Hypsometric Analysis of the Ghataprabha Sub Basin of Krishna River Basin, Karnataka, India

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Abstract: Assessment of erosion status of the watershed helps in selecting suitable conservation measures to check erosion and water conservative management practices in the watersheds. Hypsometric analysis with the aid of Geographic Information System (GIS) helps to understanding the geological development of basin and for delineation of erosional proneness of watershed. The hypsometric curve and hypsometric integrals are the important indication factors of watershed condition. Hypsometric analysis is the relationship of horizontal cross-sectional drainage basin area to elevation. The graph of hypsometric curve indicates the geological stage of watershed and erosion susceptibility of basin. The present study has been carried out by using Cartosat-1 Digital Elevation Model (CartoDEM) remotely sensed data and GIS in the Ghataprabha sub basin of Krishna River basin. The hypsometric analysis of Ghataprabha sub basin is carried out and value of hypsometric integral (Hi) is found 0.37 which indicates the watershed is at Equilibrium or Mature stage.
Keywords: CartoDEM, Hypsometric Curve, Hypsometric Integral, Remote Sensing and GIS.

I. INTRODUCTION

The hypsometric analysis can be used as a morphometric parameter, i.e. hypsometric integral, to deduce its relationship with the area of watersheds. Statistical analysis of these parameters has been carried out by classifying them into different classes based on the natural break's method. This brings out strong relationships for hypsometric integral classes and area classes with the number of watersheds in respective classes and the total area occupied by respective hypsometric and area classes. It has also been found that stronger relationships exist for watersheds The anomalous watershed has been directly attributed to the difference in geologic structure The results are inspiring and very promising as they indicate some statistically strong relationships among the hypsometric integral and area of watersheds that are not apparent in the Hypsometric analysis is the relationship of horizontal cross sectional drainage basin area to elevation. The hypsometric curve has been termed the drainage basin relief graph. Hypsometric curves and hypsometric integrals are important indicators of watershed conditions, Ritter, (2002). Differences in the shape of the curve and hypsometric integral values are related to the degree of disequilibria in the balance of erosive and tectonic forces Weissel, (1994).

Hypsometric analysis was first time introduced by Langbein, (1947) to express the overall slope and the forms of drainage basin. The hypsometric curve is related to the volume of the soil mass in the basin and the amount of erosion that had occurred in a basin against the remaining mass Hurtrez, (1999). It is a continuous function of nondimensional distribution of relative basin elevations with the relative area of the drainage basin Strahler, (1952). This surface elevation has been extensively used for topographic comparisons because of its revelation of three-dimensional information through two-dimensional approach Harrison, (1983); Rosenblatt and Pinet, (1994). Comparisons of the shape of the hypsometric curve for different drainage basins under similar hydrologic conditions provides a relative insight into the past soil movement of basins. Thus, the shape of the hypsometric curves explains the temporal changes in the slope of the original basin. Strahler, (1952) interpreted the shape of the hypsometric curves by analysing numerous basins and classified the basins as young (convex upward curves), mature (S-shaped hypsometric curves which is concave upwards at high elevations and convex downward at low elevations) and peneplain or distorted (concave upward curves). There is frequent variation in the shape of the hypsometric curve during the early geomorphic stages of development followed by minimal variation after the watershed attains a stabilized or mature stage. Hypsometric analysis is carried out to ascertain the susceptibility of watershed to erosion and prioritize them for treatment. The slope of the hypsometric curve changes with the stage of watershed development, which has a greater bearing on the erosion characteristics of watershed and it is indicative of cycle of erosion. The hypsometric integral (Hi) is also an indication of the 'cycle of erosion' Strahler, (1952); Garg, (1983). The cycle of erosion is the total time required for reduction of land area to the base level i.e. lowest level. This entire period or the cycle of erosion can be divided into the three stages viz. monadnock (old) (Hi 0.3), in which the watershed is fully stabilized; equilibrium or mature stage (Hi 0.3 to 0.6); and in equilibrium or young stage (Hi> 0.6), in which the watershed is highly susceptible to erosion Strahler, (1952). Hypsometric curves and hypsometric integral is important watershed health indicator. Hypsometric analysis using GIS has been used by several researchers in India dealing with erosional topography Pandey, (2004); Singh, (2008). Further, there is lack of hypsometric based studies to watershed health, which is attributable to the tedious nature of data acquisition and analysis is involved in estimation of hypsometric analysis. Employing Geographical Information System (GIS) techniques in hypsometric analysis of digitized contour maps helps in improving the accuracy of results and save time. Considering the above facts, this study was undertaken to determine geological stage of development of Ghataprabha sub-watershed of Krishna river basin, Karnataka, India.

II. STUDY AREA

The Ghataprabha river originates in the Western Ghats at an altitude of 884 meters and flows eastward for a distance of 283 kilometres before its confluence with the Krishna River at Almatti. The catchment area of Ghatprabha lies between latitude 15° 45' and 16° 25’ N and longitude 74° 00' and 75° 55' E. The Ghatprabha River flows eastwards for a distance of 283 km before joining Krishna at Kudalasangam, about 35 km north-east of Kaladgi at an elevation of 500 m. The river flows for about 60 km in the Ratnagiri and Kolhapur Districts of Maharashtra before entering the Belgaum District of Karnataka. In Karnataka, it flows through Belgaum and Bijapur Districts and joins the Krishna about 16 km from Almatti. The catchment area of Ghatprabha including its tributaries is 8,716 km^2. Figure.1 shows the location map of the Ghataprabha Sub basin of Krishna river basin and Table.1 shows the runoff characteristics of the Ghataprabha sub basin.

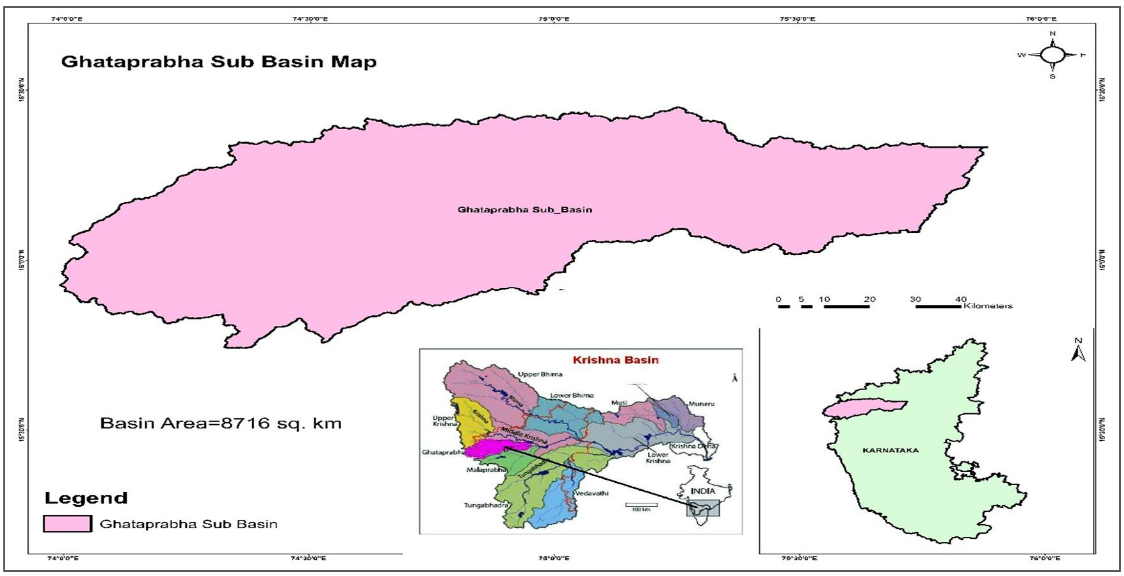

Figure.1 Location Map of the Ghataprabha Sub-basin with Krishna River Basin

Table.1 Characteristics Of The Sub-Basin With Available Runoff Data

Length (km)	283	
Area (km^2)	8,829	
Annual Rainfall Runoff (P)	718 mm 8.1 km^3	
Annual Runoff (Q) (km^3)	3.6	
Runoff Coefficient (Q: P)	Observed	0.45
	Predicted	0.38
	Curve	LM
Potential Evaporation Ep (mm/yr.)	1,385	
Aridity Index (Ep/P)	1.9	

(Source: Closing of the Krishna Basin: Irrigation,
Streamflow Depletion and Macroscale Hydrology, Research Report 111. IWMI)

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III. MATERIALS AND METHODS

The Cartosat-1 Digital Elevation Model (DEM) i.e. CartoDEM (figure.2) was used for this study and which is downloaded from the Bhuvan portal, bhuvan.nrsc.gov.in. ArcGIS 10.5 software was used for this study. The downloaded DEM tiles are mosaiced in the Arc map Version 10.5 environment. Then mosaiced data is modified by sink and generating the flow direction and flow accumulation by using spatial analysis tool. Extracted the Ghataprabha sub basin area using hydrology tool and also generated the slope map (Figure.4) and Contours map (Figure.5) of the Ghataprabha sub basin using spatial analysis tool. The Elevation map of the Ghataprabha sub basin shown in the Figue.3.

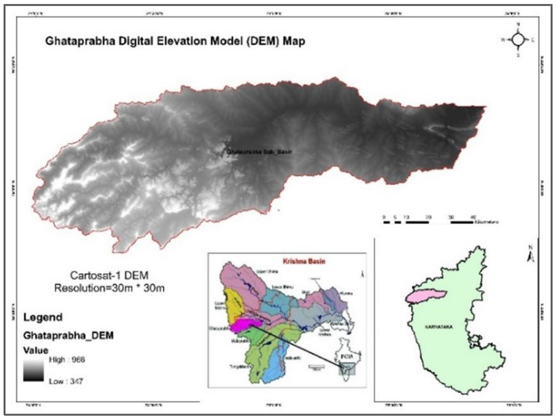

Figure.2 Cartosat-1 DEM data of Ghataprabha Sub Basin

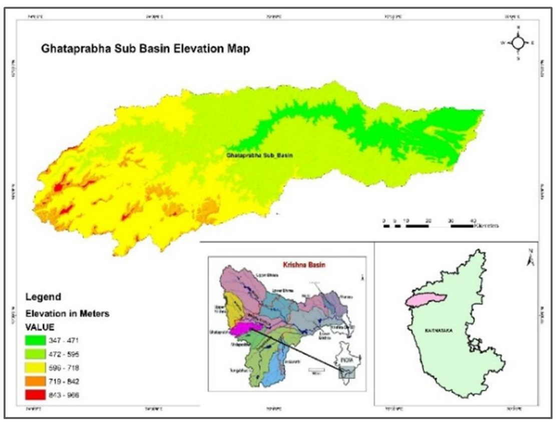

Figure.3 Elevation Map of Ghataprabha Sub Basin

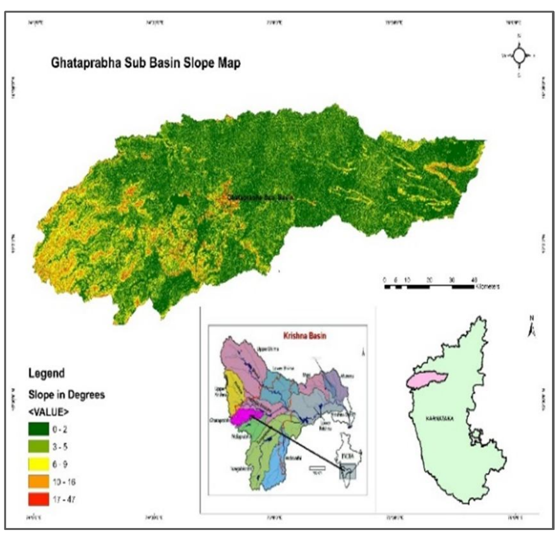

Figure.4 Slope Map of Ghataprabha Sub Basin

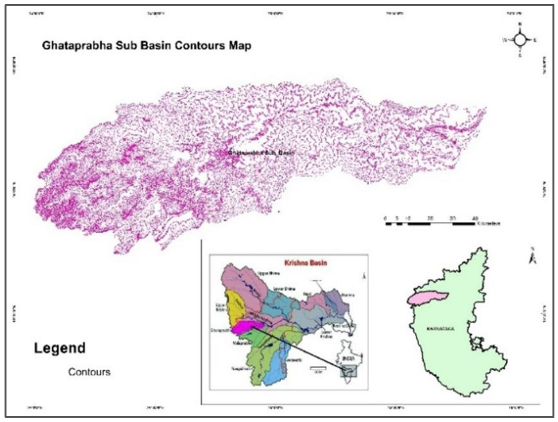

Figure.5 Contours Map of Ghataprabha Sub Basin

IV. RESULT AND DISCUSSION

A. Relative Area Map

The relative area map of Ghataprabha sub (Figure.6) basin shows the distribution of area with respect to relative elevation. Total elevation of watershed was divided into 20 equal parts and the DEM of watershed was reclassified corresponding to these values. The map does not show the absolute elevation value but shows the distribution of horizontal area in percentage. Thus, it presents comparison of the distribution of horizontal area of watershed.

B. Plotting Of Hypsometric Curves

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).

The hypsometric curve of the Ghataprabha sub basin (Figure.7) represents S-shape curve indicating an equilibrium mature stage of landscape development. The shapes of the hypsometric curve in the study area might be due to the lithological variations, incision of bed rock, down slope movement of eroded materials and removal of the sediments from the basin.

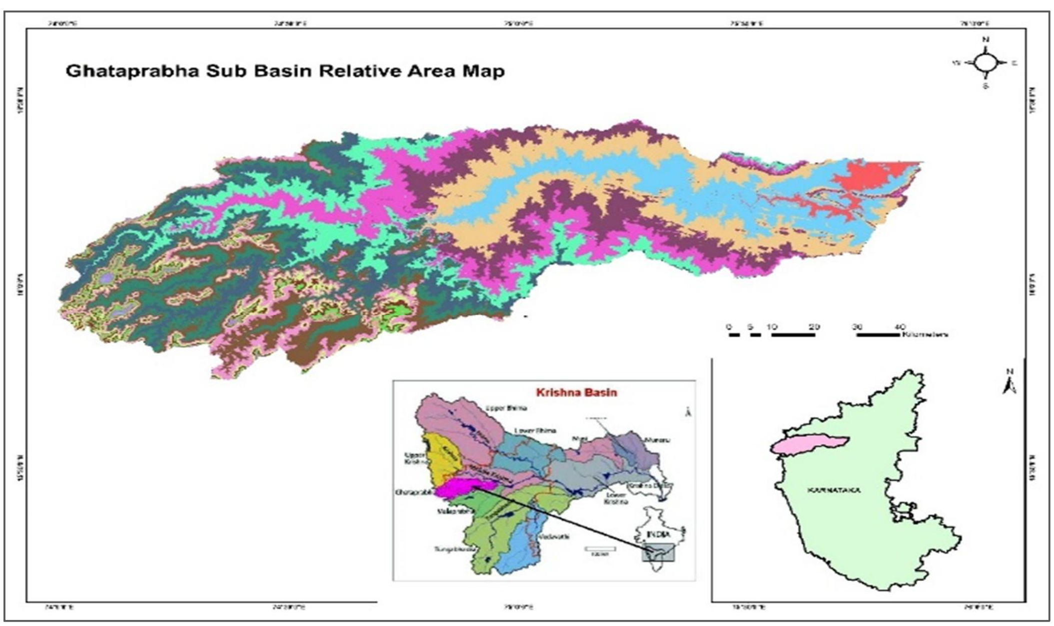

Figure.6 Relative Area map of Ghataprabha Sub Basin

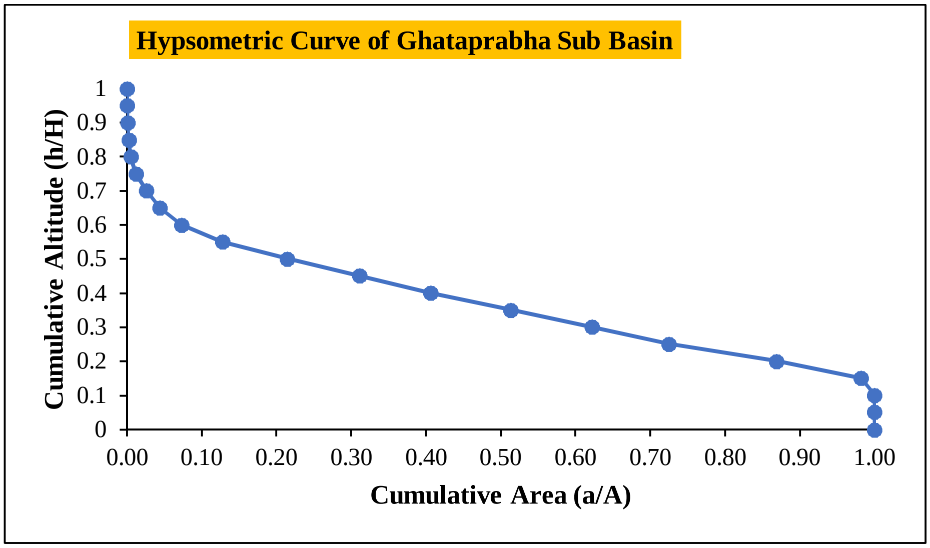

Figure.7 Hypsometric Curve of the Ghataprabha Sub Basin

C. Estimation Of Hypsometric Integral

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

$$E = Hi = Elevation\ (mean) – Elevation\ (min) / Elevation\ (max) – Elevation\ (min)$$

Elevation (max) and Elevation (min) are the maximum and minimum elevation 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

$$Elevation\ (mean) = (\sum NiEi) / (\sum Ni)$$

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.

$$Hypsometric\ Integral=[(Xi*Yi+1)- (Xi+1*Yi)]/2$$

Where Xi is the Cumulative Area and Yi Cumulative Altitude

Table.2 Estimated Hypsometric Integral Values Of Ghataprabha Sub Basin

Sub Basin Name	Area in Sq. km	Elevation (m)			Hypsometric Integral	Geological Stage
		Max.	*Min.*	*Mean*		
Ghataprabha	8716	966	347	657	0.37	Equilibrium or Mature stage

The hypsometric integral (HI) values obtained for the Ghataprabha sub basin is presented in Table.2. The HI value of the Ghataprabha sub basin is computed to be 0.37, which represents the watershed is at equilibrium or mature stage.

V. CONCLUSION

The Hypsometric analysis of a basin has several applications both hydrological and topography. The Hypsometric analysis of watershed is prerequisites the development of geological stages and it is also useful to undertaking soil and water conservation measures. Further the hypsometric integral value 0.37 (equilibrium or mature Stage) indicates the geological stage of the watershed which helps to quantifying the erosion susceptibility of the watershed. Soil erosion measures and land utilization can be done from the hypsometric analysis.

REFERENCES

[1] Reitter, D.F., Kochel, R.C. and Miller, J.R.," Process Geomorphology," McGraw Hill, Boston, 2002.
[2] Weissel, J.K., Pratson, L.F. and Malinvemo, A. Helcag&," scaling properties of topography," J. Geophys. Res. 99: 13997-14012, 1994.
[3] Langbein," Topographicchactristics of drainage basins," U.S.G.S. Water Supply Paper. 968C: 127-157, 1947.
[4] Hurtez, J.E., Sol, C., and Lucazeau, F., "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, 799–808, 1999.
[5] Strahler, A.N., "Hypsometric (area-altitude) analysis of erosional topography," Geological society of America bulletin, 63, 1117– 1141, 1952.
[6] Harrison, C.G., Miskell, K.J., Brass, G.W., Saltzman, E.S. and Sloan II, J.L.," Continental hypsography. Tectonics," 2:357-377, 1983.
[7] Rosenblatt, P. and Pinet, P.C., "Comparative hypsometric analysis of Earth and Venus," Geophysical research letters, 21, 465–468, 1994.
[8] Garg, S.K.," Geology the Science of the earth. Khan- na Publishers," New Delhi, 1983.
[9] Pandey, A., Chowdhary, V.M. and Mai, B.C.," Hypsometric analysis using Geographical Information System," J. Soil & Water Cons. India, 32: 123-127,2004.
[10] Singh, Q. Sarangi, A. and Sliarma, M.C.," Hypsometric integral estimation methods and its relevance on erosion status of north western Lesser Himalayan watershed," Water Res. Mgt. 22:1545 1560, 2008.
[11] 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.