Prioritization of Sub-Watersheds by Hypsometric Studies for Shimsha Watershed, Cauvery Basin, Karnataka, India using Remote Sensing and GIS Techniques

Dr. Ramesh L Dikpal[1] Dr. Renuka Prasad[2] Dr. G S Srinivasa Reddy[3]
[1]Junior Scientific Officer [2]Professor [3]Senior Consultant
[2]Department of Geology
[1]Karnataka State Natural Disaster Monitoring Centre, Bangalore, Karnataka, India [2]Bangalore University, Bangalore, Karnataka, India [3]Revenue Department (Disaster Management), Bangalore, Karnataka, India

Abstract— Hypsometric of drainage basins (area-elevation analysis) have generally been used to reveal the stages of geomorphic development (stabilized, mature and young). In the present study, sub-watersheds of Shimsha basin were considered towards dimensionless properties of hypsometric integral and curve analysis using Cartosat-1 digital elevation model (DEM) version 1 of resolution 1 arc Sec (~32 m) data obtained from Bhuvan is processed in ArcGIS 10.3v and are effectively used for prioritization. It is observed from the hypsometric curves and hypsometric integral values in the sixth ordered (0.11 to 0.49) and seventh ordered (0.15 to 0.38) sub-watersheds are distributed equilibrium to inequilibrium as well as monadnock stage of geomorphic development. The erosion stage of the lower order watersheds influences its stage to the higher order watershed. If the watersheds will attain a maximum number of identical stage of development will directly indicates the higher watersheds will able to attain the equivalent feature. Basin hypsometry clearly depends on lithology, whereas lithological effect is minor on relief amplitude at various spatial scales. Thus, the hypsometric integral value can be used as an estimator of erosion status of watersheds leading to watershed prioritization for taking up soil and water conservation measures in watershed systems.

Keywords: Hypsometric Integrals and Hypsometric Values, Shimsha Watershed, RS & GIS techniques and Cartosat-1 DEM

I. INTRODUCTION

The chief features prevailing the development of landscape are tectonics and/or climate and the variation in lithology (Babu, K.J., Sreekumar, S., Arish, A. and Midhun, K.P, 2014). A drainage basin which is recognizable as being of fluvial erosive origin is measured a basic essential geomorphic, topographic and hydrological areal unit of watershed management (Chorely, R. 1971). Morphometry is defined as the measurement and arithmetical estimation of the pattern of the earth's surface, and of the shape and dimensions of its landforms. The main characteristics which are habitually analyzed are: area, altitude, volume, slope, profile and texture of the land, and other different aspects of drainage basins (Clark, J. 1966). Conventional geomorphometric analysis were carried out to explore the correlation between morphometric characteristics of drainage networks and climate, relief, lithology, structure and tectonics in order to interpret the morphometric parameters (Kouli, M., Vallianatos, F., Soupios, P. and Alexakis, D. 2007), (Nageswara, R., Swarna, L., Arun, K. and Hari, K. 2010) and (Thomas, J., Joseph, S., Thrivikramji, K., Abe, G. and Kannan, N. (2012). Morphotectonic indicators are exploration tools to evaluate the relationship between tectonics and basin morphology and to identify current geological deformation (Kale, V.S., Sengupta, S., Achyuthan, H. and Jaiswal, M.K. 2014).

William Morris Davis, the inventor of the model, separated it into stages whose evolution is gradual. The model initiates with an uplifted or to-be-uplifted landscape. Then Davis describes a youthful stage where river slit is the foremost progression influential the landscape. Throughout the youthful stage elevation dissimilarities between uplands and valley bottom increases rapidly. The youthful stage is followed by a mature stage where elevation dissimilarities between valley bottoms and uplands are at their greatest. Commencement in the mature stage slope decline becomes an additional important phenomenon, and uplands lose height more quickly than rivers incise, efficiently diminishing relief. In the very latest stage erosion has acted so long that the landscape – even though original height – is reduced into rolling lowland. This landscape of low relief is called a peneplain and might hold residual heights standing out from the general level. The peneplain can be uplifted, starting a second erosion cycle.

The rapid emerging spatial information technology, remote sensing, GIS, and GPS have successful tools to overcome the majority of the problems of land and water resources planning and management relatively than conventional techniques of information process (Rao et al. 2010). Cartosat-1 Digital Elevation Model (DEM) stereo data can be considered as elevated accuracy (R. Dabrowski, W. Fedorowicz-Jackowski, M. Kedzierski, P. Walczykowski and J. Zych, 2008). The imageries captured by the satellite can be safely processed for the functions it has been designed for (Srivastava, 2007) i.e. gathered altitude data with accuracy adequate for maps with the scale of 1:25,000.

The drainage delineation illustrates superior precision and apparent demarcation of catchment ridgeline and extra reliable flow-path prediction in evaluation with ASTER. The outcome qualifies Indian DEM for using it operationally which is alike and superior to the other publicly available DEMs like SRTM and ASTERDEM (S. Muralikrishnan, Abhijit Pillai, B. Narender, Shashivardhan Reddy, V. Raghu Venkataraman & V. K. Dadhwal, 2013). In the present study, digital elevation models (DEMs) provide the nearly all standard technique to extract the requisite information which controls geomorphological processes. Additionally, DEMs can be employed to delineate the drainage networks accurately with

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all first-order streams or the "fingertip" tributaries as described earlier by Horton 1945.

Hypsometry means relative percentage of an area at different elevations within a region and hypsometric curve represents distribution of area with respect to elevation (Strahler 1952). The hypsometric integral is also a sign of the 'cycle of erosion' (Strahler 1952; Garg 1983). The 'cycle of erosion' is defined as the overall time requisite for decline of an earth topological entity to the base level i.e. the lowest level. This entire period or the 'cycle of erosion' can be divided into three stages, viz., monadnock (old) (H_{si} 0.3), in which the watershed is fully stabilized; equilibrium or mature stage (0.3 H_{si} 0.6); and inequilibrium or young stage (H_{si} 0.6), in which the watershed is extremely susceptible to erosion (Strahler 1952).

To study the regional scenario of the basin Cartosat-1 stereo data and ArcGIS v10.3 software is efficiently used. Prioritization of sixth and seventh ordered Sub watersheds are selected for the study. 3D models of the sub watersheds demonstrate the outcome of the studies through visualization.

II. Study Area

The area of Shimsha basin is having an area of 8694.45 km2 (Figure. 1) and located between latitude 12°17′24″ N to 13°08′49″ N and longitude 76°15′07″ E to 77°20′02″E. The basin is a part of the maiden area of Karnataka state. The Shimsha River rises on the border of the maiden region and flows southwards from this region. This joins Cauvery river after traversing over 221 km. A number of tanks such as Marcaonahally, Sulekere, Kadaba Amanikere, Mayasandra Kere, Kanva and others are situated in the basin. On its way the watercourse is joined by other small rivers namely Kanva, Chikkahole, Mullahalla, Veeravaishnavi, Hebbahalla and Kanihalla. The southeastern and western parts are hilly regions. The central portion of the basin is a low laying area. The Shimsha river makes a descent of 94 m before joining the Cauvery river in the region popularly called as Shimsha falls. Further south the river gently meanders. Annually the watershed receives 935 mm of rainfall; majority of the rainfall around 625 mm will be received by South–West monsoon in the months from June to September.

Geologically, the study area is covered by a wide range of rock types, ranging from the Sargur Group complex of Archaean age to Charnockite (2500 m.y.) of Archaean to Proterozoic age. The Sargur group is the oldest rock dated so far in Karnataka are a group of grey gneisses giving an age ranging from 3000-3400 m.y. these are termed ancient supracrustal (Radhakrishna and Vaidhyanathan, 1994). Important lithotectonic linear belts of Sargur group is characterized by a lack of basal unconformity with the associated of diversified igneous and sedimentary rocks. They include ultramafic-mafic volcanic rocks, pellites, quartzite, impure carbonates, iron formation and ultramafic-mafic intrusive bodies (Swaminath and Ramakrishan, 1981). Majority of the area consists of Peninsular Gneissic Complex –I (3000 – 2900 m.y.) of Tonolite-trondjhemite-granodiorite (TTG rocks) lithological sequence. TTG rocks are intrusive rocks with typical granitic composition (quartz and feldspar) but containing only a small portion of potassium feldspar. Tonalite, trondhjemite, and granodiorite often occur together in geological records, indicating similar petrogenetic processes. Archean TTG rocks appear to be strongly deformed grey gneiss, showing banding, lineation, and other metamorphic structures, whose protoliths were intrusive rocks. TTG rock is one of the major rock types in Archean cratons. Geochemically, TTG rocks often have a high silica (SiO_2) content (commonly over 70 percent SiO_2), high Na_2O content (with low K2O/Na2O ratio) compared to other plutonic rocks, and low ferromagnesian element content (the weight percentage of Fe_2O_3, MgO, MnO_2, TiO_2 added together commonly smaller than 5%).

Granitoid gneiss is a variety of metamorphic gneiss that appears to have bands of black and white minerals such as feldspar and mica. These bands form from the heating and squeezing of the rock although, granitoid gneiss may look very similar to the original granite rock. The Bababudan sediments and Volcanics suggest nearshore to shallow marine and sub aerial to shallow marine environment respectively (Chadwick et al., 1985). The rocks of Bababudan Group are metamorphosed up to lower amphibolites facies (garnet isograd) at the borders and greenschist facies at the core portions (Swami Nath and Ramakrishnan, 1981). Subsequently Closepet Granite and equivalents (2530 – 2510 m.y.) is the largest syn-tectonic, late Archaean granitic intrusion in the Eastern Dharwar Craton (Jean-Franc¸oisMoyen, Herve´ Martin, Mudlappa Jayananda B, 2000). The most characteristic rock type of this class is coarse-grained porphyritic granite with large-sized pophyroblasts of pink and grey potash feldspar. Recent geological studies have shown that the Closepet granite resulted from crust–mantle interaction, and that the crustal contaminant was a partial melt of the surrounding TTG gneisses (Jayananda et al., 1995; Moyen et al., 1997). In the Southern part of the Dharwar Craton are granulites facies rocks represented with extensive development of Charnokite and pyroxene granulite.

The course grained gneisses and schists in the area are generally weathered and fractured and serve as good aquifers. The study area consisting of different structural discontinuities like fault, major lineaments, minor lineaments and shear zones are distributed sporadically. The lineaments identified as A – type are potential zones of groundwater accumulation.

III. Materials and Methodology

Cartosat-1 stereo data sets are proved in high accuracy compared to SRTM and ASTERDEM (S. Muralikrishnan, Abhijit Pillai, B. Narender, Shashivardhan Reddy, V. Raghu Venkataraman& V. K. Dadhwal, 2013) and tile extent/spatial extent of 1° × 1° from X in 77–78 E and Y in 13–14 N is used to achieve drainage network (Figure. 2). The drainage networks are dendritic to sub-dendritic in nature The extracted stream network, and basin are projected to the regional projection (WGS_1984_UTM_Zone_43 N).

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The unique characteristics of CartoSAT-1 stereo data and planned products are given below:

Name of the dataset: C1_DEM_16b_2006-2008_V1_77E13N_D43R
Theme: Terrain
Spheroid/datum: GCS, WGS-1984
Original source: Cartosat-1 PAN (2.5 m) stereo data
Resolution: 1 arc s (32 m)
Sensor: PAN (2.5 m) stereo data
File format: Geotiff
Bits per pixel: 16 bit

IV. Extraction of Drainage Network and Sub-Watersheds

ArcGIS version 10.3 software is used for extracting drainages and delineation of sub-watersheds, also ArcScene Version 10.3 is used for 3D model of the basin (Figure. 3) to visualize the slope pattern. Extraction of stream orders is carried out by Hydrology tool from spatial analyst Arc toolbox. Model builder is developed to achieve the drainage network.

Firstly, filling sinks in a surface raster to remove small imperfections in the data. Flow direction is calculated by eight-direction (D8) flow model and follows an approach presented in Jenson and Domingue (1988), followed by flow accumulation, logarithmic accumulation and finally threshold is chosen to get the drainage network in raster format. Conversion of raster format to vector format to get the shape files. Afterwards the drainage network, watershed and sub-watersheds will be delineated by choosing pour points (Figure. 4). From the obtained sub-watershed polygons, extracted the DEM of all the sub-watersheds and classification of the percentage altitude is carried out.

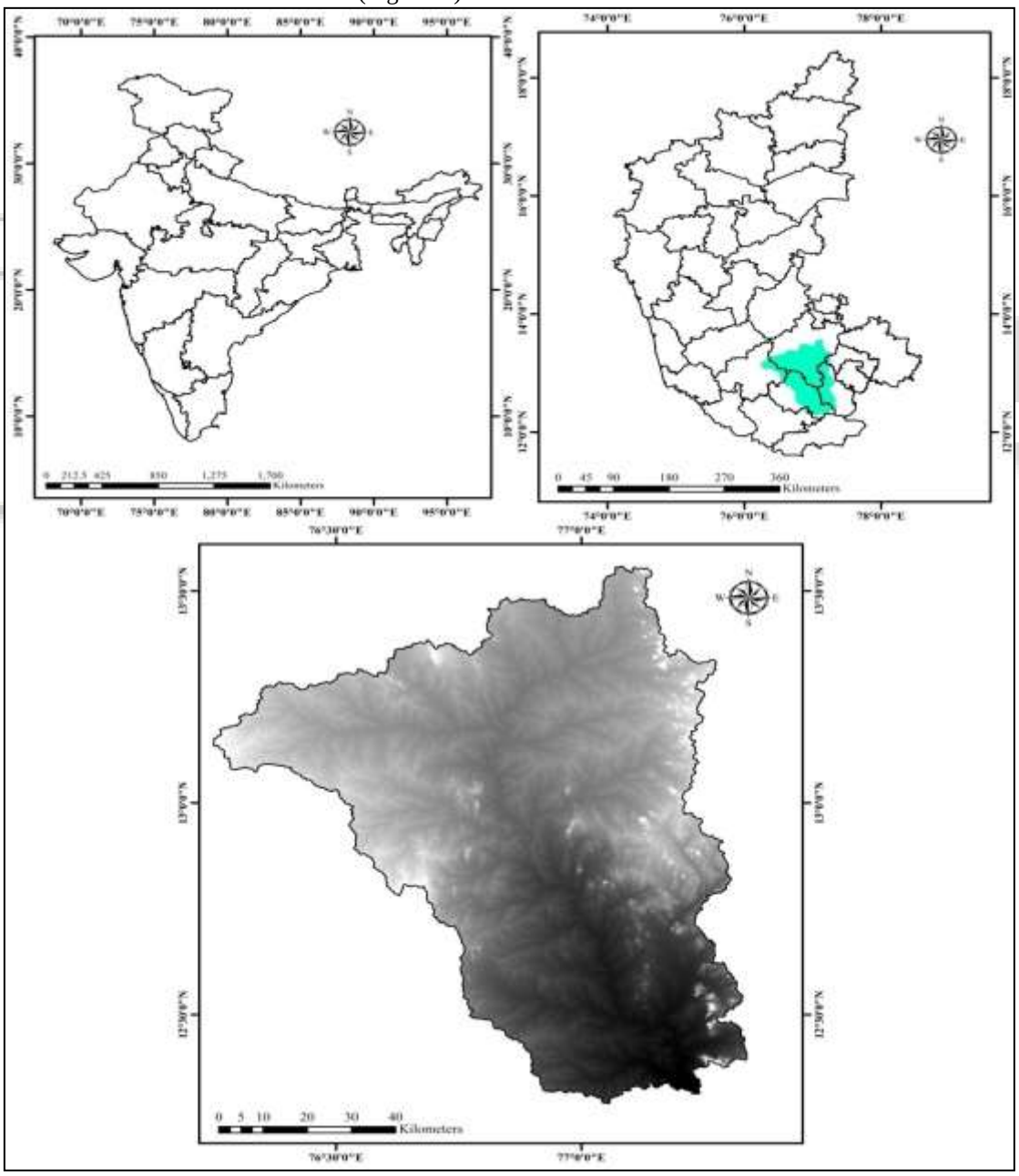

Fig. 1: Location of Shimsha watershed

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Sub-watershed details	Area in km^2	Elevation in mts			HI Value	Cycle of Erosion stage
		Minimum	Maximum	Mean		
Sixth (06) order watersheds						
1	173.55	729	904	804	0.43	Equilibrium to inequilibrium
2	232.73	730	913	798	0.37	Equilibrium
3	190.47	692	871	757	0.36	Equilibrium
4	257.54	681	949	754.5	0.27	Monadnock
5	173.51	679	882	733.8	0.27	Monadnock
6	138.34	688	787	727	0.39	Equilibrium
7	292.55	687	1193	742.6	0.11	Monadnock
8	339.71	688	1165	768.8	0.17	Monadnock
9	426.18	661	1172	730	0.13	Monadnock
10	416.41	659	1194	746.4	0.16	Monadnock
11	165.32	660	1036	729	0.18	Monadnock
12	522.93	533	955	696.3	0.39	Equilibrium
13	151.91	532	914	608.7	0.20	Monadnock
14	172.91	714	864	781.7	0.45	Equilibrium to inequilibrium
15	167.65	709	963	801.8	0.37	Equilibrium
16	200.97	596	992	716.9	0.31	Equilibrium
17	253.36	570	891	680	0.34	Equilibrium
18	179.56	551	835	620.7	0.25	Monadnock
19	525.93	511	836	603.6	0.25	Monadnock
20	405.74	329	799	559.3	0.49	Equilibrium to inequilibrium

Table 1: Estimated hypsometric integral values of the sixth order watersheds

Sub-watershed details	Area in km^2	Elevation in mts			HI Value	Cycle of Erosion stage
		Minimum	Maximum	Mean		
Seventh (07) order watersheds						
1	1402.27	663	949	762.62	0.35	Equilibrium
2	1262.21	657	1193	737.62	0.15	Monadnock
3	680.85	642	963	764.30	0.38	Equilibrium
4	750.35	626	1194	727.55	0.18	Monadnock
5	809.25	507	955	656.9	0.33	Equilibrium

Table 2: Estimated hypsometric integral values of the seventh order watersheds

Sub-watershed details	Area in km^2	Elevation in mts			HI Value	Cycle of Erosion stage
		Minimum	Maximum	Mean		
Entire Shimsha (Eighth Order) watershed						
Shimsha	8694.45	314	1194	689	0.43	Equilibrium to inequilibrium

Table 3: Estimated hypsometric integral value of the Shimsha (Eighth Order) Basin

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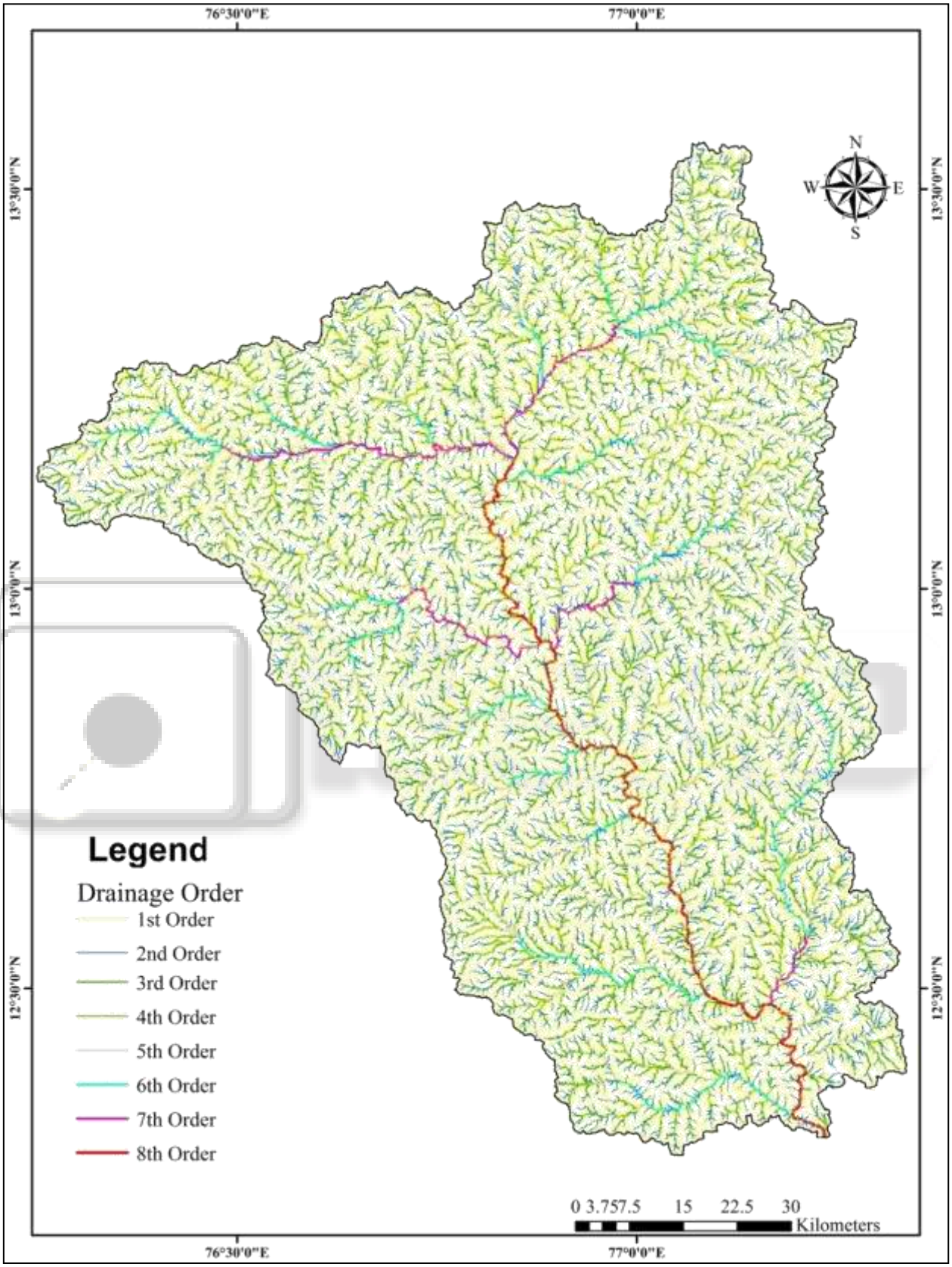

Fig. 2: Drainage order

The hypsometric curve (HC) and hypsometric integral (HI) were calculated for the watershed and sub-watersheds using ArcGIS. The attribute feature classes that accommodate these values were utilized to plot the hypsometric curves for the watershed, from which the HI values were calculated using the elevation-relief ratio method elaborated by Pike and Wilson (1971). The elevation-relief ratio method is found to be easy to apply

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and more accurate to calculate within the GIS environment. The relationship is expressed in the following equation is mentioned in Plotting of Hypsometric Curves (HC) and estimation of Hypsometric Integrals (HI) heading.

V. Results and Discussions

A. Plotting of Hypsometric Curves (HC) and Estimation of Hypsometric Integrals (HI)

Hypsometric investigation intends at emergent a relationship between horizontal cross-sectional area of the watershed and its elevation in a dimensionless form (Figure. 5). Hypsometric curves are attaining by via percentage height (h/H) and percentage area relationship (a/A) (Luo 1998). The relative area is obtained as a ratio of the area above a particular contour to the total area of the watershed encompassing the outlet (Figures. 6a & b).

In the present study, the hypsometric integral was estimated using the elevation-relief ratio method proposed by Pike and Wilson (1971). The relationship is expressed as:

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

Where E is the elevation-relief ratio equivalent to the hypsometric integral His; Elevmean is the weighted mean elevation of the watershed estimated from the identifiable contours of the delineated watershed; Elevmin and Elevmax are the minimum and maximum elevations within the watershed.

Hypsometric integral values along with the form of geomorphic cycle are illustrated and the sub watersheds HI value ranges are plotted correspondingly in Figures 6a and 6b. It was observed from the hypsometric curves of the sixth ordered watershed (Figure. 7) that the drainage system is accomplishes equilibrium to inequilibrium and monadnock stage. Seventh order sub watersheds (Figure. 8) attaining an equilibrium to monadnock stage of erosion and the eighth (Figure. 9) ordered Shimsha basin is representing equilibrium to inequilibrium stage of geomorphic development. The comparison between these curves shown in Figures.7, 8 and 9 indicated a minor variation in mass removal from the main watershed and their sub basins. It was also observed that there was a combination of concave up and S shape of the hypsometric curves for the watershed and their sub basins. This could be due to the soil erosion from the watershed and their sub basins resulting from the down slope movement of topsoil and bedrock material, washout of the soil mass.

The HI values ranging from 0.11 to 0.49 for the sixth order (Table 1) sub watersheds indicating equilibrium to inequilibrium as well as monadnock stage of geomorphic development. HI values ranging from 0.15 to 0.38 for the seventh order (Table 2) sub watersheds representing equilibrium to monadnock stage of geomorphic development and the entire Shimsha basin (eighth order) HI value of 0.43 (Table 3) represents equilibrium to inequilibrium stage of geomorphic development. Statistical moments of different hypsometric curves can be used for further analysis (Harlin 1978; Wei Luo 1998; Perez-Pena et al. 2009).

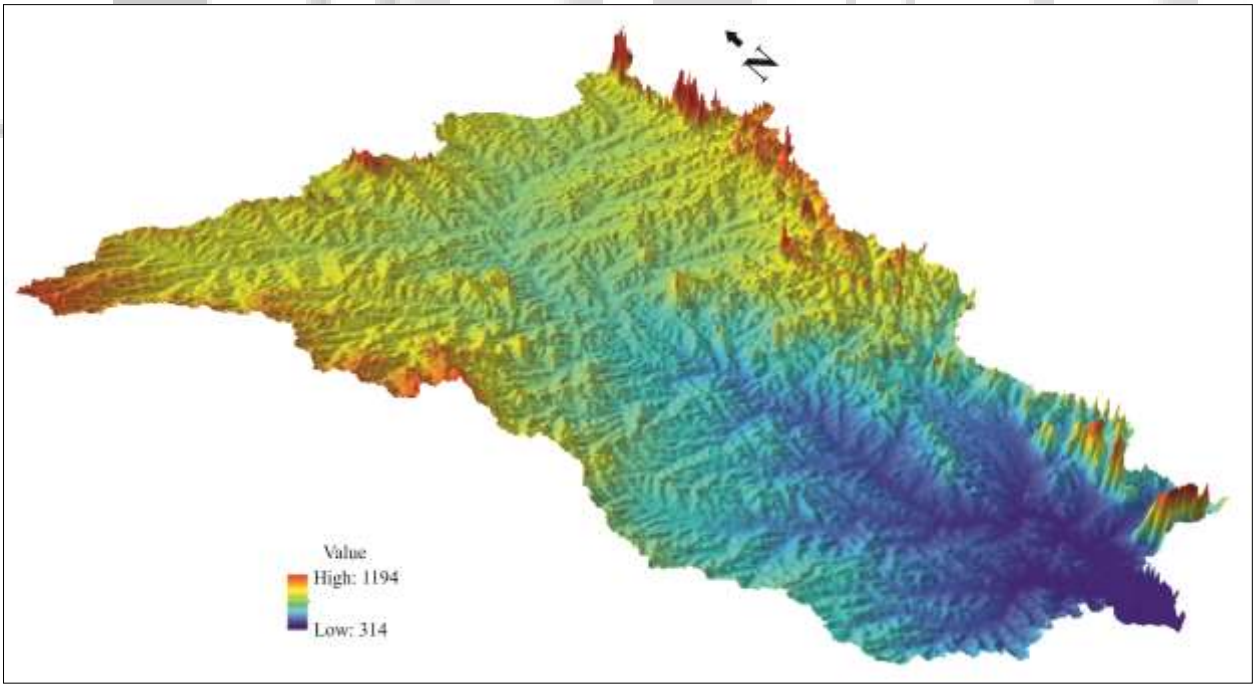

Fig. 3: 3D model of Shimsha watershed

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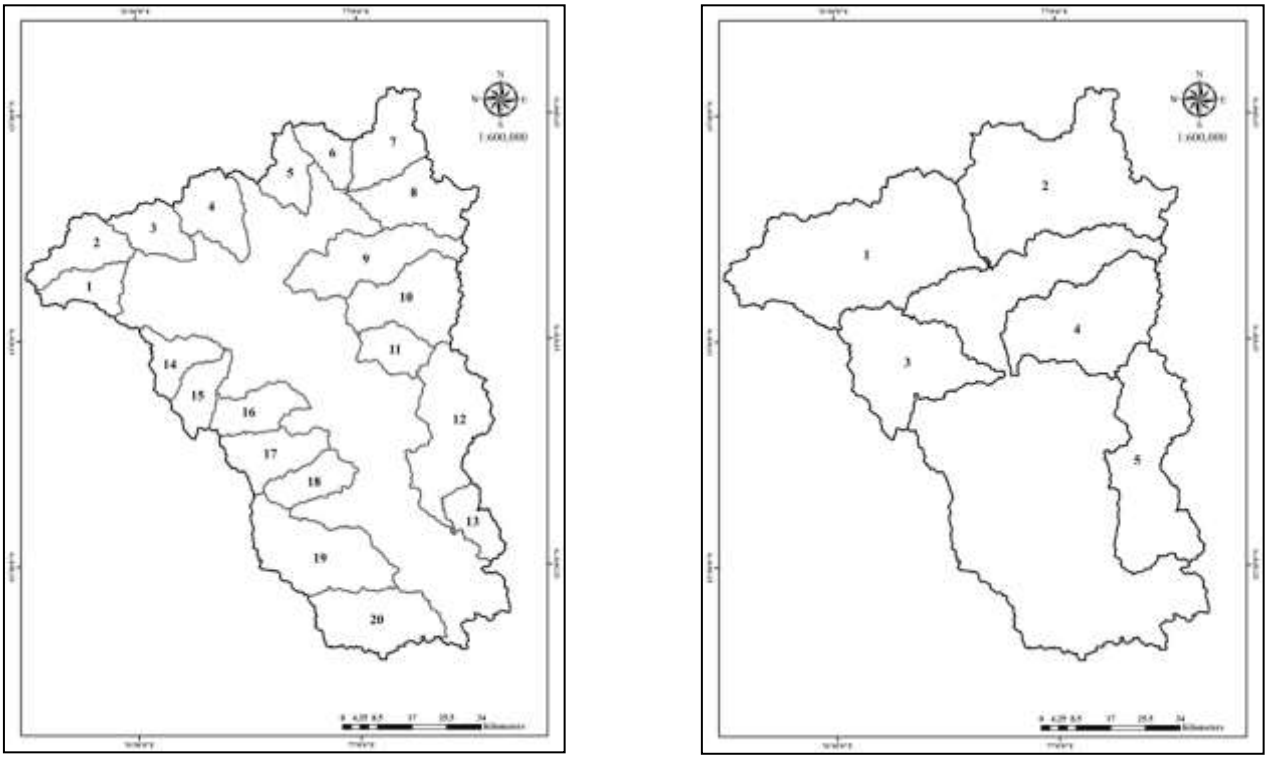

Fig. 4: Sub-watersheds of a. Sixth order basin & b. Seventh order basin

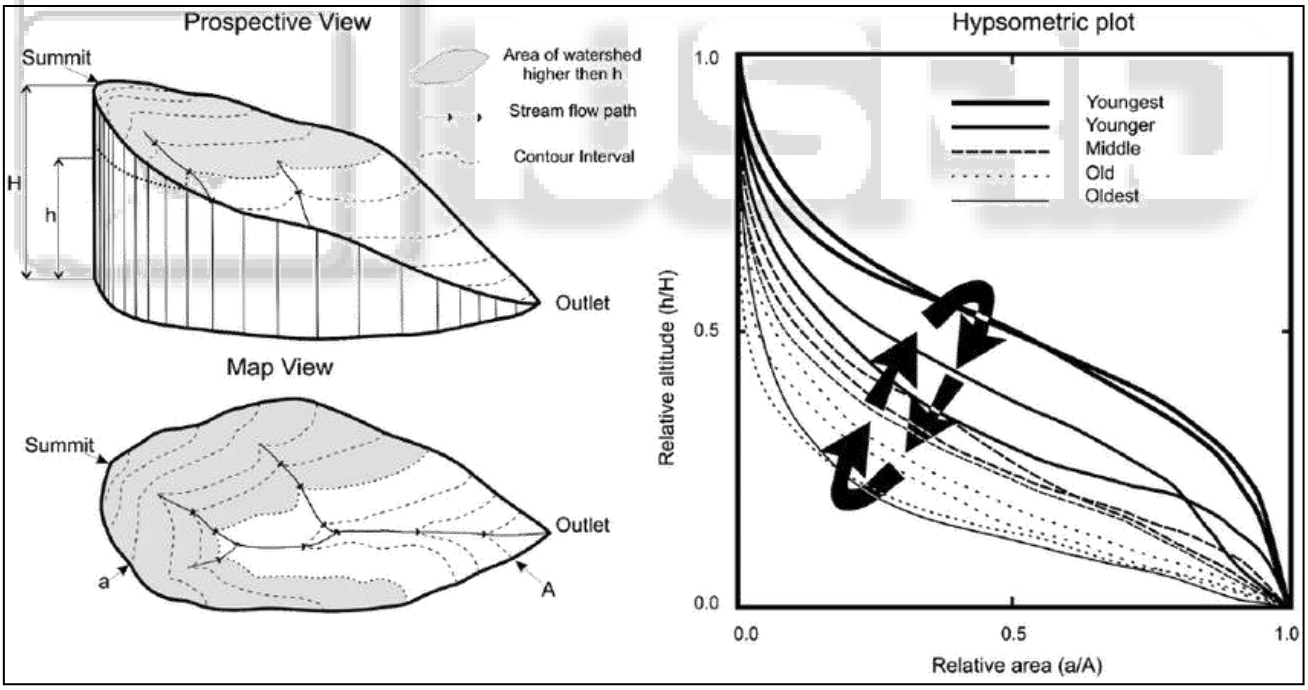

Fig 5: Calculation of hypsometric curve and their interpretation. (a) Schematic diagram shows procedure for calculating hypsometric curves using percentage height (h/H) and percentage area relationship (a/A) (Luo, 1998) and (b) Interpretation of different hypsometric curves: convex curves represent youthful stages, s-shaped and concave curves represent mature and old stages. This behavior depends on variation in orogenic elevation during a geomorphic cycle (Perez-Pena et al., 2009).

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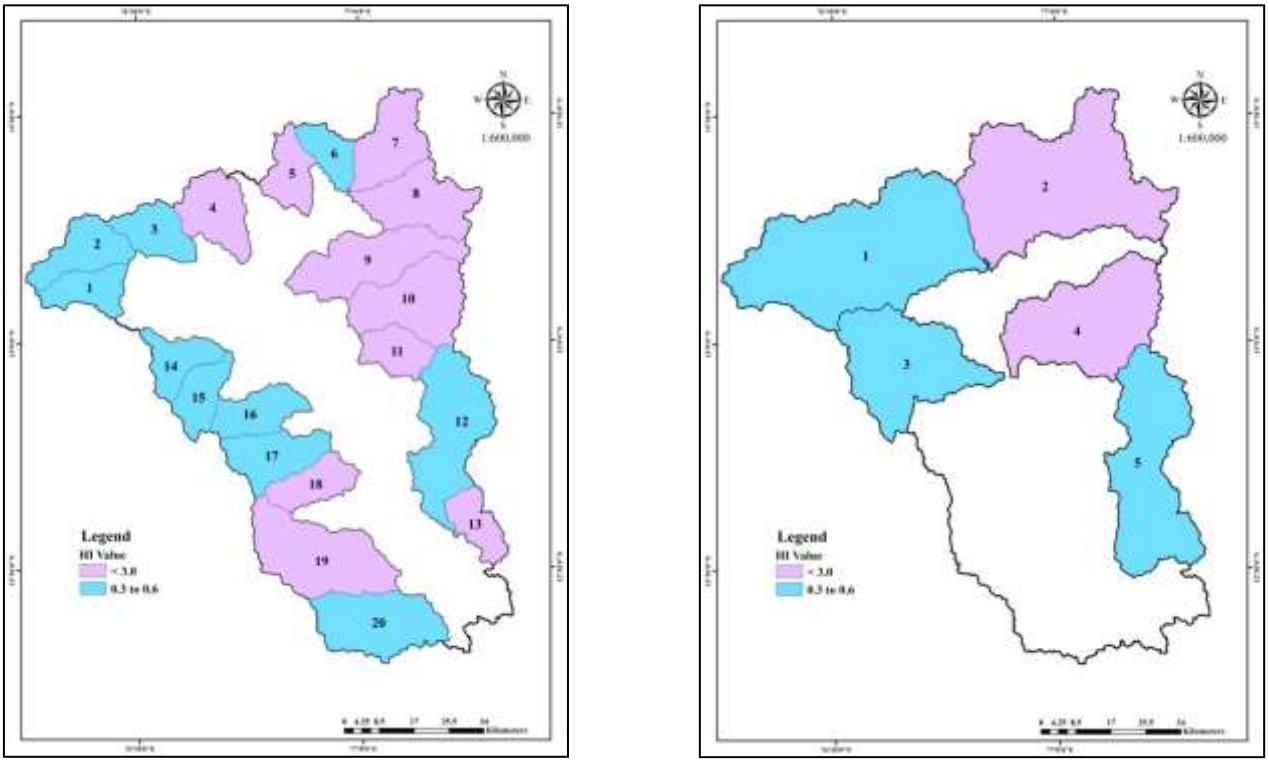

Fig. 6: Hypsometric Integral values of a. Sixth order basin & b. Seventh order basin

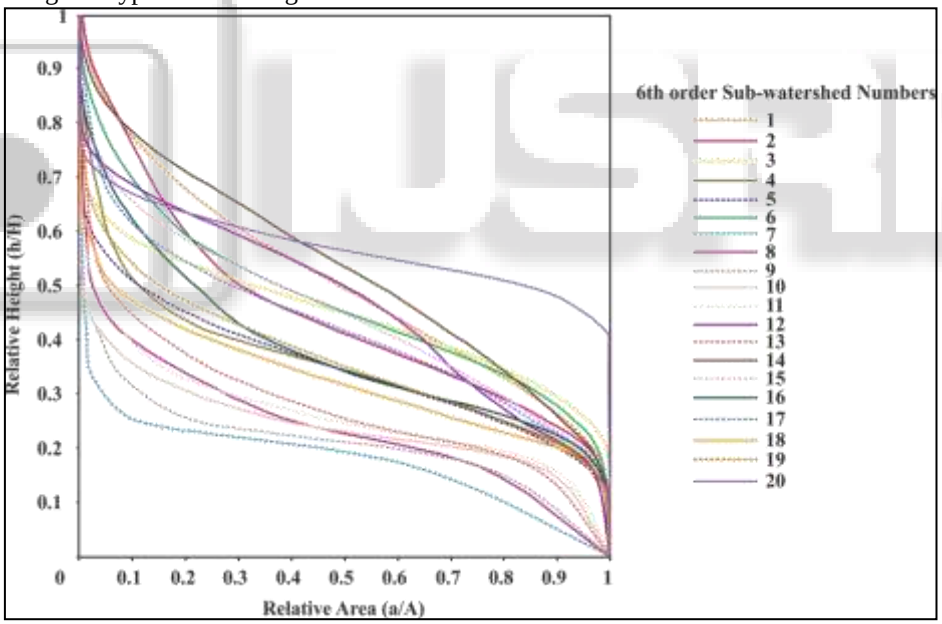

Fig. 7: Percentage Hypsometric Curves for Sixth order basin

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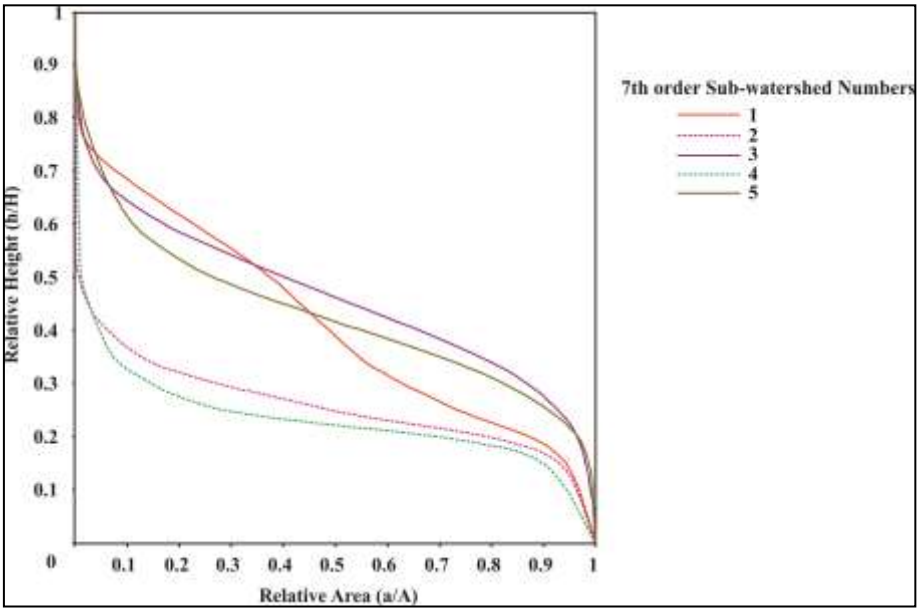

Fig. 8: Percentage Hypsometric Curves for Seventh order basin

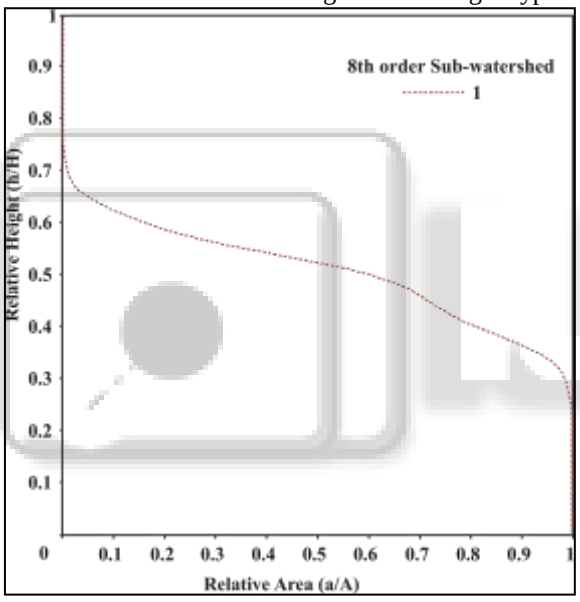

Fig. 9: Percentage Hypsometric Curve for Eighth ordered Shimsha basin

Lithological distribution in the study area (Figure. 10a) indicates that the distinct litho units having equilibrium to inequilibrium stage of geomorphic development, whereas the different and multiple litho units attaining the monadnock stage of geomorphic development. Structural discontinuities (Figure. 10b) like faults, major lineaments, minor lineaments and shear zones will not plays dominant role in controlling the drainage network.

VI. CONCLUSIONS

The rapidly emerging spatial information technology, remote sensing, GIS, and GPS have effective tools to overcome most of the problems of land and water resources planning and management rather than conventional methods of data process. The results qualify Indian DEM for using it operationally which is equivalent and better than the other publicly available DEMs like SRTM and Aster DEM. The dendritic to sub-dendritic distribution of the drainage network and the course grained gneisses and schists in the area are generally weathered and fractured terrain allows the water to percolate and minimizes the surface runoff. It is observed from the hypsometric curves and hypsometric integral values in the sixth ordered (0.11 to 0.49) and seventh ordered (0.15 to 0.38) sub-watersheds are distributed equilibrium to inequilibrium as well as monadnock stage of geomorphic development. The erosion stage of the lower order watersheds in the Shimsha basin influences its stage to the higher order watershed. Considered by entirely Shimsha basin will have Equilibrium to inequilibrium stage of erosion cycle.

REFERENCES

[1] Babu, K.J., Sreekumar, S., Arish, A. and Midhun, K.P. (2014) Hypsometry and Geomorphic Development of a Watershed: A Case Study from South India. International Journal of Science and Research (IJSR), 3, 1495-1500.
[2] Chadwick B, Ramakrishnan M and Viswanatha M N 1985a Bababudan - A Late Archaean intracratonicvolcanosedimentary basin, Karnataka, Southern India. Part I: Stratigraphy and Basin Development; J. Geol. Soc. India 26 769-801
[3] Chorely, R. (1971). The Drainage Basin as the Fundamental Geomorphic Unit. In: Chorely, R., Ed., Introduction to Fluvial Processes, Methuen and Co. Ltd., London, 30-52.
[4] Clark, J. (1966) Morphometry from Maps. In: Dury, G.H., Ed., Essays in Geomorphology, Heinemann, London, 235- 274.
[5] Garg SK (1983) Geology - the science of the earth. Khanna Publishers, New Delhi.
[6] Harlin, J.M., 1978. Statistical moments of the hypsometric curve and its density function. Mathematical Geology 10 (1), 59–72.
[7] Horton, R. (1945) Erosional Development of Streams and Their Drainage Basins; Hydrophysical Approach to

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Quantitative Morphology. Geological Society of America Bulletin, 56, 275-370.
[8] Jayananda, M., Martin, H., Peucat, J-J., Mahabaleswar, B., 1995. Late Archean crust–mantle interactions: geochemistry of LREE-enriched mantle derived magmas. Example of the Closepet batholith, southern India. Contrib. Mineral. Petrol. 199, 314–329.
[9] Jean-Francois Moyen, Herve´ Martin, MudlappaJayananda B, (2000) Multi-element geochemical modelling of crust–mantle interactions during late-Archaean crustal growth: the Closepet granite (South India), Precambrian Research 112 (2001) 87–105
[10] Jenson, S. K., and J. O. Domingue. 1988. "Extracting Topographic Structure from Digital Elevation Data for Geographic Information System Analysis." Photogrammetric Engineering and Remote Sensing 54 (11): 1593–1600.
[11] Kale, V.S., Sengupta, S., Achyuthan, H. and Jaiswal, M.K. (2014) Tectonic Controls upon Kaveri River Drainage, Cratonic Peninsular India: Inferences from Longitudinal Profiles, Morphotectonic Indices, Hanging Valleys and Fluvial Records. Geomorphology, 227, 153-165.
[12] Kouli, M., Vallianatos, F., Soupios, P. and Alexakis, D. (2007) GIS-Based Morphometric Analysis of Two Major Watersheds, Western Crete, Greece. Journal of Environmental Hydrology, 15, 1-17.
[13] Muralikrishnan S, Pillai A, Narender B, Shashivardhan Reddy V, Venkataraman Raghu, Dadhwal VK (2013) Validation of Indian National DEM from Cartosat-1 data. J Indian Soc Remote Sens 41(1):1–13.
[14] Moyen, J.-F., Martin, H., Jayananda, M., 1997. Origine du granite fini-arche´en de Closepet (Inde du Sud): apports de la mode´lisationge´ochimiques du comportement des e´le´ments en trace. C.R. Acad. Sci. Paris 325, 659– 664.
[15] Nageswara, R., Swarna, L., Arun, K. and Hari, K. (2010) Morphometric Analysis of Gostani River Basin in Andhra Pradesh State, India Using Spatial Information Technology. International Journal of Geomatics and Geosciences, 1, 179-187.
[16] Omvir Singh, A Sarangi and Milap C Sharma (2008), Hypsometric Integral Estimation methods and its relevance on erosion status of North-Western lesser Himalayan Watersheds. Water Resource Management, 22: 1545-1560.
[17] Perez-Pena, J.V., Azanon, J.M., Azor, A., 2009. CalHypso: an ArcGIS extension to calculate hypsometric curves and their statistical moments. Applications to drainage basin analysis in SE Spain. Computers & Geosciences 35 (6), 1214–1223.
[18] Pike RJ, Wilson SE (1971) Elevation-relief ratio, hypsometric integral and geomorphic area—altitude analysis. Geol Soc Am Bull 82:1079–1084.
[19] Radhakrishna, B.P. and Vaidyanathan, R. (1994) Geology of Karnataka. Geological Society of India. Bangalore.
[20] Rao N. K, Swarna L. P, Kumar A. P, Krishna H. M (2010) Morphometric analysis of Gostani River Basin in Andhra Pradesh State, Indian using spatial information technology. Int J GeomatGeosci 1(2):179–187.
[21] R. Dabrowski , W. Fedorowicz-Jackowski , M. Kedzierski , P. Walczykowski and J. Zych, 2008; The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B1. Beijing pp: 1309 – 1313.
[22] Srivastava P.K., Srinivasan T.P., Amit Gupta, Sanjay Singh, Jagjeet Singh Nain, Amitabh, Shilpa Prakash, Kartikeyan B., Gopala Krishna B. 2007. Recent Advances In Cartosat-1 Data Processing, Proceedings of ISPRS International Symposium "High Resolution Earth Imaging for Geospatial Information" 29.05-01.06 2007 Hannover, Germany.
[23] Strahler AN (1952) Hypsometric (area-altitude) analysis of erosional topography. Geol Soc Am Bull 63:1117–1142
[24] Strahler A N (1964) Quantitative geomorphology of drainage basins and channel networks. In: Chow VT (ed) Handbook of applied hydrology. McGraw-Hill, New York, pp 439–476.
[25] Swami Nath, J. and Ramakrishnan, M. (1981)The Early Precambrian Supracrustals of Southern Karnataka. Mem. Geol. Surv. India, v. 112, 350p.
[26] Thomas, J., Joseph, S., Thrivikramji, K., Abe, G. and Kannan, N. (2012)Morphometrical Analysis of Two Tropical River Basins of Contrasting Environmental Settings, the Southern Western Ghats, India. Environmental Earth Sciences, 66, 2353-2366.
[27] Wei Luo (1998), Hypsometric analysis with a Geographic Information System, Computers and Geosciences Vol.24, No.8, pp: 815-821.

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