International Journal For Technological Research In Engineering
Volume 1, Issue 10, June-2014 *ISSN (Online): 2347 - 4718*

ANALYSIS OF MORPHOMETRIC PARAMETERS USING REMOTE-SENSING AND GIS TECHNIQUES IN THE LONAR NALA IN AKOLA DISTRICT, MAHARASHTRA, INDIA

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Abstract: In the present paper, an attempt has been made to study the detail Morphometric characteristics of the Lonar nala watershed have study. For detailed study, we used SRTM data for preparing digital elevation model (DEM), and geographical information system (GIS) was used in evaluation of linear, areal and relief aspects of morphometric parameters. Watershed boundary, slope, hill shade, stream ordering have prepared using spatial analysis Tools and contour, aspect, have prepared using Surface Tool in ArcGIS-10.1 software. Different thematic maps i.e. drainage density, slope, relief, have prepared by using Arc GIS software. Based on all morphometric parameters analysis that the erosional development of the area by the streams has progressed well beyond maturity and that lithology has an influence in the drainage development. These studies are very useful for planning rainwater harvesting and watershed management.
Index terms: Geographical Information System & Remote Sensing, Stream Order Map, GPS, Morphometric Analysis.

I. INTRODUCTION

Water is a key driver of economic and social development and one of the fundamental elements in sustaining the integrity of the natural environment. It is the major renewable resource amongst the various natural resources. Water being an indispensable constituent for all life supporting processes, its assessment, conservation, development and management is of great concern for all those who manage, facilitate and utilize. Issues related to water resources development and management are not in isolation but are inter-related with other human activities. Water resources of India are quantitatively large but significantly divergent in their occurrence, distribution and utilization.

Therefore the conservation and optimal utilization of this scarce resource is extremely important for sustainable development. In order to meet present/ future demands for food, the world food production is to have an annual growth rate of about 3%. The total water requirements of the country are expected to be around 1450 km3 by the year 2050, which is significantly higher than the present estimate of utilizable water resources potential of 1122 km3. Indian water resources utilization mostly dominated by agricultural sector nearly accounting to 428 km3 (around 69% of total water use) with 300 km3 from surface resources and 128 km3 from ground water resources. Watershed characterization involves measurement of related parameters, such as geological, hydro geological, geomorphologic, and hydrological, Soil, land cover/land use etc. Watershed is a natural hydrologic unit, considered as the most appropriate basis for sustainable integrated management of the land and water resources. GIS and remote sensing techniques have opened up wide range of avenues for effective watershed management. The remote sensing data combined with field survey data can provide a unique and hybrid database for optimal planning and management of watershed (Solanke, et al. 2005). Space borne remote sensing technology is a unique tool to provide spatial, multi-spectral and repetitive information for effective planning (Lillesand and Keiffer, 2004). GIS data can be used in conjunction with conventional data for delineation of ridge line, characterization, priority evaluation, problem identification, potential and management needs assessment, selection of site for check dam and reservoirs etc.

II. AIMS AND OBJECTIVES

- Generation of thematic map from satellite data and top sheets data for the watershed management.
- Preparation of Slope Map, Hill shade Map, DEM Map, Aspect Map, Topographic Model and Contour Map from SRTM 90m Resolution Data.

III. DATABASE

The data require for watershed management includes drainage, Slope Map, Hill shade Map, Aspect Map, Cut-Fill Map etc.

- SOI Toposheet (55C/8)
- Satellite image LISS-III Data and ASTER SRTM DATA 90m Resolutions'.

IV. STUDY AREA

The study area is situated in Akola Districts of Maharashtra which is located between 20°51′30 ” to 76°58’8” N latitude and 20°51’30’’ to 76°58’8’’ E longitude. The study area is covered by Survey of India (SOI) toposheet 55H/11 and on 1:50,000 scale.

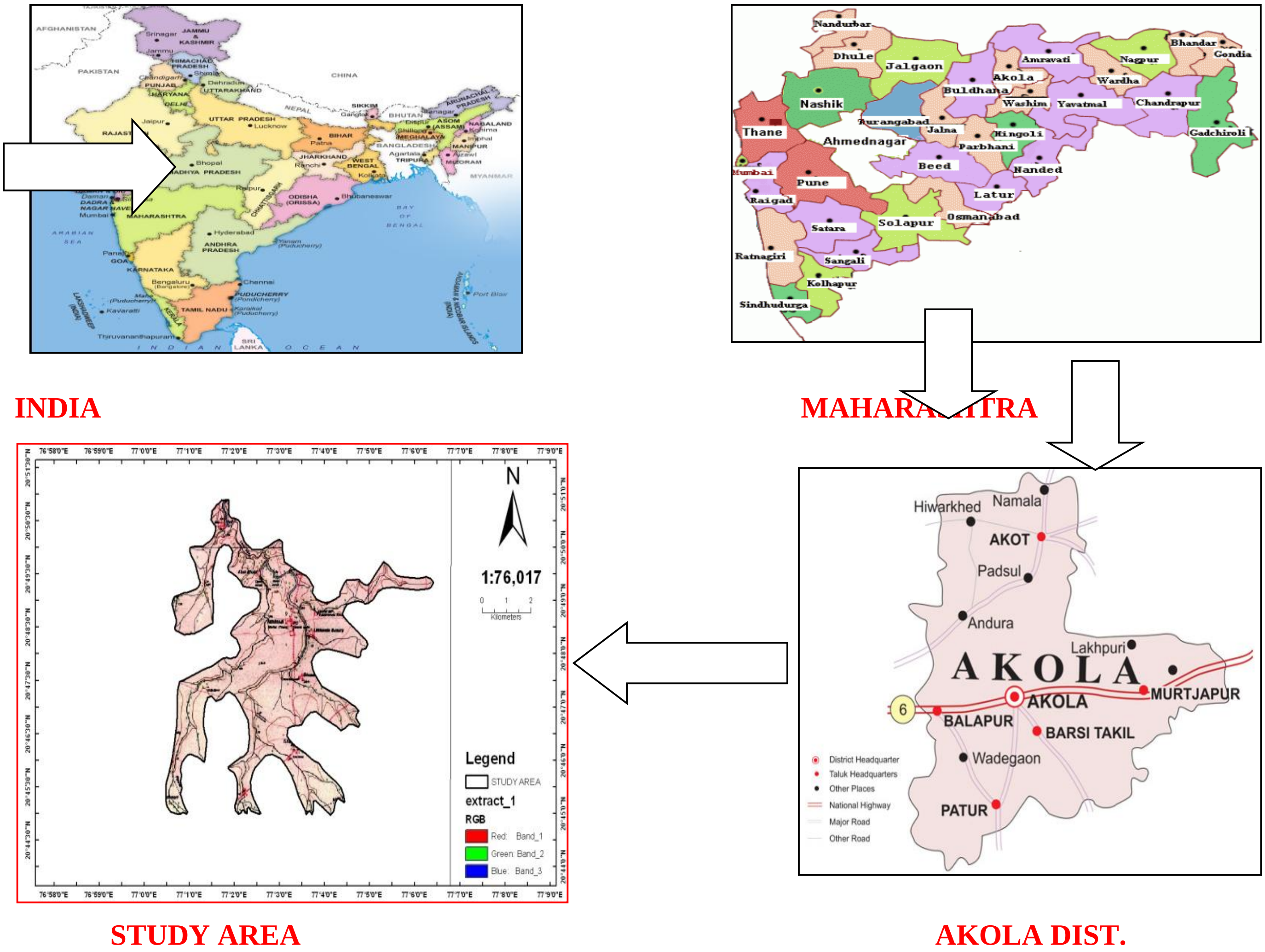

Fig.1: Location Map of Lonar Nala

V. METHODOLOGY & DATA USED

The study area which is located in the survey of India toposheet Nos. 55H/11 is present in the Akola district of Maharashtra and also uses the LISS- III satellite image. The database is created using various techniques for the watershed management; the maps are prepared by Georeferencing and digitization from SOI toposheet and LISS- III satellite image using Arc GIS 9.3, digital database. The Survey of India toposheets of scale 1: 50,000 and LISS- III satellite image are used for delineating the watershed boundary, drainage pattern for the preparation of drainage map. The order was assigned stream by following Strahler, (1964) stream ordering technique. Various morphometric parameters are presented in the following Table. The drainage basin characteristics help in deciphering and understanding the interrelated relief and slope properties. Previously mentioned DEM models are used to understand the detail nature of Study area. Data is very important for any project. The research is depending on the nature and quality if the data. Up to data is very essential for any information system. Data is the soul of any research and development activity including planning. GIS gives the power to create, manipulate, store and use spatial data, it is much faster than the conventional methods.

VI. DATA REQUIRED IS AS FOLLOWS

- Toposheet-55H/11.
- SRTM image of study area.

VII. Tools used

- ESRI Arc GIS 9.3
- Arc GIS 10.1 was used for digitization, map layouts.
- Spatial Analyst.

VIII. MORPHOMETRIC ANALYSIS

The measurement and mathematical analysis of the configuration of the earth's surface shape and dimensions of its landform provides the basis of the investigation of maps for a geomorphological survey (Bates & Jackson, 1980). This approach has recently been termed as morphometric. The area, altitude, volume, slope, profile and texture of landforms comprise principal parameters of investigation. Dury (1952), Christian, Jenning and Tuidale (1957) applied various methods for landform analysis, which could be classified in different ways and their results presented in the form of graphs, maps or statistical indices. The morphometric analysis of the Lonar Nala basin was carried out on the Survey of India topographical maps No. 55/H11 on the scale 1:50,000 and DEM with 30m spatial resolution. The lengths of the streams, areas of the watershed were measured by using ArcGIS-9.3 software, and stream ordering has been generated using Strahler (1953) system, and Arc Hydro tool in ArcGIS3-9 software. The linear aspects were studied using the methods of Horton (1945), Strahler (1953), Chorley (1957), the areal aspects using those of Schumm (1956), Strahler (1956, 1968), Miller (1953), and Horton (1932), and the relief aspects employing the techniques of Horton (1945), Broscoe (1959), Melton (1957), Schumm (1954), Strahler (1952), and Pareta (2004). The average slope analysis of the watershed area was done using the Wentworth (1930) method. The Drainage density and frequency distribution analysis of the watershed area were done using the spatial analyst tool in ArcGIS-9.3 software.

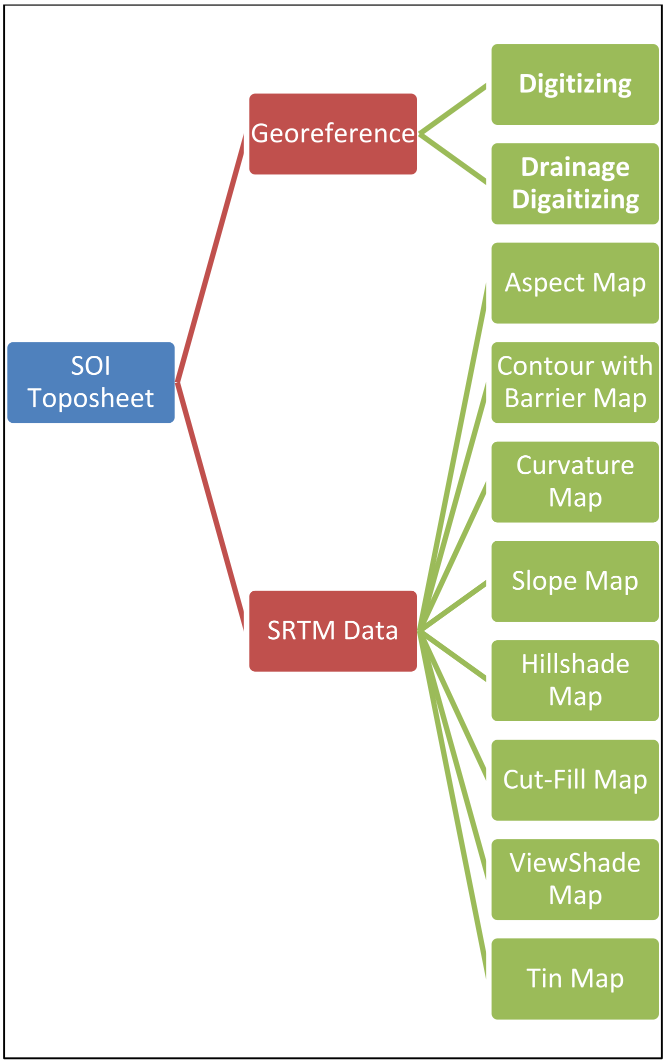

Fig. 2: Flow Chart of Methodology

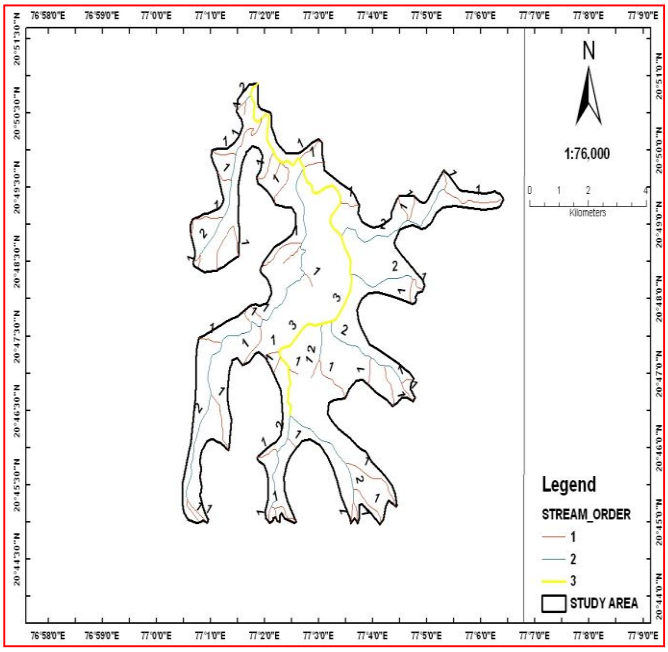

Fig.3: Stream order of Study area

IX. DRAINAGE NETWORK

A. Stream Order (Su)

Stream ordering is the first step of quantitative analysis of the watershed. The stream ordering systems has first advocated by Horton (1945), but Strahler (1952) has proposed this ordering system with some modifications. Author has been carried out the stream ordering based on the method proposed by Strahler, Table 1. It has observed that the maximum frequency is in the case of first order streams. It has also noticed that there is a decrease in stream frequency as the stream order increases.

B. Stream Number (Nu)

The total of order wise stream segments is known as stream number. Horton (1945) states that the numbers of stream segments of each order form an inverse geometric sequence with order number, Table 1.

C. Stream Length (Lu)

The total stream lengths of the Lonar Nala basin have various orders, which have been computed with the help of SOI topographical sheets and Arc GIS software. Horton's law of
A stream length supports the theory that geometrical similarity is preserved generally in watershed of increasing order (Strahler, 1964). Author has been computed the stream length based on the low proposed by Horton (1945), Table 1

D. Mean Stream Length (Lum)

Mean Stream length is a dimensional property revealing the characteristic size of components of a drainage network and its Contributing watershed surfaces (Strahler, 1964). It is obtained by dividing the total length of stream of an order by total number of segments in the order.

Table. 1: Stream Order, Streams Number, and Bifurcation Ratios of Lonar Nala watershed

Su	Nu	Rb	Nu-r	Rb*Nu-r	Rbwm
I	49				
II	11	4.45	61	271.45	
III	1	11	12	132	15.45
Total	61	15.45	73	1127.85	
Mean	20.33				

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

E. Stream Length Ratio (Lurm)

Horton (1945, p.291) states that the length ratio is the ratio of the mean (Lu) of segments of order (So) to mean length of segments of the next lower order (Lu-1), which tends to be constant throughout the successive orders of a basin. His law of stream lengths refers that the mean stream lengths of stream segments of each of the successive orders of a watershed tend to approximate a direct geometric sequence in which the first term (stream length) is the average length of segments of the first order (Table 2). Changes of stream length ratio from one order to another order indicating their late youth stage of geomorphic development (Singh and Singh, 1997).

F. Bifurcation Ratio (Rb)

The bifurcation ratio is the ratio of the number of the stream segments of given order 'Nu' to the number of streams in the next higher order (Nu+1), Table 1. Horton (1945) considered the bifurcation ratio as index of relief and dissertation. Strahler (1957) demonstrated that bifurcation shows a small range of variation for different regions or for different environment except where the powerful geological control dominates. It is observed from the Rb is not same from one order to its next order these irregularities are dependent upon the geological and lithological development of the drainage basin (Strahler 1964). The bifurcation ratio is dimensionless property and generally ranges from 3.0 to 5.0. The lower values of Rb are characteristics of the watersheds, which have suffered less structural disturbances (Strahler 1964) and the drainage pattern has not been distorted because of the structural disturbances (Nag 1998). In the present study, the higher values of Rb indicates strong structural control on the drainage pattern, while the lower values indicative of watershed that are not affect by structural disturbances.

G. Weighted Mean Bifurcation Ratio (Rbwm)

To arrive at a more representative bifurcation number Strahler (1953) used a weighted mean bifurcation ratio obtained by multiplying the bifurcation ratio for each successive pair of orders by the total numbers of streams involved in the ratio and taking the mean of the sum of these values. Schumm (1956, pp 603) has used this method to determine the mean bifurcation ratio of the value of **15.45** of the drainage of Perth Amboy, N.J. The values of the weighted mean bifurcation ratio this determined are very close to each other.

X. RESULT AND DISCUSSION

The TIN is a vector topological network of triangular facets generated by joining the irregular points with straight line segments. It attempts to incorporate the topography of mapped features. It consists of a multitude of node with known elevation, which is connected by link segment to other nodes to form triangles. These triangles represent area of uniform slope and can be of various sizes. The TIN model can be used to calculate flow direction and watershed areas, as well as a variety of other application.

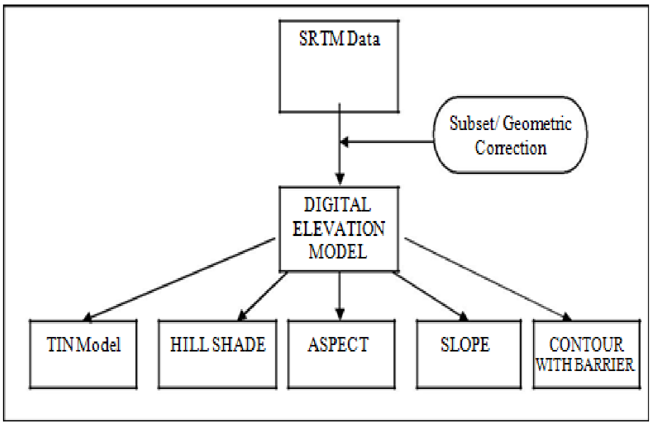

Fig. 4: GIS Approach

XI. TIN MODEL

A Triangulated Irregular Network (TIN) is terrain model that uses a sheet of continuous, connected triangular facets based on Delaunay triangulation of irregularly spaced nodes which approximates the land surface with a series of non-overlapping triangles. A TIN model of the study region has been generated by using the DEM data.

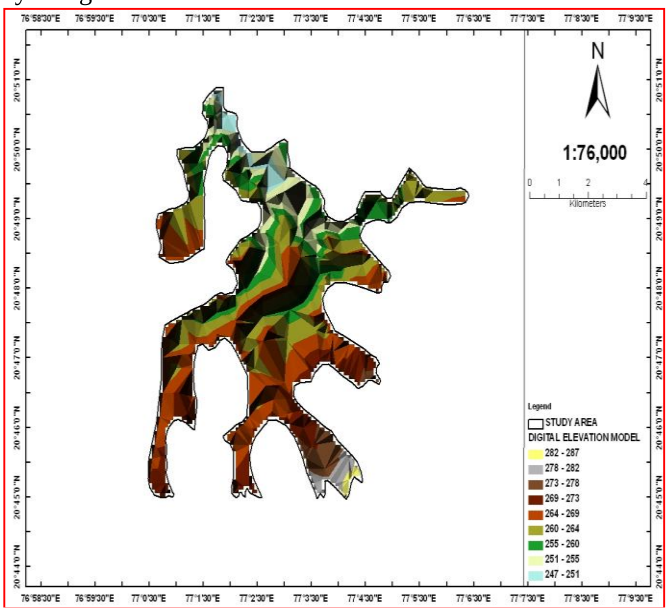

Fig.5: Digital elevation map of Study area

XII. SLOPE AND ASPECT

Slope and aspect are the basic elements for analyzing and visualizing landform characteristics. They are important in studies of watershed units, landscape units, and morphometric measures (Moore et al., 1991). When used with other variables slope and aspect can assist in runoff calculation, forest inventory estimates, soil erosion, wild life habitat suitability and site analysis (Wilson and Gallant, 2000). An aspect-slope map simultaneously shows the aspect (direction) and degree (steepness) of slope for a terrain. Aspect categories are symbolized using hues (e .g. red, orange, yellow, etc.) and degree of slope classes are mapped with saturation (or brilliance of colour) so that the steeper slopes are brighter. Aspect is the directional measure of slope.

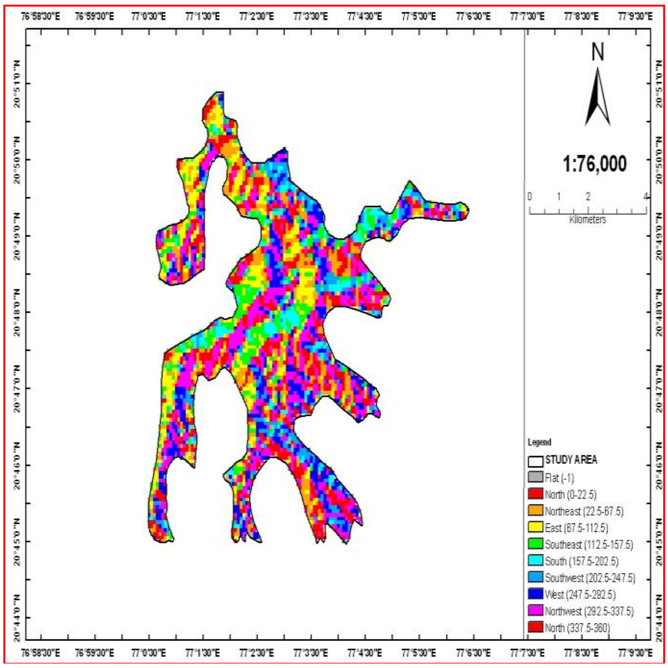

Fig.6: Aspect map of Study area

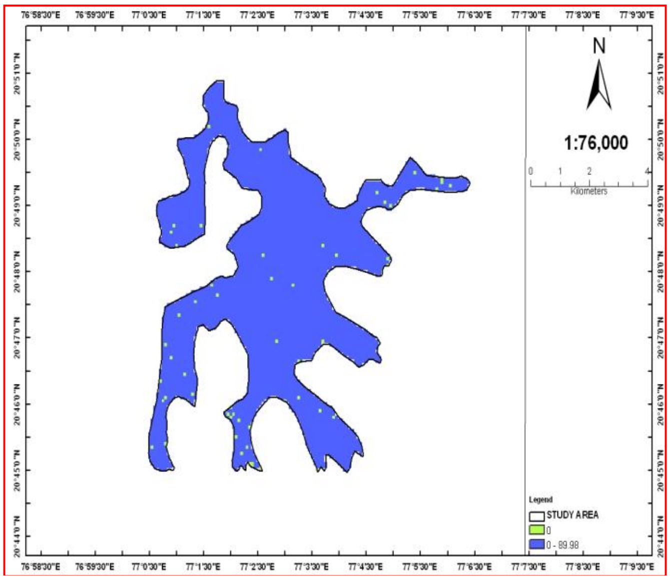

Fig.7: Slope Map of Study area

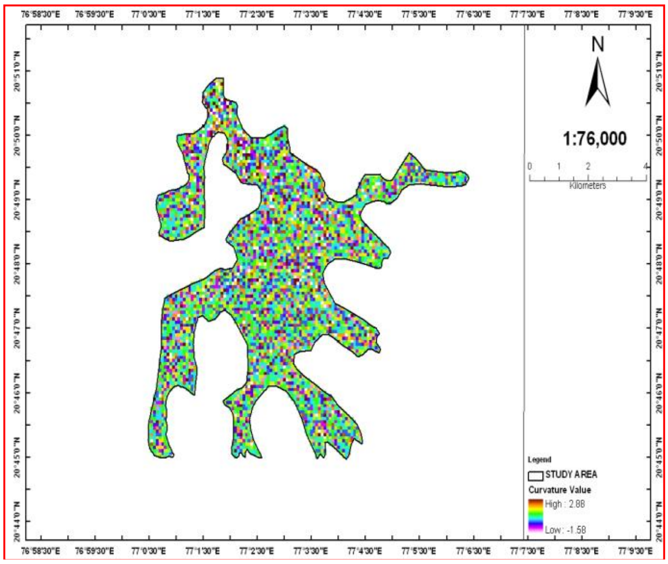

Fig.8: Curvature Map of Study area

XIII. PREPARATION OF CONTOUR MAP

A contour line (also isoline, isopleth, or isarithm) of a function of two variables is a curve along which the function has a constant value. In cartography, a contour line (often just called a "contour") joins points of equal elevation (height) above a given level, such as mean sea level. A contour map is a map illustrated with contour lines. A contour line for a function of two variables is a curve connecting points where the function has the same particular value. The gradient of the function is always perpendicular to the contour lines. When the lines are close together the magnitude of the gradient is large: the variation is steep. A level set is a generalization of a contour line for functions of any number of variables. Contour lines are curved, straight or a mixture of both lines on a map describing the intersection of a real or hypothetical surface with one or more horizontal planes.

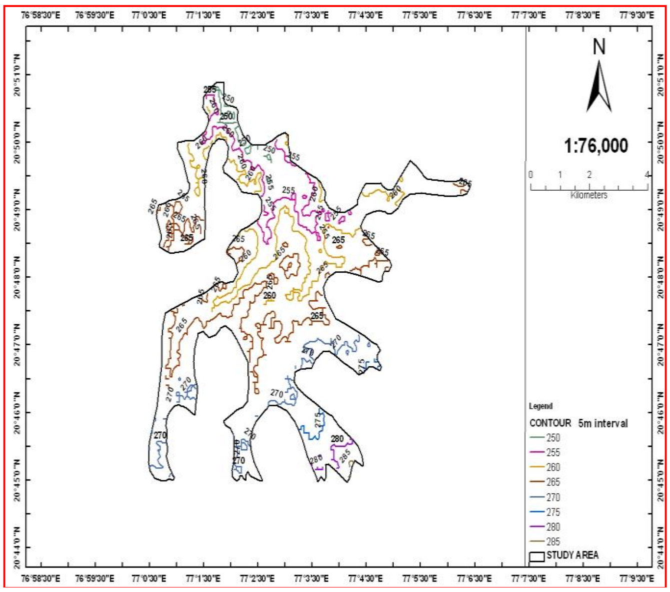

Fig.9: Contour map with Barrier of Study area

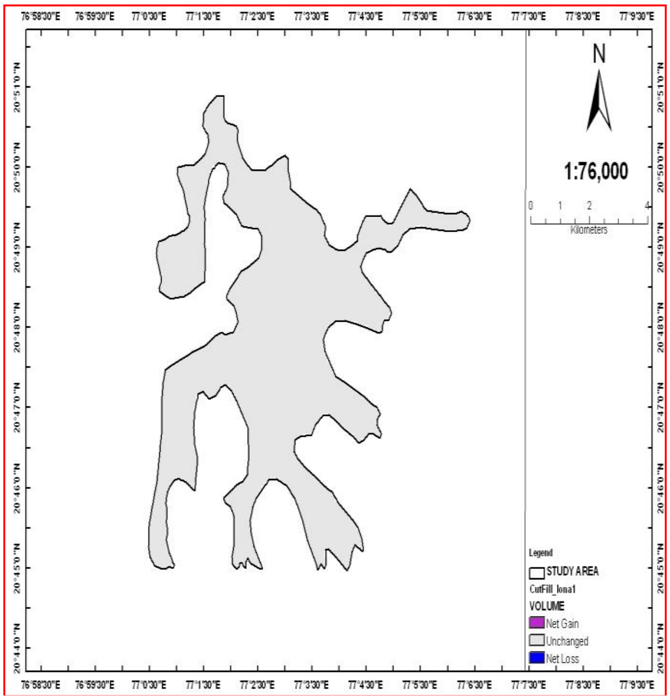

Fig.10: Cut-Fill Map of Study area

XIV. HILL SHADE

By using 3D analyst extension of Arc GIS 9.3 software, a shaded relief map of the study region has been prepared. It works as a model and simulates how the terrain looks with the interaction between sunlight and surface features. A mountain slope directly facing towards sunlight will be very bright and a slope opposite to the light will be dark. The analysis reveals that the south western part of the study region is hilly and undulating as compare to north eastern part.

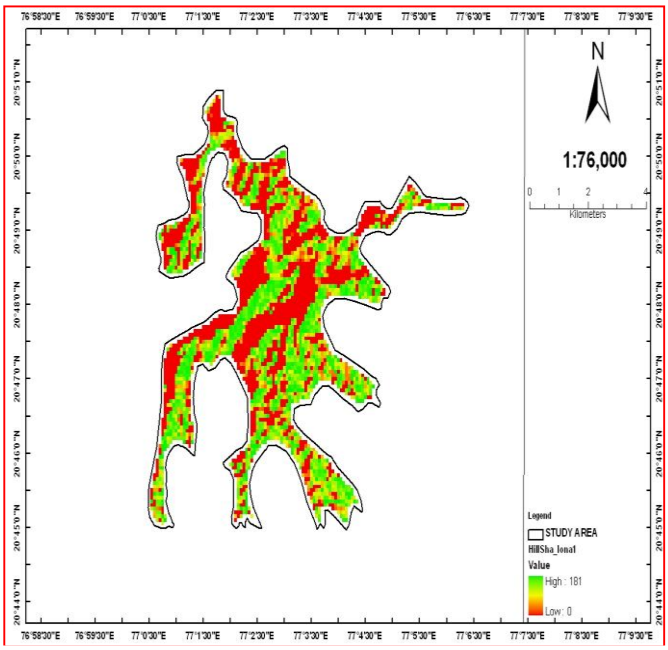

Fig.11: Hill-Shade Map of Study area

XV. CONCLUSION

Optimal utilization of land and water resources is essential for sustainable development. Resource management using watersheds as an organizing unit has proven to be an effective scale for natural resource management. It presents a common reference point for the many different activities and actors that affect the system, and promotes greater integration and collaboration among those actions. Remote sensing and its image processing technology provide access to spatial and temporal information on watershed, regional, continental and global scales (Yassir Arafat 2010). Further, new sensors and imaging technology are increasing the capability of remote sensing to acquire information at a variety of spatial and temporal scales. The scope of hydrological applications has broadened dramatically, although the problems of flood protection and water resources management continue to be of importance and relevance for the security of communities and for human, social and economic development (Rokade, et al. 2004).GIS and remote sensing applications have proved to be indispensable tools in decision making in the case of problem involving watershed conservation because of the enormity of spatial data involved.

The land forms along with slope gradient and relief intensity are other parameters to determine the type of water harvesting and water conservation structures. In this present study, illustration of how we can benefit from remote sensing and GIS technologies in watershed management and planning. The remote sensing data combined with field survey data can provide a unique and hybrid database for optimal planning and management of watershed. Space borne remote sensing technology is a unique tool to provide spatial, multi-spectral and repetitive information for effective planning.

Water is valuable and essential resource which forms the basis of all economic activities ranging from agriculture to industry. The importance of conservation of water and land assumes special significance in countries like India where the main stay of people is agriculture. Water resources development is a continuous process which has to be resorted on account of ever-increasing demands.

The morphometric analysis of the drainage network of the watershed show dendritic and radial patterns with moderate drainage texture. The morphometric analysis of the drainage network of the watershed show dendritic and with coarse drainage texture. The variation in stream length ratio due to change in slope and topography. The bifurcation ratio in the watershed indicates normal watershed category and the presence of moderate drainage density suggesting that it has moderate permeable sub-soil, and coarse drainage texture. The value of stream frequency indicate that the watershed show positive correlation with increasing stream population with respect to increasing drainage density. Hence, from the study it can be concluded that (DEM) data, coupled with GIS techniques, prove to be a competent tool in morphometric analysis.

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