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RESEARCH ARTICLE

Assessment of Hypsometric Integral Status for Kumaradhara River of Dakshina Kannada, GIS Based Approach

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Abstract

The present study is aiming to find the Hypsometric characterises of Kumaradhara river basin area, which is located in central western ghat region at an altitude of 1480 average MSL. Hypsometric concept which helps in understanding the condition of river over period of time that river has been gone through stage of different life cycles of erosional activities. Hypsometric Integral (HI) is other important factor which helps in identifying the state of river condition that is going through with calculational factor elevation and rate of erosion that occurred in river basin or region that river flows. The study area region is located at mid of Central western ghat region which falls under the category tropical evergreen forest region and semi evergreen region. Very rich in flora and fauna. Home for nearly 70 types endemic plants types which are very crucial in condition. Providing shelter for nearly 12000 types of species from unicellular bacteria to angiosperms, 4000 types of flowering plants, and hub of various international and national acts such as (ECZ) Ecological Sensitive Zone, Biodiversity Heritage zone, Western Ghat Ecological Expert panel (EGEEP) and Hotspot zone for many Endangered species. For the study ALOS PALSAR data of DEM (Digital Elevation Model) is main source which is having resolution of 12.5meter data, is very high-resolution data of free of cost and Terrain Error corrected data. Student version ArcGIS Software 10.8 is used for analysis work Bhukosh and Survey of India (SOI) Toposheet data are utilized in this research work. In terms of Methodology to carryout activity DEM is classified according to elevation Range difference and classified into groups and area basin is calculated and according to Strahler method streams order of six classified and later Hypsometric Integral (HI) is calculated and finally by using that Hypsometric curve is plotted on map along with this various theme based maps were generated like Geology, Lithology, Stram order and Hill shade and Relief maps of study area is generated and maps were used in analysis work. The result of Hypsometric integral analysis revels that the Kumaradhara river is in between of Monodoc to Equilibrium stage where it gives hint of river is stage of erosion, still there is lot of stable bases for river erosion activity and different course erosional activity is still allowed and process is in stage of continuation of river erosional

activities.

Keywords: Hypsometric; River Equilibrium; Hypsometric Integral; HI analysis

Introduction

The surface of the earth is been in continuous state of erosion since form its beginning and will continue for ever. Surface as a mater fact eroded by various agents of erosion, in various way at different velocity, few examples River, Glacier, Wind, Human activities and these human activities includes various factor, such as Agricultural activity, all sorts of constructional activity, chemical and bio-anthropogenic activities, etc… all these in one or the other way contributing at different proportion for erosional activity. as there is saying all agents of erosion moto is to erode earth surface completely, this led to the present surface of earth that look as it is now. This study is concentrated about a factor that which already caused erosion and here we are identifying to what level the activity of erosion had occurred and currently it's in which state of it, for this the Concept of Hypsometry is used and Hypsometric Integral factor which helps in understanding this with respect to base elevation and Hypsometric curve, graphical representation of same integral data gives a clear calculational way to represent the curve by scientific mathematical and graphical way to understand it.

The word Hypsometry derived from Greek 'Hupsos' which means "height" and 'Metron' represent "measure" which means the measurement of land elevation (relative to mean sea level). Concept of Hypsometry was used by Langebein in (1947) [(1)] to illustrate, express slope and forms of drainage basin. Hypsometry it is science of measuring the elevation and depth of features on Earth's surface with respect to sea level by keeping it as base. In other words, it can be expressed as relationship of horizontal cross-sectional drainage basin area to the elevation, here the elevation factor may take different values which could be of negative or positive or both which is mainly depends on natural topography of the place. Different types of instruments and techniques are used to collect data to know about hypsometry such as by using hypsometers, wire sounders, other instrument like echo sounders, and satellite-based altimeters were also used to quantify the distribution of land at different elevations across a given area and the surface-area distribution of the oceans and their marginal seas with depth. this was the way to show how different features like oceans, terrestrial basins, and marginal seas and changes of these with respect to the elevation and depth of the features.

Hypsometric curve in simple terms relief graph of drainage basin. It is a graphical representation of data of Hypsometric Curve and integral value in two-dimensional plane graph. The curve of hypsometric which is having relation with the integral value of Hypsometry tells degree of disequilibrium in balance of erosive and tectonic forces [(2)]. Same thing could be expressed as volume of soil mass in the basin and total amount of erosion that occurred in the basin against the remaining mass [(3)]. The study mainly concentrates on finding and understanding the hypsometric stage of river and it's in which state of erosion. HI (Hypsometric Integral) which helps in understating the erosion cycle, which are broadly categorised into three major category or stages or groups. 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 [(4)] . This research is carried out to find hypsometric integral of Kumaradhara river which is in mid of Dakshina Kannada District, where the rivers flow in the mid of western ghat region.

The river Kumaradhara originates at the height of 1480 Meter AMSL (Average mean sea level) height in Kodagu district which is called as the Scot land of India, and Kashmir of Karnataka, specifically at Kumaradhara hill range which is located at mid of western ghat region. The geographical factor clearly shows harsh topographical nature and conditions of place. Kumaradhara River watershed covers area of three major districts namely Dakshina Kannada, Hassan and Kodagu. The origin place river in its native place is very impact to nominal, as it proceeds further it start flowing river basin spread across area with catchment area of nearly 1776 sq.km. The locational extent of study area is 12°29'4" to 12°58'33" North and 72°9'58" to 75°47'48" East. The river reaches to the coast at an average mean sea level height of 33meter near in Uppina Angadi a place in Puttur taluk and from that onwards it mixes or joins with another minor river named Netravthi. Precisely river Kumaradhara is not a major river, and at later point of time it is going to join with other minor tributary called Gundai and finally it becomes water basin called Kumaradhara water basin. The region very rich in biodiversity factors, and it falls in tropical evergreen, and semi evergreen forest region. Region is mainly producing Rubber, Arecanut which are major commercial crops and in terms of agricultural crops rice is the major producer where at yield which shows record of 62 quintals per hectare. Apart from these forest products are other outcomes.

Study area region has its importance in terms of forest species also. Western ghats are typical well know place for the Critically Endangered species according to the survey there are nearly 34 global hotspot regions in biodiversity category itself, and out of those many Kumaradhara river basin and its adjacent area is also one among the list. river basin and its surrounding place is also Ecologically sensitive as per the Environment protection act of 1986 of sub - section (2) and with clause of (v), and concept called Ecotone and species which are pertaining to certain conditional development and its related aspects can be easily identifiable and also very helpful in protecting and also identifying different zonal way by different criteria-based way. Kumaradhara water shed region is also a part of ESZ. which means Ecological Sensitive Zone. This is according to the Western Ghat Ecological Expert Panel i.e. (WGEEP). Region once again has its speciality in terms of trees, it is a hotspot for plant endemis. According to the Biological Diversity act of 2002 region having Cultural and Bioecological importance and it is considers as Biodiversity Heritage site (BHS). It is found that place is home for nearly endemic plants of 70 types of Documented samples of species such as *Madhuca Insignis*. There is one more case study where a special and unique sample of tree which exit only in two places namely Germany and British Museum of London, the tree species is *Syzygium Travabcoriumn*. Only in these two places these can be noticeable and not anywhere else in this world. In terms of Endangered species, the study area region itself home for *Hopea ponga* and *Vateria indica* and *Ochreinauclea missionis* and Gymnacranthera canarica and so many other species *Madhuca Neeriifolia* and so many others are well settled in this place and surroundings. In this way study area region has its own importance.

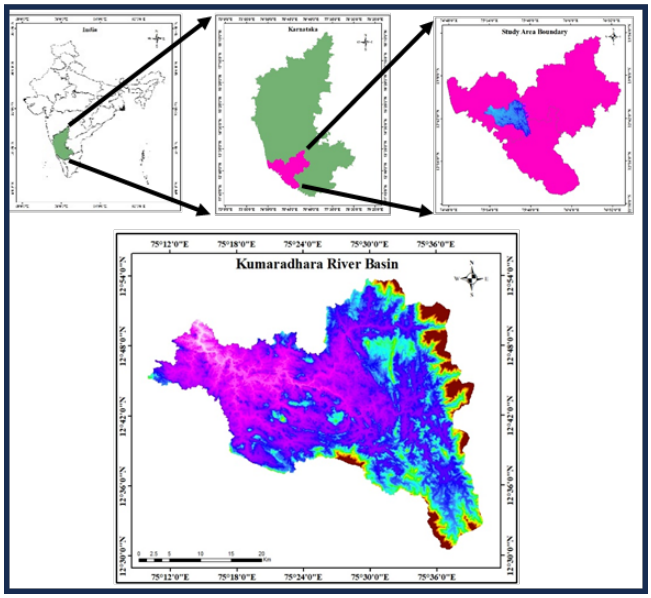

Fig. 1. Location map of the Study Area

Data Collection Sources

Data is the main components for any types research work. Various factors are taken into account before start like Authenticated sources, authenticity, Accuracy, and trustworthiness of data, compatibility and version of data and software's and cost effectiveness and time all these things are taken into account and further analysis work carried out. Digital elevation data (DEM) the most important sources of material that downloaded from the ALOS PALSOR - Radiometric terrain corrected (TRC) data form Alaska satellite and which give Synthetic aperture radar (SAR) satellite data is taken initially. ALSOR satellite data comes with 12.5-meter-high resolution data. Performed Geometrically auto corrected still for the sake of better result and to conformity manually once again cross checking is done. Removal of peaks and sinks are taken care.

The next important study material data is Toposheet. To access the toposheet (SOI) Survey of India website is accessed.by providing credential details toposheet of study area region, namely 48p/1, 48p/2, 48p/5 48p/6 and 48p/9 finally 48/p14 is downloaded and used them in creating a full pledged mosaiced image to extract required study area.

Later point of time geological data such as Lithology data has been taken from BHUKOSH, this data will help us to understand how the interior structure of earth is made, so that

it percolation and denudational process can be understood and can help us to predict in future where erosional can cause more damages may occur and preventive measure can be taken care in advance itself. So that damages can be controlled as early as possible.

The next important resources Rainfall data. Rainfall data really helps us to understand in terms of Hypsometry curve structure to a lot extent. The amount of rain fall over period of time can easily provide data in predicting what would be the next stage of curve and level erosion and level withstanding capacity of basin and structural condition of watershed both man made and natural phenomena etc…. Al these are predictable out of rainfall data source. For this rain fall data water portal, IMD, and KSNDMC organisational data has been approached and 10-year data is downloaded and with the comparative study of availability and in terms of utilization IMD data is used for analysis and same data used for maps creation.

Soil data is another most important factor in Hypsometric analysis and not only for this study, any study area assessment requires soil data, for this once again Geological survey of India and BHUKOSH is the data sources, Geology is another important factor which will help in getting details of the surface feature of study area, helps in understanding basic topography of the place and also rock age and period which it belongs to, all these things will really matters in finding the ageing factor of drainage basin. For these details once again BUKOSH is the sources provider, maps of each factor are generated and presented.

Methodology

For the finding of HI of Kumaradhara river, DEM (Digital Elevation Model) is main source which is downloaded from ALOS PALSAR website which provides Dem with the resolution of 12.5 meter with. TIF file format., and student version of ArcGIS software version 10.8.2 analysing and processing work starts. For better understating of this to make sure area ground truthing SOI toposheet maps were overlayed on DEM and confirmed. Flow chart has been clearly representing how activity is carried out to generate HI.

DEM (Digital Elevation Model)

Digital elevation model of ALOS PALSAR data with the 12.5-meter resolution data sources elevation map is generated by removing peaks and sinks in it. Further with DEM classification is carried out for better understanding with different general class interval and ten classes were generated. The Figure 3 clearly shows the number of classes and extraction of study area and with elevation details of maximum which is 1192 metre and lowest elevation of 21meter from the mean sea level height. Difference between these two maximum and minimum is called as relief. Higher the difference indicated more degree of changes and less of it shows less of vulnerability and tells land is more plane in nature and topography is more of like plan land region.

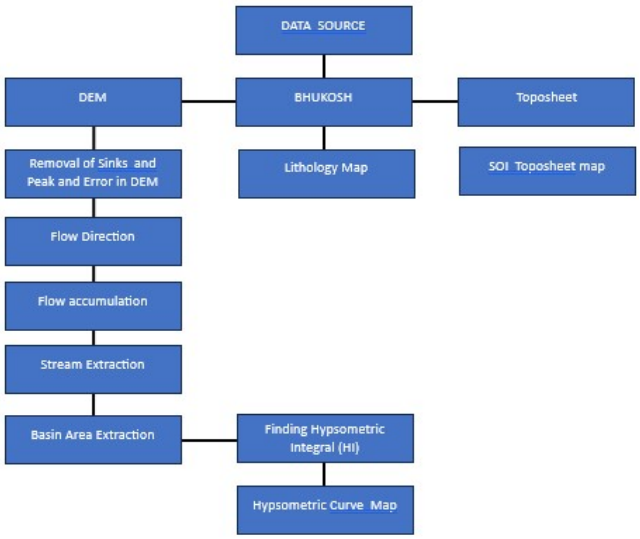

Fig. 2. Flowchart of Methodology

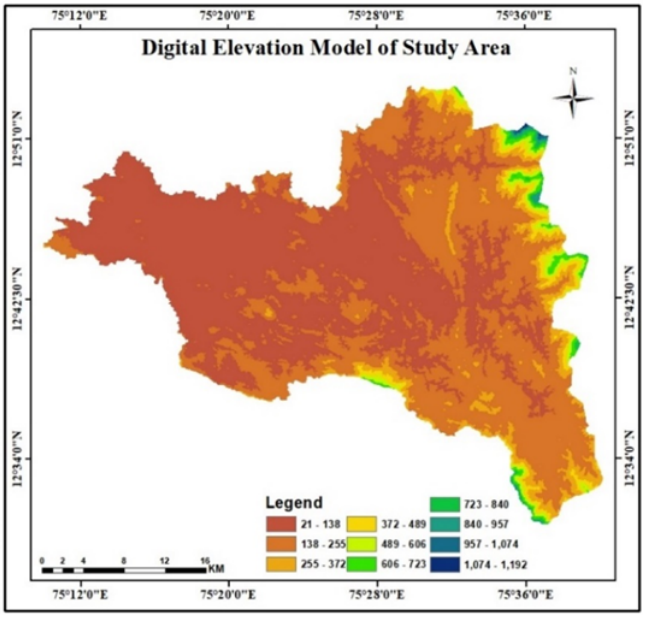

Fig. 3. Digital Elevation Model

Hill shade

Hill shade concept is technically helps in understanding 3d representation of the earth surface with respect to the sun position. It is mainly used to get the shading view of object, were height and dimension of feature could be very easy to

understand the position and aerial view of the place. Shadows of region helps clearly to understand the features with bare yeses. With the study area DEM hill shade feature is created and same shown in Figure 4 .

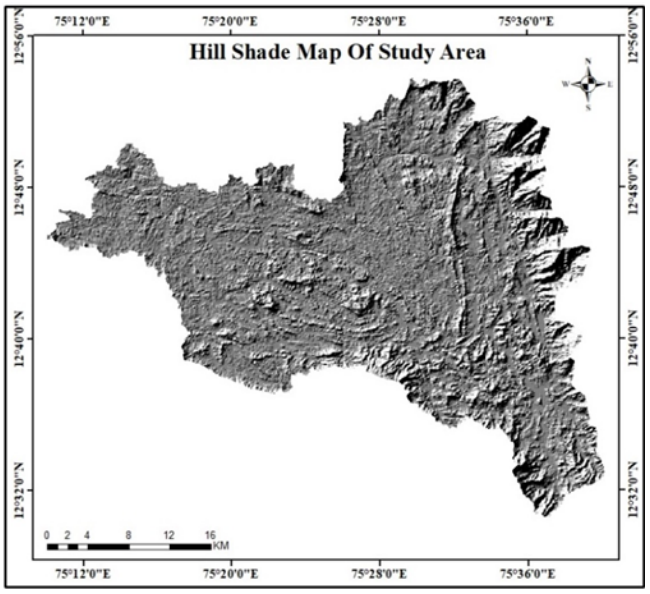

Fig. 4. Hillshade view of Study Area

Flow Direction

Flow direction, It's the direction of flow of water. Keeping DEM as base source of information and Hill shade as evidence and by keeping sun as source of angle, its becomes easy to find the direction in which it is. Concept of Hypsometric integral is all about how the curve looks, and what is factor that responsible to move water in particular way only and how these things are responsible in finding HI, directional flow things explain flow of water direction and which indicates movement erosional activity, Sediment movements and depositional activity of various items are all these things can be easily available and which helps in finding directional flow of water also and in category class totally eight colour codes are given to understand the importance flow direction.

Geology

The concept geology is study of solid earth surface features, it includes all terrestrial features of the earth. The modern geology significantly overlaps all other surface features it may include outer terrestrial features data also, like may be moon, mars, or any other surface features. In present study the geology surface feature data is collected from the GSI (Geological Survey of India). The study area data is captured and map is generated. Region is having broadly two major

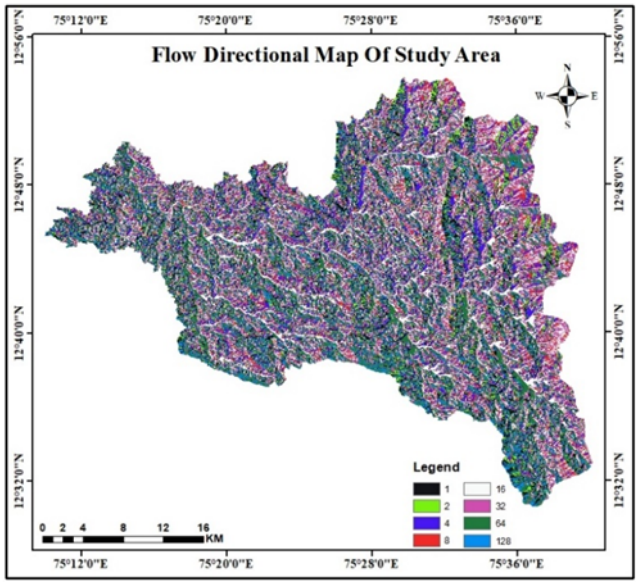

Fig. 5. Flow Direction Map

rocks structures details, namely Charnokite and Peninsular Genesis rock age groups. peninsular genesis. Other rock types is Charnokite, it is generally felsic and rich in Quartz and Microcline. There are so many compositions within it, but region is composed of these two rock types. The age group of rock same age of previous rock type which is 2.5 billion years ago formation time with high intensive pressure.

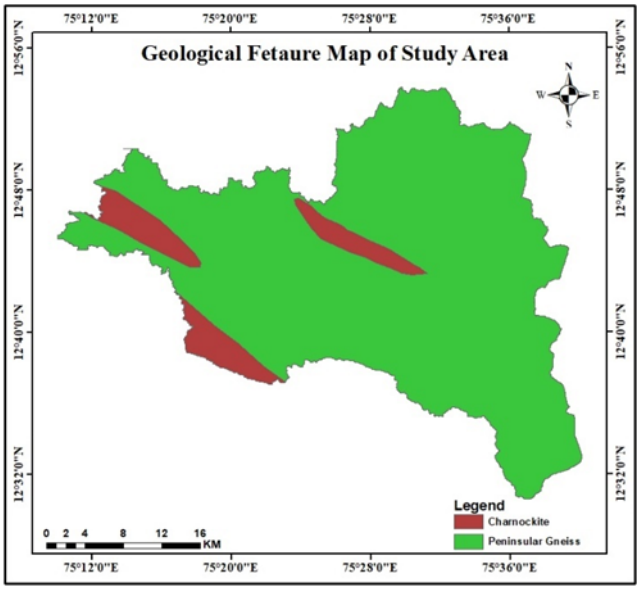

Fig. 6. Geology Map of Study region

Soil

Soil is one of the most important factor. Quality of soil is definitely varying from place to place. The quality also assessed by taking various parameter from mode of what actually need to do with that soil, but overall based on composition of material which it contains in it, based on that its characteristics or its nature is defined. The present study area is mainly dominated with majorly two types of soil factor. They are Plinthis Acrisols and other one is Distric Notosols. These two types of soil are dominant in study area.

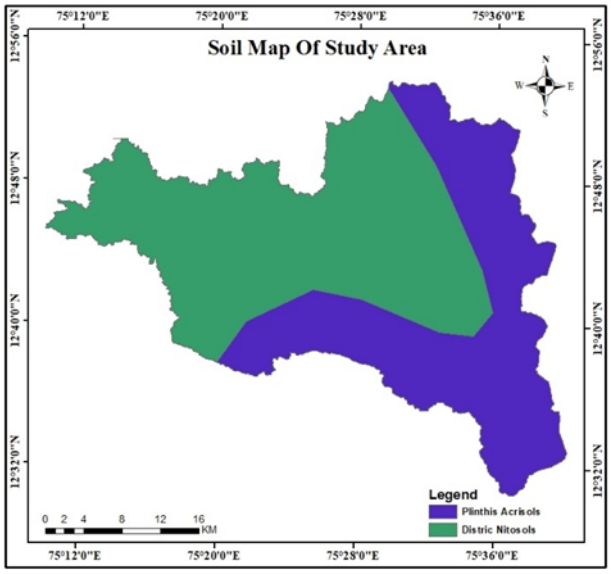

Fig. 7. Soil Type Map

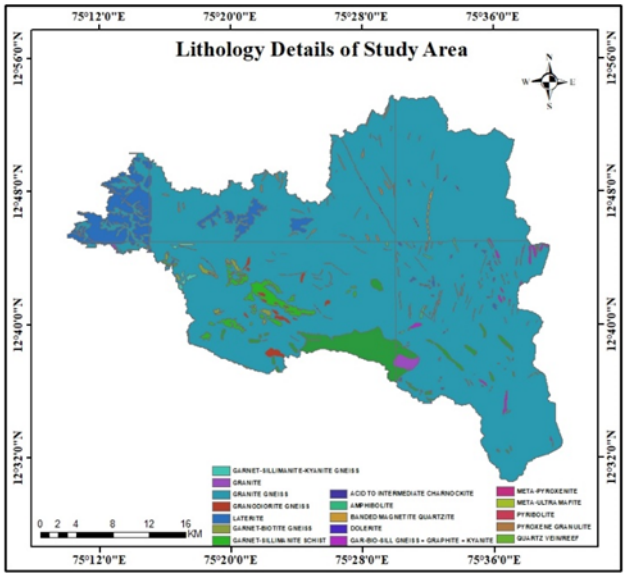

Fig. 8. Lithology Map

Lithology

Geological and Lithological evidences give information about interior and exterior details of soil and Petrology and brief information about landscape geological data material which found in study region such as Granites of various types, Amphibolite, Dolerite, Laterite, Pyribole, Pyroxene Granulite, Quart vein reef, Garnet biotite gneiss, Meta Ultra Mafite, like various other source materials, all these are shown in image with details.

Stream Orders

With the help of DEM watershed is delineated by using ArcGIS software, with that basin area is extracted and. Extraction of basin area led to understand the features clearly and further with help of flow direction and flow accumulation, and pour point by using Raster calculator, where cell values more than hundred asked to extract stream order. *Strahler AN* order method is used for extraction of stream order and found up to six order level streams are generated, here ALOS PALSAR data played a vital role in stream extraction. the total area is covered by the Basin area is 1095.106 Sq./km of area. This is the total amount of area and out of this Hypsometric Integral value and Hypsometric Curve and other related all data need to generated and result need to be generated.

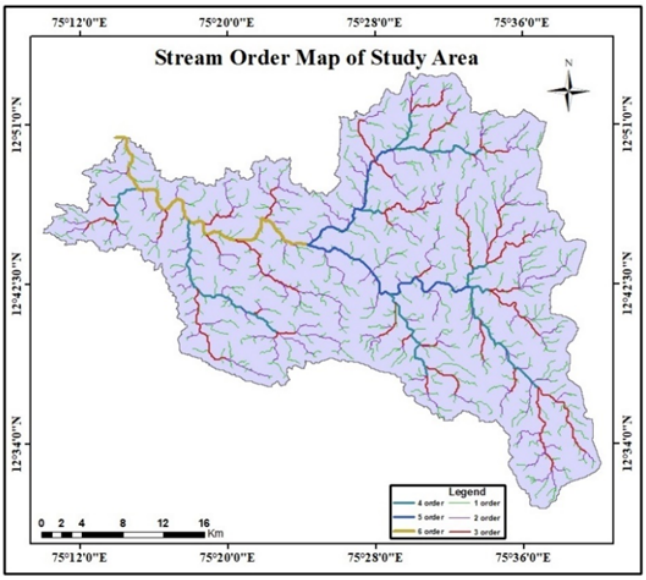

Fig. 9. Stream Order Map

Understanding the working Process of Hypsometry

Working process of hypsometry is already explained in Introduction to Hypsometry at initial stage itself. To make

it further easy to understand proportion of area at various different level of elevation with in defined region with respect to its altitude. Further in common measuring area from the base to its highest level by keeping idea area and its elevation. Let's understand this with simple image which explains about this.

As explained in introduction to hypsometry at the beginning after invention of Hypsometric integral curve it become easy to understand the difference that arises within the same watershed region comparative study of different water streams gives different result, it's because of how regional and physiological factor plays vital role and even curve result clearly shows that the level of erosional activity that result in different structural curve design, entire concept just by seeing into the picture of curves itself can identify what is the stage of river and what will be the next stage and even health condition of river or basin and adjust area can be easily predictable.

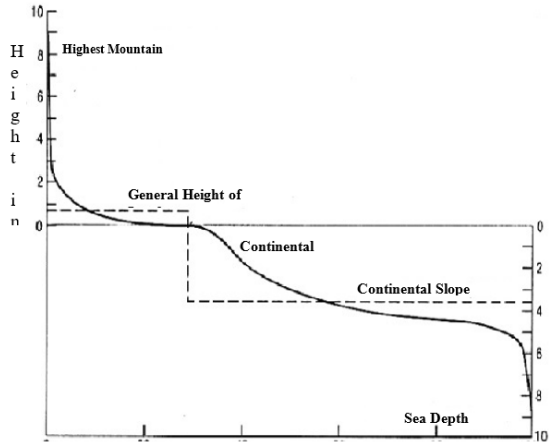

Fig. 10. Hypsometric detail map

Finding Hypsometric details

Keeping DEM as abase class intervals are created and by looking at the difference between highest elevation and lowest elevation class are divide. In this study highest elevation is 1192 meter and lowest Elevation being 21meter and out of this range ten classes are generated. for same next formula were applied and Cumulative area below height is calculated. Then calculation of Cumulative area Below the value and Relative area, Relative Height and Reverse Relative Height calculated and further map of Hypsometric integral need to be calculated.

Relative Area concept is calculated by taking the area of the basin. Here that is 1094.756 Sq.km total area and it needs to be subtracted with Cumulative area of each basin data of that particular elevation data and all of these values need to be divided with the area of the basin once again. It gives us the relative height of that particular height relative area. The formula for this as fallows.

Height below contour	Cum area below height	Relative Area	Relative Height	Reversed relative height
21	0	1	1	0
138	543.04	0.503962611	0.900085397	0.100768
255	962.183	0.121098367	0.800170794	0.200683
372	1030.3838	0.05880066	0.700256191	0.300597
489	1058.8122	0.032832869	0.600341588	0.400512
606	1076.0648	0.017073561	0.500426985	0.500426
723	1087.3828	0.006735186	0.400512383	0.600341
840	1091.76612	0.002731262	0.30059778	0.700256
957	1093.7217	0.000944946	0.200683177	0.80017
1074	1094.468054	0.000263193	0.100768574	0.900085
1192	1094.756186	0	0	1

Fig. 11. Hypsometric detail table

Relative Area = Area Basin − Cumulative Area below Contour / Area

Relative Height is also the same concept, where Relief i.e. the difference between the maximum Height and Minimum Height their difference is called as Relative Height. In this case Maximum Height is 1094 meter and Minimum Height is 21 meter and the relief is 1171 mater. All these data should be applied according to the formula and result need to be calculated. The formula as fallows.

Relative Height = (Relief − (Contour Height − Minimum Height)/ Relief

Hypsometric Integral

The Hypsometric Integral it considered to be the one of the most commonly used tool or way to measure or to describe the shape of earth. The general way of calculating is by plotting the cumulative Height and Cumulative area under the height of each individual watershed or water basin and later by taking the area under that curve to get the Hypsometric Integral. There are developed tools with in ArcGIS software itself and additionally there are more to find Hypsometric integral. Within software there are two different sets of tools which are useable at different situational circumstances. One is Hypsometric Integral for main model and other one is for Sub-Model watershed. The formula for the Hypsometric integral is as fallows.

$$HI = \frac{\text{Mean Elevation} - \text{Minimum Elevation}}{\text{Maximum Elevation} - \text{Minimum Elevation}}$$

So according to the formula in this study the Mean elevation values is 1171 meter and Minimum elevation is 21 meter and remaining maximum elevation is 1192 meter. Now apply the formula and find the Hypsometric integral result 0.982067

Height maximum	Height Minimum	Relief	HI
1192	21	1171	0.982067

Fig. 12. Shows Hypsometric Integral details

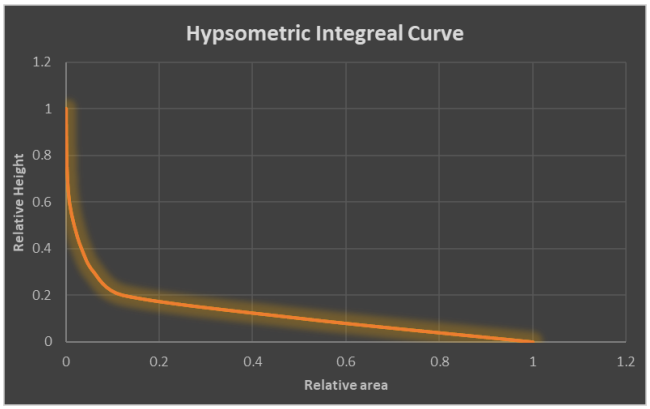

Fig. 14. Hypsometric Curve map

Plotting of Hypsometric Curve

Hypsometric curve is generally the altitude or elevation across the area of land which is used to evaluate the different evolutionary stages of the different landforms. Overall, in simple terminology amount of soil mass erosion that occurred in basin area and remaining amount of mass remained against the basin area. Early date back to 1956 onwards[3,4]. All these scholas are made attempts to explain Concept of Hypsometry Curve.

Plotting of curve helps us in understanding different erosional data of different river basin data, and it helps us know better about the condition of different watershed and erosional amount and their health condition and damages that it can undergo, stage to what extent further it can erode and preventive measures that can be taken in advance to avoid damages or losses and there is other so many uses full things are there if we want to know about hypsometry and hypsometric integral.

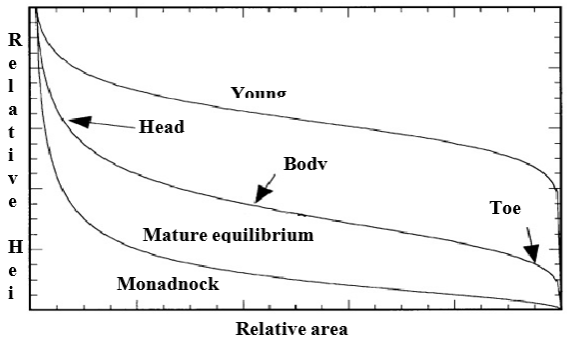

Fig. 13. Hypsometric detail map

Here in this hypsometric analysis research work I used predefined plotting technique which is developed by[4] Strahler in 1952. In this research work Strahler model where he explain entire erosion cycle into three different stages, (A) Fully Stabilised watershed geologically called as Monadnock or (old) stage where value ranges form (HSI <0.3) (B) Mature stage or Equilibrium stage (His 0.3≤ His <0.6 and Finally (C) In equilibrium stage, where value comes in between (HSI ≥ 0.6). These are three different stages of Hypsometry and this reference sources data used in this work and accordingly tried to interpret.

Result

It is hypsometric Integral result finally identified as 0.982067. which says that, the river basin is in young stage, and the same thing is also shown by creating graph. Figure 10 which explains about various stages of Hypsometric level. According to the Strahler categorisation river is in the stage of Unstable. HIS ≥ 0.6 value is indicating that if the values come His ≥ 0.6 is considered to be as Unstable and not exactly young and in a stage of Maturity or to reach stage of Balanced Equilibrium stage.

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