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Geospatial study on Morphometric characterization of Tapi micro watershed of Asirgarh, Burhanpur District, MP, India

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Abstract

Geospatial study is, remote sensing (RS), geographical information system (GIS) and global positioning system (GPS) have proved to be an efficient tool in the field of modern day geographical and geological studies. GIS and Remote sensing techniques have been adopted for the identification of different morphological features and to analyze their existence in a hilly river basin of Asirgarh volcanic, which is located in the Burhanpur district, MP, India. Morphometric analysis of any drainage basin in a systematic method has a great importance in understanding hydrological behavior of the basin. The morphometric parameters of the study area have been discussed with respect to linear, areal and relief aspects. The morphometric parameters viz; stream order, stream length, bifurcation ratio, drainage density, drainage frequency, drainage texture, form factor, circulatory ratio, elongation ratio and compactness ratio, etc. were measured. The results clearly indicate relations among various morphometric attributes of the basin and help to understand their role for delineating groundwater potential zones for the sustainable development of the region. By utilizing the remote sensing and GIS techniques, various maps have been prepared to delineate the groundwater potential zones for the sustainable development of the Tapi micro watershed . The drainage network in the study area is dendritic to sub-dendritic which indicates the influence of lithology and terrain on drainage pattern.

Keywords: Morph metric Parameters; Aspect map; Hill shed map; TIN; GIS etc.

Introduction:-

Space based earth observation system have become an essential part of any study on natural resources of a country. Scientific planning of the watersheds using Geographical Information system (GIS) is become an integral part of the watershed development programme at government level but not efficiently used. Spatial information technology (SIT) i.e. remote sensing (RS), Geographical Information system (GIS) has proved to be efficient tools in the delineation of drainage pattern and water resource management. GIS based Morphometric analysis has been carried out considering IS parameters.

Study area:

The Tapi River is one of the three peninsular rivers in India that flow in an eastto west itinerary. The river originates in the eastern portion of the Satpura Mountain ranges in south Madhya Pradesh. The geographical features of the Tapi River are somewhat similar to the geography of Indian peninsula. The source of Tapi River is located in the Betual district. The location is also known as Multai. The tributaries of Tapi River are. The some tributaries of Tapi River around Asirgarhbelong to latitude21^{o} 11'-21^{0} 52' N and longitude75^{o}55' – 76^{o}30' E in the survey of India toposheet numbers 55C/3, 55C/4, 55C/7, 55C/10, 55C/11, on a scale of 1:50,000.

The study area has a subtropical climate like most it has a hot dry summer (April-June) followed by monsoon rains (July-September) and a cool and relatively dry winter.Geologically,the study area rocks ranging in age from upper cretaceous to lower eocene. In this area Laterite and Basalt are the main rock types found. The study area is a part of Deccan. The Deccan Traps are a large igneous provinces located on the Deccan plateau and one of the largest volcanic feature of the earth. The Deccan trap formed between 60 and 68 million periods.

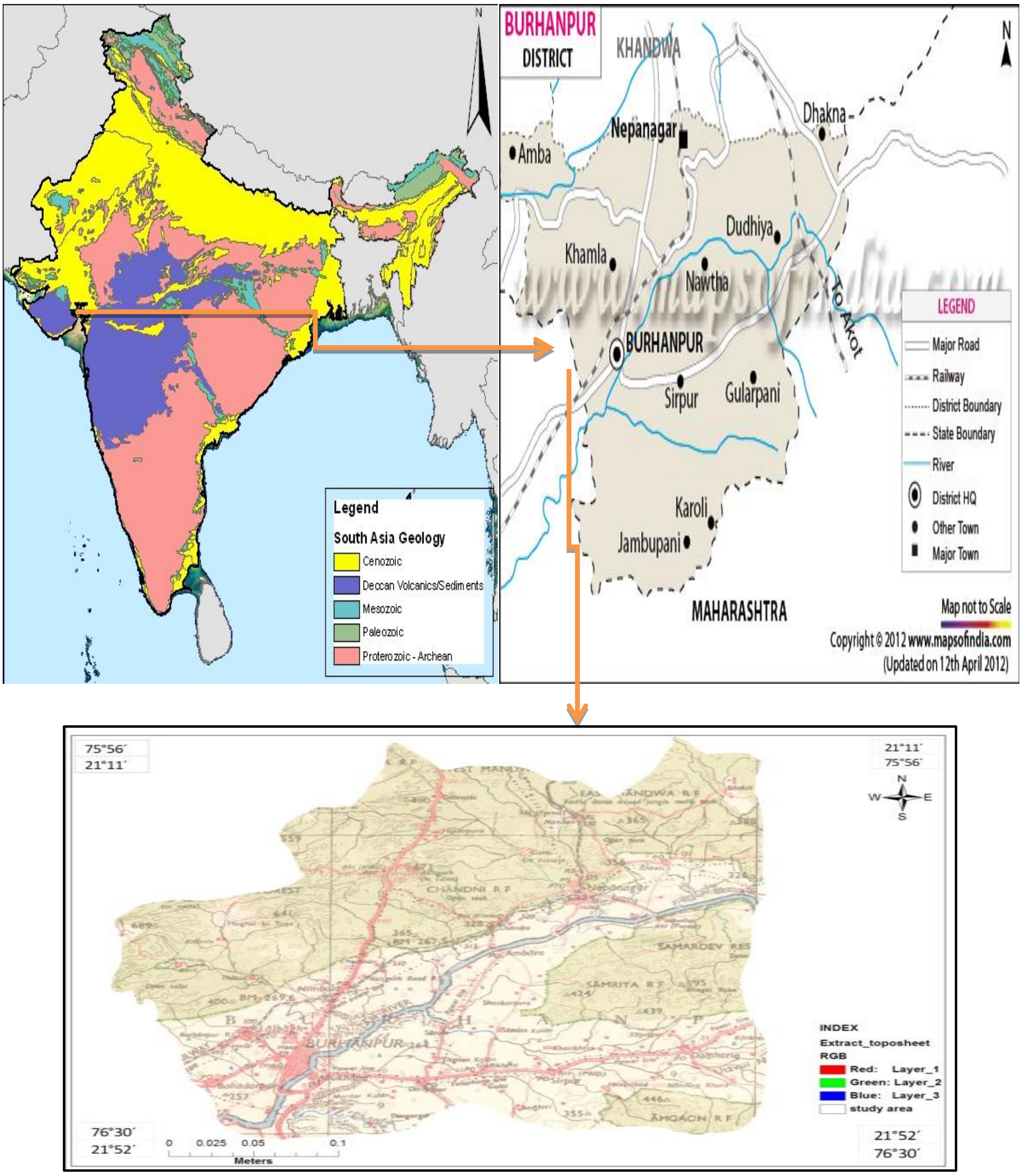

Fig.1 Location map of Study Area

Structurally the area shows the major fault (SON NARMADA FAULT), Plateau (DECCAN), Fold (Satpura hill ranges) etc. Therefore seismicity in this area is characterized by deep intraplate earthquakes are followed by aftershock sequences.Hydrologically, in the study area groundwater occurs under phreatic (unconfined) condition in Laterites and Basalt below Laterites occur under semi confined to confined condition. The groundwater is exploited by either dug well or bore well in the study area.

Table 1. Stratigraphic succession exposed in the study area.

ERA	PERIOD	EPOCH	AGE (M.Y.)	REPRESENTIVE ROCK FORMATION
CENOZOIC	QUATERNARY	RECENT PLISTOCENE	0.01 –1.65	ALLUVIUM LATERITE SAND SOILS
	TERTIARY	EOCENE	34-13.5	DECCAN TRAP BASALT FLOWS
MESOZOIC	CRETACEOUS			

Methodology:

Material used:

The data used in morphometric analysis are the topographical data and other collateral data. Geological Survey of India toposheet on the scale of 1:50,000. There are five toposheets are used in carried outto study which are 55C/3, 55C/4, 55C/7, 55C/10, 55C/11. Other collateral data like existing maps and reports were also used for additional information for morphometric analysis.

The data used in morpho tectonic analysis. There are eight toposheets were used to carry out the study which are 55C/3, 55C/4, 55C/7, 55C/10, 55C/11.Other collateral data like existing maps and reports were also used to additional information on the morpho tectonic and for preparing base maps.

The morphometric analysis of the tributaries of Tapi river basins around Asirgarh volcanic on published topographical maps on a 1:50,000 scale. The quantitative analysis of the morphometriccharacteristics of the basin include stream order, stream length, etc. which determines drainage characteristics, topography of the area, geomorphic stage of development of the area and hydrological investigation.

The morphometric analysis of drainage basinis analyzed as per the law of Horton (1945) and stream ordering is Strahler (1964) and other analysis drawn by computer software. The flowchart of morph tectonic methodology given in figure:

Result and discussion:

The morphometric analysis provides as quantitative description of the basin (Pamela Deb 2012). The morphometric analysis defined as the measurements and mathematical analysis of the configuration of the earth surface, shape and dimension of its landforms (Agrawal, 1998; Obi Reddy et al, 2002).The analysis of various morphometric parameter of basins are given in this paper, which are calculated as per the mathematical expression as detailed in table.

The stream orders are calculated as per the law of Strahlers (1964). In this analysis it is observed that higer no. of streams belonging to lower order and goes on decreasing with higher order. It is observed that more the no of streams in an area, more the soil erosion and poor soil development and vice versa. In the stream length , there are first order has higher stream length and seventh order has lower stream length from this lower order indicated that the area is high attitudal zones which are characterized by steep

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slope and low ground water potential and vice versa

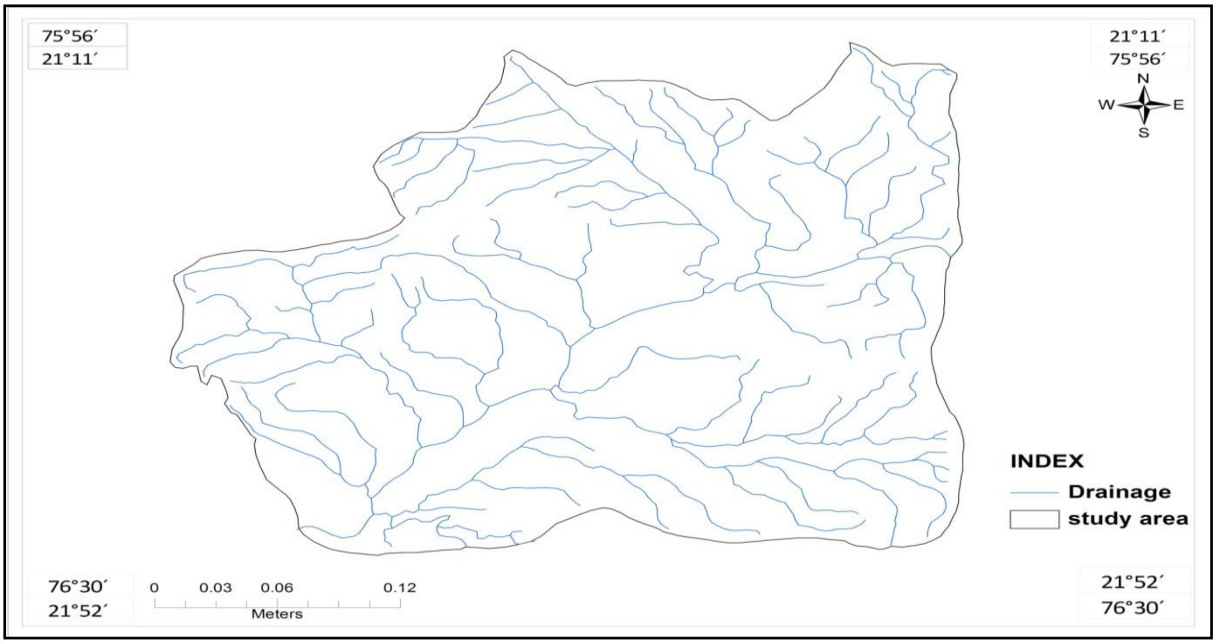

Fig 2: DRAINGE MAP

Drainage Network:

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.

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.

Stream Length (Lu)

The total stream lengths of the Tapimicro watershed have various orders, which have computed with the help of SOI topographical sheets and ArcGIS software. Horton's law of stream lengths 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

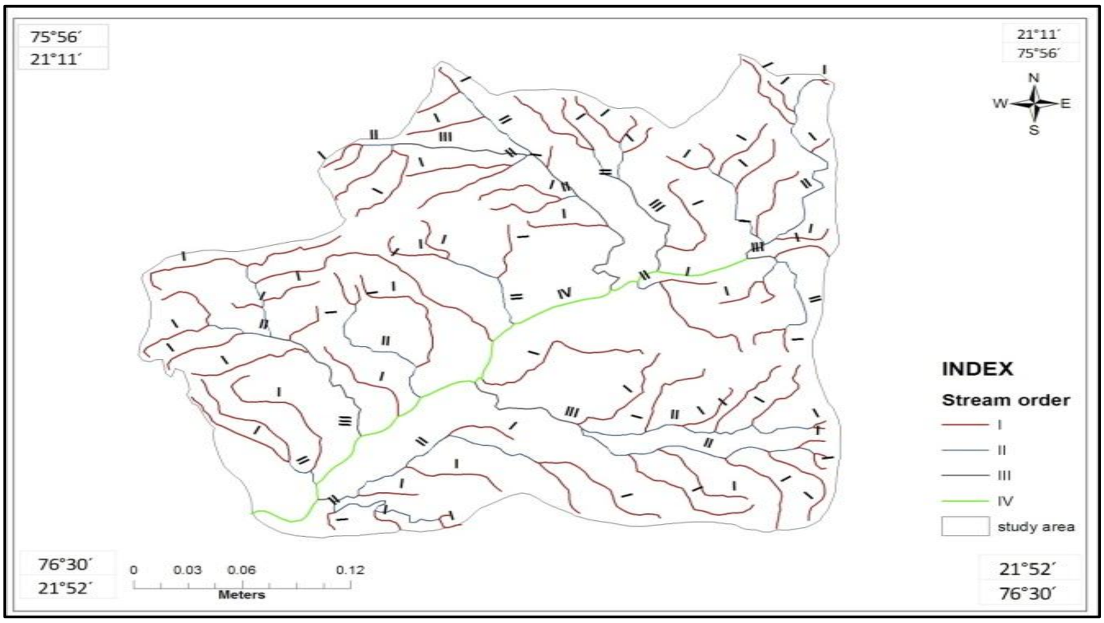

Fig.3 Stream order map of study area

Table 2: Stream Order, Streams Number, and Bifurcation Ratios of study area

S_u	N_u	R_b	N_{u-r}	R_b*N_{u-r}	R_{bwm}
I	82	---	---	---	
II	21	3.90	103	407.1	
III	7	3.00	28	84	0.41
IV	1	7.00	8	56	
Total	183	13.90	139	57.1	
Mean		4.63*			

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

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.

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.

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 3.35 to 4.0. 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 2005). 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.

Weighted Mean Bifurcation Ratio (Rbwm)

To arrive at a more representative bifurcation number 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 **1.73** of the drainage of Perth Amboy, N.J. The values of the weighted mean bifurcation ratio this determined are very close to each other.

Table 3: stream length and stream length ratio in study area.

S_u	L_u	L_u/S_u	Lur	L_{ur-r}	$L_{ur}*L_{ur-r}$	L_{uwm}
I	3.72	0.045	---	---	---	1.73
II	1.28	0.060	1.33	5.0	6.65	
III	0.52	0.074	1.23	1.8	2.21	
IV	0.37	0.37	5.00	0.89	4.45	
Total	5.89	37.179	7.56	7.69	13.31	
Mean			2.52			

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

Length of Main Channel (Cl)

This is the length along the longest watercourse from the outflow point of designated sun watershed to the upper limit to the watershed boundary. Author has computed the main channel length by using ArcGIS-10 software, which is **0.00054**Kms.

Basin Geometry

Length of the Basin (Lb)

Several people defined basin length in different ways, such as Schumm (1956) defined the basin length as the longest dimension of the basin parallel to the principal drainage line. Defined the basin length as the longest in the basin in which are end being the mouth. Gardiner (1975) defined the basin length as the length of the line from a basin mouth to a point on the perimeter equidistant from the basin mouth in either direction around the perimeter. The length of the Tapimicro watershed in accordance with the definition of Schumm (1956) that is **3.73** Kms.

Table 4: Morphometric Analysis of Tapi micro-watershed Comparative Characteristics

S. N	Morphometric Parameter	Formula	Reference	Results
A	**Drainage Network**			
1	Stream Order (S_u)	Hierarchical Rank	Strahler (1952)	**1 to 4**
2	1st Order Stream (S_{uf})	Suf = N1	Strahler (1952)	**82.00**
3	Stream Number (N_u)	Nu = $N_1+N_2+ \dots N_n$	Horton (1945)	**111.00**
4	Stream Length (L_u) Kms	Lu = $L_1+L_2 \dots L_n$	Strahler (1964)	**5.89**
5	Stream Length Ratio (L_{ur})	see Table 2.3	Strahler (1964)	**7.56**
6	Mean Stream Length Ratio (L_{urm})	see Table 2.3	Horton (1945)	**2.52**
7	Weighted Mean Stream Length Ratio (L_{uwm})	see Table 2.3	Horton (1945)	**1.73**
8	Bifurcation Ratio (R_b)	see Table2.2	Strahler (1964)	**4.63-13.90**
9	Mean Bifurcation Ratio (R_{bm})	see Table 2.2	Strahler (1964)	**4.63**
10	Weighted Mean Bifurcation Ratio (R_b)	see Table 2.2	Strahler (1953)	**0.41**
11	Main Channel Length (C_1) Km.	GIS Software Analysis		**0.00054**
12	Valley Length (Vl) Kms	GIS Software Analysis		**3.73**
13	Basin Length (L_b) Kms	GIS Software Analysis	Schumm(1956)	**3.73**
14	Basin Perimeter (P)Kms	GIS Software Analysis	Schumm(1956)	**8.412**
15	Basin Area (A) Sq Kms			**9.719**

Basin Area (A)

The area of the Tapi micro watershed is another important parameter like the length of the stream drainage. Schumm (1956) established an interesting relation between the total Tapi micro watershed areas and the total stream lengths, which are supported by the contributing areas. The author has computed the basin area by using ArcGIS-10 software, which is **9.719**Sq. Kms.

Basin Perimeter (P)

Basin perimeter is the outer boundary of the watershed that enclosed its area. It is measured along the divides between watersheds and may be used as an indicator of watershed size and shape. The author has computed the basin perimeter by using ArcGIS-10 software, which is **8.412** Kms.

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. It is a vector topological network of triangular facets generated by joining the irregular points with straight-line segments.

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These are irregularly spaced triangles that represent a surface as contiguous non-overlapping triangular elements.A TIN model can be used to calculate flow direction of watershed areas, as well as a variety of other applications. It represents the surface as a set of contiguous, non-overlapping network of triangles by storing the topological relationships of the triangles. The triangles vary in size according to need based on the roughness of the terrain. The TIN creates triangles from a set of points called mass points, which always become nodes.

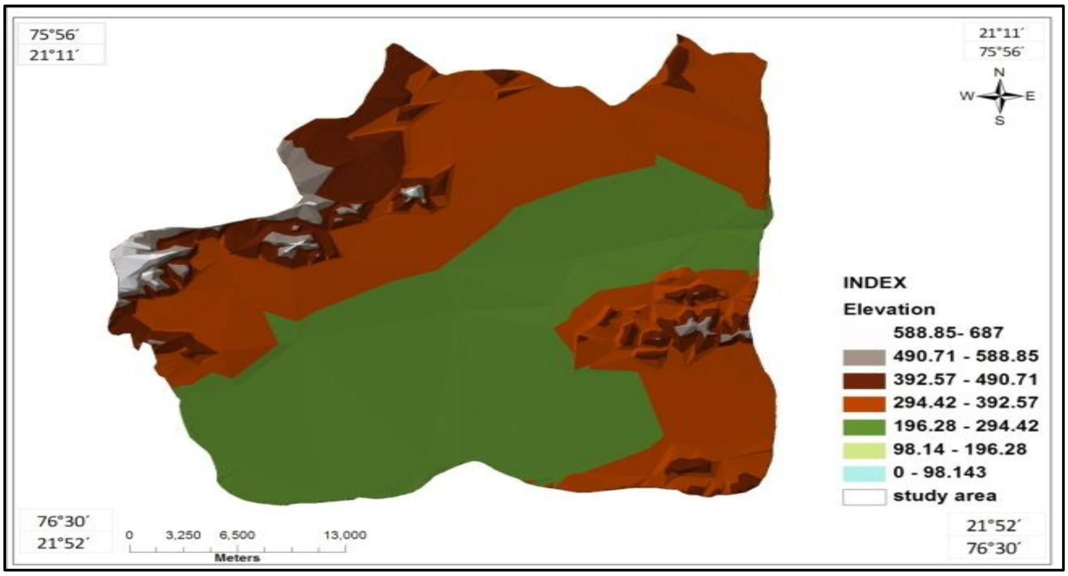

Fig 4:Triangular Irregular Network (TIN) Map

HILL SHADE:

By using 3D analyst extension of ArcGIS 10.00 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.

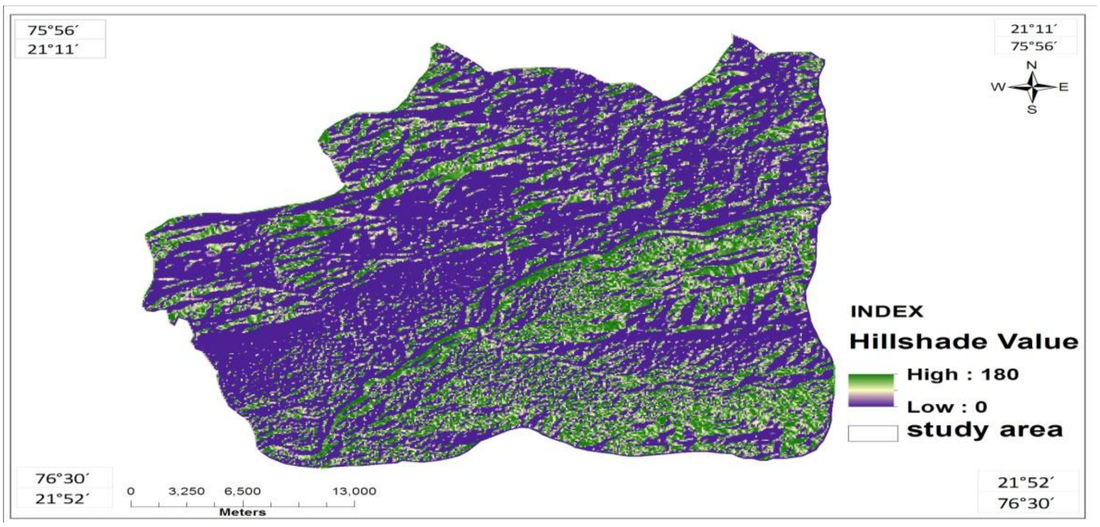

Fig 5: HILLSHADE MAP

Aspect map

Aspect is 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 aspect can assist in runoff calculation, forest inventory estimates, soil erosion, wild life habitat suitability and site analysis (Wilson and Gallant, 2000). An aspectmap simultaneously shows the aspect (direction) for a terrain. Aspect categories are symbolized using hues (e .g. red, orange, yellow, etc.) so that the steeper slopes are brighter.

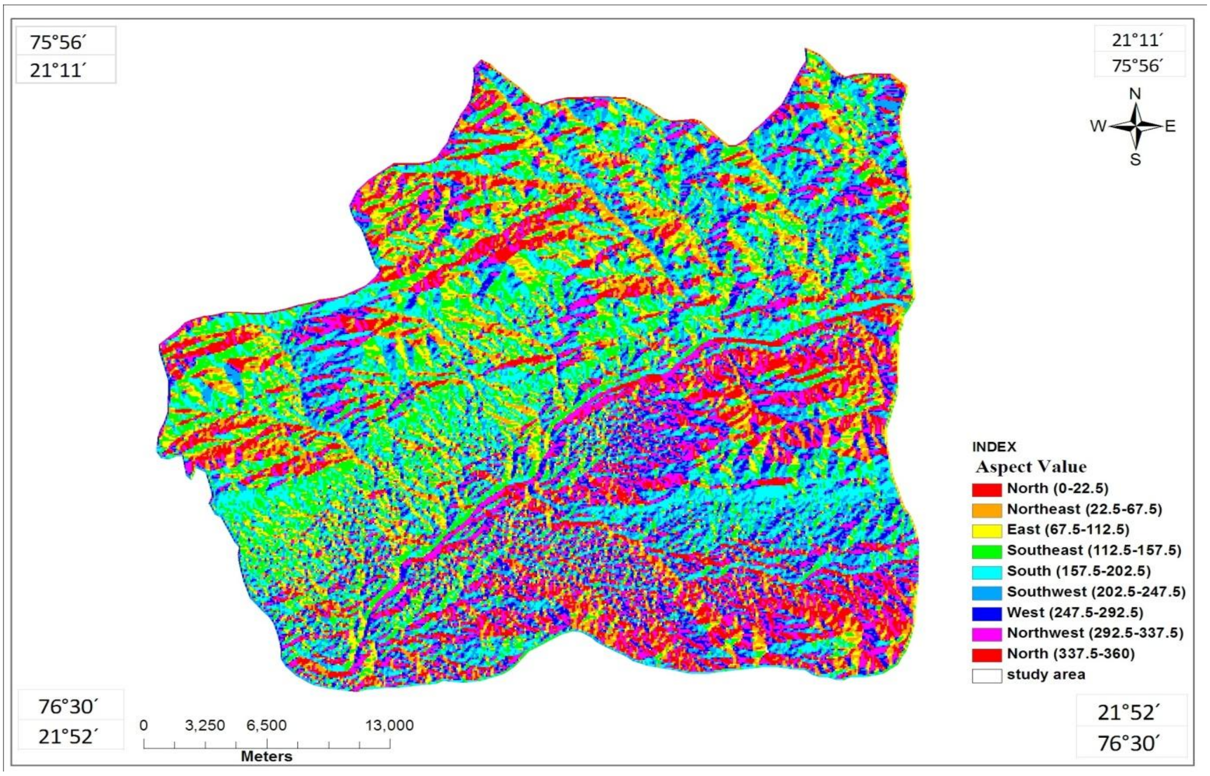

Fig 6: ASPECT MAP

Conclusion

The study reveals that remotely sensed data and GIS based approach in evaluation of drainage morphometric parameters and their influence on landforms, soils and eroded land characteristics at river basin level is more appropriate than the conventional methods. GIS techniques characterized by high accuracy of mapping and measurement prove to be a competent tool in morph metric analysis. The morph metric analyses were carried out through measurement of linear, areal and relief aspects of the watershed with more than 15 morphometric parameters. 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 GIS techniques, prove to be a competent tool in morphometric analysis.

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