Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol. 4, No.3, 2014

Determination of Stages of Landscape Evolution of Sankha Nadi, Jharkhand; an Integrated Approach of Morphometry and GIS

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Abstract

The idea of stages of landscape evolution related to Davis. With this kind of understanding we can easily understand the nature and the present geomorphological status of that particular drainage basin as well as the rate of erosional activity going on. In understanding the stage of landscape evolution we have derived chief and dominant variables, with the help of GIS, responsible for the present day landscape as it play a significant role for shaping the landscape, and through discussion and analysis of these variables we come to an end.

Keywords: Stages of landscape evolution, Geomorphological status, Sankha Nadi,

1. 0 Introduction

Geomorphologically drainage basin morphometry can be divided in to mainly three categories such as linear, areal ad relief aspect. The relief aspect of the basin are related to the study of three dimensional features of the basis involving area, volume ad altitude of vertical dimensions of landform wherein different drainage basin morphometric methods and GIS are used to analysis terrain characteristics, which are the result of basin processes (Singh S., 2002) and these are the indicative of the potential energy of a drainage basin system by virtue of elevation of above a given datum (Prashad N., 1985).

2.0 Objective

Relief aspects are indicative of the potential energy of a drainage basin system by virtue of elevation of above a given datum (Prashad N., 1985) and these are an important aspect of evaluating of a stage of landscape evolution of a drainage basin. My main objective of this study is to evaluate the stage of landscape evolution of SankhaNadi drainage basin through measurement of relief aspect with the help GIS.

3.0Database and methodology

For this investigation several literatures based on this topic as well as on the region collected from several sources. Topographical sheets of 73 J/6, 73J/7 & 73J/1 (1:50,000 scale) published by Survey of India in 1978 on polyconic projection system of this area have been collected. To extract the relief aspect, total basin area has been divided in to 436 grid of one square km. grid and then extraction of different morphometric variables of the Sankha Nadi drainage basin done with the help of GIS software done and then interpretation and analysis have been done. Then dominant factors responsible for present day landscape identified through Principle Component Analysis. After extraction of dominant factors, we are going to in detail discussion of these variables so that we can achieve our goal of determination of stage of landscape evolution in a very precise manner.

4.0 Study Area

The SankhaNadi, a right bank sub-tributary of Subarnarekha River is a museum of geology and geomorphology. Administratively belongs to the East Singhbhum district of Jharkhand. It possess a rich panorama of geological history from Precambrian to present with distinctive geological events as well as rich topographical features characterized by structural hills, scarps zones, multiple erosional surfaces, high rise cliffs and residual hills (dungri) etc. The basin has been tectonically active over a long period of time. Rejuvenation of the topography in late Tertiary times and tilting of the Singhbhum plateau south east consistent with uplift resulted the development of relatively shorter and smaller tributaries, among which SankhaNadi is one of them. The extensive level surfaces in many parts of the basins are related to complex geomorphological history involving several cycle of erosion. The general shape of the basin area is more or less circular and its general slope as well as elevation gradually comes down in the direction from south-west towards north-east following the main trunk stream. An extensive area lies between 100 to 300 metres.

5.0 Geology of the Basin

Geologically this region belongs to the Dhanjhori highlands of south-east Chotonagpur Plateau. The Basin has glimpses of ancient Dharwar formation (Mica Schists and Phyltite), Dhanjhori stage (Sandstone and Conglomerate), Iron-ore Stage, Dhanjori Basalt, Singhbhum Granite etc. this region belongs to Red-loamy to lateritic soil with the presence of thick morum bed. Four possible erosion surfaces (i.e. 600, 450, 300 and 150 meters) are identified by D.P.P. Satpathi in 1971. Climatically moderate to Selva Morphogenetic region (after Peltier, 1950). Most important processes- Sheet wash, Rill wash, Gully erosion, valley incision, moderate to high chemical weathering, pluvial erosion, Laterisation, Physiographically this region is mainly hilly in nature most of the area is under dense mixed jungle mainly Sal to fairly dense mixed jungle mainly Sal, Fairly dense mixed jungle mainly Douta, Open mixed jungle mainly Sal, Open mixed jungle, Dense mixed jungle 64.25% of total area is under forest condition.

6.0 Drainage Basin Characteristics

The first step in morphometric analysis is Stream ordering Stream ordering (Strahler A. N., 1957).In studying Sankha Nadi Drainage Basin Ranking of streams has been carried out based on the method proposed by Strahler (1964) and we have found 6thorder hierarchical stream order in total, these are arranged in a systematic manner and the following facts of the drainage basin came into light (Table: 1).

There are different kinds of morphometric variable in drainage basin and they together sculpture the present day landscape, among which some of them act as a major role in determination of the nature of present day landscape development. Since the morphometric and hydrologic variables do not work in isolation but as closely interlinked phenomena, a multivariate analysis seems to be quite necessary to find out the relative importance of each variable (Sen P.K., 1993). In this portion eight morphometric variables of Sankha Nadi drainage basin for extracting of the major morphometric variable responsible for preset status of the Sankha Nadi done statistically by Principle Component Analysis (PCA)

At first twelve morphometric variables are selected to find out the dominant variables based on grid mesh data. The Pearsonian Product Moment correlation matrix is not positive definite. Among them relief properties (other Absolute Relief, Relative Relief, Average Relief, Dissection Index, Ruggedness Index and Average Slope) are strongly related to each other whereas correlations of other variables are insignificant With 50.12% explanation of 1st principle component ruggedness index is the chief determinant of the drainage basin properties; side by side it is clear that relief properties are the dominant variables responsible for the drainage basin development.

7.0 Discussion and Analysis

7.1 Absolute Relief: SakhaNadi drainage basin express elevation ranges 77m to 765m. Maximum elevation mainly located along the drainage divider of the basin in a continuous manner and it rapidly comes down to 200m, from this contour gradual declination of elevation noticed. This indicates presence of structural hills. Maximum area of the basin belongs to 100m to 300m contour indicate presence of vast plain land surfaces, which suggest this drainage basin belongs to mature stag of landscape evolution. So from this discussion we can conclude that the Sankha Nadi basin has experienced epeirogenetic uplift, and is characterized by intrusive bodies with vast planation surface, i.e. this basin belongs to mature stage with presence of intrusive structural hills.

7.2 Relative Relief: Relative relief is one of spatial analysis of average slope; the term introduced by G.H. Smith (1945) to ascertain the virtually the difference between maximum and minimum elevations of a particular area. It is noticed that the high values of Rr indicate steep slope and high relief (250 m), while the lower values may indicate the presence of basement rocks that are exposed in the form of small ridges and mounds with lower degree of slope (GIS 1981). Lines of equal relief provide a better idea of relief than general contour map of the area, since they are a measure of general steepness though not of local steepness” (Fairbridge, 1963). Rr of SankhaNadi within an area of one sq. km. grid ranges from 6m to 374m. Maximum Rr of >300m lies above the contour of 350m covering an area of only 3.22% of the total basin. This suggests that these represent hill tops. Side by sideRr of >225m lies above 200m covering an area of only 14.7% of the area. So such extremes values are limited to a few grids onlyand the continuous nature of these grids along the margin of the basin reveal that the basin possesses a numbers of high and extensively continuous structural hills, as well as it alsothat suggested that the basin is not dissected by high Rr extensively. 60.46% of the area lies in low relative relief. Moderate Rr of 150m to 225m covering an area of 24.83% starting from base of the structural hills ad characterized by presence of scattered hills (*Dungri*). The region of low Rr extends to the whole lower SankhaNadi basin is an area of vast area of planation surface. Lastly it may be said that most of the area of SakhaNadi belongs to the low to moderate Rr. It may, therefore, be concluded that this basin is most probably in mature stage.

7.3 Average Relief: Average relief is the expression of intensity of relief of a particular area (Prasad N, 1985). Average relief is the mean elevation of maximum and minimum elevation of one sq. km. grid.Ar ranges from 85m to 655m. Ar of SankhaNadi. But most of the area (63.07%) remain in low average relief ranging from 85m to150m, along with moderate average relief occupy 24.54% area of the basin and only 12.38% area is under high average relief.

A comparative study of physiography and average relief indicates that the basin is not highly dissected rather it present undulating surfaces of varying elevations along with we have said earlier that the region is characterized by entrenched river valley in most of the cases it is due to epiro-genetic uplift.

7.4 Dissection Index: Dissection index (Di) is a ratio between maximum relief and to the maximum absolute relief, it is an important indicator of how much dissection has occurred on the terrain and it gives us a clue of landscape development under the preview of fluvial geomorphic cycle of erosion. By this kind of morphometric measurement we can identify whether the regions belongs to youth, mature or old stage, it further indicates slope regions.In this study area of SankhaNadi drainage basin average index value is 0.34 which indicates the mature stage of erosion of this basin. Very high Di value (>0.55) found mainly along the eastern part of the basin due to presence of high rise cliff, high Di value is more or less continuous along the outer erosional fringe of the hilly regions and in case of eastern part the basin its concentration is much more higher as this area is associated with frequent deep cut river valley. The high degree of Di value on the scarps and hills indirectly suggest that these relief features are not the product of denudation as a whole, but these features have suffered from tectonic activity. The hills are no doubt, the intrusive bodies or remnants of older mountain chain, which being resistance to erosion have maintained their high degree of slope to produce the high dissection index.The zones of medium Di value (33.56%) embrace mainly parallel to foot hills. The zone of moderate and high Di value zones in some places is characterized by deep river valleys due to presence of high isolated hills and scarps of closer contour.Low and very low Di is concentrated in the lower central part of the basin, and from this figure it is clear that due to epiro-genetic activity it becomes narrower in its lower course.The high dissectio idex on the scarps and hills indicate that these relief features are not only the product of the denudation as a whole but these features have suffered from tectonic events and leads to the development of high rise scarps epeirogenetically.

7.5 Average Slope: Slope defined as angular inclinations of terrain between hill-tops and valley bottoms, resulting from the combination of many causative factors like geological structure, absolute and relative reliefs, climate, vegetation cover, drainage texture and frequency, dissection index etc. (Singh S. and Srivastava R., 1975). In case of slope analysis of Sankha Nadi method of Wentworth (1930) has been followed. Maximum average slope of this region has been found to be 26^{o} degrees and minimum of 0.04^{o}, very high average slope mainly concentrated in the outer boundary characterized by hilly range, deep cut river valley, high rise scarps it indirectly indicate these are intrusive bodies and towards from it average slope gradually decline. The gradual decline of average slope noticed in all the sub-watershed also of this drainage basin. If we notice the distribution of average slope then we will find out that increasing area with decline slope. Greater percentage of area (733%) is under very low ($<5^{o}$) to medium (10^{o} -15^{o}) that shows presences of vast plantation surfaces and posses mature to late mature stage of erosion.

7.6 Hypsometric analysis: After taking all the dominant variables for better understanding another additional measure of relief propertied have taken, i.e. Hypsometric analysis. Hypsometric analysis deals with measurement of relationship between basin area and altitude of basin. There are several techniques to deal with hypsometric analysis of a drainage basin e.g. area height curve, hypsometric curve, percentage hypsometric curve etc. The idea of hypsometry was introduced by Langbein & Basil in 1947 and was later extended by Strahler (1952) to include the percentage hypsometric curve (area-altitude curve) and the hypsometric integral. Historically, hypsometry has been used as an indicator of the geomorphic form of the catchments and landforms. It is strongly dependent on the channel network and catchment geometry. Hypsometric analysis is the useful procedure to identify the erosional stage of this drainage basin. Hypsometry of Sankha Nadi (Fig: 1- 0) shows the presence of several leveled curved indicates the presence erosional surfaces at those levels of erosional topographic elevations that region belongs to the polycyclic topography with multiple erosional surfaces.

8.0 Conclusion

From our above discussion and analysis it is clear that the chief determinant of the drainage basin development is ruggedness index, along with major determinants are relative relief, absolute relief, average relief, average slope, so, basically here relief features play the key role in shaping the landform. Relief measures of this study shows that spatial variation of these variables resulted from the epeirogenetic upliftment, which leads to the development of structural hills, scarps zones, multiple erosional surfaces, high rise cliffs and residual hills (*dungri*) etc..

Analysis of relative relief, absolute relief, average relief, average slope and dissection index shows that presences of high rise scarps in a continuous manner associated with high degree of slope, high degree of relative relief, dissection index, and ruggedness index indicate, presence of deep cut river valley, intrusive bodies resulted from epeirogenetic upliftment. Presences of different small isolated residual hills namely *buru* and *dungri* and vast plantation surfaces at different elevation directly shows multi cyclic nature of the drainage basin. Greater percentage (>45 %) of the area of Sankha Nadi of all the variables discussed above comes under medium to low category, that indirectly indicates mature stage of landscape development. Hypsometric curve also shows the presence of several leveled curved indicates the presence of erosional surfaces at those levels of erosional topographic elevations that region belongs to the polycyclic topography with multiple erosional surfaces whereas hypsometric integral (HI) value 0.28 (Fig. No.6) shows that the whole basin belongs to mature to senile topography. So from all the above relief measures leads to the conclusion that most of the area of the basin is in low lands associated with residual hills and few but continuous area is under upland area characterized by deep narrow cut valley, high rise scarps. Therefore the basin is most probably within mature stage with intrusive character, better say; it is progressing towards old stage but obstacle by intrusive nature of the Sankha Nadi basin due to epeirogenetic upliftment.

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Table-1: Stream hierarchy of total Sankha Nadi drainage basin

Order (u)	No. of Segments (N_u)	Bifurcation Ratio (R_b)	Total Length (Km.)	Mean Length in km. (*Lsm*)	Cumulative Mean Length km. (L_u)	Length Ratio ($R_L=L_u/L_{u-1}$)
1st order	780	-	442.44	0.57	0.57	
2nd	182	4.286	176.1	0.97	1.54	2.702
3rd	48	3.792	106.87	2.23	3.2	2.078
4th	11	4.364	53.547	4.87	7.10	2.219
5th	3	3.667	37.04	12.3	17.17	2.418
6th	1	3.000	14.75	14.8	27.1	1.578
Mean		(Rbm)=3.822		5.96		2.199

Source: Computed from Topographical Maps with the help of Arc GIS 9.3

Table-2: Pearsonian Product Moment correlation matrix

Variables	Ar	Rr	AvgR	Di	Sf	Dd	Ri	Sh	Cf	As	CCM	LOF
Ar	1	**0.86**	**0.99**	0.5	0.44	0.23	0.75	0.55	0.2	**0.87**	-0.1	0.23
Rr		1	0.75	**0.83**	0.38	0.18	**0.85**	0.48	0.16	**0.84**	-0.09	0.18
Avg.R			1	0.36	0.43	0.22	0.66	0.54	0.2	**0.82**	-0.09	0.22
Di				1	0.32	0.2	0.71	0.33	0.17	0.62	-0.08	0.2
Sf					1	0.62	0.54	0.53	0.75	0.47	-0.15	0.62
Dd						1	0.58	0.14	0.63	0.25	-0.24	**1**
Ri							1	0.41	0.41	0.74	-0.14	0.58
Sh								1	0.09	0.6	-0.08	0.14
Cf									1	0.22	-0.13	0.63
As										1	-0.11	0.25
CCM											1	-0.2
LOF												1

Absolute Relief (Ar), Relative Relief (Rr), Average Relief (Avg.R), Dissection Index (Di), Ruggedness Index (Ri), Stream Frequency (Sf), Source Head (Sh), Confluence Point (Cp), Average Slope (As), Constant of Channel Maintenance (CCM) and Length of Overland Flow (LOF)

Table 3. Extraction of principle and dominant factors with cumulative percentages of varibles

Vaeiables	Max-Rr	Rr	Avg R	Di	Sf	Dd	Ri	Sh	Cf	Avg.S	CCM	LOF
PCA 1 50.12%	**0.87**	**0.86**	**0.81**	0.67	0.72	0.6	**0.91**	0.6	0.5	**0.87**	-0.2	0.57
PCA 2 70.63%	-0.37	-0.41	-0.34	-0.3	0.43	0.8	0.01	-0.2	0.7	-0.3	-0.2	0.75
PCA 3 78.66%	0.07	-0.17	0.15	-0.3	0.33	-0.1	-0.2	0.3	0.2	0.02	0.69	-0.1

PCA 1,2 and 3 = Principle Component Analysis 1,2 and 3

Table-4: Distribution of relative relief of the Sankha Nadi drainage basin

SankhaNadi	Relative Relief (Rr), Area in sq. km.				
	Very High Rr>300	High Rr225-300	Medium Rr225-150	Low Rr75-150	Very Low Rr<75
	High		Moderate	Low	
Area in Sq. Km.	14	50	108	112	151
% of Area	3.22	11.49	24.83	25.75	34.71

Table-5: Distribution of average relief of the Sankha Nadi drainage basin

SankhaNadi	Average Relief (Ar), Area in sq. km.				
	Very High Ar >600	High Ar 450-600	Medium Ar 300-450	Low Ar 150-300	Very Low Ar <150
	High		Moderate	Low	
Area in Sq. Km.	11	43	107	118	157
% of Area	2.52	9.86	24.54	27.06	36.01

Table-6: Distribution of dissectionindex of the Sankha Nadi drainage basin

SankhaNadi	Dissection Index (Di)/Sq.km.				
	Very High >0.55	High Rr 0.40-0.55	Medium Rr 0.25-0.40	Low Rr0.10-0.25	Very Low Rr<0.10
	High		Moderate	Low	
Area in Sq. Km.	32	131	146	111	15
% of Area	7.36	30.12	33.56	25.52	3.45

Source: Computed from Topographical Maps

Table- 7: Distribution of Average Slope

Name of the Basin	Distribution of Average Slope (Area in sq. km.)				
	Very High $>20^o$	High 15^o -20^o	Medium 10^o -15^o	Low 5^o to 10^o	Very Low $<5^o$
Total Basin	15	79	107	99	135
Area in %	3.45	18.17	24.60	22.3	31.03

Source: Computed from Topographical Maps

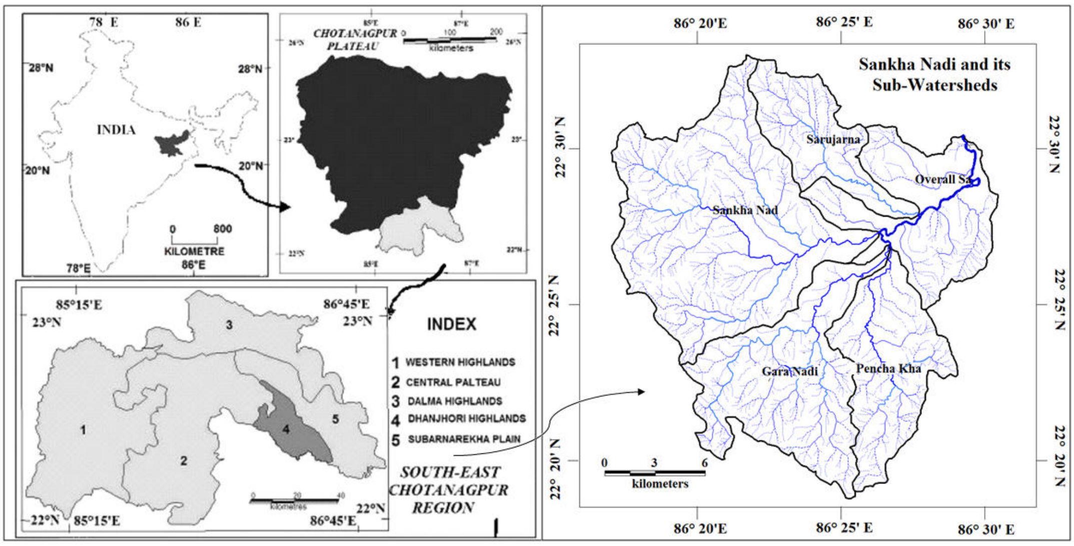

Figure 1. Location Map of the Study Area

South of Copper Belt Thrust | North of Copper Belt Thrust

-------------- End of Singhbhum orogenic cycle --------------------
(ca. 850 ma)

South of Copper Belt Thrust	North of Copper Belt Thrust
Granite gneiss, granophyres, gabbro-anorthosites	Granite and granophyres
Ultrabasics	Dalma lava
Kolhan Group(metasedimentaries) (ca. 1500- 1600 ma.)	——overlap——
Dhanjori formation: volcanics and sediments	singhbhum Group: Dhalbhum Formation, Chaibasa Formation

---------------- - - Unconformity ----------------------------

—— End of I.O. orgenic cycle ——
(ca. 2900 ma.)

Singhbhum gra
Epidiorite
Iron Ore Group: sedimentaries and volcanics (slightly more metamorphosed)

----- - Unconformity -----------

——End of older metamorphic cycle——
(ca. 3200 ma.)

Granitic and basic rocks
Older metamorphic group: moderate to high grade metasedimentaries and basic intrusives

Figure 2. Stratigraphic sequence of Precambrian rocks of Singhbhum after Sarkar & Saha (1977) and Sarkar et al. (1979).

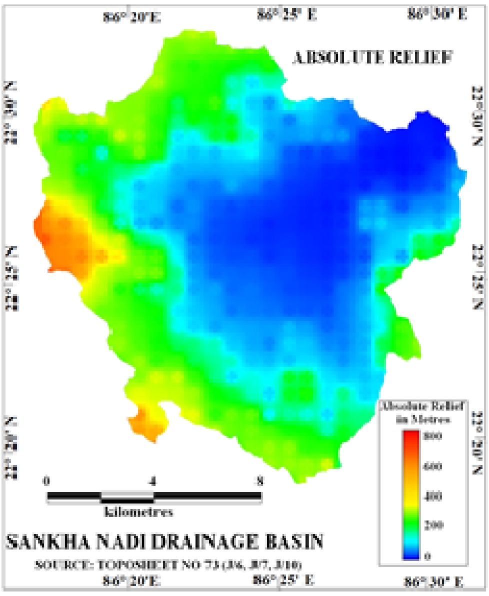

Figure 3. Absolute Relief of Sankha Nadi drainage Basin

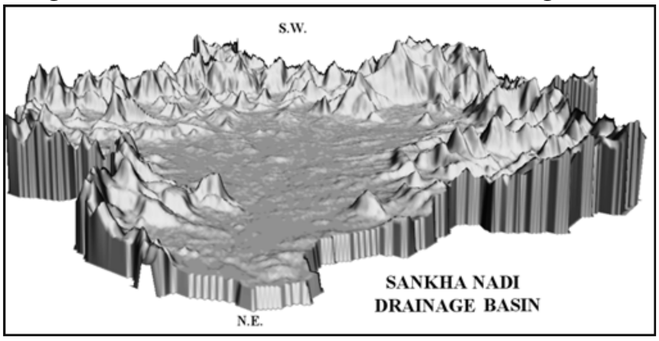

Figure 4. Digital Eleviation Model of Sankha Nadi prepared with the help of Erdas Imagine 9.2

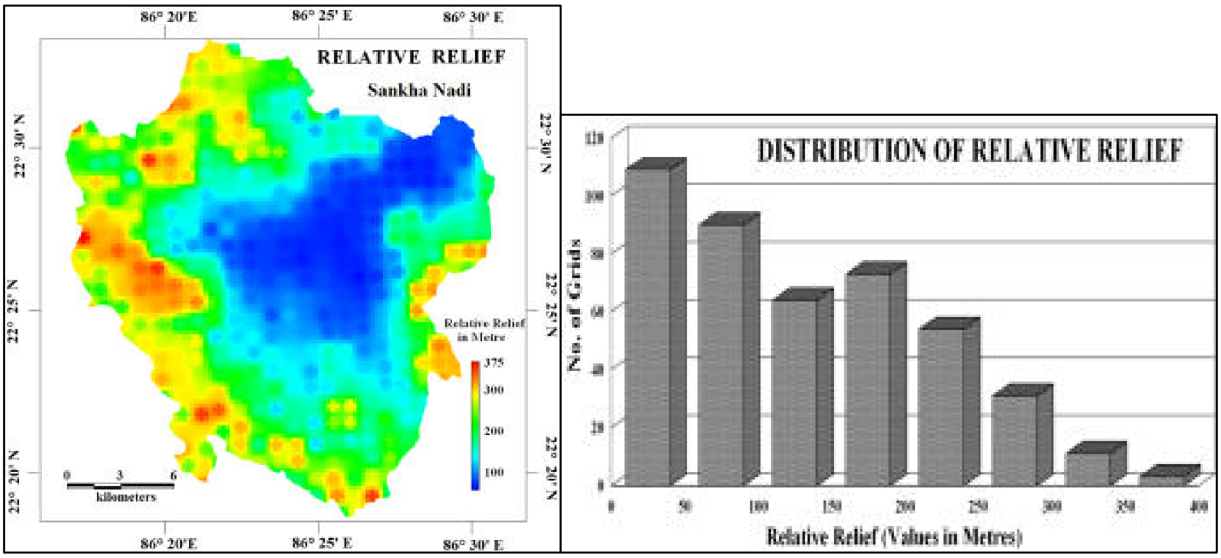

Figure 5. Relative relief of Snkha Nadi

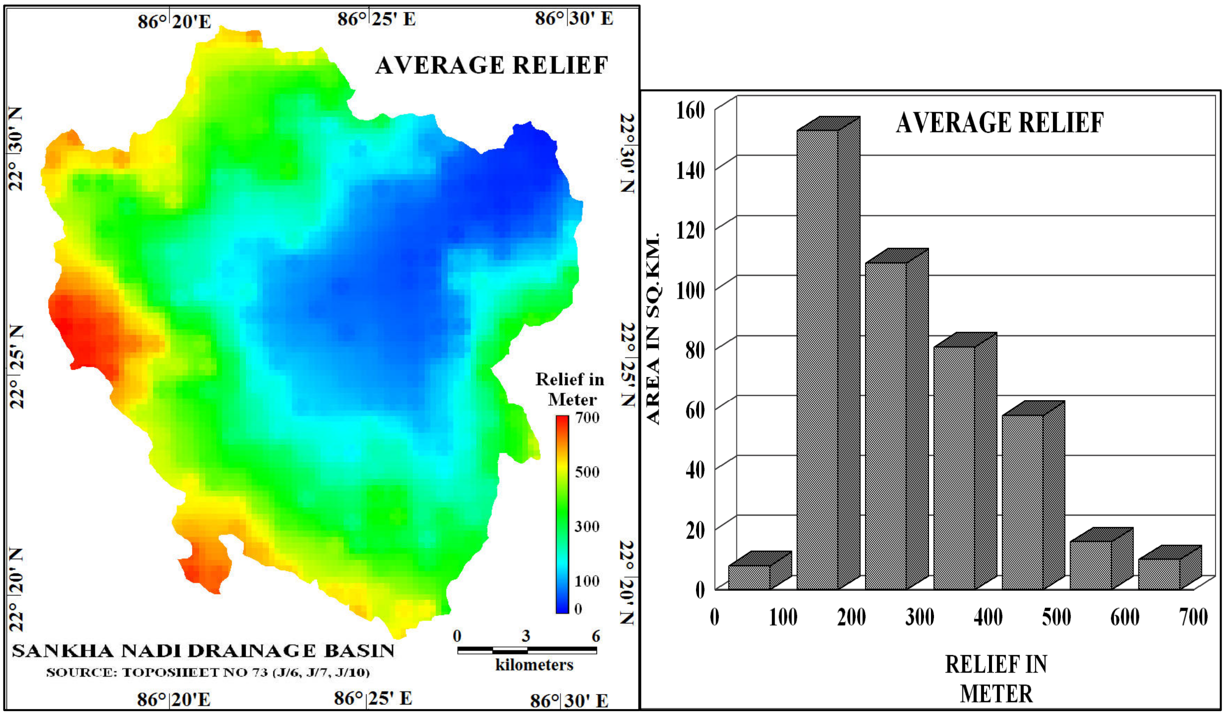

Figure 6. Distribution of average relief

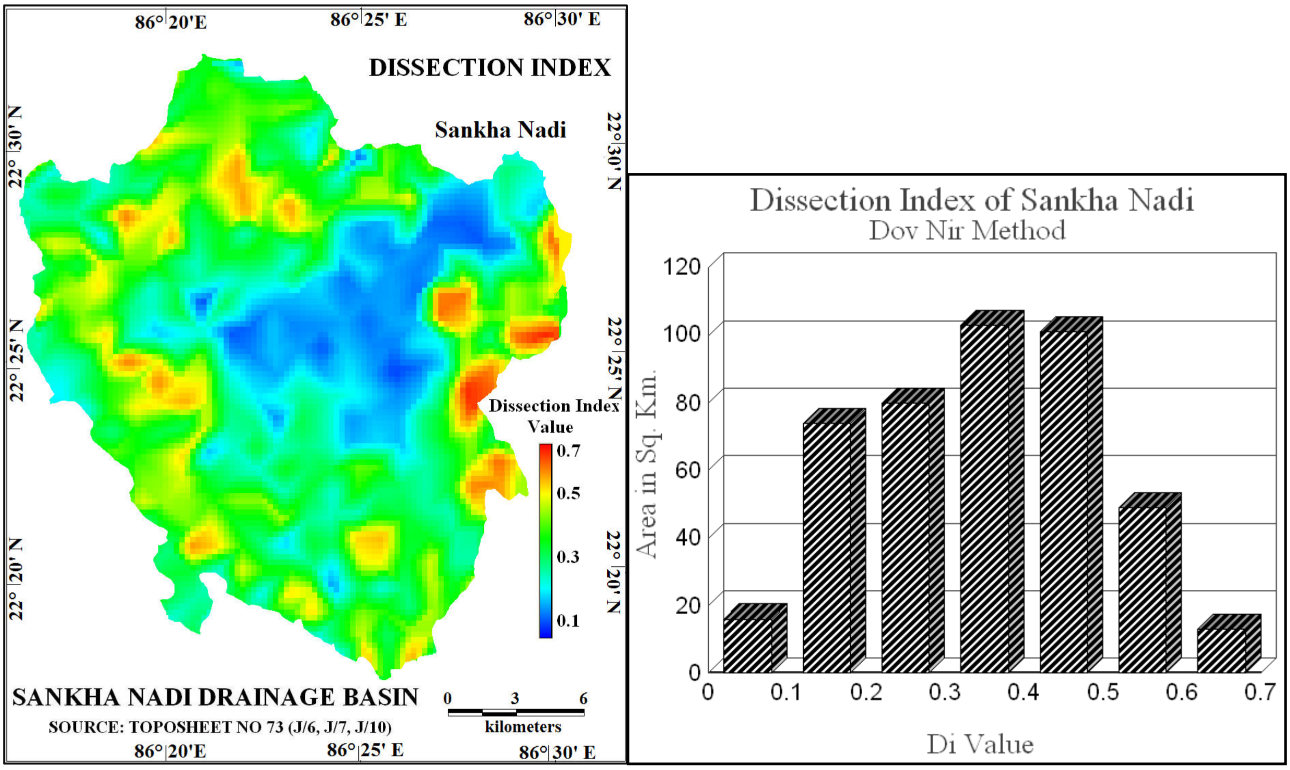

Figure 7. Distribution of dissection index

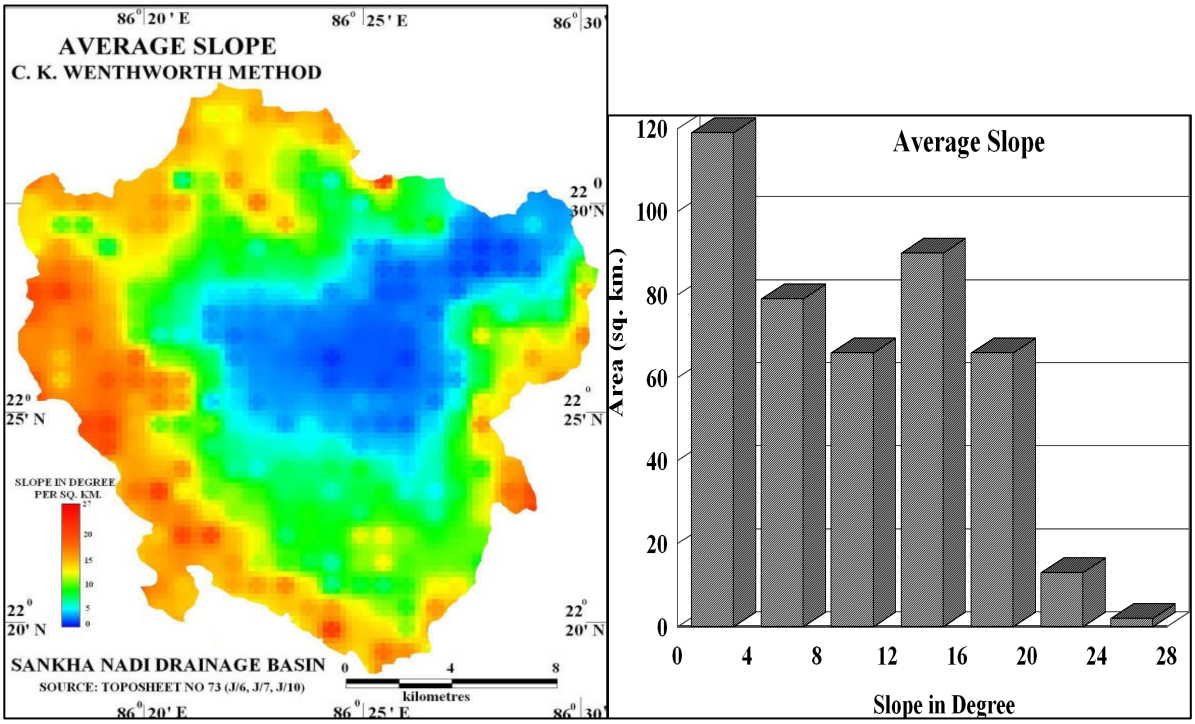

Figure 8. Average slope of Sankha Nadi

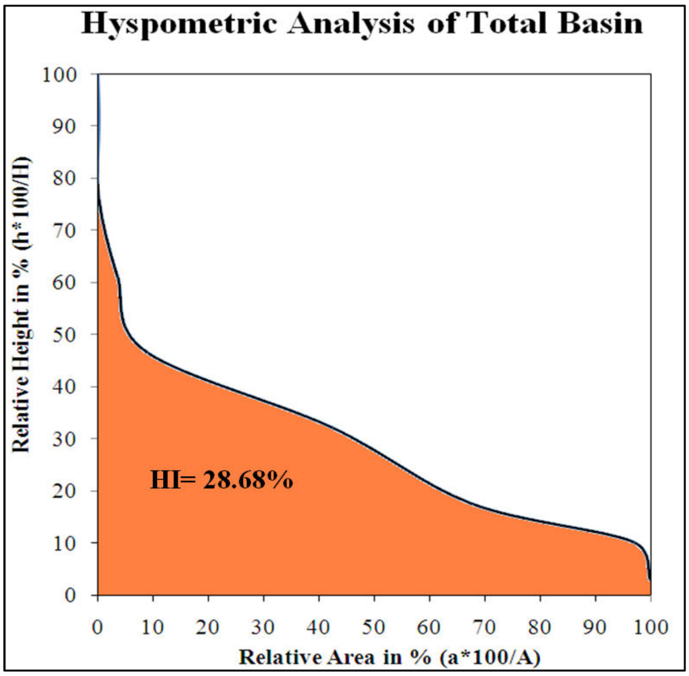

Figure 9. Hypsometry of Sankha Nadi