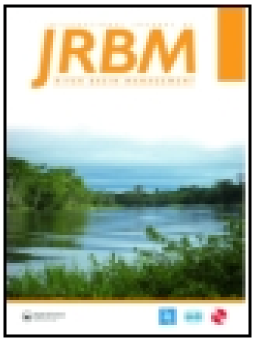

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Assessment of Morphometric and Hypsometric study for watershed development using spatial technology – A Case Study of Wardha river basin in the Maharashtra, India

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Abstract

The assessable results of the Wardha river basin are essential for the behavior of the drainage and river network and to know its geology, slope and geo-hydrological condition. The Wardha river basin is covered by 1730.85 sq. km^2 with dendritic and sub-dentric drainage patterns. This study area is delineated into nine sub-watersheds from digital elevation model data using Arc hydro tools. The study of morphometric characters were observed for understand the drainage and watershed characteristics and its impact on groundwater resources for occurrence of bifurcation ratio shows very high runoff and low infiltration of groundwater recharge at the basaltic terrain rocks. Slope and topographic maps may be used for groundwater development, theses maps can be used for suitable wells point and artificial and ground water recharge sites at the Wardha river basin. The slope values were inversely proportional to infiltration and it has been lead to analyze the hypsometric analysis using Arc GIS 10.3 software. In this study different types of morphometric characteristics were measured using computations of linear and areal aspect using geospatial technology domain. The total streams order (3509) has been identified from digital elevation model data. Hence shows large number of stream are presenting in this area for scope of water harvesting structures play a main role in groundwater development and controlling soil erosion factors. In this study various morphometric parameter were calculated using mathematical equation and spatial data for understanding of surface runoff, slope, watershed characteristics and watershed condition. To study of hypsometric investigation has been generally used for reveal the steps of geomorphic growth or land forms. The hypsometric integral value shows nine sub-watersheds observed was a mature stage at the Wardha river basin. The hypsometric analysis results have been calculated for watershed and groundwater development. During study of Bifurcation ratio values such as 2.5 to 4.25 suggests morphological and the basic control for watershed management and drainage network analysis in the area, while drainage density and fine drainage texture suggests is high runoff in basin. To study of drainage basin characteristics has been made to assessment of many linear factors likes Stream order, Stream number, Stream length, stream length ratio, Bifurcation ratio, Drainage density, Texture ratio, Stream frequency) and Channel index (Ci) Valley index (Vi), Rho coefficient (q) and Basin Area. These all of results may be useful for watershed development programme in the semi- arid area most influence of basaltic hard rock areas.

Keywords: Morphometry analysis, Hypsometric analysis, Digital Elevation Model, GIS, Remote Sensing.

INTRODUCTION:

Remote sensing and GIS method have been demonstrated in identification of stream parameters and water resources development and planning of watershed or basin (Hlaing et al. 2008, Javed et al. 2009, Pankaj and Kumar 2009, Pande and Moharir 2015 and Praveen Kumar Rai et al. 2017). The stream network analysis is a main unit in morphometric parameters study of hydrological, geology and geomorphic procedures occur within the basin and watershed area, where mesa, butte and denudational are most implicitly displayed and it is showed by different morphometric charactertics studies (Horton 1945, Strahler 1952, 1964; Muller 1968; Shreve 1969; Evans 1972, 1984; Chorley et al. 1984; Merritts and Vincent 1989; Ohmori 1993; Cox 1994; Oguchi 1997; Burrough and McDonnell 1998; Hurtrez et al. 1999). Morphometry characteristics is the measurement based on mathematical equation study of the structure in the ground's surface, character and dimension of its different landforms (Agarwal 1998; Obi Reddy et al. 2002; Clarke 1996)

The stream network basin is a simple unit of morphometric analysis because total hydrologic and geomorphic process occurs within the watershed area where denudational and gradational processes are greatest openly demonstrated. A maximum important result in geomorphology landform's study over the history some periods has been on the expansion of quantitative physiographic landforms process to describe the progression and actions of surface stream networks (Leopold and Maddock, 1953).

Awasthi et al. (2002) has estimation of hypsometric curves and integrals to describe the watershed. The study of results has been observed using Arc GIS 10.3software. During the study of hypsometric analysis has been generated contour line from SRTM data through surface analysis tool and improving the correctness of results and save time. However, due to the departure of GIS technique, the evaluation processes of watershed characteristics become less number few and more accurate methods. Considering the above truths, this result was assumed to control the erosion status and geological stages of development for the Wardha watersheds and their sub basins.

Hypsometric study aims to develop an association amongst horizontal cross-sectional area and its height in a dimensionless form that authorizations comparison of watersheds related of scale issues (Dowling et al. 1998). Hypsometric curves (HC) and hypsometric integrals are vital displays of watershed situations (Ritter et al.2002). Alterations in the shape of hypsometric curves and the hypsometric integral values were associated to the degree of imbalances in the stability of erosive and tectonic forces (Weissel et. al.1994). Hypsometric parameters were first time presented and to precise the overall slope ranges and the methods of drainage basin using remote sensing technology (Langbein 1947).

Therefore common variation in the shape of the hypsometric curves during geomorphic phases for watershed development monitored by insignificant variation after the area reaches stabilized or mature stages. Convex shapes of hypsometric curves shows are stabilized in hypsometric graphs shown by more proneness of the erosion processes (Hurtrez et at. 1999). Hypsometric curves had plotted for homogenous geomorphic various landforms in the hundreds of micro-watershed of various area and regions and the commonly show hypsometric curves shows soil and rock erosion stages were demarcated using estimation of hypsometric parameters.

The present study integrated approach of GIS and remote sensing approaches has been used for drainage parameters and geological stages for groundwater and soil and water conservation in the Wardha river basin. These watershed selected for watershed project is the important source of water for agriculture and domestics purpose in watershed area, which impact of Wardha river basin study of the groundwater situation are considered planning and strategic management for the future of hydrological investigation and water resources activity in terms of groundwater reservoirs, land resource development and proposed of rainwater harvesting structure and watershed development and management. Moreover, such analyses support in the awareness of the geomorphological land form types, especially the analysis of drainage patterns and identification of the morphometric parameters situation and geological and topographic settings of the Wardha river basin.

STUDY AREA

The Wardha river basin is located by Survey of India Topographic Sheets No. 55L/13, 55L/14. The study area lies in between 78°10'00"E 21°20'00"N latitude and longitude 78°20'00"E 20°50'00"N. The area is most of the land under dryland condition and few years overall area is suffering from drought condition. The watershed area was monitored rainfall 800-1200mm and maximum-minimum temperature ranges such as 10^0 to 47^0. The present study of annual normal rainfall has been observed such as 810-900 mm and major rainfall of 250–450 mm is received by South–West monsoon during June to September months of the Wardha river basin (Fig. 1). The Wardha river basin is under in Deccan trap rock and the study area shows basaltic rocks has been observed using field verification and geological map (Fig.12).

Place here Fig.1 and 12

MATERIALS METHODOLOGY:

The Wardha river basin boundary was delineated from DEM data with 30 m resolution using Arc hydro tools in the Arc GIS 10.1 software. Direct measurements of geometric characteristics have been obtained from vector data for calculation of morphometric parameters. During study of linear, relief and areal aspects parameters were calculated using Horton 1945; Miller 1953; Schumm 1956; Strahler 1964, (Sarangi et al. 2004), Pareta (2011), Rai et al. (2014), Magesh et al. (2013), Mangesh and Chandrasekar (2014) and Pande and Moharir (2015). The extraction of drainage network basin was prepared from DEM data by using Arc GIS 10.1 software. During thematic mapping such as flow direction and slope maps were prepared from SRTM data using spatial analysis tools (Fig.3). During study of contour with 10 m intervals lines were generated using DEM data and spatial analysis tools. During estimation of hypsometric analysis were used SRTM data with 30 m resolution (Shuttle Radar Terrain Mission) for find out the hypsometric integral ranges of drainage basin and geological stages by using remote sensing and GIS data. The whole basin area was divided into nine sub-watersheds with fifth to seventh stream orders from DEM data is shown in Table 4. The contours lines were digitized from digital elevation model data using spatial analysis tools. The total sub-watersheds area is covered 1730.85 sq. km. by using Arc GIS 10.3 software. In this study area to prepare nine sub-watersheds were used for evaluated geological stages and all of these sub-watersheds were mature stages from estimation of hypsometric integral values. This analysis are based on mathematical and software analysis from derived satellite data for further process of watershed planning, development and management projects at the Wardha river basin.

Results and discussion:

During study of drainage basin analysis is the measurement from a scientific analysis of the earth's size, shape and aspect of its land forms. The morphometric analysis requires the calculation for planning of drainage network and contributing earth's hills of the Wardha river basin. During analysis of dimensional form a ground truth basis for the study of geological and arithmetic characteristics and help in understanding the surface water, management and ground water measure in the basin area. The quantitative study is carried out of morphometric characteristics contain likes drainage order, number and length etc. The most previous morphometric parameters were depend on random areas or individual drainage segments. The Wardha river basin is the surface area drained by a part or the totality of one or several given water courses and can be taken as a basic erosion landscape element where sustainable water resources interact in a perceptible manner. The approach of morphometry analysis was very important in considerate for the geomorphological landform processes, soil erosional characteristics. This result focus on a hypsometric analysis for rainwater harvest structure conservation practices and management for the Wardha river basin at the suitable sites for controlling further soil erosion, reducing the runoff, increasing the groundwater depth in the basaltic hard rock area. So with geospatial data and GIS tools it is develops less deadly to create hypsometric integrals value and curves for watershed planning. The remote sensing data, GIS tools and module has been definite limitations, it can be measured to be a help for further development project likes soil and water conservation activity, planning of water harvested conservation and hydrology projects.

Place here Table 1 and Table 2

Morphometric Analysis:

The study of morphometric parameters can be utilized for any hydrology and groundwater related activity such as CCT, CNB, Farm Pond and other conservation structures in the basaltic rocks, since it provides an idea regarding basin features in relation of elevation, geography, soil health runoff elements and surface water potential. This measure description of stream network, basin characteristics and hypsometric factors were calculated by using remote sensing and GIS methods. During study of various parameters likes stream number and lengths of streams and also Drainage order, drainage area, basin perimeter. The drainage line and orders were calculated through GIS environment. During various drainage parameters analysis were calculated such as bifurcation ratio (Rb), Main channel length (C1), Valley length (VI), Minimum aerial distance (Adm), Channel index (Ci), Valley index (Vi), Rho coefficient (q), Basin area (A), Basin length (Lb), Drainage density (Dd), Hypsometric integral (Hi) may be used for micro-watershed and any basin development studies.

Assement of Morphometric parameters for drainage basin analysis has been planned for primary level water resource development in the Wardha river basin. Morphometric descriptions of stream characteristics were measured through GIS data. The Wardha river basin area is developed for groundwater development by using basin terrain parameters like slope, topography, sub-watershed and digital elevation model were created using SRTM data (30m). The two aspects shows relation of morphometric and hypsometric analysis for important role of identifying suitable rainwater harvesting structures, artificial recharge structures and groundwater development.

The assessable analysis of drainage has been found to be of most usefulness results have used for estimation of the watershed development. This study shows of elongation, and circulatory ratio and form feature has been elongated shape, which point toward the low surface runoff.

Linear Aspects:

The study of results has been included likes stream order (u) and bifurcation ratio (R_b) was discussed (Table 1).

Place here Table 3

Stream Order (u):

During Stream ordering analysis is simple step of analysis of drainage in the Wardha river basin; the stream ordering has suggested for watershed planning (Strahler 1964). This study, stream ordering was carried out using Strahler's method of stream calculation from DEM data in the Arc GIS 10.3 software. The drainage ordering has been depending on drainage and the streams network was extracted from DEM data using Arc Hydro Tools. Stream that originate at a source are defined as the first stream order. The study area seven stream orders are observed and observed the maximum drainage frequency is in first orders drainage at the Wardha river basin (Table 1, 3 and Fig. 2). It is identify that there are a reduction of drainage quantity as the drainage order increases at the Wardha river basin.

Place here Fig.2

Stream Number:

The study of stream number has been analysis of various stream orders and in reverse comparative to the drainage orders. The stream number of the drainage fragments reductions as the drainage order increases, the higher stream orders to direct lesser permeability and infiltration. This result of analysis is shown in the Table 1 and 3, that the large frequency is show in the 1^{st} drainage order of drainage network. The drainage order and their linear parameters have been shown in Table 1. The total stream number observed is 3509 from drainage network in the

Wardha River Basin. That is most large runoff show in drainage network has reported in the basin area.

Bifurcation Ratio (Rb):

The Bifurcation Ratio is required for drainage line treatment and basin analysis as it is the most relevant parameter to groundwater regime of sub-watersheds under dryland condition and climatic conditions. It helps to have an knowledge about the shape of the Wardha basin as well as in deciphering the runoff behavior. $R_b = Nu/Nu+1$. The study of bifurcation ratio is the part of the total of the drainage segments and assumed order of Nu to the amount of drainage in the next greater order (Nu+1). Horton (1945) has measured of ratio the index of relief has dissection in the Wardha river basin. (Strahler, 1964) had established of bifurcation ratio displays a small range values of change for dissimilar areas or for different environment excluding where powerful geological control dominates at the Wardha river basin. In this paper, it is detected from the R_b is not similar from one order to its next order. The results show varies in between 2 – 4.25 (Table 1 and 3). These irregularities are reliant upon the hydrological, geological and watershed development of the morphometric analysis at the Wardha river basin (Strahler, 1964).

Weighted mean bifurcation ratio (R_{bwm}):

To study of R_{bwm} ratio was calculated from obtained bifurcation ratio of every sequential pair for stream orders using total numbers of drainage orders were involved of ratio and giving the mean of the amount of bifurcation values at the Wardha river basin Strahler (1953). Schumm (1956) has been based on current method and to carry out ratio values observed was 3.96 at the Wardha river basin (Table 1).These ratio is used of watershed development planning for groundwater regime development.

Stream length (L_u):

During study of stream total length for drainage lines are the large stream first-order decreases with an increase in the drainage orders at the Wardha river basin. The studies of drainage parameters with moderately short lengths are demonstrative of dryland areas and vertical slopes and better texture, whereas longer lengths of drainage has been normally indicative of low hills (Strahler 1964). This result of value was measured from opening of the Wardha river basin into stream length by using Arc GIS 10.1 software. This length has been considered and based on the law planned by using Horton's law. The total stream length of the Wardha river basin is 3323.23. During stream length has been computed from drainage network and digital elevation model (Table 2).

Mean stream length (L_{um})

The study of mean stream length has associated to the stream network modules also it's contributing of morphometric analysis at the Wardha river basin (Strahler 1964). It is found by separating the whole length of drainage of a stream order using total number of drainage segments. The L_{sm} values differ with respect to different basins, basins, as they are directly relational to the size and topography of the Wardha river basin. It was showed values are based on drainage network analysis and its associated hard rock terrain surfaces (Table 2).

Basin length (L_b)

The drainage basin length (L_b) is shows of longest basin length from the head surface waters to the main point of meeting (Gregory and Walling 1973). The basin length has been controlled of shape of the basin length from drainage network analysis for harvested activity through Arc GIS 10.1 software. This study was observed by high basin length and a shows elongated basin at the Wardha river area. During analysis of basin length ($L_{b)}$ has been observed by 2.537 km (Table 3).

Channel index (Ci) and valley index (Vi)

The study of Channel and valley index was separated into amount of stream segments for determination for sinuosity characteristics at the Wardha river basin. During measurement of channel and valley length of direct distance among the basis and the source of the Wardha river basin (A_{dm}), and air lengths have been used for control of Channel index and valley index.

Basin area (A)

The parameter analysis of area has been strategized for river basin development and management of basaltic hard rock area. According to Schumm (1956) had recognized an fascinating connection in between the total basin area and total tributary lengths, which have been supported by the contributing basin areas. The Wardha river basin area was calculated like 1730.90 km^2 with the help of Arc GIS 10.1 software (Table 3).

Drainage density (Dd)

The analysis of drainage density is necessary parameters for the linear scales of geomorphology landform components in drainage-wrinkled topography. It is observed drainage density ratio of total channel fragment lengths has been cumulated of the total stream orders at the Wardha river basin. The study of drainage density has observed such as high drainage density is the preceding of weak or resistant sub-surface material, thin plants, and mountainous relief.

The present study of has been observed by low values leads to coarse drainage surface, while high values is showed of leads to fine drainage surface using digital elevation model (Strahler 1964).

Place here Fig.3

Watershed Delineation and Digital Elevation model:

During watershed delineation has been depend upon DEM data with 30 m resolution, which terms in the basaltic rock terrain structures were generated for hypsometric analysis and watershed development (Fig. 4 to 6). The contour lines data were created from SRTM data for identification of hypsometric analysis and curve (Gossain and Rao 2005 and Dabral et al. 2008). During process of sub-watershed boundary was generated from SRTM data with 30 m resolution using GIS software analysis. It is depend upon linear interpolation method in between pixels with elevation values and to obtained elevations are undefined values of the raster contour lines (Fig.4). Further, the watershed boundary was delineated into 9 sub-watersheds (SW) using the automatic delineation tool using Arc hydro tools with a threshold of 5000 hectare (Fig.7). During analysis of SRTM data has been used of various thematic maps likes flow direction, slope and DEM map at the Wardha river basin (fig.5). During analysis of sub-watershed delineation has been performed by a process of finding of flow direction data from each drainage network cell until either an outlet cell or the advantage of grid extent has been encountered. From the demarcated sub-watersheds for analysis of geomorphic parameters such as length of the sub-watersheds, length of the longest stream, slope of longest stream and slope of the watershed were derived from digital elevation model using Arc hydro tools at the Wardha river basin. The sub-watershed was numbered as 1, 2 ... and so on for estimation of hypsometric curves at the Wardha river basin.

Place here Fig.4

Place here Fig.5

INTEGRATION OF HYPSOMETRIC CURVE (HC):

During integration of hypsometric curves were fixed with a trend line to denote an equation of hypsometric curves and to the finest suitable equation was observed for highest coefficient (R2) range values of the Wardha river basin. The comparative area is attained as value ranges of the region above specific contour lines in the river basin including the outlet. Similarly, signifying to considering in the watershed area to be surrounded by vertical sides and a horizontal base surface passing using outlet, the relative elevations were observed as the ratio from height of a known contour lines (h) using the base surface to the highest elevation (H) at the river basin (Sarangi et al. 2001; Ritter et al.2002). The hypsometric equation has been further integrated in between of limits 0 to 1 for assessing the sub-watershed area in the curves shown on geological stages and prioritizing of sub-watershed area at the Wardha river basin. The results of study has been established for polynomial equation due to hypsometric curves values of the mini-watershed 1 as a sample set through remote sensing data. However, geospatial and GIS methods has been easy observed for sub-watershed condition, geological stages and groundwater regime development and necessitated mathematical equation was integration methods and following mathematical calculation within the preferred limits values of HC using geospatial technology.

Place here Table 1

Plotting of Hypsometric Curves

During study of hypsometric curves has been plotted for required a regularized elevation values of cumulative frequency distribution (Strahler, 1954). This curve was constructed from total number of GPS points information to greatest than incremental edges of elevation, starting at the maximum elevation (Fig. 6). Typically, the hypsometric curves analysis has been utilized to distinguish between erosion all and forms at various levels in this evaluation of study (Strahler, 1952; Schumm, 1956). The results of hypsometric integral (HI) values are the area under of plotting curves which communicates the measurement of total relief to cumulative frequency distribution percentage of sub-watershed area. The analysis of hypsometric values ranges has been perceived by 0 to 1. During study of plotting for curves can be understood in the expressions of degree of watershed division and relation of terrestrial form of age: Convex-up curves with high integrals has typical for the study of different parameters such as youth, undisseceted, land scapes; smooth, s-shaped curves were crossing of the centre of the graph describe mature stage of lands and dipped up with low integrals values characterize old and deeply divided landscapes of the any watershed (Strahler, 1952).

Place here Fig.6 to 8

Estimation of hypsometric integrals (Hsi)

The estimation of hypsometric integral (Hsi) has been measured by using mean sea level elevation of relief-ratio process (Pike and Wilson 1971). The relationship is describe as

$$E \approx His = \underline{\hspace{6cm}} \text{----------} \ (1)$$

Where, E means elevation of relief ratio equal to the estimation of hypsometric integral (His), In this study shows elevation mean values are weighted mean elevation of the sub-watershed to estimate values from contours data. In this analysis shows highest and lowest elevation values has been based on hypsometric integrals values and to identify geological stages at the sub-watershed. The hypsometric integral ranges are describes in the form of percentage units for geological stages within sub-watershed area. However, this method was observed to be less cumbersome and faster than the other methods in practice HsiSingh et al. (2008). To carried out during hypsometric curves values to provide valuable information for deciding geological stage in the watershed management and planning under basaltic terrain rocks. The thresholds limits have been recommended which method adopted for deciding the geological stages at the Wardha river basin Strahler (1952).

(i) This watershed is as equilibrium (youthful) stage if the HIe> 0.6

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

(iii) The watershed is as monadnock stage if HI< 0.35

In this equilibrium stage is still in the watershed development process. The equilibrium stage is observed like mature stage in the watershed development i.e. the development has been attained using steady state condition. The monadnock phase ensues mainly, when isolated water bodies of resistant rocks from prominent hills (monadnock) has been found earth surface and it is indicated by the distorted hypsometric curves values at the Wardha river basin (Fig. 10 and 11 and Table 4).

Place here Fig.10 and 11

Watershed Management and Prioritization of Watershed:

During the study of higher runoff generation of watershed characteristic is reflected for lower part of the Wardha river basin in the form of chronic floods. As per the estimate available, the loss of life and property in this part has been reported of $ 6000 million (Goa, 2004). It is therefore, necessary to take up necessary steps to control the surface runoff in the upper catchments. The HI values have indicated that 13 sub-watersheds form the convex hypsometry, thereby, contributing for maximum total runoff. The HI values have been taken as an indicator for prioritizing of sub-watersheds at the Wardha river basin. In this study of sub-watersheds has been identified most favorable places measures has been planned on the basis of finances available. For moderating the impact of surface runoff from such watershed two pronged strategy has been suggested by using remote sensing and GIS techniques. As the Wardha river basin is mostly forested and inaccessible small structures on 1-4th order stream may not be practicable. In such case medium size structures can be planned on streams of 5th order and above in prioritized sub-watersheds having moderate slopes. To identify location for suitable measures, integrated maps need to be prepared. The study of results may be helped for *In-situ* water conservation structures or suitable measures at the Wardha river basin.

SLOPE:

The study of slope analysis is a significant role in the land and water resources management. The inclination of the terrain is the result of several factors, such as relief, drainage, climate, geology, and tectonics operates in the area. The slope values ranges such as 0 to 89.64 has been observed from DEM data using spatial analysis tools. The most of the land is having slope between 89.64-89.99 (Fig.8 and 9).

Place here Fig.9

CONCLUSION

This paper focus on morphometric parameters has been demonstrated as an important tool for hydrological evaluation, soil water resource management, watershed management and drainage network analysis by using Geospatial techniques. The computation of linear, areal and relief parameters and hypsometric analysis of the Wardha river basin confirms that there is a positive correlation between hydrological condition and their associated various landforms which is the potential sites of water harvesting activates and ground water management activities. The morphological parameters and hydrological parameters of Wardha river basin likes drainage order, number, length and bifurcation ratio, basin area and mean bifurcation ratio etc. The overall drainage analysis in the sub-basin likes shape, drainage pattern and changes. To carried out study such as hydrologic, hypsometric and morphometric parameters of a drainage analysis and hypsometric integral and geological stages in basin area. Hypsometric integral of sub-watersheds allow classification of Wardha river basin with respect to erosion stage. These indicators have revealed the characteristics of each basin with respect to run off and associated erosion. The Wardha river basin in most of the southern part is inaccessible and only these terrain based indicators can aid in indicating the hydrologic nature, thereby, assuming the suitable soil and water conservation measures of watershed management and development using remote sensing and GIS technology. In watershed with scarce data was observed as surface runoff and deposit yield such as indicators provides valuable insight into the dominant processes going on. The result in the hypsometric analysis can be used for planning of engineering measures in watershed with scanty information. The study is to recommend suitable sites for rainwater harvesting activity, groundwater recharge zone and *In-situ* activity of the Wardha river basin, Maharashtra, India. This study area has enclosed by Deccan trap region (basalts rock) with reference of geological map and field verification. These results shows of hydrological project may be help to take suitable methods to conserve soil and water resources for sustainable development at the Wardha River basin.

REFERENCES:

1. Agrawal, C.S. (1998) Study of drainage pattern through aerial data in Naugarh area of Varanasi district, U.P. Tour Indian soc. Remote sensing 26: pp 169-175.
2. Awasthi, K.D., Sitaula, B.K., Singh, B.R. and Bajacharaya, R.M. (2002) Land-use changes in two Nepalese watersheds: GIS and geo-morphometric analysis. Land Degrad.

   & Dev, 13: 495-513.
3. Chaitanya B. Pande and Kanak Moharir (2015), GIS based quantitative morphometric analysis and its consequences: a case study from Shanur River Basin, Maharashtra, India, Applied Water Science, Springer, ISSN 2190-5487.
4. Dowling, T.I., Richarson, D.P., O'sullivan, A., Summerell, G. K. and Walker, J. (1998) Application of hypsometric integral and other terrain based indicators of catchment health: A preliminary analysis. CSIRO Land and Water, Canberra, Technical Report20/98, April 1998. pp.49.
5. Goa. (2004) Economic Survey of Assam. Published by Government of Assam. Chapter VIII, 34-37.
6. Gregory KJ, Walling DE (1973) Drainage basin form and process ageo-morphological approach. Edward Arnold, London.
7. Javed A, Khanday MY, Ahmed R (2009) Prioritization of sub-watershed based on morphometric and land use analysis using remote sensing and GIS techniques. J Indian Soc Remote Sens 37:261–274

8. Horton, R. E. (1945) Erosional development of streams and their drainage basins: Hydro-physical approach to quantitative morphology. Geol. Soc. Am. Bull.56: 275-370.
9. Hurtrez, J.E., Sol, C. and Lucazeau, F. (1999) Effect of drainage area on hypsometry from analysis of small scale drainage basins in the Siwalik Hills (Central Nepal). Earth Surface Processes and Landforms, v.24(9), pp.799-808.
10. Langebein, W.B. and Basil W. (1947). Topographic characteristics of drainage basins. USGS Water Supply Paper. 947-C.
11. Leopold and Maddock (1953). The Hydraulic Geometry of Stream Channels and Some Physiographic Implications. Geological Survey Professional Paper 252, 1-57.
12. Miller VC (1953) A quantitative geomorphologic study of drainage basin characteristics in the clinch mountain area, Virginia and Tennessee Columbia University, Department of Geology, Technical Report, No. 3, Contract N6 ONR 271–300.
13. Obi Reddy, G.E., Maji, A.K. and Gajbhiye, K.S.(2002) GIS for Morphometric Analysis of Drainage Basins. GIS lndia, 4 (11) 9-14.
14. Pankaj A, Kumar P. (2009) GIS based morphometric analysis of five major sub-watershed of Song River, Dehradun district, Uttarakhand with special reference to landslide incidences. Journal Indian Society Remote Sensing 37:157–166.
15. Pande CB, Moharir K (2015) GIS based quantitative morphometric analysis and its consequences: a case study from Shanur River Basin, Maharashtra India. Applied Water Science, doi:10.1007/s13201-015-0298-7.
16. Pike, R.J. and Wilson, S.E. (1971) Elevation-relief ratio, hypsometric integral and geomorphic area-altitude analysis. Geological Soc. Am. Bull. 82: 1079-1084.

17. Praveen Kumar Rai, Pawan Kumar Chaubey, Kshitij Mohan and Praful Singh (2017) Geoinformatics for assessing the inferences of quantitative drainage morphometry of the Narmada Basin in India, Applied Geomatics, DOI 10.1007/s12518-017-0191-1
18. Ritter, D.F., Kochel, R.C. and Miller, J.R. (2002). Process Geomorphology. McGraw Hill, Boston.
19. Sarangi, A., Bhattacharaya, A.K., Singh, A. and Singh, A.K. (2004). Use of geographical Information System (GIS) in assessing the erosion status of watersheds. Indian J. Soil. Cons. 29 (3): 190-195.
20. Schumm SA (1956) Evolution of drainage systems and slopes in bed lands at Perth Amboy, New Jersey, Bull Geol. Soc. Am 67:597–646.
21. Singh, 0, Sharma, M.C, Sarangi, A, Singh. P. (2008). Spatial and temporal variability of sediment and dissolved loads from two alpine watersheds of the Lesser Himalayas, Catena, 76: 27-35
22. Strahler A.N. (1964). Quantitative geomorphology of drainage basins and channel networks. In: Chow V T (ed) 63:1117-1141.
23. Strahler AN (1953) Hypsometric analysis of erosional topography. Bull Geol. Soc. Am 63:1117–1142.
24. Strahler AN (1957) Quantitative analysis of watershed geomorphology. Trans Am Geophysical Union 38:913–920.
25. Strahler, A.N. (1952) Hypsometric (Area- altitude) analysis of erosional topography. Geol. Soc. Amer. Bull., v.63, pp.1117-1142.
26. Strahler, A.N. (1954) Statistical analysis in geomorphic research. Jour. Geol., v.62, pp.1-25.

27. Hlaing TK, Haruyama S, Aye MM (2008) Using GIS-based distributed soil loss modeling and morphometric analysis to prioritize watershed for soil conservation in Bago river basin of lower Myanmar, Front Earth Science China 2:465–478.
28. Weissel, J.K., Pratson, L.F. and Malinverno, A. (1994). The length scaling properties of topography. J. Geophys. Res. 99: 13997-14012.

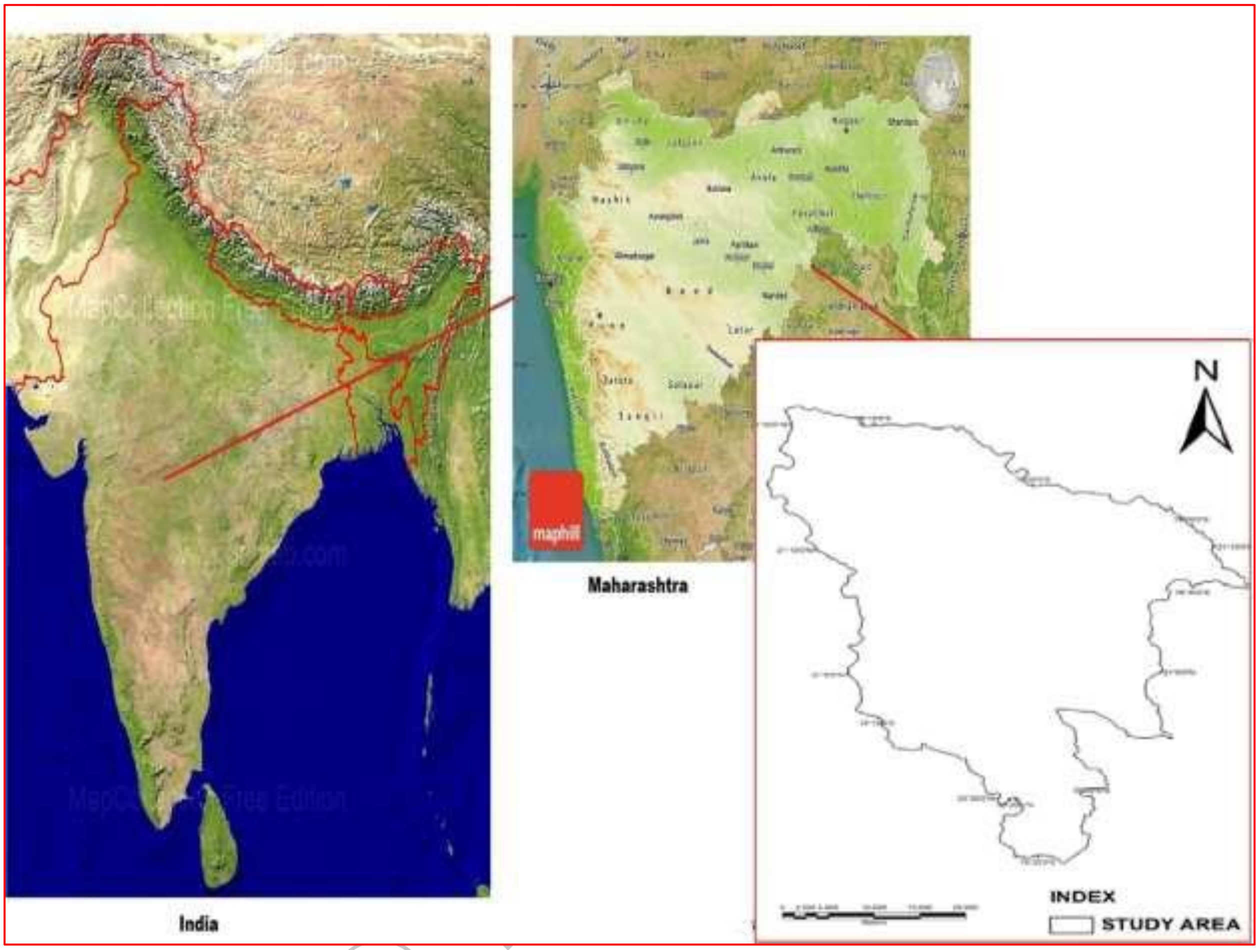


Fig.1: Location Map at the Wardha river basin

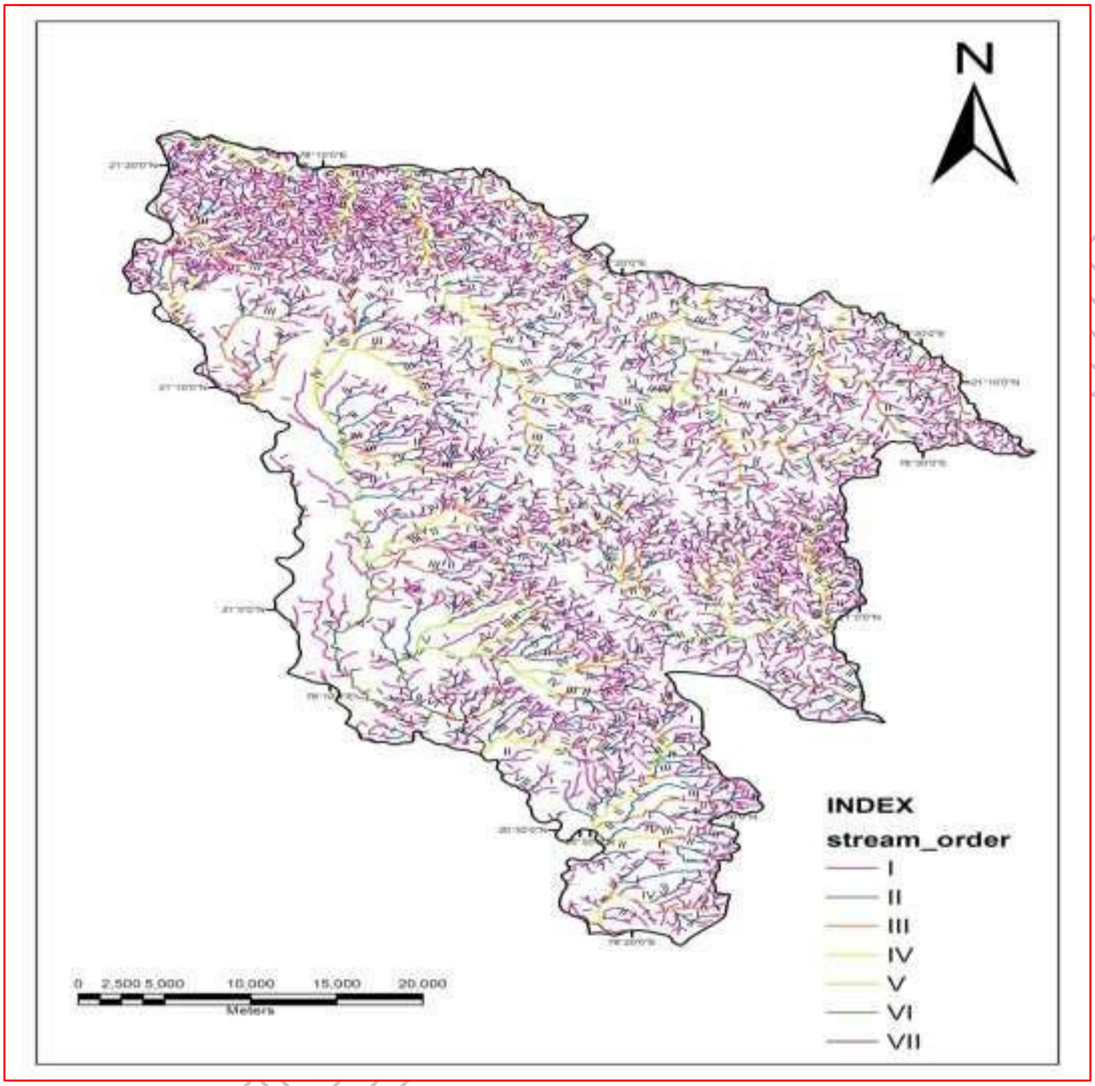


Fig.2: Stream order map of Wardha river basin

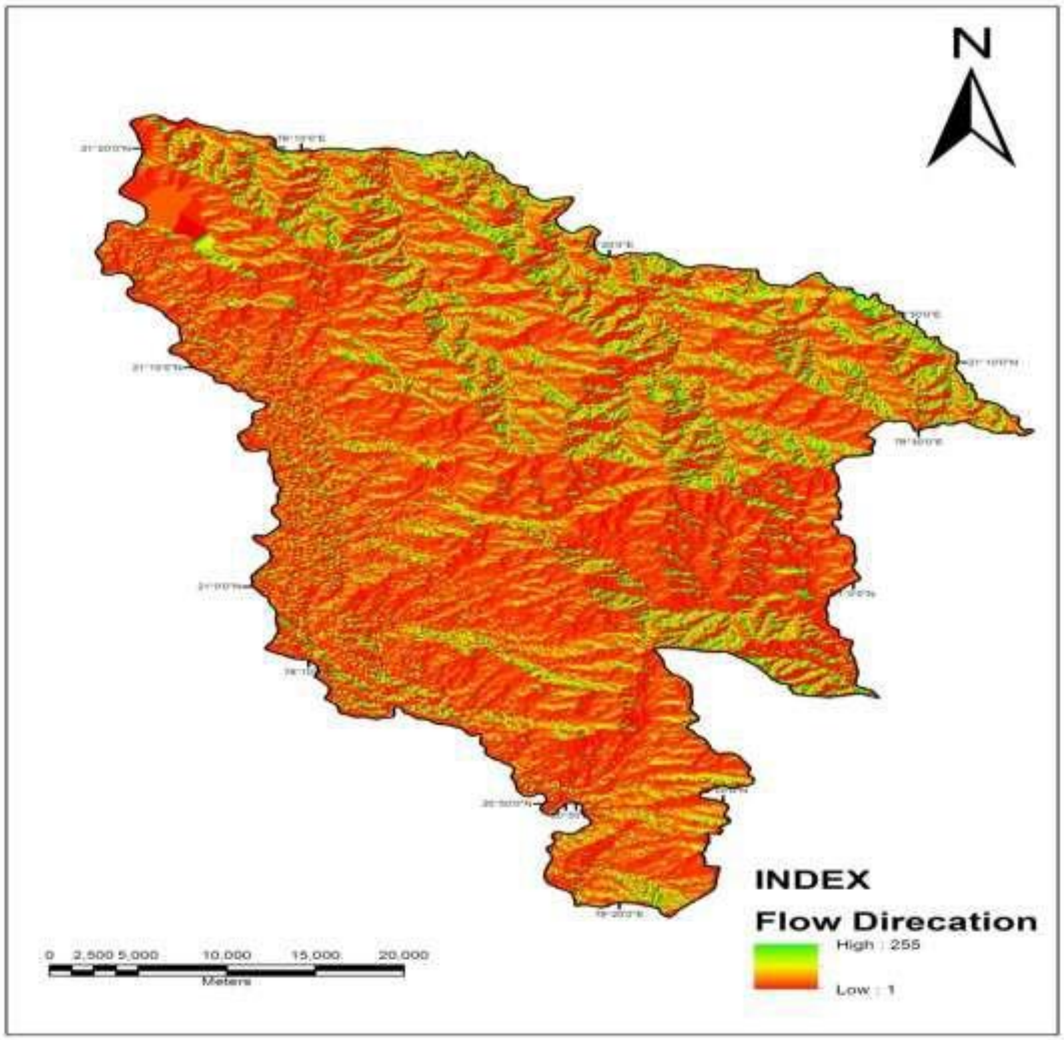


Fig.3: Flow direction map of Wardha river basin

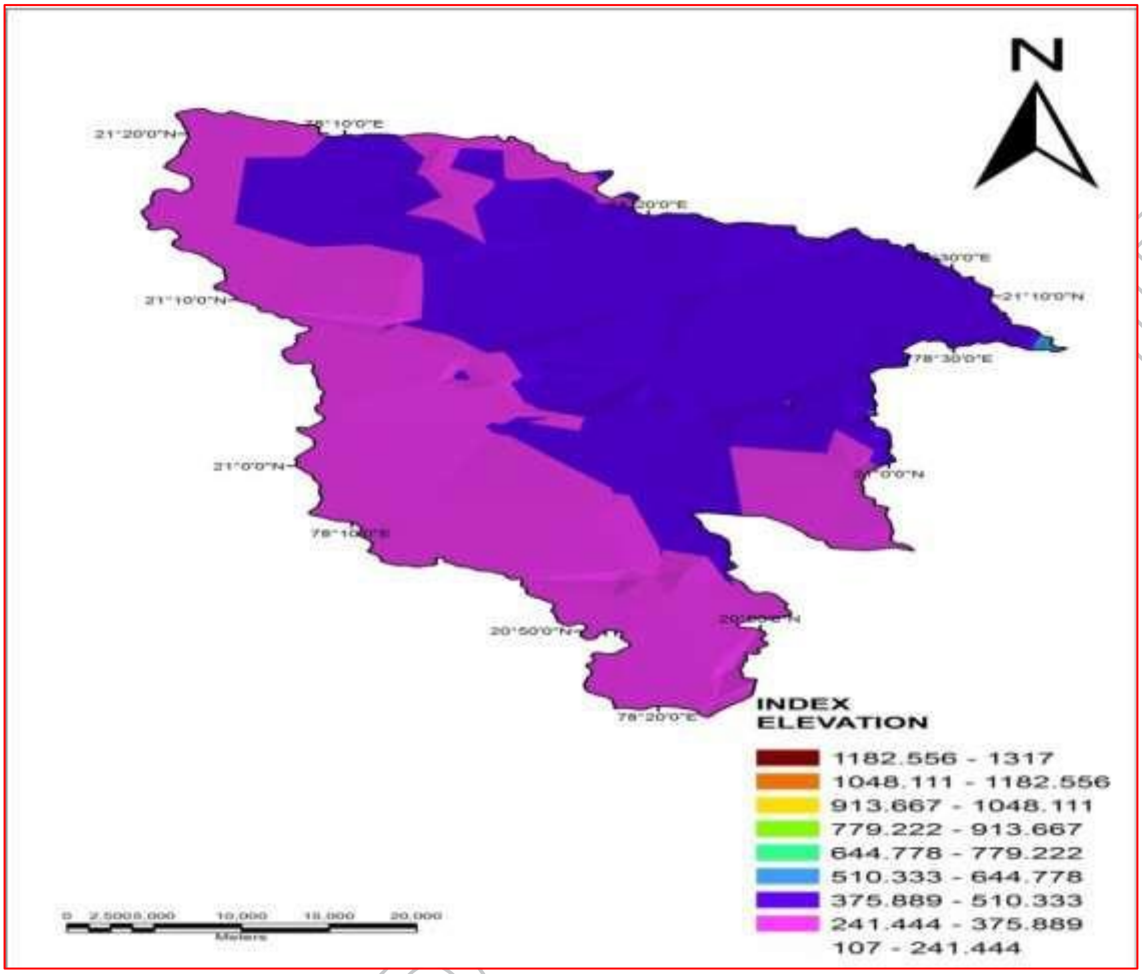


Fig.4: Digital Elevation Model of Wardha river basin

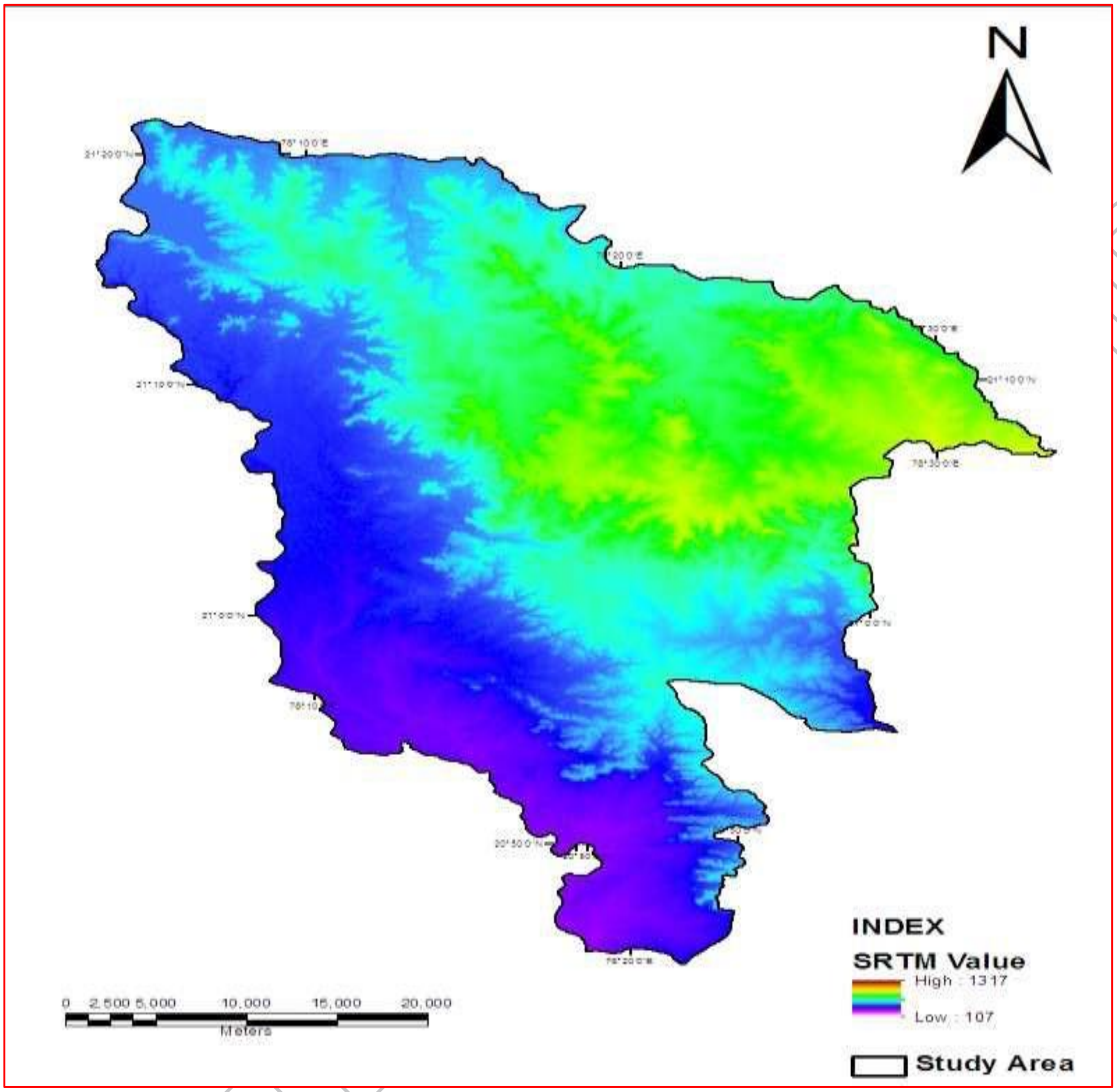


Fig.5: SRTM map of Wardha river basin

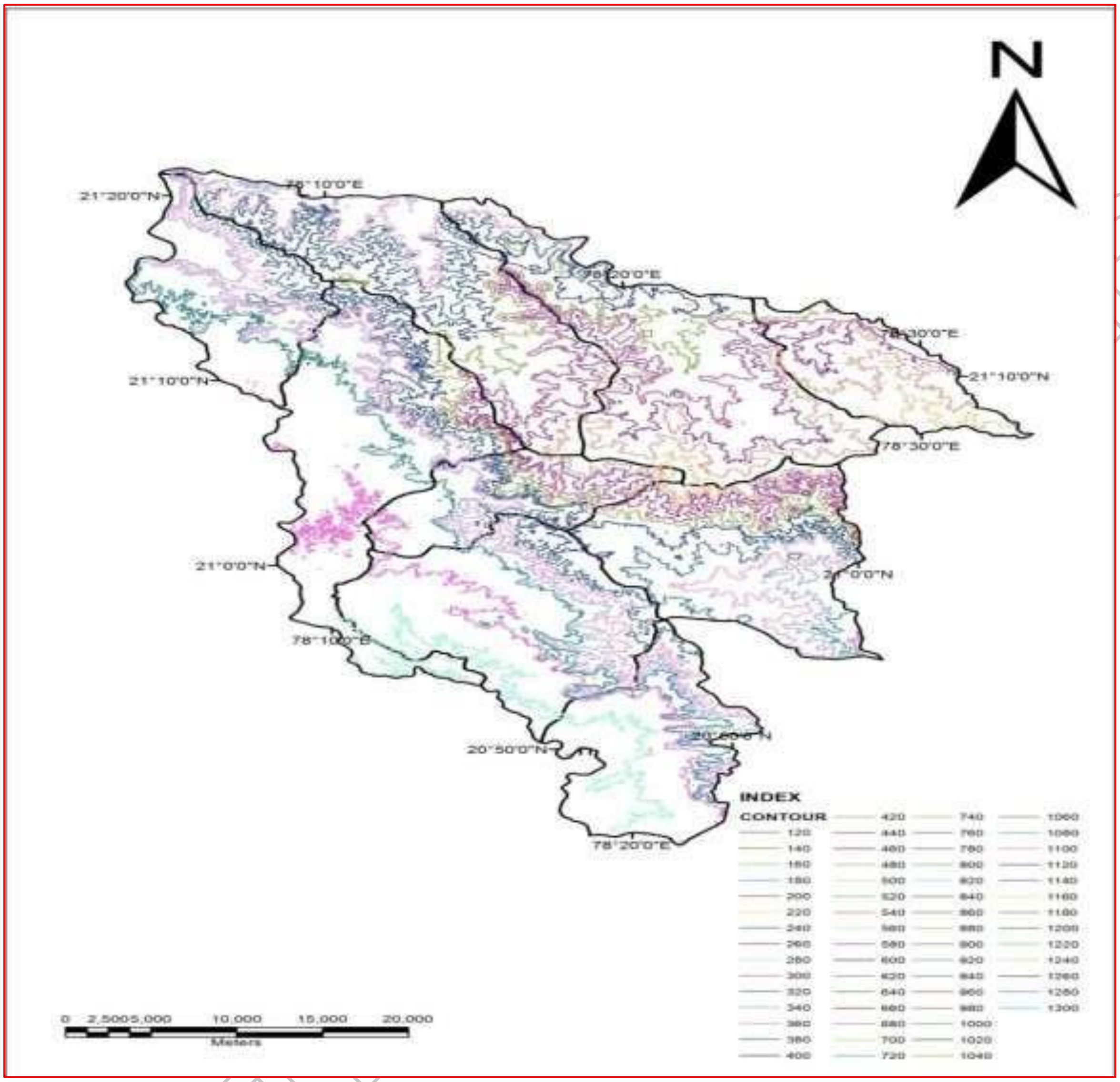


Fig.6: Contour map of Wardha river basin

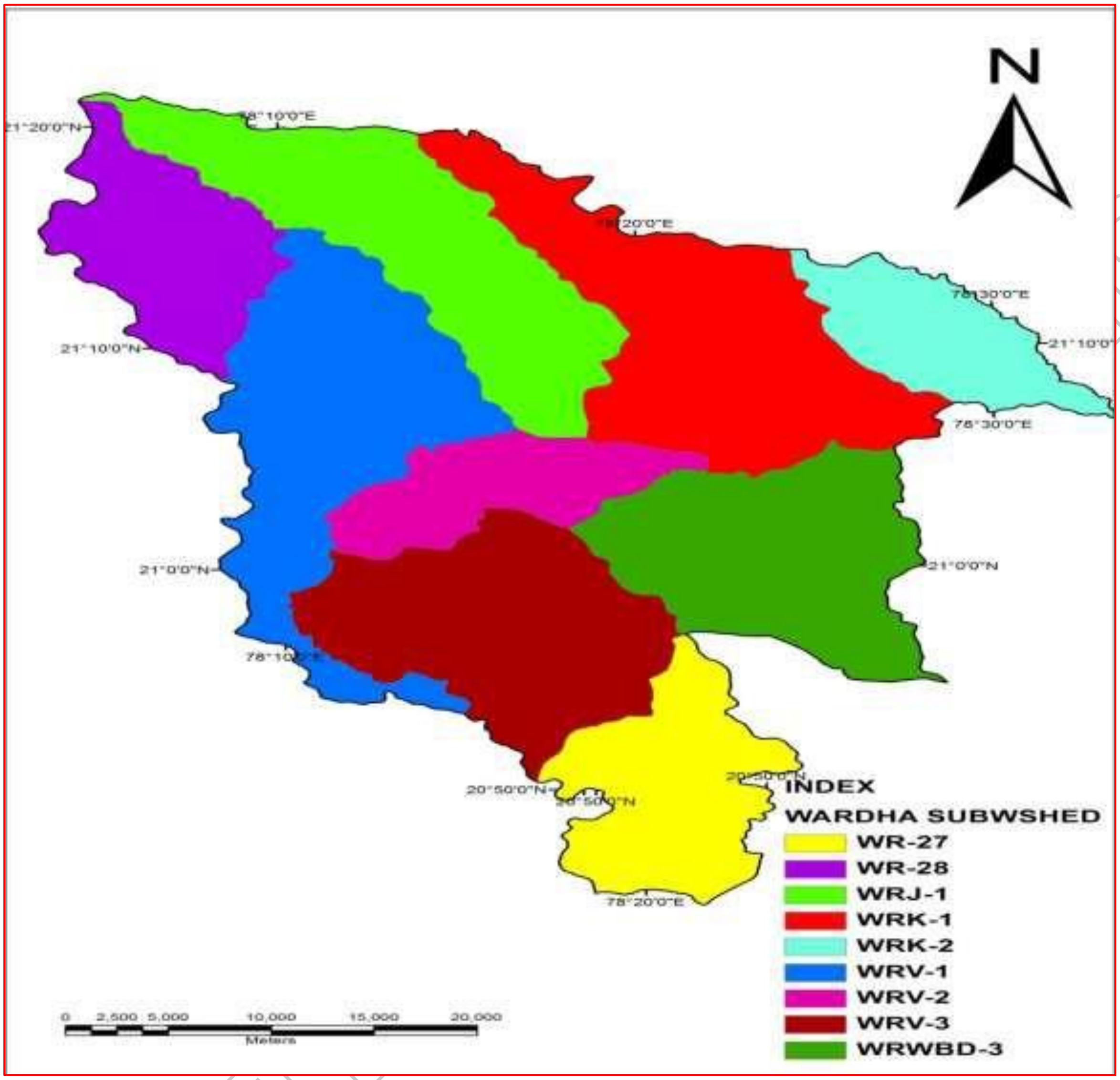


Fig.7:Sub-watershed map of Wardha river basin

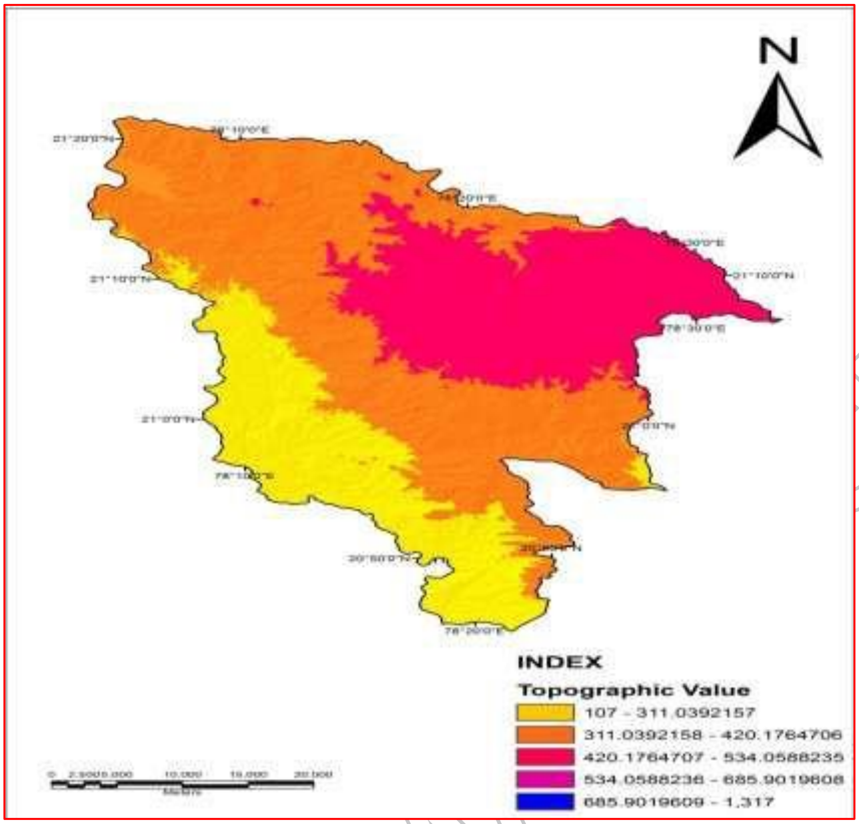


Fig.8: Topographic model of Wardha river basin

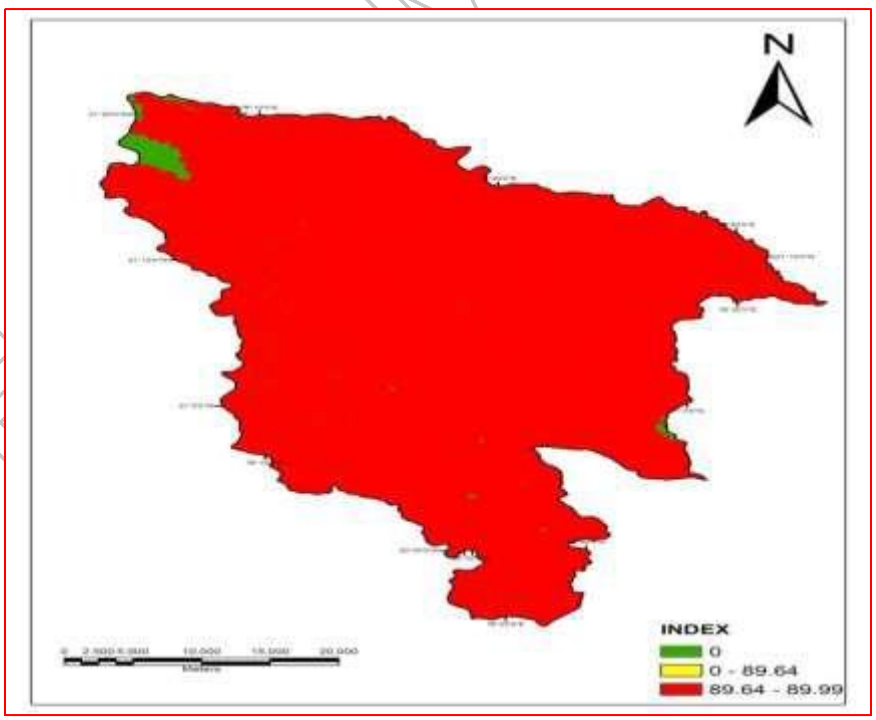


Fig.9: Slope map of Wardha river basin

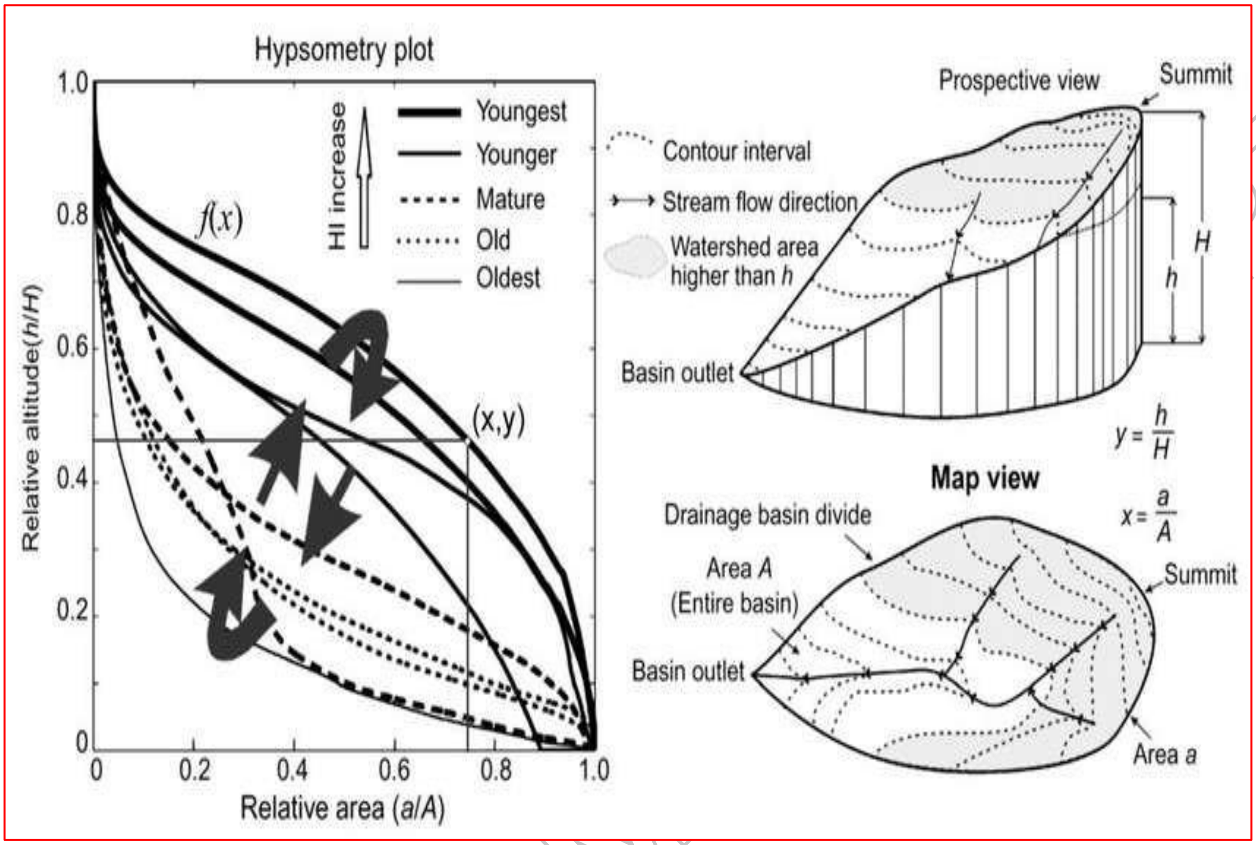
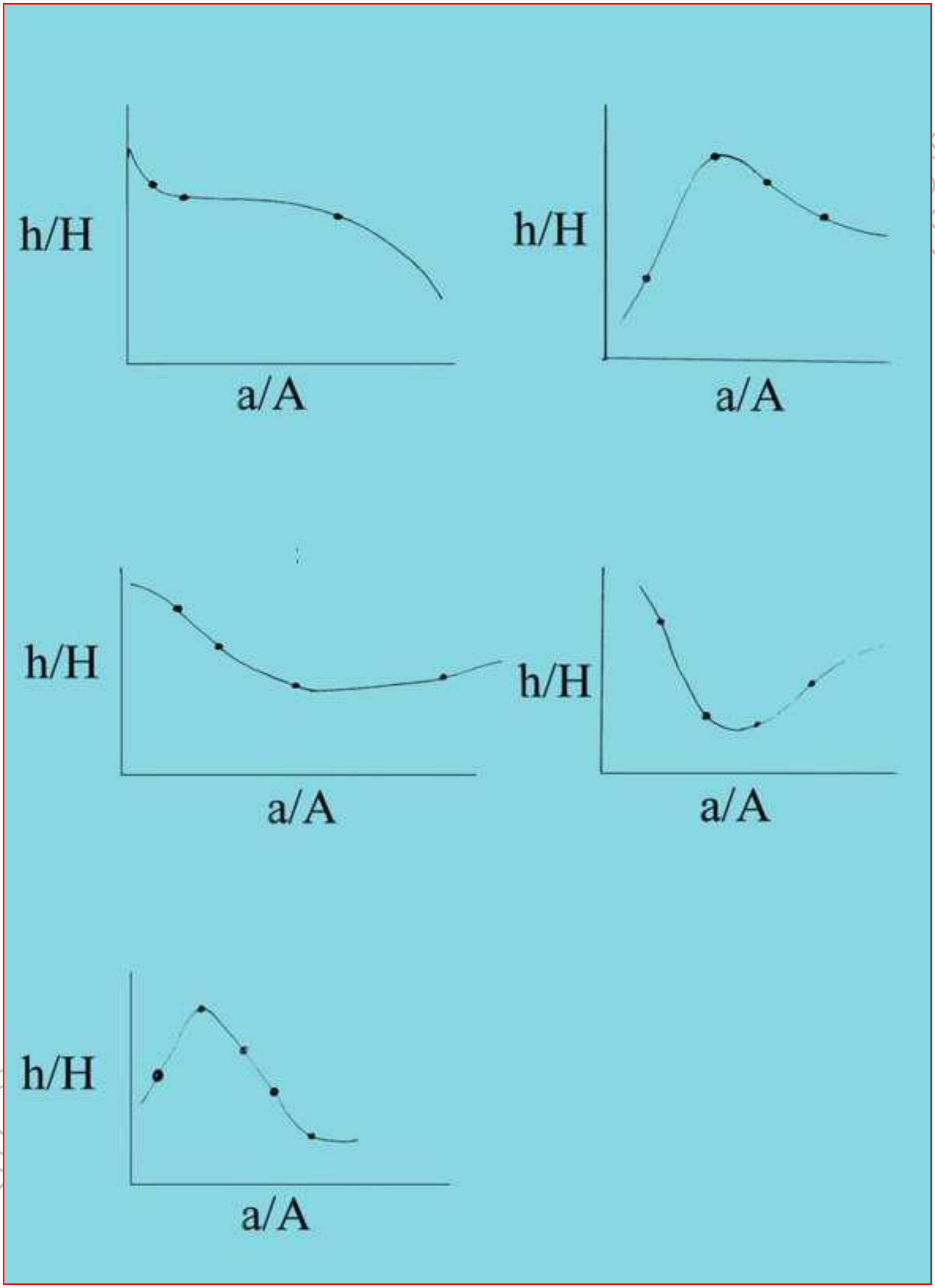


Fig.10 Show of Hypsometry Plot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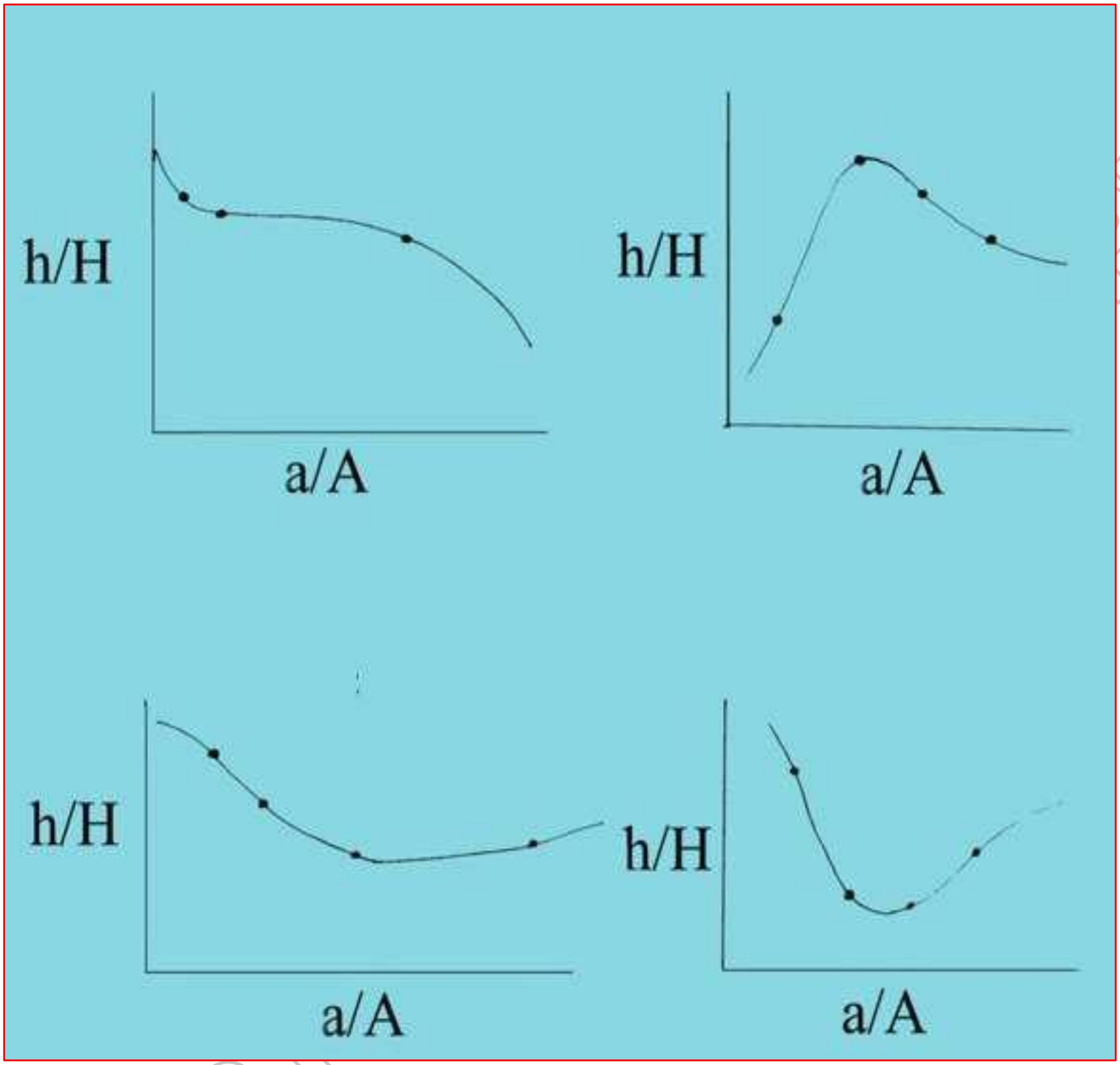

Fig.11 Show of Plotting of Hypsometric Curve

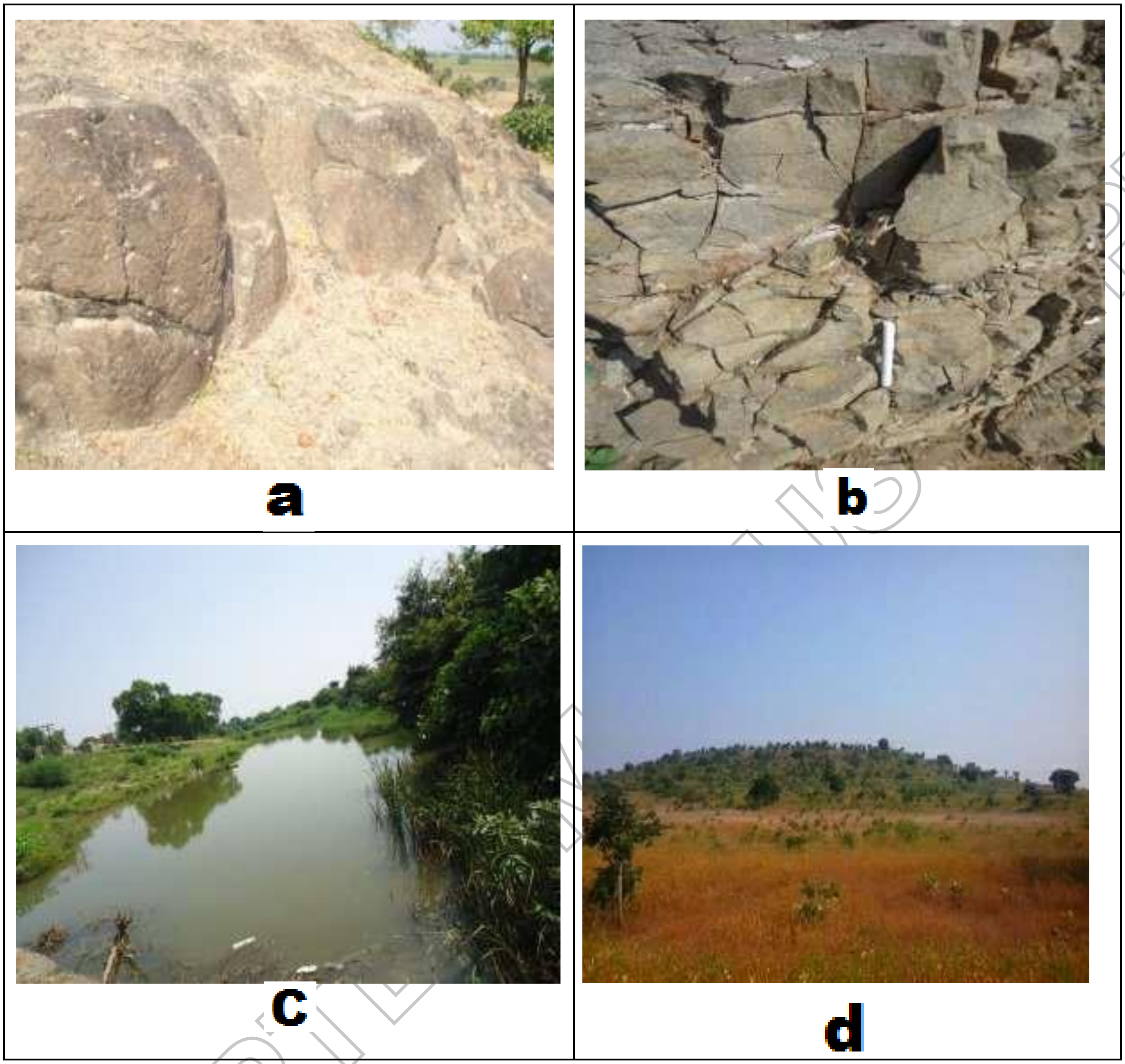

Fig. 12 a) Fine grained, amygdaloidal, jointed basalt b) showing coarse grained amygdaloidal Basalt c) show of Wardha river basin d) Show of basaltic hard rock area in the Wardha river basin

Table 1 Stream order, streams number, and bifurcation ratios of Wardha River Basin

S_u	N_u	R_b	N_{u-r}	R_b x N_{u-r}	R_{bwm}
I	2624				**3.96**
II	665	3.94	3289	12958.66	
III	166	4.00	831	3324	
IV	39	4.25	205	871.25	
V	10	3.9	49	191.1	
VI	4	2.5	14	35	
VII	1	4	5	20	
Total	3509	22.59	4393	17400.01	
Mean		3.76			

S_u Stream order, Nu Number of streams, R_b Bifurcation ratios, N_{u-r} Number of stream used in the ratio, R_{bwm} Weighted mean bifurcation ratio R_{bm} Mean bifurcation ratio

Table 2 Stream length and stream length ratio in Wardha River Basin

S_u	L_u	$L_{u/Su}$	L_{ur}	L_{ur-r}	L_{ur} x L_{ur-r}	L_{uwm}
I	1771.54	0.67				**1.89**
II	671.55	1.00	1.49	2443.09	3640.20	
III	378.56	2.28	2.28	1050.11	2394.25	
IV	219.05	5.61	2.46	597.61	1470.12	
V	99.99	9.99	1.78	319.04	567.89	
VI	149.97	37.49	3.75	249.96	937.35	
VII	32.57	32.57	0.86	182.54	156.98	
Total	3323.23	89.61	12.62	4841.99	9166.79	
Mean			2.10			

S_u Stream order, L_u Stream length, L_{ur} Stream length ratio, L_{ur-r} Stream length used in the ratio, L_{uwm} Weighted mean stream length ratio L_{urm} Mean stream length ratio

Table 3 Result of morphometric parameters at the Wardha River Basin

1	Stream order (Su)	Hierarchical rank	Strahler (1952)	1–7
2	1st order	Suf = N1	Strahler (1952)	2624
3	Stream number (Nu)	Nu = N1 + N2 +…Nn	Horton (1945)	3509
4	Stream length (Lu) Kms	Lu = L1 + L2…Ln	Strahler (1964)	3323.23
5	Stream length ratio (Lur)	-	Strahler (1964)	1.49-0.89
6	Mean stream length ratio (Lurm)	–	Horton (1945)	2.10
7	Weighted mean stream length ratio (Luwm)	–	Horton (1945)	1.89
8	Bifurcation ratio (Rb)	–	Strahler (1964)	3.94-4
9	Mean bifurcation ratio (Rbm)	–	Strahler (1964)	3.76
10	Weighted mean bifurcation ratio (Rb)	–	Strahler (1953)	3.96
11	Main channel length (C1) km.	GIS software analysis	-------------------	32.57
12	Valley length (VI) Kms	GIS software analysis	-------------------	86.86
13	Minimum aerial distance (Adm) Kms	GIS software analysis	-------------------	73.26
14	Channel index (Ci)	Ci = Cl/Adm (Hand TS)	Miller (1968)	0.44
15	Valley index (Vi)	Vi = Vl/Adm (TS)	Miller (1968)	1.18
16	Rho coefficient (q)	q = Lur/Rb	Horton (1945)	0.55
17	Basin area (A) Sq. Kms	GIS software analysis	Schumm(1956)	1730.90
18	Basin length (Lb) Kms	GIS software analysis	Schumm(1956)	32.57
19	Drainage density (Dd)	Dd = Lu-A	Horton (1945)	1592.33

Table: 4 Show of Hypsometric integral values at the Wardha River Basin

Sub-watershed No.	Area (sq.km)	Maximum elevation (m)	Minimum elevation (m)	Mean elevation (-)	Hypsometric integral	Geological stage
1	139.48	400	300	350	0.5	Mature Stage
2	241.62	440	360	400	0.5	Mature Stage
3	264.32	400	280	340	0.5	Mature Stage
4	278.44	500	380	440	0.5	Mature Stage
5	103.33	500	440	470	0.5	Mature Stage
6	213.71	500	360	430	0.5	Mature Stage
7	103.96	440	300	370	0.5	Mature Stage
8	231.75	400	280	340	0.5	Mature Stage
9	154.24	360	280	320	0.5	Mature Stage
Total	**1730.85**				**4.5**	