Hypsometric Analysis of the Berne River Watershed using Geographical Information System

[1]Kusum Pathak, [2]Medha Jha, [3]Sanjay Tignath, [4]S.K Sharma

[1]Research Scholar, [2]Associate Professor, [3]Professor, [4]Professor
Department of Geology
[1,3]Government Science College, Jabalpur, M.P, 482001, India
[2]INDIAN INSTITUTE OF TECHNOLOGY (BHU) VARANASI U.P
[4]J.N.K.V.V JABALPUR M.P

***Abstract*: Hypsometry is the relationship between the area of the basin to the altitude of the basin, which is derived to understand the erosional development and the progressive stages of a river basin which offers a finite effect of the influence of climatic, geological and tectonic factors. The present study was conducted on the Berne River watershed in ArcGIS environment with extraction of contours from the SRTM DEM. The analysis results in the hypsometric integral of the order of 0.637 which indicates that the area has approximately approached equilibrium' or mature stage, though still being slightly in the young stage or Inequillibriuam stage and forms the sloping/denduational plains with higher lands which shows that the area suffers degradational or erosional activity and sediment loss from the watershed.**

***Keywords*: Hypsometric analysis, Hypsometric integral, DEM, GIS.**

INTRODUCTION

The study area falls under the longitude 79^{o} 30'00"E – 79^{o} 47'00"E and latitude 24^{o} 45'00"- 25^{o} 0' N 25^{o} 0' N (fig 1). The Berne River watershed is a tributary of Ken River which eventually merges into the Yamuna River. The total area of the watershed is 302.084 km^2. The maximum and minimum elevation ranges from 384 to 247 m from the mean sea level. The watershed lies in the part of Rajnagar Block, Chhatarpur District, Madhya Pradesh, India. It falls in south eastern part of the Bundelkhand Craton consisting dominantly of Bundelkhand Granites with associated quartz reefs, rare felsic volcanic and mafic dyke swarms, Ramakrishnan and Vaidyanadhan (2008).

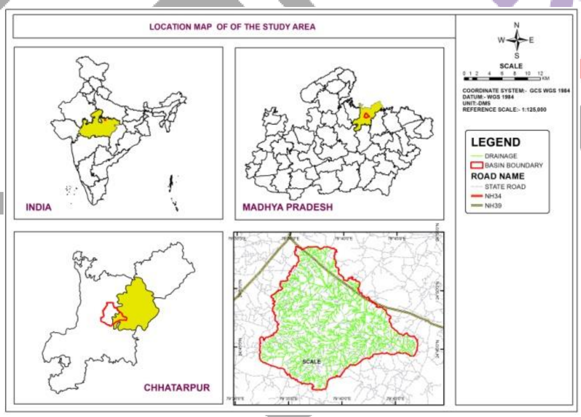

Fig-1 Location map of the study area.

Concept of Hypsometry

Hypsometry refers to the relative proportions of an area at different elevations within a region, and the hypsometric curve is an area-elevation relationship curve which depicts distribution of the area with respect to elevation (Langbein, W.B 1947, Strahler, A.N. 1952). Land degradation and topological changes within watersheds are accomplished by weathering processes, stream erosion and sediment transportation by surface runoff (S.K. Sharma et.al.2013). Denudational processes are many, complex and long term in nature which have been operative with ever changing intensity and therefore, it is difficult to interpret the topographical changes. The hypsometric curve (HC) and hypsometric integral (HI) are crucial indicators of watershed conditions and are attributed to the degree of disequilibria in the balance of erosive and tectonic forces (Weissel, J, et.al.,1994, Ritter et.al, 2002). The shapes of the hypsometric curves, by analyzing numerous basins, were classified for the basins as young (convex upward curves), matured (S-shaped hypsometric curves which is concave upwards at high elevation and convex downward at low elevation) and peneplain distorted (concave upward curves) Strahler (1952).

The hypsometric integral is also an indication of the 'cycle of erosion' (Strahler, 1952; Garg, 1983). The conceptual diagram is given in (fig 2).

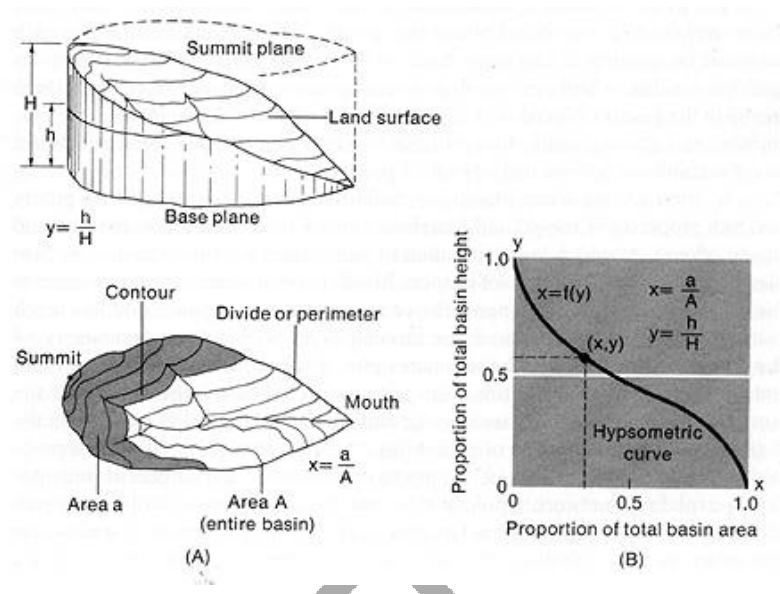

Fig- 2 Hypsometric Analysis and the Model Hypsometric Curves (Ritter et., al.2002)

This entire period or the 'cycle of erosion' can be divided into the three stages: A. monadnock stage (old) (Hi 0.3), in which the watershed is fully stabilized; B. equilibrium or mature stage (Hi 0.3 to 0.6); and C. inequilibrium or young stage (Hi>0.6), in which the watershed is highly susceptible to erosion with increase in the value of the integral (Strahler, 1952).

METHODS AND MATERIALS

Watershed Delineation

The study area was delineated from the published toposheets of Survey of India. It was georeferened and mosaic in the ArcGIS environment and then rectified and projected to the world space coordinate system, UTM 1984. The drainage map was digitized along the water divide followed by the ridge of the area, (fig-3) and the satellite data SRTM DEM (fig-4) was used to extract contour map (fig 5). All the hypsometric parameters were calculated in the attribute table in ArcGIS. GIS is gaining importance as a powerful tool in the natural resources management and its conservative work. Thus, GIS technique has been used substituting for convenient tools for hypsometric analysis.

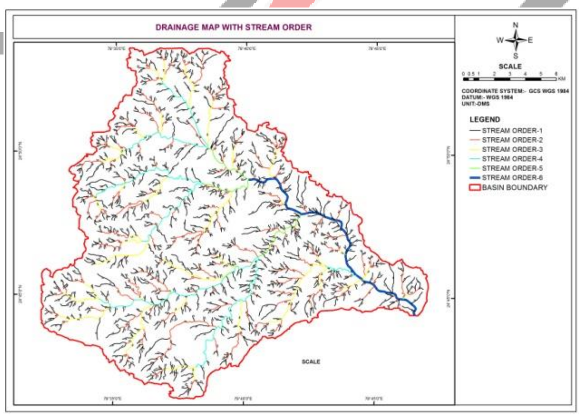

Fig-3 Drainage map of the Study Area.

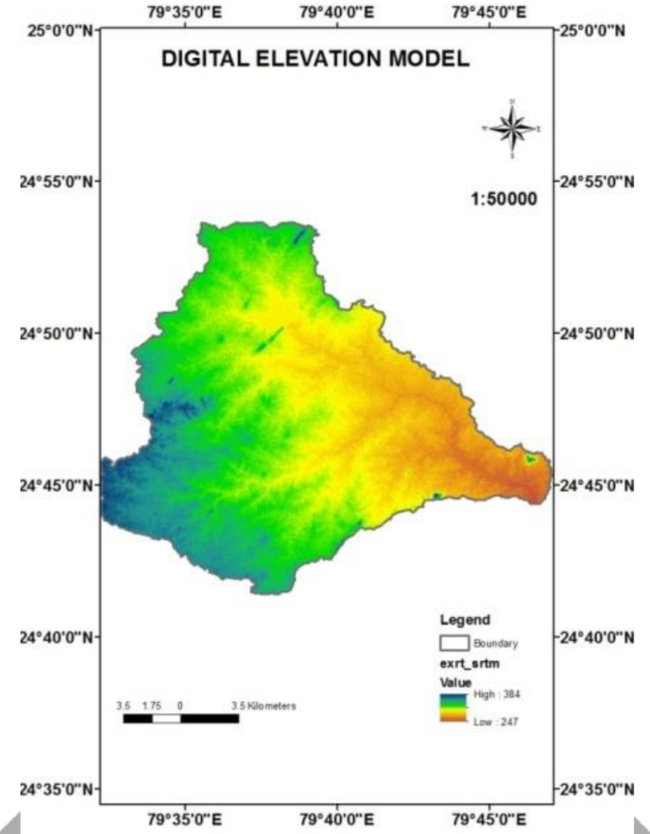

Fig 4 DEM of the study area

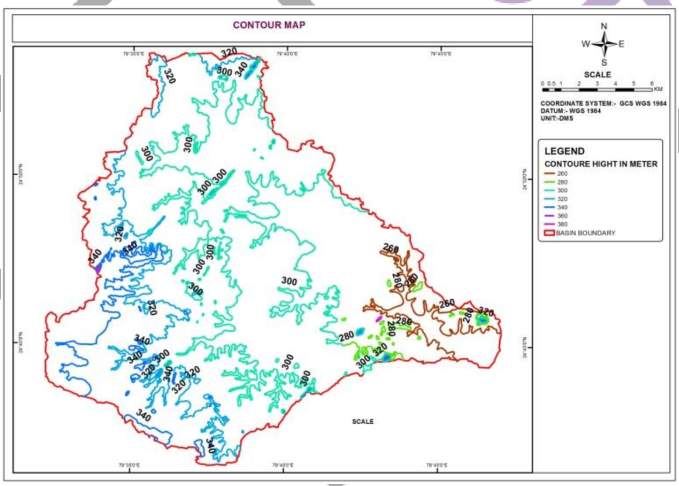

Fig-5 Contour map of the study area.

RESULT AND DISCUSSION

PLOTTING OF HYPSOMETRIC CURVE (HC)

The hypsometric curve describes the distribution of elevations across an area of land, which has been used to evaluate the evolutionary status of landforms. It is related to the volume of the soil/rock mass removed from or aggraded in the basin and the amount of erosion that had occurred in a basin against the remaining mass (Hurtrez et al., 1999). Hypsometric curves are related to geomorphic and tectonic evolution of drainage basins in terms of their forms and processes (Schumm, 1956; Strahler, 1964; Leopold et al., 1964; Hurtrez et al., 1999).

The percentage hypsometric method has been used for the present study. There are two ratios involved in this method and plotted against each other on a graph. The ordinate represents the ratio of relative elevation (h/H) and the abscissa represents the ratio of relative area (a/A). The relative elevation is computed as the ratio of the height of a given contour (h) from the base plane to the maximum basin elevation (H). The relative area is obtained as a ratio of the area above a particular contour (a) to the total area of the basin above the outlet (A). The value of relative area (a/A) is in a range from one to zero. One at the lowest point in the drainage basin (h/H = 0) and zero at the highest point in the basin (h/H = 1). (Table-1) (fig- 6)

Table :1 Hypsometric data of Berne river watershed				
Area(A)= 302.084 sq. Km			**Total relief(H)= 137 m**	
Contour Intervals	**Area (a)km^2**	**Relative Area (a/A)km^2**	**Contour height(h)m**	**Relative Area(h/H)m**
380	8.101	0.027	133	0.971
360	52.074	0.172	113	0.825
340	129.151	0.428	93	0.679
320	218.244	0.722	73	0.533
300	267.343	0.885	53	0.387
280	299.07	0.990	33	0.241
260	301.997	1.000	3	0.022

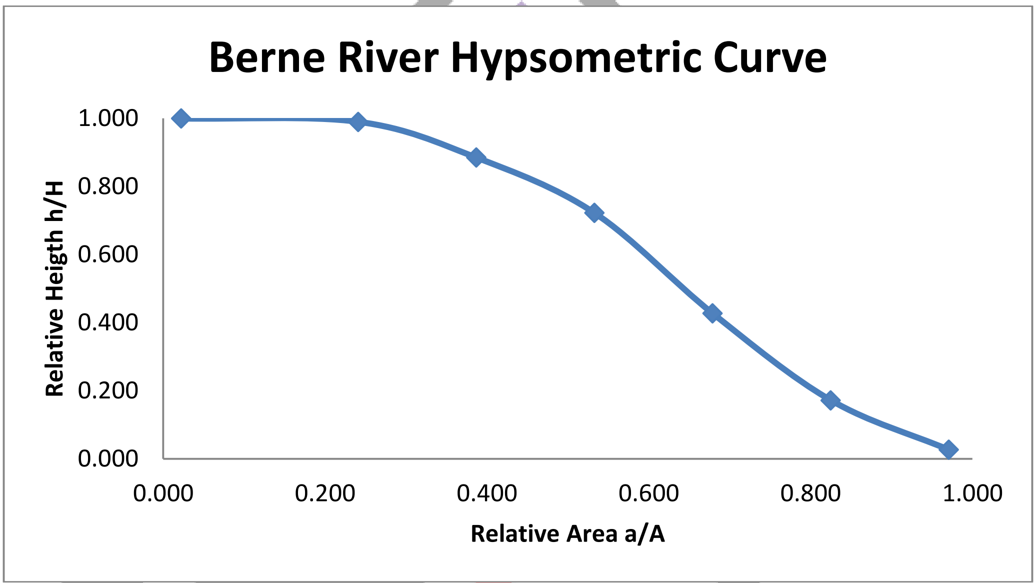

Fig-6 Hypsometric Curve of the study area.

ESTIMATION OF HYPSOMETRIC INTEGRAL (HI)

The hypsometric integral (HI) was estimated using the elevation relief ratio method as proposed by (Pike R.J et., al 1971). The relationship is expressed as:

E ≈ HI = Elev (mean) - Elev(min) / Elev(max) - Elev(min) ...(1)

Where, E is the elevation-relief ratio equivalent to the hypsometric integral HI; Elev(mean) is the '*weighted mean elevation'* which is obtained with respect to area of the watershed and elevation-area product estimated from the identifiable contours of the delineated watershed; Elev(max) and Elev(min) are the maximum and minimum elevations within the watershed. The hypsometric integral of the Berne River is 0.637.

On the basis of hypsometric integral (HI), the threshold limits recommended by Miller (1953) as given below were adopted for deciding the stage of watershed:

The watershed is at youthful stage, if the HI $\geq$ 0.6.
ii. The watershed is at equilibrium or mature stage, if the 0.35 $\leq$ HI< 0.6.
iii. The watershed is at mature (old) stage, if the HI< 0.35.

The watershed in youthful stage is more prone to erosion in comparison to equilibrium or mature stage.

CONCLUSION

Although the general geomorphic features of the granitic parts of the Bundelkhand granitic landforms represent peneplain with Tors and relicts hillocks yet the area of study in particular is far away from the stage of old stage degraded morphology. The area shows a transition from young to mature stage in landscape evolution. The Berne river basin has the hypsometric integral with the value of near transition stage. The hypsometric curve results in the convex curve and hypsometric integral value is 0.637 obtained for the entire Berne river basin reflects decline of Inequilibrium Stage or nearly at the transition from young to mature stage of geomorphic cycle development. This analysis will help to take appropriate measures to conserve soil and water resources for sustainable development of the basin area.

ACKNOWLEDGEMENT

The first author expresses her gratitude to Dr. Sanjay Tignath, Professor, Department of Geology, Government Science College, Jabalpur, Dr. Medha Jha, Associate Professor, Civil Department, IIT (BHU) and Dr. S.K Sharma, Professor, Department of Soil and Water Engineering Department, J.N.K.V.V Jabalpur, for their guidance, encouragement and support in carrying out this research work and the preparation of this manuscript.

REFERENCES

[1.] Strahler, A.N. (1952) Hypsometric (Area-Altitude) Analysis of Erosional Topography. *Geological Society of America Bulletin*, **63**, 1117-114

[2.] Shailesh Kumar Sharma, Sanjay Tignath, Sarita Gajbhiye, Rupesh Patil (2013) Use of Geographical Information System In Hypsometric Analysis of Kanhiya nala Watershed. *International Journal of Remote Sensing & Geoscience (IJRSG)*, VOL-2, pg 30-35.

[3.] Ritter, D.F., Kochel, R.C. and Miller, J.R. (2002) Process Geomorphology. McGraw Hill, Boston.

[4.] Weissel, J., Pratson, L. and Malinverno, A. (1994) The Length-Scaling Properties of Topography. *Journal of Geophysical Research*, **30**, 151-159.

[5.] Langbein, W.B. (1947) Topographic Characteristics of Drainage Basins. USGS Water Supply Paper, 947-C. 157 p.

[6.] Hurtrez, J.E., and Lucazeau, F., (1999), Lithological control on relief and hypsometry in the Herault drainage basin (France), Comptes Rendues Acade mie des Sciences de la terre et des planets. *Earth and Planetary Sciences*, 328 (10), pp 687–694.

[7.] Hurtrez, J.E., Sol, C., and Lucazeau, F., (1999), Effect of drainage area on hypsometry from an analysis of small-scale drainage basins in the Siwalik hills (Central Nepal). *Earth Surface Processes and Landforms*, 24, pp 799–808.

[8.] Pike, R.J., and Wilson, S.E., (1971), Elevation- relief ratio hypsometric integral and geomorphic area-altitude analysis. *Geological Society of America Bulletin*, 82, pp 1079–1084.

[9.] Fuzal Ahmed and Srinivasa Rao K.(2016) Hypsometric analysis of the Tuirini drainage basin: A Geographic Information System approach. *INTERNATIONAL JOURNAL OF GEOMATICS AND GEOSCIENCES* Volume 6,pg 1685-1695.

[10.] Miller, V.C., A quantitative geomorphic study of drainage basin characteristics in the Clinich Mountain Area, Virginia, and Tennessee: Office of Navel Research 389-042 Technical Report no. 330 pp, (1953).

[11.] Shailesh Kumar Sharma et.al (2016) Hypsometric analysis using Geographical Information System of Gour River Watershed, Jabalpur, Madhya Pradesh, India. *Current World Environment* Vol. **11**(1), 56-64

[12.] Kusum Pathak, Sanjay Tignath (2013) Morphometric analysis of the Berne River Basin, tributary of Ken River, part of Rajnagar block, Chhatarpur, M.P, India. *International Journal of Research in Engineering, Science and Management*. Vol-2 Issue-3, 702-706.

[13.] S C Bhatt et.,al (2017) Geological structure control on Sukhnai basin and status of land use/land cover pattern in mauranipur and adjoining areas, Bundelkhand craton, central India. *Journal of Geological Society of Sri Lanka Vol. 18-Issue 2, 53-61.*

[14.] M. Ramakrishnan, R Vidyanadhan (2008) Geology of India, *Geological Society of India Banglore*. Vol-1. 249-260.