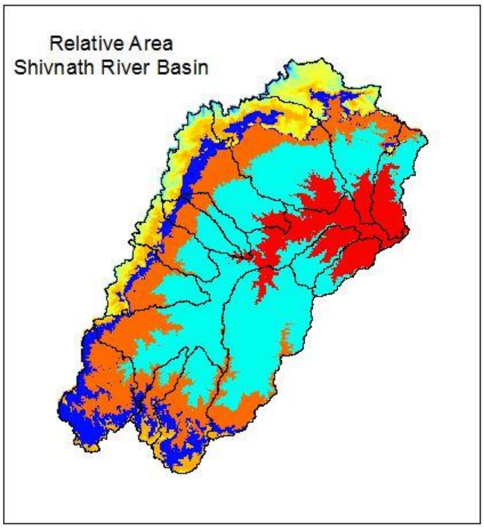
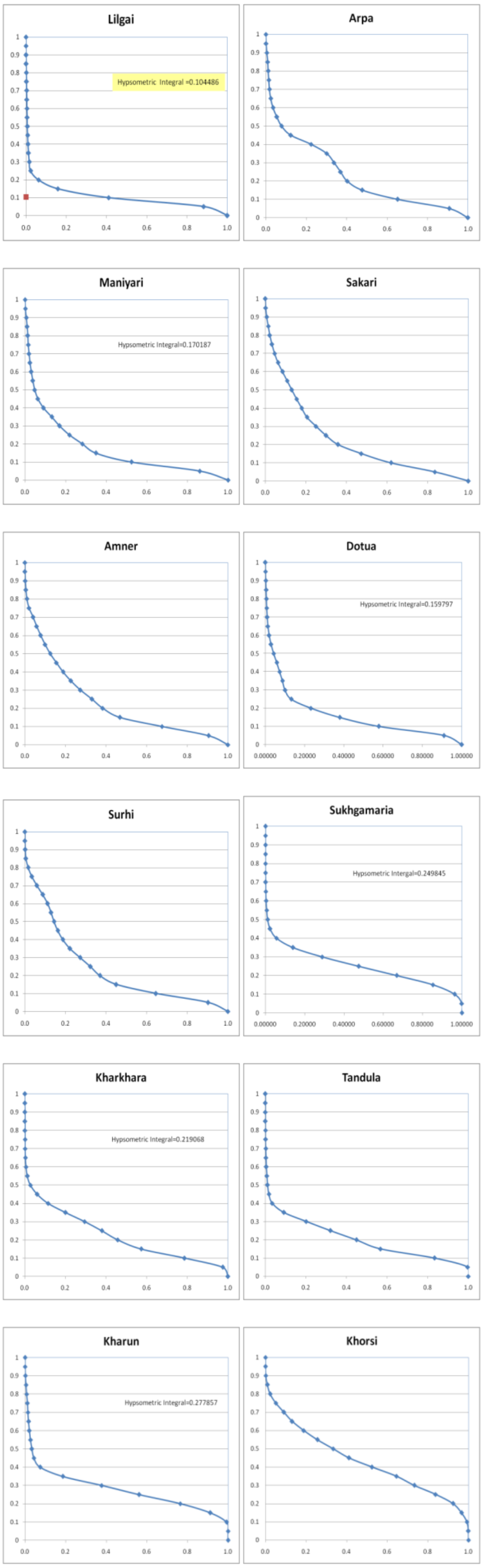


Figure-4 Relative Area Map of Sheonath River Basin

C. *Hypsometric Curve*

The hypsometric curve exhibits its widest range of forms in the sequence of drainage basins commencing with early youth (in equilibrium stage), progressing through full maturity (equilibrium stage) and attaining temporarily the monadnock phase of old age.



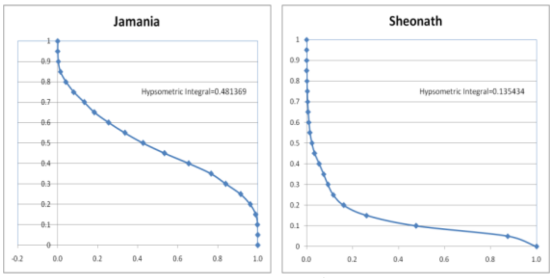


Figure-5 : Hypsometric curve of Sheonath River and its Sub watersheds

From the analysis of the hypsometric curves of the sub watersheds it has been observed that the each curve has distinct characteristics and shape. Hypsometric curve of some watersheds falls sharply at initial stage which indicate very steep slope in upper region. Hypsometric curve of sub watersheds Lilagar, Dotua, Sukhgamaria, Kharkhara, Tandula, Kharun have similar pattern with with unform slope at higher relative area with small convexity at the end. Hypsometric curve of Maniyari, Sakari, Amner and Surhi show a concave pattern throughout the length with small convexity at the end. However the steepness of slope of hypsometric curve does not represent the steepness of slope in the watershed because it depends upon the average length of contour in a given elevation range. Only in a condition when all the contours are equal length the slope of hypsometric curve will resemble the slope of the ground. The hypsometric curve of Jamania and Khorsi indicate the equilibrium stage of watershed.

D. *Hypsometric Integral*

The area, total relief, maximum, minimum and mean elevation and hypsometric integral value of sub watersheds and Sheonath basin has been tabulated in table-3.

TABLE-3 : AREA, TOTAL RELIEF, MAXIMIM, MINIMUM AND MEAN ELEVATION AND HYPSOMETRIC INTEGRAL OF SUB WATERSHEDS AND SHEONATH BASIN

S. No.	Sub Basin Name	Area in sq km	Relief in m	Elevation			Hypso-metrical Integral	Stage
				Max.	Min.	Mean		
1	Lilagar	1447	594	752	158	215.58	0.105	Monadnock
2	Arpa	3952	914	1076	162	368.57	0.227	Monadnock
3	Maniyari	4580	799	970	171	304.48	0.170	Monadnock
4	Sakari	3192	729	913	184	343.85	0.219	Monadnock
5	Dotua	860	523	712	189	272.57	0.160	Monadnock
6	Surhi	1434	557	754	197	325.63	0.231	Monadnock
7	Amner	1902	547	750	203	327.48	0.228	Monadnock
8	Sukhgamaria	2557	298	532	234	298.70	0.250	Monadnock
9	Kharkhara	862	366	583	217	291.71	0.219	Monadnock
10	Tandula	2359	434	648	214	289.67	0.202	Monadnock
11	Kharun	4797	203	387	184	236.07	0.278	Monadnock
12	Jamania	915	97	258	161	207.69	0.481	Equilibrium
13	Khorsi	815	92	253	161	199.49	0.431	Equilibrium
14	Sheonath	30860	919	1079	160	284.46	0.135	Monadnock

Jamania and Khorsi sub watershed have an integral value of 0.481 and 0.431 respectively indicating these watersheds have attained an equilibrium stage. The value of the hypsometric integral of other sub-watersheds is less than 0.3. Out of remaining 11 watersheds two have the value of hypsometric integral in the range of 0.25-0.3, seven sub-watersheds in the range of 0.2-0.25 and remaining two watersheds have the value less than 0.2. These values indicate that these watersheds are in monadnock phase of old age. The hypsometric curve of Sheonath river indicates the monadnock stage of the watershed with a hypsometric integral value of only 0.135.

V. DISCUSSION

The hypsometric analysis of a drainage basin has several applications both hydrologic and topographic. Variation in precipitation, runoff and temperature with change in altitude is an indication of utility of area-altitude distribution curve. Since the hypsometric function combines the value slope and surface area at any elevation, it might help to obtain a more precise computation of expected source of sediment derived from surface runoff in a typical basin. Erosion control measures and land utilization planning can be done more effectively from topographic analysis where hypsometric qualities are quantitatively stated.

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