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Morphometric Resolution of Laphri River Basin, Chotonagpur Plateau, India

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ABSTRACT

The morphometric study is a quantitative description and analysis of the terrain surface and any landform unit. In the present study an attempt has been made to analyze the morphometric resolution of the Laphri river basin flowing in the western part of the Chotonagpur plateau. Based on the secondary data obtained from the topographical map bearing sheet no. 73 A/4 on the scale of 1:50,000 of Survey of India, various parameters covering linear, areal, and relief aspects of morphometry have been adopted to study the morphometric characteristics of the said river basin. For the cartographic representation, QGIS (Version 2.14.21) software has been used. The results show that the watershed is classified 5th order drainage basin having a bifurcation ratio of 3.46, which indicates homogeneous rock type and drainage pattern is less disturbed by geological structure. Hypsometric analysis indicates the mature stage of the river basin. More than 50% area is having low relative relief (20m – 88m) and more than 63% of the area are under moderate slope (6° - 11°). However, this work tries to deal with the theoretical view on the river basin; this may be helpful to plan the land use pattern for the demographic change for the basin dwellers.

Keywords: Homogeneous, Hypsometric, Morphometric, Profile, Stream order.

I. INTRODUCTION

Morphometry is the process of measuring the external shape and dimensions of landforms or living organisms. In a geomorphological study, the science of morphometry is concerned with the quantitative measurement and generalization of land surface geometry (Chorley et al.1984:317). The various morphometric properties depend on various aspects like geology, tectonics, vegetation and climate, etc. (Singh 2003). It is related to quantitative description and analysis of the landforms which applies to a particular kind of landform or a drainage basin and large regions generally (Kumar et al. 2016). In this present study, the Laphri river basin, situated in the western part of the Chotonagpur plateau, particularly in the northern part of the Jashpur district of Chhattisgarh and the southern part of the Gumla district of Jharkhand state have been taken as a study area. Here, for the study purpose stream order, bifurcation ratio, drainage density, hypsometric curve, relative relief, average slope, etc. parameters have been taken. With these said parameters an endeavor has been made to study the relief, drainage pattern

and their inter-relationship, stage of landform, erosional character and its relation to geological structure, etc. of the particular river basin. This study will provide an opportunity to the researchers for a better insight into the field and may be helpful for effective information for in-depth study of integrated basin management. Besides, it may pave the way to suggest a planned land use pattern for the demographic change for the basin dwellers. However, in this particular study area, no work has been done taking this theme. In this regard, the present study demands to be worthwhile.

II. METHODS AND MATERIAL

2.1 Study Area

The study area lies in the Jashpur district of Chhattisgarh and Gumla district of Jharkhand state in India, situated between the 23°1′38′′N & 23°9′22′′N Latitudes and 84°2′56′′E & 84°8′14′′E Longitudes, areal extension of about 52.94 sq. km. The total length of the Laphri River is 17.5 km from its head to the point of its confluence with Basa River in the river basin.

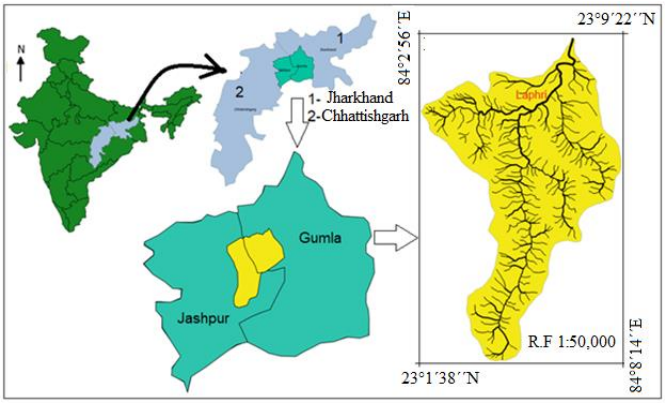

Fig.1. Location Map of the Study area: left Jharkhand and Chhattishgarh state in India, top middle Gumla and Jashpur district in Jharkhand and Chhattishgarh state, bottom middle Laphri basin in Gumla and Jashpur district, right Laphri River basin and its flow path.

2.2 Data Analysis

For the study of the Laphri river basin, the entire work has been carried out based on the Topographical map bearing sheet no. 73A/4 on the scale of 1:50,000 of Survey of India.

For morphometric analysis three types of parameters have been taken, i.e. linear aspect, areal aspect, and relief aspect.

Different parameters, formulas, and respective references are given below.

Linear Aspects

Parameters	Formula/ Concept	Reference
Stream Order (U)	The smallest stream/fingertips are called '1st order stream', Two 1st order stream make 2nd order stream and so on; Smaller stream joining into a higher order stream do not change its order number.	Strahler (1964)
Bifurcation Ratio(Rb)	$Rb = \frac{Nu}{Nu + 1}$	Horton (1932)

Areal Aspect

Parameters	Formula/ Concept	Reference
Drainage Density(Dd)	$Dd = \frac{Lu}{A}$	Horton (1945)

Relief Aspects:

Parameters	Formula/ Concept	Reference
Relative Relief	$\frac{\text{Maximum height} - \text{Minimum height}}{\text{Area}}$	Smith"s method of relief analysis(1935)
Hypsometric Curve and Hypsometric Integral	It is an Ogive indicating a cumulative land surface area in different elevation stages. The ratio of the area under the hypsometric curve to the total area bounded by the limits of coordinates	Chorley(1969) Strahler (1952)
Average Slope	$\tan^{-1}(\frac{\text{Average contour crossing} \times \text{contour interval}}{636.6 \text{ metre}})$	Wentworth method (1930)

The data are taken from the said topographical map, test for the association of variables accomplished by MS Excel: 2007, IBM SPSS Statistics Version 23

For the cartographic representation Quantum Geographical Information System (Version: 2.14.21) Software is used.

III. RESULTS AND DISCUSSION

3.1 Stream Ordering

The stream order is a positive number used in geomorphology and hydrology to indicate the level of branching in a river system in a basin area. In Laphri River basin are having the highest range up to the 5th order shows the smallness of the basin with a 52.94 km² area and 97% of streams are headwater streams.

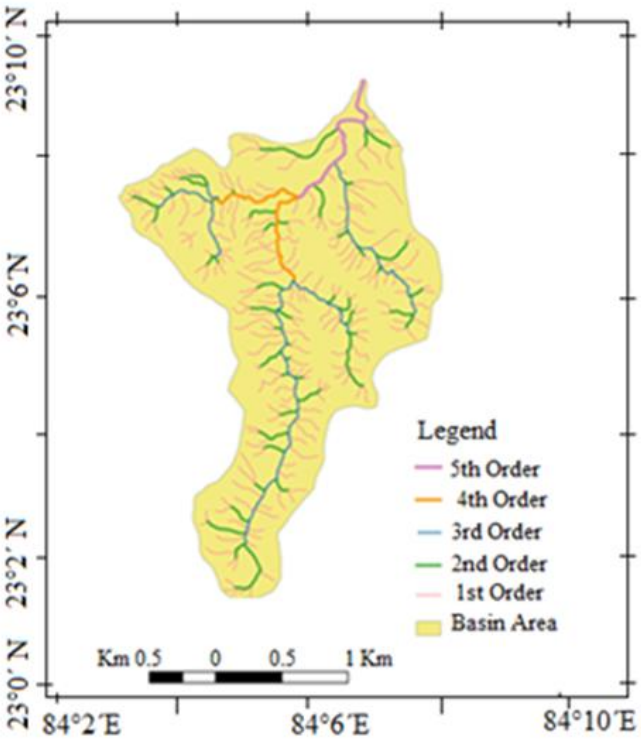

Fig. 2. Stream Orders of Laphri River Basin

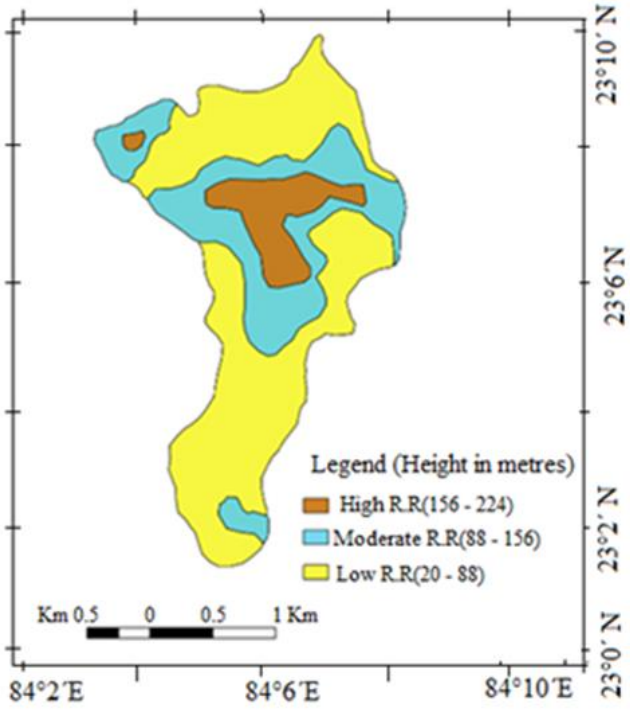

Fig. 3. Relative Relief of Laphri River Basin

Bifurcation ratio is a dimensionless number denoting the ratio between the number of streams of one order and those of the next-higher order in a drainage network. The Bifurcation ratio looks at the relationship between streams of different orders in a drainage basin. Horton (1945) considered the bifurcation ratio as the index of relief and dissertation.

Table 1 - Stream order, Number of Streams and Bifurcation Ratio

Stream Order	No. of Stream Order	Bifurcation Ratio(Rb)	Mean Rb
1st	82		
2nd	46	1.78	
3rd	7	6.57	3.46
4th	2	3.5	
5th	1	2	
		∑ 13.85	

Source : Calculated by Authors from 73 A/4 Topographical Sheet.

The bifurcation ratio for the successive orders of the Laphri river basin from 1st t to 4th order is 1:1.78, 1: 6.57, 1:3.5, and 1:2. The mean bifurcation ratio for the Laphri river basin is 1:3.46.

However, the mean bifurcation ratio value is 3.46 for the study area (Table 1). Bifurcation ratios characteristically range between 3.0 and 5.0 for basins in which the geologic structures do not distort the drainage pattern (Strahler, 1964). The mean bifurcation ratio value is 3.46 for the study area (table-1) which indicates that the drainage patterns are less disturbing by geological structure and also the rock types are homogenous.

3.2 Relief Analysis

The meaning of the term relief may be defined as the difference in elevation of any part of the earth's surface or relative vertical inequality of land surface. Relative relief is among the techniques, that are effectively capable of presenting three-dimensional relief characteristics with the help of two-dimensional maps, without considering sea level.

3.2.1 Relative Relief

The term relative relief means the actual variation of height i.e. difference between maximum height and minimum height per grid. For the study of spatial variation, relative relief in each grid square is calculated on the basis of the highest and lowest elevations and the data of relative relief are derived and classified into categories viz. i) low relative relief, ii) moderately relative relief, iii) high relative relief.

3.2.1.1 Low Relative Relief (20m – 88m)

This category accounts for57.03 % of the basin, covering an area of about 30.19 sq. km (fig. 3). This group accounts for the maximum area among the categories in the southern and the northern portion of the basin. It shows that this category is having very less or no degree of dissection and lies in the river

valley plains region, where the height is not more than 88 m.

3.2.1.2 Moderate Relative Relief (88m -156m)

It spreads over 13.92 sq. km and covers an area of about 26.30 % of the total basin area (fig. 3). This category is concentrated in the central portion and scattered in the northwestern portion of the basin, where we found the degree of dissection is high.

3.2.1.3 High Relative Relief (156m – 224m)

It accounts for 16.67 % of the basin, covering an area of about 8.83 sq. km (fig. 3), and is found in the absolute middle of the basin and scattered in the northwestern portion of the basin. The region is having the maximum degree of dissection.

Prolonged erosion over the basin area and surrounding plateau region has left most of the study area with low relative relief (20m-88m). It may be the outcome of the plantation surface by the fluvial action over the granite-gneiss basement.

3.3 Hypsometric Curve and Hypsometric Integral

The hypsometric curve is generally used to show the proportion of an area of the surface at various elevations above or below or datum (FJ Monkhouse and HR Wilkinson 1967). It describes the elevation distribution across an area of the land surface. It is an important tool to assess and compare the geomorphic evolution of various landforms irrespective of the factor that may be responsible for it.

Table 2 - Calculation Table for Hypsometric Curve and Hypsometric Integral

Elevation zone(contour interval in meters)	Area in km²(a)	Relative Area a/A	Cumulative value (Less than) of a/A	Cumulative value (More than) of a/A (X_i)	Relative Height h/H (y_i)	$X_i.y_{i+1}$	$y_i.x_{i+1}$
758 – 800	12.13	0.23	0.23	1	0.79	.84	.61
800 – 850	6.88	0.13	0.36	0.77	0.84	.69	.54
850 – 900	8.75	0.17	0.53	0.64	0.89	.60	.42
900 – 950	18.44	0.35	0.88	0.47	0.94	.47	.11
950 – 1007	6.74	0.12	1	0.12	1		
	Σ 52.94					Σ 2.6	Σ1.68
A Ξ Total Basin Area(52.94 km²), H Ξ Maximum Height(1007 meters)							

Source: Calculated by Author from 73 A/4 Topographical Map.

$$\text{Hypsometric Integral} = \frac{(\Sigma Xi.\, yi + 1) - (\Sigma yi.\, xi + 1)}{2}$$

$$\text{Hypsometric Integral} = \frac{2.6 - 1.68}{2}$$

$$\text{Hypsometric Integral} = 0.46, \text{Hypsometric Integral in percentage} = 46$$

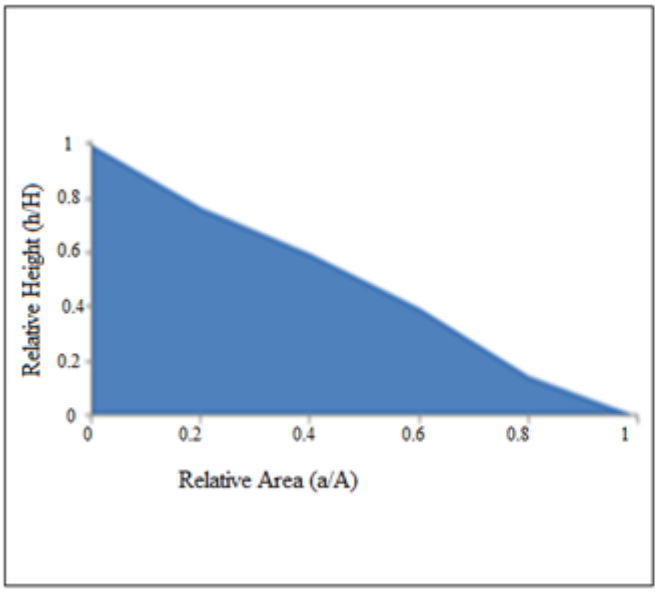

Fig. 4. Hypsometric Curve of Laphri River Basin

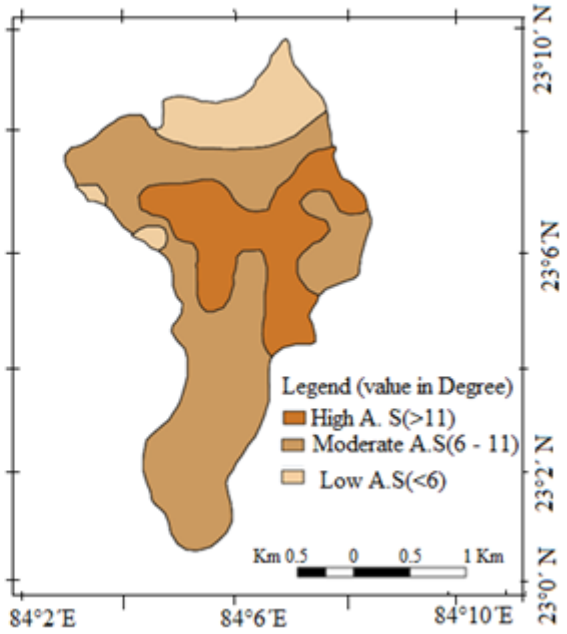

Fig. 5. Average Slope Map of Laphri River Basin

From the hypsometric integral value (table 2) and hypsometric curve (fig. 4), it is found that the region is still in the mature stages.

3.4 Slope Analysis

The term 'slope' as described in geomorphology, denotes some small portion of the land surface, this is inclined from the horizontal base. The slope is an important terrain aspect that is affected by tectonic activities, geological structure and climatic characteristics of an area, and anthropogenic factors. In a watershed, slope analysis is an important step towards rationalization of land use. It provides the basis for land capability classification, land use planning, and soil conservation needs.

3.4.1 Average Slope

The representation and analysis of slope have great significance in landform study. The degree of slope controls the amount of run-off, velocity of river, erosion, transportation, and deposition. Thus, it plays a crucial role in landform development. Its study helps in describing various landform features as well as identifying the stages of landform development. The data of average slope in the Laphri river basin are derived and classified into three categories viz. i) low average slope, ii) moderate average slope, iii) high average slope.

3.4.2 Low Average Slope (Below 6°)

This category accounts for15.28 % of the basin, covering an area of about 8.09 sq. km. The maximum account of this category is found in the northern portion and scattered found in the northwestern portion of the basin (fig. 5). Lithologically, this area might be of less resistant rock and fertile soil that has had a very low average slope.

3.4.2.1 Moderate Average Slope (6° - 11°)

It spreads over 33.82 sq. km and covers an area of about 63.89 % of the total basin area (fig. 5). This group accounts for the maximum area among the categories except the central and northern portions of the basin.

3.4.2.2 High Average Slope (Above 11°)

It accounts for 20.83 % of the basin, covering an area of about 11.03 sq. km, and is found in the central portion of the basin (fig. 5). Lithologically, this area might be of more or very high resistant rock that has

had a steep landform. These areas are covered with dense vegetation and not suitable for agriculture.

Fig. 6 represents the positive correlation between relative relief and drainage density which indicates the changes of elevated height positively signifies the change of drainage density in the Laphri river basin.

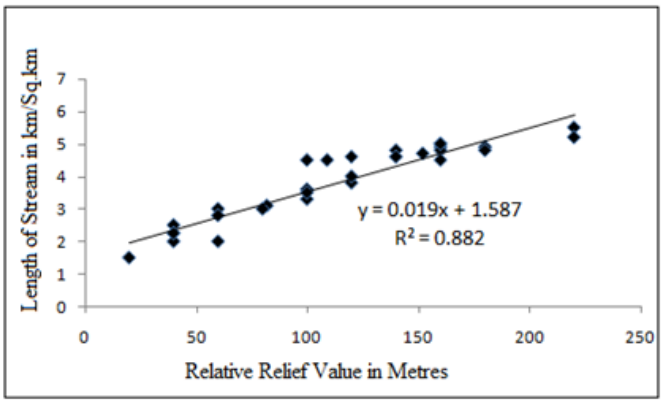

Fig. 6. Relationship between Relative Relief and Drainage Density

IV.CONCLUSION

The present study has revealed that the varied characteristics of the Laphri river basin mostly depend on the geological structure and climatic conditions. Drainage pattern (dendritic) and bifurcation ratio (3.46) indicate in favor of homogeneity of prevailing rocks and it is less disturbed by geological structure. As far as the slope is concerned 63.89% area has a moderate average slope (6° - 11°). The proportion of land having a low and high average slope is 15.28% and 20.83% respectively. This micro-regional variation in slope may be associated with tectonic movement with a high degree of denudational activities and other factors, such weathering, erosion and transportation processes, etc. The nature of surface, slope, and dissection of the basin area are expressed by relative relief. The southern and northern part of the basin which occupies more than 57% of the land area is characterized by low relative relief (20m – 88m). It may be the outcome of the planation surface predominantly eroded by fluvial action over the Archaean basement. Only 16.67% area of the total basin area is covered by high relative relief (156m – 224m) which is concentrated mainly in the middle of the basin area and scattered in the northwestern portion showing a highly dissected and undulating topography.

To conclude, it can be said that the Laphri river basin and adjacent areas are situated in the western part of the gradually descending Chotonagpur plateau. Except for Laphri river many small and homogeneous rivers like Basa, Banki, Ari and Lawa, etc rivers are flowing in this region. From this morphometric study of the Laphri river basin, the geomorphic character of other associated rivers may be assessed.

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