Hypsometric Analysis of Jamuna Watershed, Assam with Application of Geographical Information System

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ABSTRACT

Hypsometric analysis (area-altitude study) is useful to understand the stages of geomorphic development of a river basin. In a hypsometric analysis, hypsometric curve and hypsometric integral are the two important indicators of study. The shapes and values of the hypsometric curve and hypsometric integral reveal the stage of development of the basin. In this present study, hypsometric analysis of ten sub-watersheds of Jamuna river has been carried out to compute hypsometric integral values. The values of hypsometric integral for the sub-watersheds range from 0.12 to 0.52, which indicates that the sub-watersheds of the Jamuna river are either in equilibrium or monadnock state. GIS provides an advanced and accurate tool to obtain hypsometric information and facilitates to compute the associated parameters of landforms.

Keywords: GIS, hypsometric curve. Hypsometric integral, Jamuna river, watershed

I. INTRODUCTION

Hypsometric analysis (area-altitude analysis) is the study of the distribution of the horizontal cross-sectional area of a landmass concerning elevation (Strahler, 1952). Langebein (1947) was the first person to introduce a hypsometric analysis to express the overall slope and the forms of a drainage basin. Naturally, hypsometric analysis has been used to differentiate between erosional landforms at different stages during their evolution (Strahler, 1952, Schumm, 1956). Hypsometric analysis of drainage basins (area-elevation analysis) has been evaluated to determine the geological stages of development and to study the influence of varying forcing factors on watershed topology. It deals with the measurement of the interrelationships between the basin area and altitude of the basin, which has been used to understand the influence of climatic, geologic and tectonic factors on topographic changes. It is considered as an effective tool for understanding the stages of geomorphic evolution and geological development of river catchment, and for the delineation of the erosional proneness of a watershed. Hypsometric integrals and hypsometric curve are the two important indicators of watershed conditions (Ritter et al. 2002; Singh et al. 2008).

II. STUDY AREA

The Jamuna watershed lies in an area between $25^0 41'$N to $26^0 27'$ N latitude and $92^0 44'$ E to $93^0 40'$ E longitude (Figure 1). It is a principal tributary of Kopiliriver. The river Jamunadrains through an area of 3903 sq km from its source to its confluence with the river Kopili. It flows through Hojai and Karbi

Anglong district of Assam. Out of the total geographical area of the watershed; 753.6 sq km (20 per cent of the entire basin) area lies in Hojai district and remaining 3149.4 sq km area (80 per cent of the total geographical area of the watershed) in the Karbi Anglong district of Assam. It originates at Khumbaman hills of Diphu sub-division at an elevation of 1360 meters above mean sea level located at 26°8′ N and 93°30′ E longitude and descends to about 60 meters above mean sea level before meeting Kopili river at Jamunamukh. With a total length of 172.8 km, Jamuna is one of the significant perennial river systems of KarbiAnglong district.

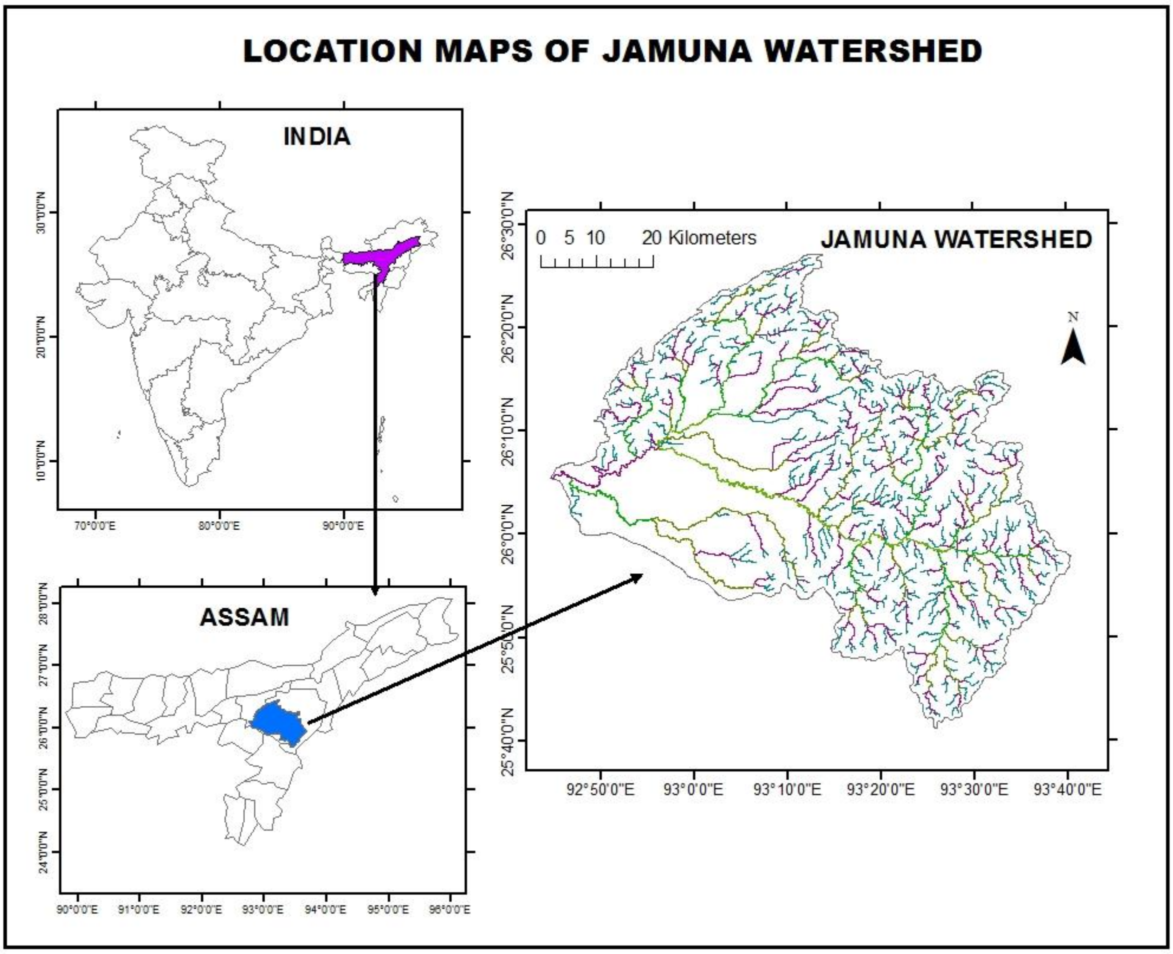


Fig: 1 Location map

Jamuna flows southwards from its source region for about 32.4 km, then joins Dilai river near Manja and flows westwards until it meets Kopili river at Jamunamukh. The Mikir hills located to the north of the river Jamuna, forming the northern boundary of the watershed. The Nambor Reserve Forest and Dhansiri Reserve Forest are situated to the eastern and southern side of the basin, while the Kopili river forms the western boundary of Jamuna watershed. A significant portion of the study area is hilly and comprises of hills with the plain area in the south-western part of the basin. The plain area is minimal in comparison to the upland. The population concentration is very high only in the small plain area of the basin. The maximum elevation is more than 1100 meters in the northern area of the watershed, while the minimum elevation is less than 50 meters (Figure 2). About 70% of the total area lies within 300 meters elevation value

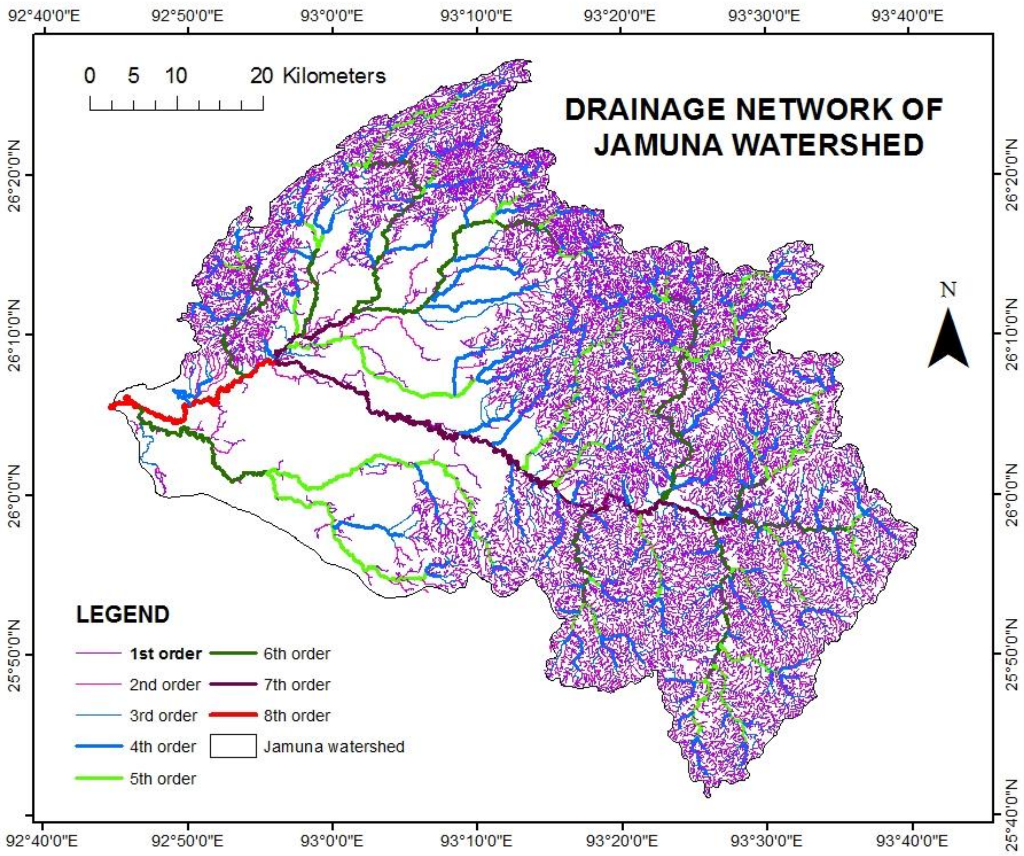


Fig 2: Drainage map of Jamuna watershed

III. MATERIALS AND METHODS

The boundary of Jamuna watershed has been delineated from Survey of India toposheets of 1;50000 (83B/12, 83B/15, 83B/16, 83C/13, 83F/3, 83F/4, 83F/7, 83F/8, 83F/11, 83F/12, 83G/1, 83G/5, 83G/6, 83G/9) in ArcGIS 10.2 following water divide line. The entire drainage segments are digitised as lines separately for each order (Strahler, 1952), and drainage map was prepared (Figure 2). The highest order of Jamuna river is eight. All the sixth ordered sub-basins are delineated following surface water divide (Figure3).

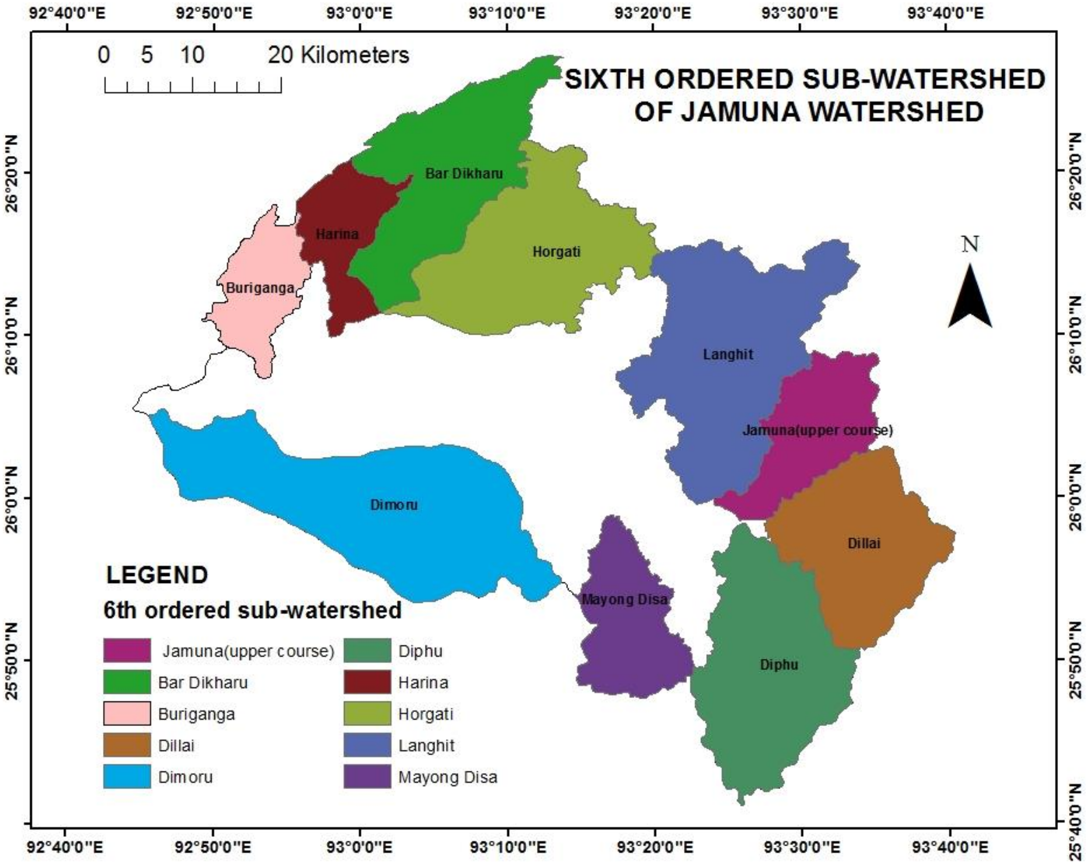


Fig 3: Sixth ordered sub-watershed of Jamuna river

Hypsometric analysis has been done for all the sixth-ordered sub-watershed of Jamuna river. ASTER DEM of 30-meter resolution has been used for carrying out hypsometric analysis. Elevation map was also generated by using the DEM in ArcGIS (Figure 4). Contours on 100-meter interval were extracted from ASTER DEM using Spatial Analysis Tool in ArcGIS 10.2, and then it was polygonised to determine the area enclosed by each contour. The hypsometric curve is obtained by plotting the relative area along the abscissa and relative elevation along the ordinate. The relative area is obtained as a ratio of the area above a particular contour to the total area of the sub-watershed encompassing the outlet. The relative elevation is calculated as the ratio of the height of a given contour from the base plane to the maximum basin elevation (Ritter et al. 2002). Hypsometric integral for all the sub-watersheds was computed by the formula given by Pike and Wilson (1971)

$$E \approx HI = \frac{Elev_{mean} - Elev_{min}}{Elev_{max} - Elev_{min}}$$

Where E is the elevation-relief ratio equivalent to the hypsometric integral HI; $Elev_{mean}$ is the weighted mean elevation of the watershed estimated from the identifiable contours of the delineated watershed; $Elev_{max}$ and $Elev_{min}$ are the maximum and minimum elevations within the watershed.

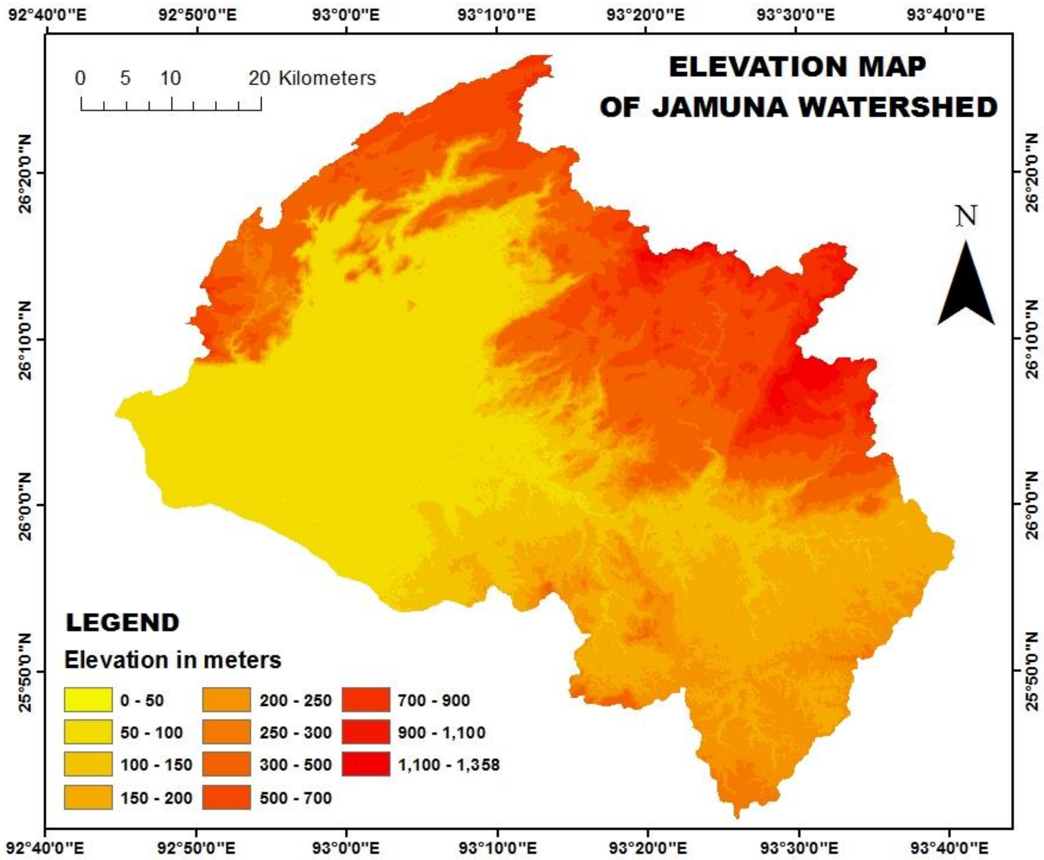
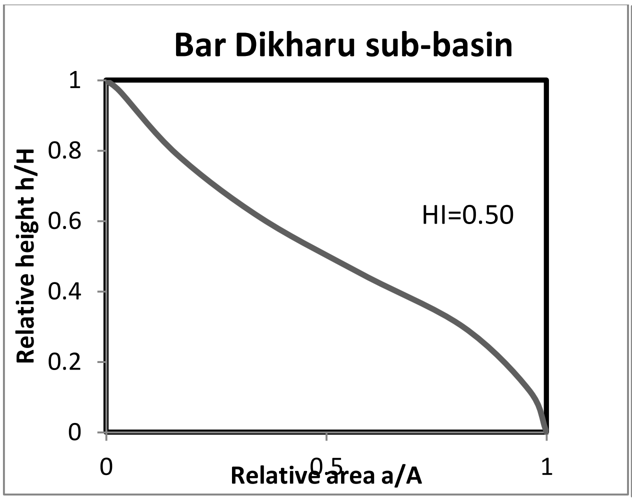
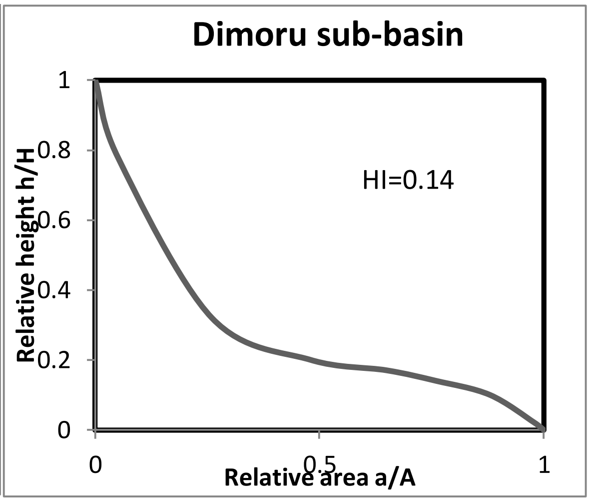


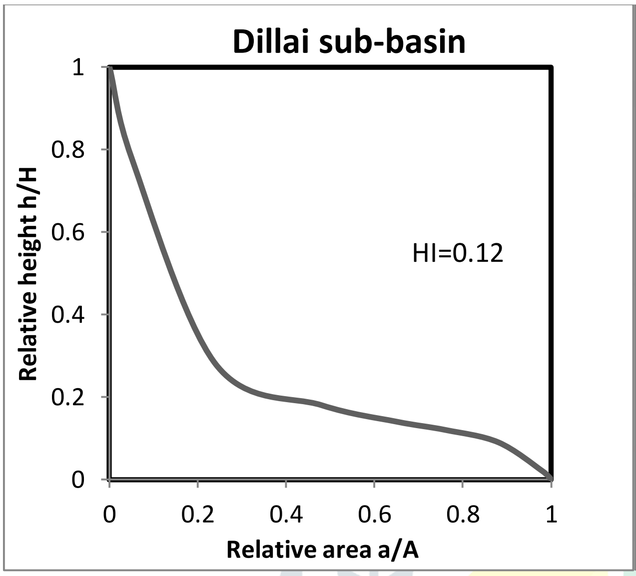
Fig 4: Elevation map of Jamuna watershed

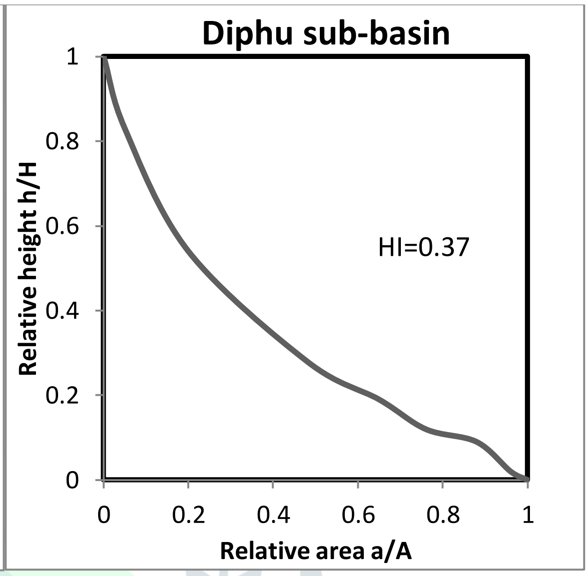
IV. RESULTS AND DISCUSSION

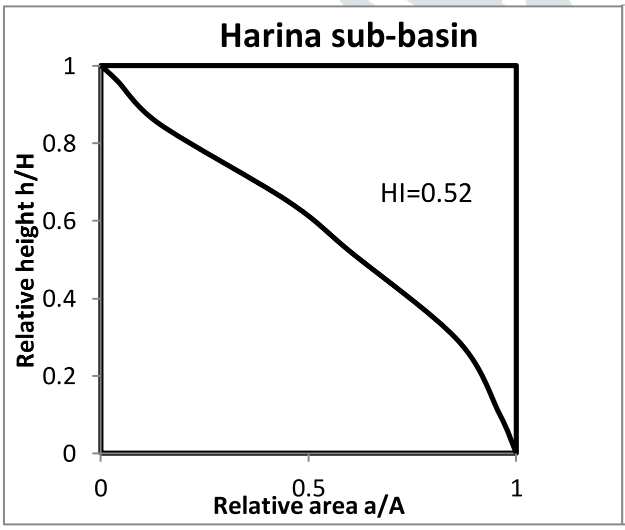
The hypsometric curve and HI value provide valuable information in deciding the geological stage of the development of a watershed. The hypsometric curve is essentially a normalised cumulative frequency distribution of elevation (Strahler, 1954). The hypsometric curve is related to the volume of the 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 the non-dimensional distribution of relative basin elevations with the relative area of the drainage basin (Strahler, 1952). Strahler (1952) interpreted shapes of hypsometric curves by analysing numerous drainage basins and classified the basins as the youth (convex upward curves), mature (S-shaped curves which are concave upwards at high elevations and convex downwards at low elevations) and peneplain or old (concave upward curves). For all the ten sub-watershed hypsometric curves have been prepared (Figure 5) and it is observed that Dimoru, Dillai, MayongDisa and Horgati sub-watershed show concave hypsometric curve which indicates these four sub-watersheds belong to old or monadnock stage of landform evolution. On the other hand, Bar Dikharu, Harina, Buriganga, Diphu, Langhit and Jamuna (upper course) show S-shaped hypsometric curve indicating a mature stage of landform evolution.

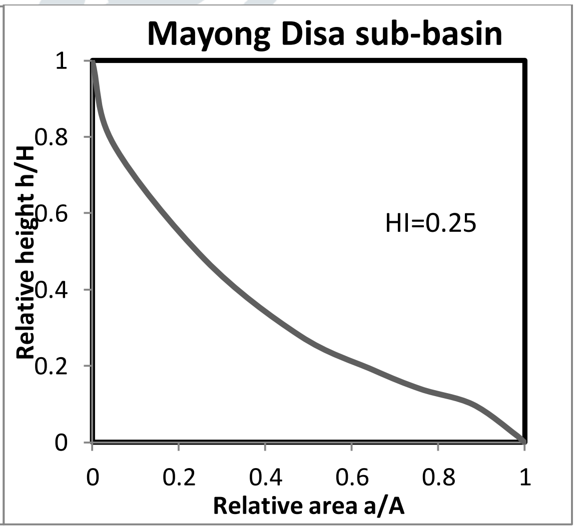

Bar Dikharu sub-basin
HI=0.50
Relative height h/H
Relative area a/A
0
0.2
0.4
0.6
0.8
1
0.5


Dimoru sub-basin
HI=0.14
Relative height h/H
Relative area a/A
0
0.2
0.4
0.6
0.8
1
0.5


Dillai sub-basin
HI=0.12
Relative height h/H
Relative area a/A
0
0.2
0.4
0.6
0.8
1


Diphu sub-basin
HI=0.37
Relative height h/H
Relative area a/A
0
0.2
0.4
0.6
0.8
1


Harina sub-basin
HI=0.52
Relative height h/H
Relative area a/A
0
0.2
0.4
0.6
0.8
1
0.5


Mayong Disa sub-basin
HI=0.25
Relative height h/H
Relative area a/A
0
0.2
0.4
0.6
0.8
1

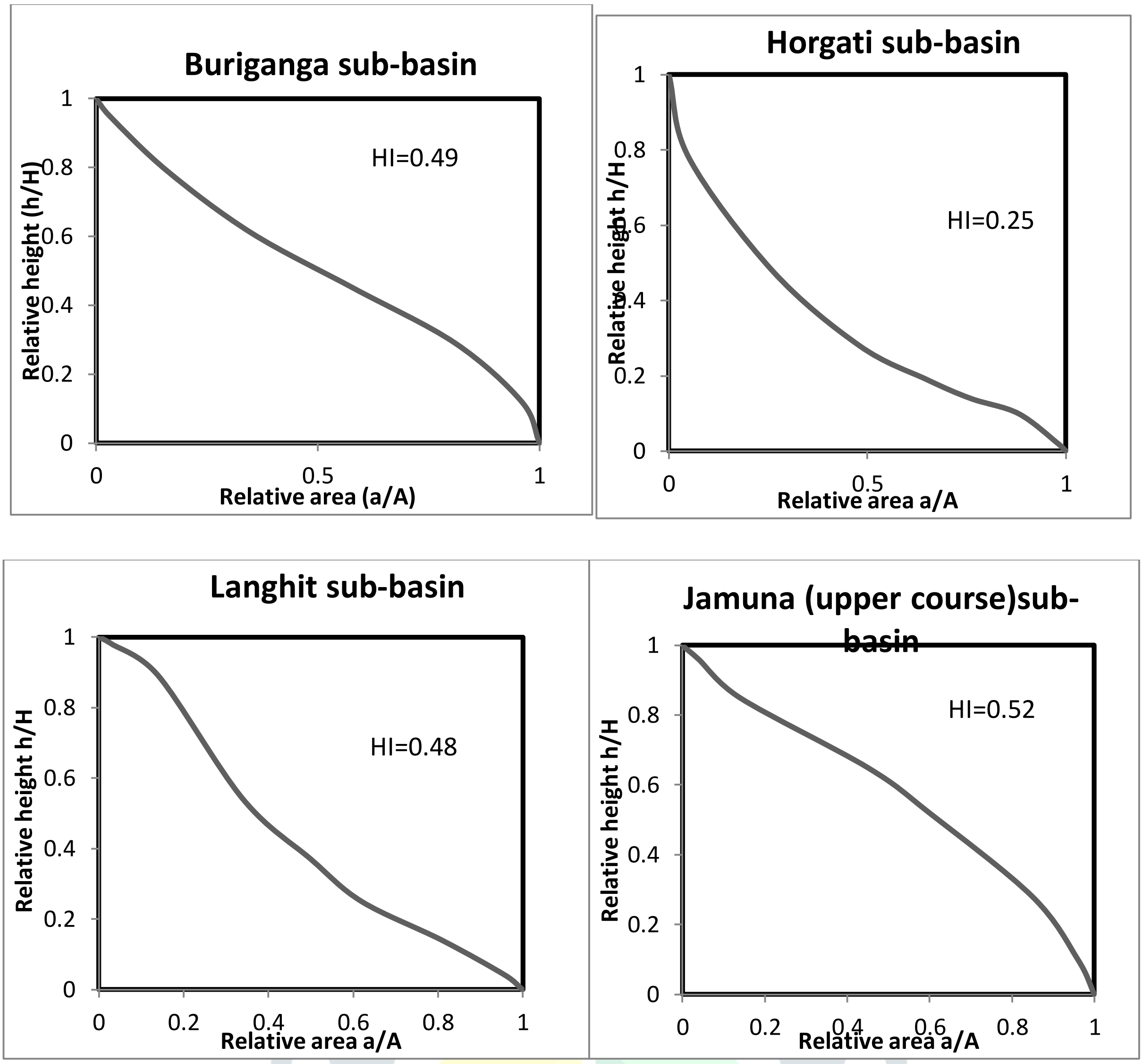


Fig 5: hypsometric curve of all the sub-watersheds of the study area

Integration of the hypsometric curve gives the hypsometric integral HI. The threshold limits recommended by Strahler (1952), as given below, were adopted for deciding the stage of the watershed.

(i) The watershed is at in-equilibrium (youthful) stage if the HIe = 0.6

(ii) The watershed is at equilibrium stage if 0.35 = HI< 0.6.

(iii) The watershed is at Monadnock stage if HI< 0.35

In the in-equilibrium stage, the watershed is still under development. The equilibrium stage is the mature stage of watershed development, i.e. the development has attained steady state condition. The Monadnock phase occurs particularly when isolated bodies of resistant rock from prominent hills Monadnock) are found above the subdued surface and is indicated by the distorted hypsometric curve(Kusre, 2013).

Table 1: Hypsometric integral value of the sub-watersheds of the study area

Sl no	Sub-watershed	Max Elev	Min Elev	Mean Elev	HI	Stage
1	Buriganga	820	80	448.20	0.49	Equilibrium
2	Dimaru	340	60	101.52	0.14	Monadnock
3	Harina	540	80	323.73	0.52	Equilibrium
4	Bar Dikharu	800	80	441.87	0.50	Equilibrium
5	Horgati	1280	80	387.60	0.25	Monadnock
6	Langhit	1340	160	732.07	0.48	Equilibrium
7	Dillai	700	160	226.90	0.12	Monadnock
8	Diphu	300	160	212.02	0.37	Equilibrium
9	MayongDisa	480	140	225.35	0.25	Monadnock
10	Jamuna (Upper course)	1340	160	784.97	0.52	Equilibrium

Hypsometric Integral has been computed for all the sub-watersheds of Jamuna watershed. The HI values for the sub-watersheds range from 0.12 to 0.52 (table 1). The HI values indicate that all the sub-watersheds are either in equilibrium or monadnock state. Out of the ten sub-watersheds, six watersheds fall under equilibrium state and four watersheds fall under monadnock stage. Buriganga, Harina, Bar- Dikharu, Langhit, Diphu and Upper course of Jamuna sub-watersheds are in equilibrium stage and are susceptible to erosion. On the other hand, Dimaru, Horgati, Dillai and MayongDisa are attaining monadnock stage. Watershed with higher HI values indicated higher soil moisture, whereas a watershed with lower HI values is characterized by soil moisture being concentrated at the shallow depth. (Vivoni et al. 2008).This means that watershed with lower HI values has less total runoff contributed from surface runoff. Whereas, a watershed with higher HI values shows surface runoff is a significant process contributing to the total runoff.

V. CONCLUSION

Hypsometric analysis of river basin expresses the degree of denudation and rate of morphological changes. Therefore it is useful to comprehend the erosion status of watersheds and prioritise them for undertaking soil and water conservation measures. The hypsometric value for the sub-watersheds of Jamuna river ranges from 0.12 to 0.52, indicating that the watersheds are either in mature stage or old stage. The hypsometric analysis indicated that Jamunawatershed is relatively matured and erosional processes have stabilised. Surface runoff is the dominant process in the entire watershed, thereby, contributing significantly to the floods in the downstream areas.

References

- 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, 799–808.
- Kusre B.C.(2013): Hypsometric Analysis and Watershed Management of Diyung watershed in North Eastern India, Journal of Geological Society of India, vol.82, pp.262-270
- Markose, V.J and Jayappa, K.S. (2011): Hypsometric analysis of Kali River Basin, Karnataka, India, using the geographic information system. Geocarto International, v 26, pp 553-568
- Pradeep P. and Vinaya M.S.(2016): GIS and Hypsometry based Analysis on the evolution of Sub Basins of Ponnaiyar River, Krishnagiri District, Tamil Nadu, International Journal for Innovative Research in Science & Technology, v2,
- Ritter, D.F., Kochel, R.C. and Miller, I.R. (2002) Process Geomorphology. McGraw Hill, Boston.
- Schumm, S.A. (1956), Evolution of drainage systems and slopes in bad-lands atPerth Amboy, New Jersey, Geol. Soc. Am. Bull., 67, pp 597–646.
- Singh, O., Sarangi, A. and Sharma, M.C. (2008), Hypsometric integral estimation methods and its relevance on erosion status of north-western Lesser Himalayan Watersheds, Water Res. Mgt., 22, pp 1545-1560.
- Strahler, A.N., (1952): Hypsometric (area-altitude) analysis of erosional topography. Geological society of America bulletin, 63, 1117–1141
- Vivoni, E.R., DiBenedetto,F, Grimaldi, S. and Eltahir, E.A.B.(2008): Hypsometric control on surface and subsurface runoff, Water Resour. Res., v.44, W12502, doi:10.1029/2008WR006931