GEOMORPHOLOGICAL APPROACH FOR DIGITAL ELEVATION MODEL (DEM) AND HYPSOMETRIC ANALYSIS: A CASE STUDY FOR KHADKI NALA BASIN, SOLAPUR DISTRICT, MAHARASHTRA, INDIA.

Dr. Aniket Deshpande

Civil Department, Siddhant College of Engineering, Sudumbare, Pune

ABSTRACT: Digital elevation models (DEMs) are more and more used for visual analysis of topography, landforms, as well as modeling of surface processes. Digital elevation models are widely used to study the influence of geological structures and neo- tectonic processes upon geomorphology. In present investigation Khadki Nala basin which falls geographically under Solapur district of Maharashtra. Khadki nala is a tributary of Man river and occupies the south western part of Solapur district. Digital Elevation Model (DEM) has been made for the Khadki Nala Basin. The drainage divides for the first, second, third, fourth and fifth order has been clearly distinguished for the Khadki Nala Basin. Hypsometric analysis deals with measurement of the interrelationships between basin area and altitude of basin which has been used to understand the influence of climatic, geologic and tectonic factors on topographic changes. Erosional landforms of different stages during their evolution are differentiated by hypsometric analysis.

Keywords: DEM, geomorphology, GIS, Khadki Nala, hypsometric

I. Introduction

The term digital elevation model is used to refer representation of topographic surface. This has become possible because of rapid technological progress in electronic and the analytical tool availability. This has facilitated in widespread application of digital elevation model (DEM) for geomorphological and geological research. Topographic data can now easily be transformed in to DEMs and analyses on a regular PC. Suitable DEM software such as Surfer, Arc GIS enables to generate shaded relief maps using differently oriented source of light and also log diagrams can be constructed. Depending on DEM resolution, one can analyses either single landforms or regional distribution of assemblages of landforms. It is also used for many purposes like providing flood and landslide risk zone, highways and corridor selection including cut and fill estimation etc. According to Burrough (1986) "Digital Elevation Model is regular gridded matrix representation of the continuous variation of relief over space". Elevation can be defined as "the height above the horizon". The term horizon refers to the sea level. DEM involves creation of regular array of elevations in the form of squares or hexagon pattern over the terrain. DTM represents the altitude of ground itself while DEM refers to the maximum altitude everywhere. The present study was carried out using ArcGIS - 10.2 tools. The idea of hypsometry was first introduced by Langbein and Basil in 1947 to express the overall slope and the forms of drainage basin, and was later extended by Strahler (1952) to include the percentage hypsometric curve and the hypsometric integral. Hypsometry describes the measurement and analysis of relationships between the distribution of elevations across an area of land surface and basin area. Weissel et al. (1994) suggested that hypsometry may reflects the interaction between tectonic and degree of disequilibria in the balance of erosive, and could provide a valuable geomorphic index that constrains the relative importance of these processes. Hypsometric analysis is a useful method to identify the stage reached by a drainage basin in the present cycle of erosion and evaluate the erosional status of a basin, and also expresses the denudational processes over a region. Besides erosional stage of landform evolution, the influence of tectonic activity, climate change and lithological factors controlling on landform evolution can be analyzed from hypsometric analysis

The area falls under the rain shadow zone and frequent drought is a common feature in the area due to adverse climatic conditions. Geologically the area falls under the hard rock terrain consisting of basaltic lava flows. The study area is located on Survey of India Topo Sheet No.47O/6, 47O/7, on the scale of 1: 50,000. It lies between latitudes 17^0 19' 00" N to 17^0 33' 00" N and longitude 75^0 17' 00" E to 75^0 25' 00" E. The total area is about 167.26 sq.km. The maximum elevation is 568 m and minimum elevation is 457 m.

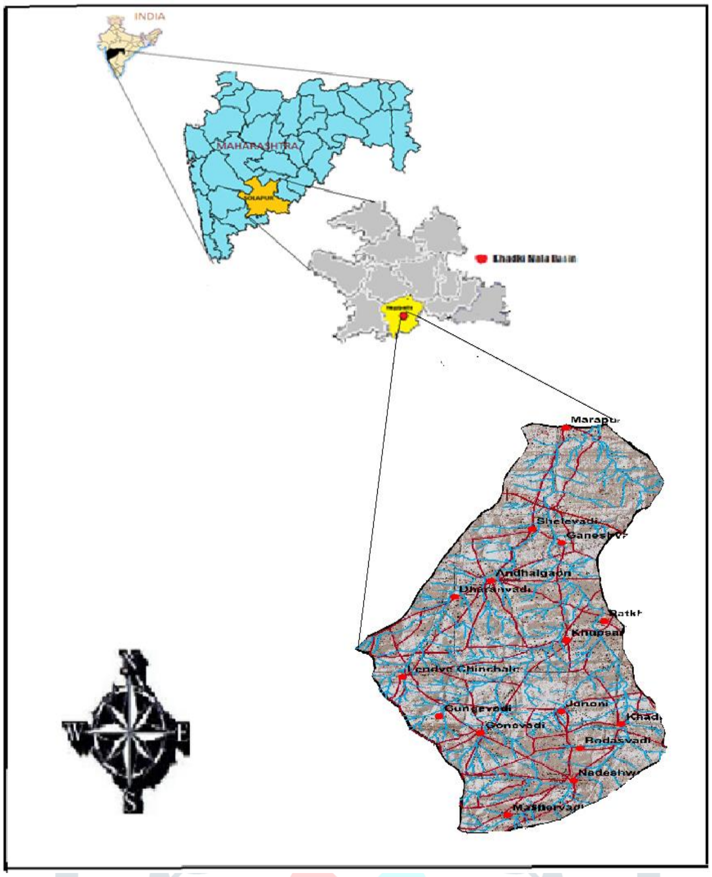

Fig No: 1 Location Map of Khadki nala Basin

II. Geology of Area

The basin consists of unclassified basaltic lava flows (GSI, 2001) representing Indrayani stratigraphic unit of Sahyadri group of Deccan trap. The general dip of the basin is towards North direction. Massive basalt formation is exposed at south, central and north eastern portion of the basin around Masnervadi, Nandeshwar, Gonevadi, Junoni, Patkhal, Kupsangi, Gungevadi, Khadki, Bodasvadi villages. North eastern direction of Ganeshvadi village also exhibit massive basaltic formation. The thickness of this flow is about 68 m. Vesicular basalt or Zeolitic basalt is exposed in north east to north west portion of the basin as well as in some eastern portion of basin. Vesicular basalt or zeolitic basalt is of thickness 30 m and occurring north direction of Dharanvadi, Andhalgaon villages, north eastern direction of Shelevadi village. While some portion is also exposed at south direction of Khupsangi village. Weathered basalt is exposed in the around Shelevadi, Ganeshvadi, Lendve Chinchale villages. Weathered basalt is also exposed at north eastern direction of Nandeshwar, East direction of Khadki and South direction of Patkhal village. Weathered basalt is thickness of about 25 meters.

III. Methodology

(A) Digital Elevation Model (DEM)

DEM is frequently used to refer to any digital representation of a topographic surface. DEM is the simplest form of digital representation of topography. Each digital elevation model requires a spatial data base where in points on the earth surface are assigned coordinates XY on the planes and the vertical coordinate Z in order to construct digital map and block diagrams. It is necessary to transform XYZ data into the grid, i.e. 3D network which is recognized by the computer as a model of the Earth's surface. Such grids can be generated by different software programs such as surfer or Arc GIS. The Southern margin of the basin represents highest elevation peak 540-568 meters above mean sea level, such village is Masnervadi. Second highest elevation peak 520-540 meters above mean sea level, such villages are Nandeshwar, Junoni, Bodasvadi, Khadki, Gonevadi, Gungevadi, Lendve Chinchale. This is followed by a fringe of elevation difference 480 to 520 meters above mean sea level, such villages are Patkhal, Khupsangi, Andhalgaon, Dharanvadi. Northern portion of the basin represent lowest elevation of 455-480 meters covering villages are Shelevadi, Ganeshvadi, Marapur. In the present DEM model Khadki Nala basin drainage network is superimposed, which shows the principal component of the drainage which is dendretic in nature and this gives the complete partitioning of the space with respect to elevation. It is also clearly noticed that the drainage divides for the first order, second order, third order, fourth order and fifth order can be clearly seen in the DEM model of Khadki Nala basin. This is an important first step in the development of a Hydrologic information system. Qualitatively the high elevation portion, moderate elevation portion and the low line area in the basin has been visualized in the map. In the present case the red, and yellow patches represent high elevation region. The Sky blue zone with moderate elevated structure blue portion represents the low line area.

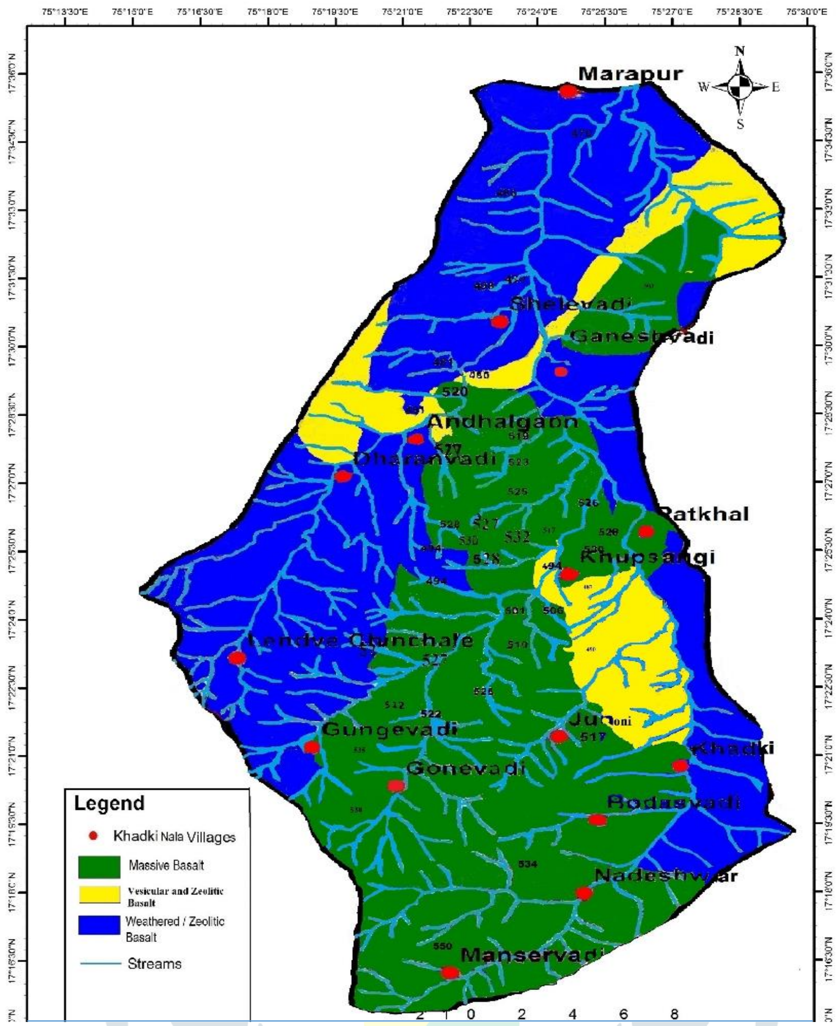

Fig No: 2 Geological map of Khadki Nala basin

(B) Hypsometric Analysis

Leopard and Langbein, (1947) described hypsometric analysis (area altitude analysis) is the distribution of horizontal cross-sectional area of a part of an earth surface with respect to elevation. Normalize cumulative frequency distribution of elevation has been described as hypsometric curve by Strahler (1954). Erosional landforms of different stages during their evolution are differentiated by hypsometric analysis. This is done by constructing the curve using summations of the number of data points higher than incremental threshold of elevation, starting at the maximum elevation (Strahler 1952; Schumm 1956). Different catchments could be compared without any error by this analysis as it is a dimensional less parameter. A measure of area distribution of landmass volume remaining beneath and above a basal reference plane is known as the hypsometric integral (HI). The area beneath the curve relates to the percent of area. In theory hypsometric volume ranges from 0 to 1. Hypsometric curve and integral are useful terms to decide the degree of basin dissection and relative landform age. Convex up curve with high integral is a typical youth stage. Undissected landscape with a smooth 'S' shape crossing the center of a curve indicates mature landscape. A curve with low integral values having concave up shape indicates an old and deeply dissected landscape this represent generally mature stage. Three threshold values for youthful stage that is hypsometric integrals have been recommended by Strahler (1952).

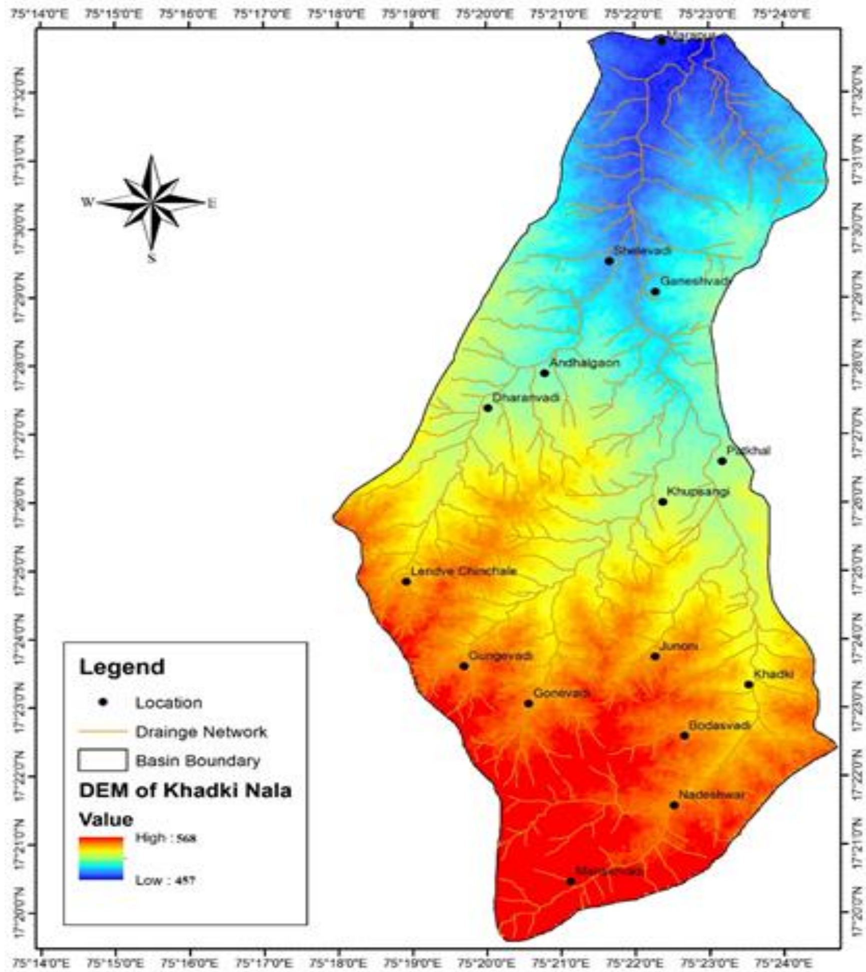

Fig No: 3 Digital Elevation Model (DEM) of Khadki Nala Basin

- Youthful stage (HI≥ 0.6)
- Equilibrium stage (HI ≥0.35)
- Monodnock stage (HI≤0.35)

Kusre, (2013) classified these hypsometric integrals into five categories (A to E) and therefore the status of evolution of sub-watershed. HI values of each category of watershed are also results of the kind of heterogeneity encountered by the flowing water. This heterogeneity may be a result of tectonic activity. Strahler, (1957) relates hypsometric distribution to basin age. Monglane and Brass (1955) state that the rock types over which the drainage flows controls the hypsometric distribution. Watershed with higher HI values indicates higher soil moisture near the channel and watershed with lower HI values has shallow depth soil moisture concentration, (Vivoni et. al 2008). This also means that the watershed with higher HI values has higher total runoff, with subsurface runoff as major process. Based on runoff generation characteristics of watershed ranking of the watershed are done by Kusre (2013). The watershed with higher HI values has rank 1 (lower ranking) and watershed with lower values of HI has higher ranking. Hypsometric integrals have also been used to understand groundwater recharge in different basins of basaltic terrains (Narayanpethkar et al. 1991, 1997; Sable et al. 2007, 2009; and Raut et al. 2011). Hypsometric curves were derived by plotting the relative heights (h/H) and relative areas (a/A) for all the sub-watersheds. The relative area is the ratio of the area above a particular contour to the total area of the basin or watershed. The relative elevation is represented as the ratio of the height of a given contour (h) from the base plan to the maximum basin elevation (H). This provides a measure of a distribution of landmass volume remaining beneath a reference elevation and a basal reference plane.

Pike and Wilson, (1971) defined elevation-relief ratio E, as equivalent to hypsometric integral (HI). Hypsometric curves and hypsometric integrals are important indicators of watershed conditions. This is obtained from integration of the hypsometric curve and is denoted by the following equation.

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

Where E is the elevation-relief ratio equivalent to the hypsometric integral HI, Elev mean is the weighted mean elevation of the watershed estimated from the identifiable contour of the delineated watershed, Elev min and Elev max are the minimum and maximum elevations in the watershed. The hypsometric integral is expressed in percentage units. The h ypsometric analysis is carried out for Khadki Nala basin in Table no 1. The hypsometric curve for Khadki Nala basin is given in fig. no 3. It has moderately high HI value (0.5) and on the basis of shape of the curve it falls under category E representing higher runoff.

Table No: 1 Hypsometric data of hypsometric integral of Khadki Nala basin

Contour value in mtrs	Area above given contour (a) sq.km	Total of area of the basin (A) sq.km	Area ratio a/A	Height of the contour above the base (h) mtrs	Total height of the contour (H) mtrs	Height of the altitude ratio h/H
560	15.5	167.26	0.0926	110	111	0.990
560-540	36.6	167.26	0.2188	90	111	0.810
540-520	73.4	167.26	0.4388	70	111	0.630
520-500	104.7	167.26	0.6259	50	111	0.450
500-480	135.2	167.26	0.8083	30	111	0.270
480-460	156.5	167.26	0.9356	10	111	0.090
460	167.26	167.26	1			

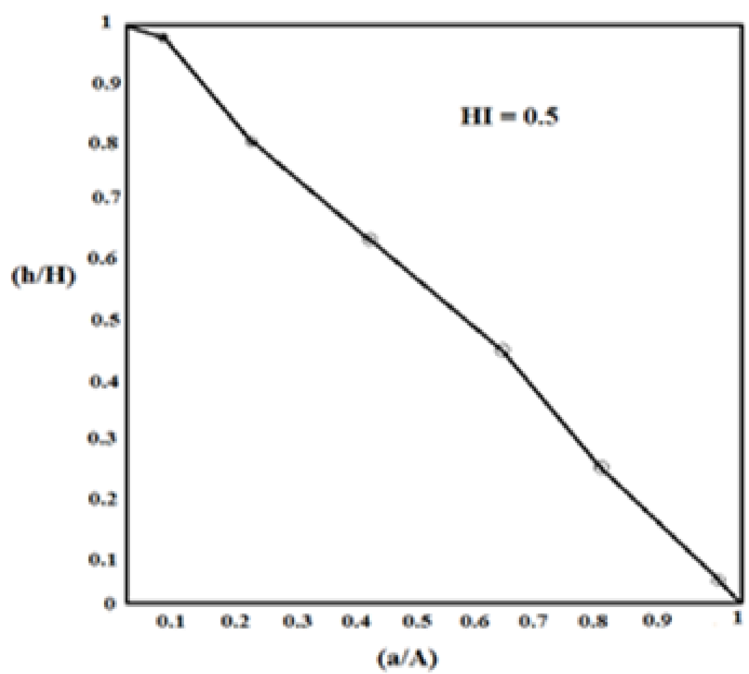

Fig No 4 Hypsometric curve for Khadki nala basin

Conclusion

DEM data can be used for visualization and interpretation of the area in terms of geology and geomorphology. The drainage divides for the first, second, third, fourth and fifth order has been clearly distinguished for the Khadki Nala Basin. The southern margin of the basin represents highest elevation peak while northern portion of the basin represent lowest elevation. DEM data, however cannot be ignored altogether as it can be very useful in giving an overview of the geology and geomorphology of any area especially where any other data. Over all this study will help in improving the hydrogeological conditions of the area for the sustainable development of the region. The hypsometric analysis is carried out for Khadki Nala basin. The hypsometric curves for Khadki Nala basin for fifth order is 0.5. The hypsometric values are lower indicating that the soil moisture is concentrated at shallow depth and has less total runoff, with major contribution from surface runoff. The hypsometric integral provides a very good idea about the distribution of land surface at various elevations. It is also a strong indicator of tectonic control, i.e. active tectonics, irrespective of area, lithology and climate. Hypsometric integral is a useful parameter for assessing the nature of active tectonic deformation. It also helps in ascertaining the dominance of either tectonic or erosional processes in shaping the watersheds.

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