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Morphometric and Morphotectonic Analyses of the Upper Son River basin, near Bansagar, Central India; Using Remote Sensing and GIS Technique with DEM and TIN

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Abstract—*Morphometric and Morphotectonic analyses have been used to obtain information, that effects the drainage basins, basically they are mandatory modifications of enculcated morphometric and tectonic changes and the quantitative descriptions of landforms. Upper Son River Basin having Dendritic type drainage pattern have description of morphometric i.e Linear, Areal and relief aspects as well as Morphotectonic i.e Asymmetry factor, Transverse topography asymmetry etc aspects using Remote Sensing (Data preparation) and GIS (Calculations and mapping) techniques. Upper Son basin (Down side of Bansagar) located between 23˚ 51' 53''N to 22˚ 44' 17''N latitude and 80˚ 56' 51''E to 81˚ 54' 56''E longitude. Its geographical area is 9455.934 km^2. The maximum and minimum elevation encountered in the study area is 1172 m and 305 m above mean sea level respectively. The main tributaries of Son River are Gopad River, Rihand River, Kanhar River, North Koel River, Johilla River having 9 Subwatersheds viz. Beli, Umariya, shahdol, Jaitpur, Bodari, Batura, Gaurella, Kothi, Pendraroad. The quantitative approach of analyses of Basin have been carried out through SRTM data(Analyses) having resolution of 90m and Glovis dataset for lineations marking. The basin showed high structural control over it through high bifurcation ratio. The assessment of morphotectonic indices may be used to evaluate the control of asymmetry factor, active faults on hydrographic systems. The analyses points out westward tilting of drainage basins with strong asymmetry in some reaches, Elongation ratio of subwatersheds and close alignment with lineaments of lower order streams. Study facilitated the function of active morphomism and tectonism in advancement and management of Basin.*

Keywords*: Morphometric, Morphotectonic, Remote Sensing and GIS Techniques, Central India.*

1. INTRODUCTION

The Son River (784 km long) is a vital branch of the Ganga River and flows through the Madhya Pradesh, Uttar Pradesh, Bihar, and Jharkhand states of India. The Son River originates near Amarkantak in Madhya Pradesh, just east of the headwater of the Narmada River, and flows north-northwest through Madhya Pradesh state before turning sharply eastward where it encounters the southwest-northeast-running by Kaimur Range. The study of drainage basin analysis has clearly established the inherent control of lithology and tectonics of an area in the development of fluvial landforms (Ritter, 1986; Pati et al.2006, 2008).The geomorphological and morphotectonic study of drainage systemprovides useful indicators about the recent tectonic regime of a region (Argyriou et al. 2016; Singh 2014, 2015).The analysis of linear features haveseveral applications. The linear structures of tectonic origin offer valuable information concerning the seismic hazards and (neo) tectonics in the terrain (Macenzie1978; Rastogi 2001). This can have main influence on the distribution of vegetation and bio-diversity in the study area and is very helpful for the agricultural development in the watersheds.

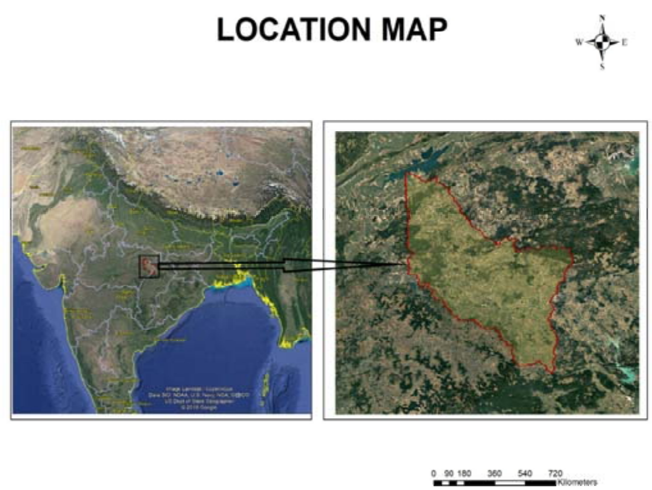

FIG. 1: Location Map

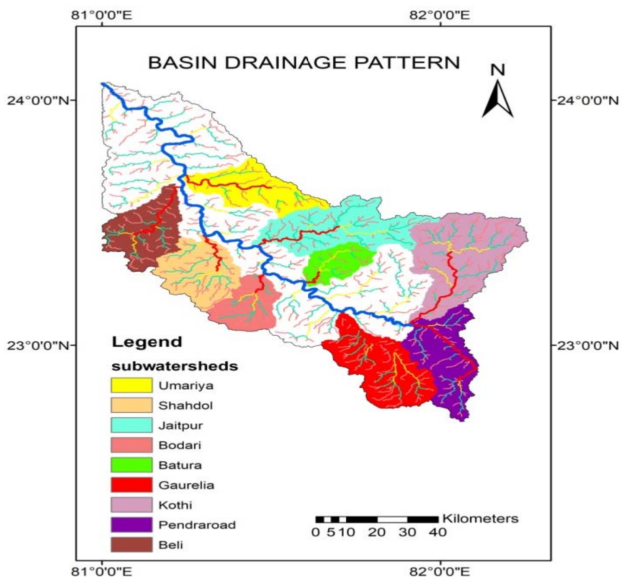

FIG. 2: Subwatersheds

2. DATA USED AND METHODOLOGY

The detail about data used and methodology adopted for accomplishing the research objectives are SRTM (Shuttle Radar Topography Mission) a product of NGA (National Geospatial- intelligence Agency) and NASA with WRS-2 satellite with capture resolution of 3 arc second and pixel resolution of 90 m has been used for extraction of the drainage networks and sub-basin in the study area and was consequently developed for preparation of digital elevation model, slope and aspect map of the area., using hydrology tools in ARC GIS platform. Glovis dataset for lineations marking.Data were downloaded from the website of United States Geological Survey (USGS); Earth Explorer http://earthexplorer.usgs.gov. Digital elevation model (DEM) and Triangular Irregular Network (TIN) model using SRTM data is also prepared only for the synoptic view of the Upper Son basin. Many of the important basin morphometric characteristics pertain to three dimensional surfaces which are represented by a Digital Elevation Model. The Arc hydro approach is used for drainage extraction which is more consistent and dependable tool when matched to a manual method (Engelhardt et al., 2011).The Upper Son basin boundary and its main sub watershed is delineated from SRTM databy the option given in the ArcGIS spatial analyst tool. The stream order can be separated from each other by using advanced editing tools i.e. explore multiple Feature, planarize tool, merge and select by attributes. The systematic extraction of the Upper Son basin and drainage network are shown in figures-

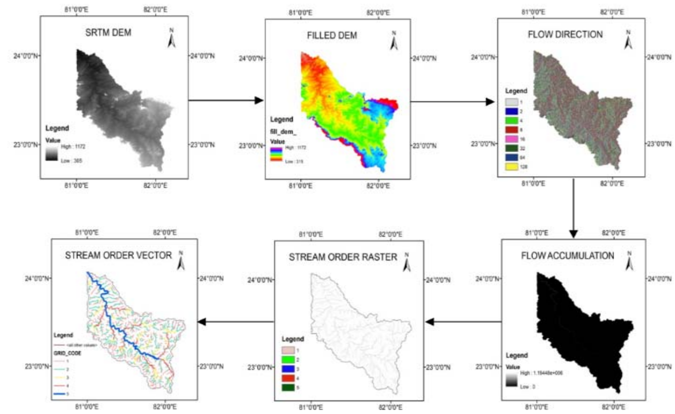

FIG. 3. Extraction of Drainage Network from DEM

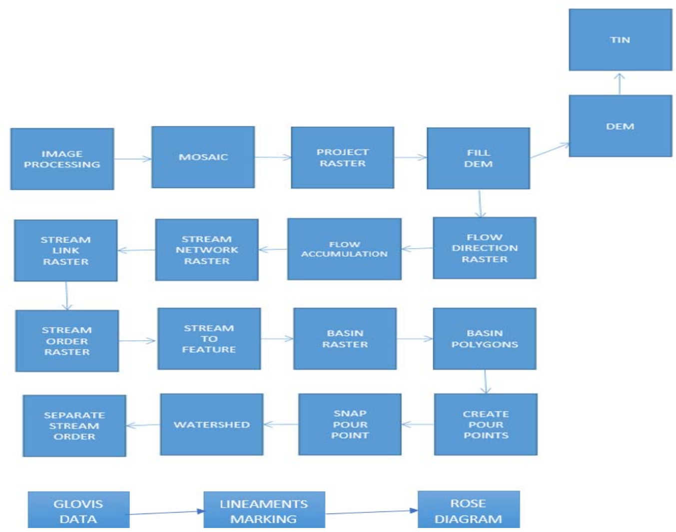

FIG. 4: Flow diagram

The lineament mapping has been done through given Glovis data through identifying linear features or structures or the forceful bending of river during tectonism. A Rose diagram which is based upon the lineations marking has been created which shows various directions of our structures or lineaments in various zones.

3. RESULT AND DISCUSSION

In this section the various aspects of morphometric and morphotectonic analysis based on remote sensing and GIS technology approaches have been discussed which incorporates the measurement and mathematical analysis of Linear, Aerial, Relief and Tectonic aspect followed by various maps. In the present study, catchment area of Upper Son river with nine subwatersheds (by capturing 3rd stream order) have been thoroughly examined in Software.

3.1 Drainage pattern

The Upper Son watershed shows polymodal distribution (NE-SW, NW-SE, N-S, E-W) regarding drainage orientations. Dendritic drainage pattern is the most common and widespread pattern found in the study area followed by little trellis pattern. The Dendritic patterns evolved in the area closely resemble to the area having homogeneous bed materials with a very gentle regional slope.

3.2 Linear aspects

3.2.1 Perimeter (P)

Perimeter is defined as the basin boundary distance and found to be 645.335km for Upper Son watershed.

3.2.2 Basin length (Lb)

It is the longest diagonal distance across the basin and found to be 188.298km.

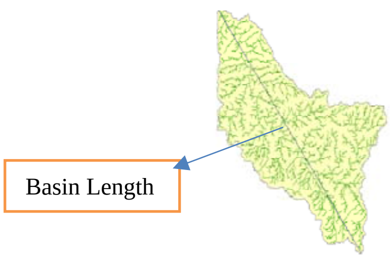

FIG. 5: Basin Length

3.2.3 Stream order (Su)

It is defined as the segmentation and hierarchical ordering of streams. The classification of streams based on the number and type of tributaries junction have proven to be useful indicator of stream size, discharge and drainage area (Strahler 1957). The figure below shows the stream order of Upper Son watershed which signifies that number of streams decreases in geometric progression as the stream order (Su) increases.

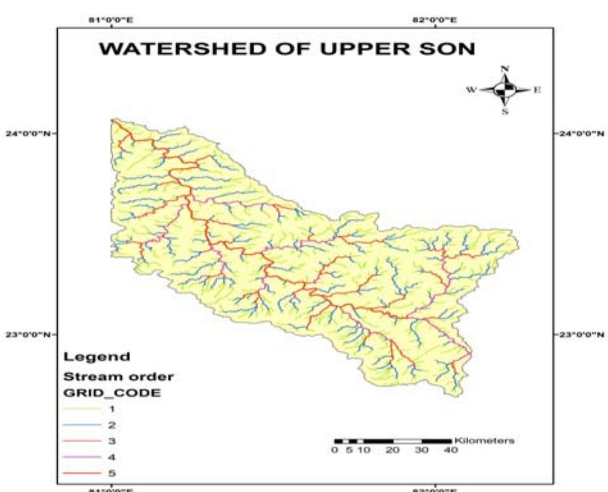

FIG. 6: Stream Orders

3.2.4 Stream number (Nu)

It is defined as the total number of stream in a given basin or in each order of the given basin. Total number of stream in Upper Son is 863.

3.2.5 Stream length (Lu)

Stream length is the total length of all the rivers which have stream order 'Su' in a given drainage basin. The total length of stream segment is higher in first order streams and decreases as the stream order increases pursuing the (Horton's 1945) law of stream length. The total stream Length of the watershed is 3709.96 km. stream length for various order found to be-

Table 1: Stream Length and number

Stream order	Stream length	Stream no.
1	1762.963	668
2	1055.826	149
3	383.576	36
4	283.647	9
5	223.945	1

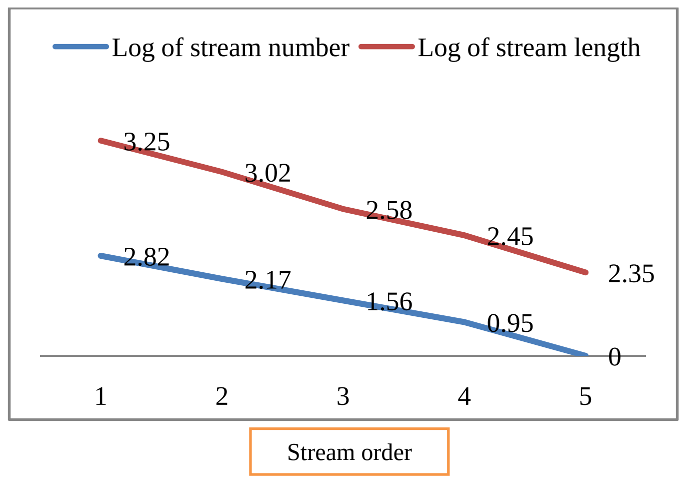

FIG. 7: Line diagram between stream order and logarithm of stream number and logarithm of stream length.

3.2.6 Bifurcation Ratio (Rb)

It is dimensionless quantity. It describes the ratio of stream of any order to the number of stream of next higher order. The value ofRb generally set in between 2 to 5 for drainage network. Such network generally developed inconsistent lithologies and signifies the minimum structural control over it. For Upper Son basin ,Rb is found to be 4 to 9 which signifies that structural control has played dominant role on drainage network development.

3.3 Aerial Aspects

3.3.1 Basin Area (A)

It is defined as the basin boundary area found to be 9455.934km^2.

3.3.2 Drainage Density (Dd)

It is the ratio of total length of all stream of all order within basin to the total area of the basin. A higher density specifies a highly dissected drainage basin within a comparatively quick hydrological response to rainfall events. The Dd for Upper Son basin is found to be 0.392km km^{-2}i.e lower.

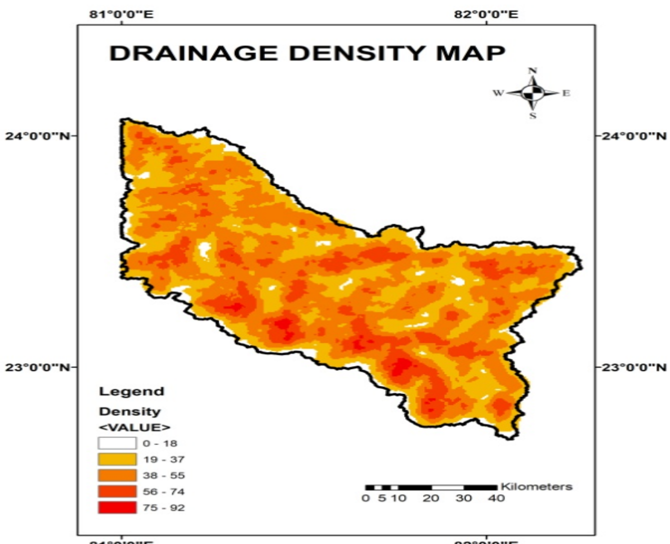

FIG. 8: Drainage Density

3.3.3 Drainage Texture (T)

It is the relative spacing of drainage lines. It is the total number of stream segments of all orders per perimeter of that area. The relative values for different texture are very course (<2), Moderate (4 to 6), very fine (>8), Course (2 to 4), and Fine (6 to 8). The Drainage texture of the Upper Son basin is found to be 0.035km^{-3} which means very coarse drainage texture ofthe basin.

3.3.4. Form Factor (Ff)

It is defined as the ratio of basin area to square of basin length. The value of Ff would be less than 0.754(for perfectly circular watershed). Low Ff value are categorized by shorter flow peak of longer direction. Smaller the value, more elongated will be the watershed. High values are characterized by longer flow peak of shorter duration. The Ff of Upper Son basin is found to be 0.2, which means the basin has shorter flow peak of longer duration and have a elongated watershed.

3.3.5. Circulatory Ratio (Rc)

It is the ratio of basin area of circle having the same circumference as the basin. The value upto 0.4 to 0.5 indicates strongly elongated and highly permeable homogeneous geological materials. Low value shows elongated basin and high value show near circular basin.It is found to be 0.28 for basin i.e elongated.

3.4. Relief Aspects

3.4.1. Basin Relief (R)

It is the difference between the highest and lowest elevation within the catchment area of the river. It isused to determine the stream gradient and transformation capacity of channel and also provides better understanding of denudation process of the basin. The R of Upper Son basin is found to be 876m.

3.4.2. Relief Ratio (Rr)

It is the ratio between the total relief of a basin and the longest dimension of basin parallel to main drainage line. Low Rr are mostly due to hard basement rocks of thebasin and low degree of slope. For Upper Son basin, it is found to be 4.65.

3.4.3. Gradient Ratio (Rg)

It is the indicator of channel slope which enables assessment of runoff volume. For Upper Son basin, it is found to be 4.65.

3.5. Tectonic Aspects

3.5.1. Elongation Ratio(Re)

Elongation ratio(Re), defined as the ratio of the diameter of circle of the same area as the basin to maximum basin length. The ratio is generally vary between 0.40 and 1.0 over an ample diversity of the climate and geology. The varying slope of watershed can be classified with help of the index of the elongation ratio. Circular (0.9-1.0), Oval (0.8-0.9), Less Elongated (0.7-0.8), Elongated (0.5- 0.7), More Elongate (<0.5). The Elongated ratio of the Upper Son basin is found to be 0.58, which mean the varying slope of watershed is Elongated.

3.5.2. Asymmetry Factor(AF)

This is the product of 100 to the ratio between the drainage basin area on the downstream right side of the main channel (Ar) and total drainage area (At).

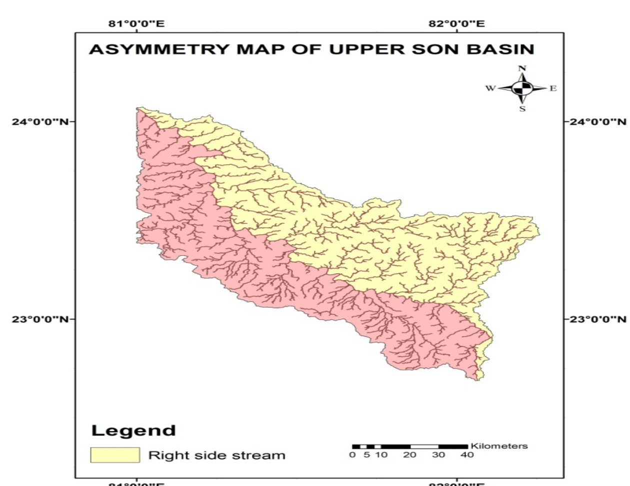

FIG. 9: Asymmetry factor

It is calculated as AF equals to 100(Ar/At). The AF also includes the direction of asymmetry, i.e. direction of probable differential tilting in the basin caused by tectonic activity in the area. The AF for general watersheds are found to be more than 50 which shows that the channel shift towards the left side of the drainage basin. For Upper Son basin, AF is found to be 52, which shows the tilting of basin to the left side of the drainage.

3.5.3. Channel Sinuosity (S)

Channel sinuosity is defined as the ratio of channel length to river valley length (Mueller 1968).Values between 1.0 and 1.5 indicate sinuous rivers, whereas channel sinuosity >1.5 represents meandering course. Many causative factors such as geographical, hydrological, etc. force it to deviate from its straight course. Sinuosity of the river helps in understanding the role of tectonics (Bhatt, 2007). The high value of this index shows that the river is closer to equilibrium, while low value of this index indicates tectonic activity in the area (Jabbari et. al, 2012). The channel sinuosity of Upper Sone basin is found to be 1.5, which indicate the sinuous rivers.

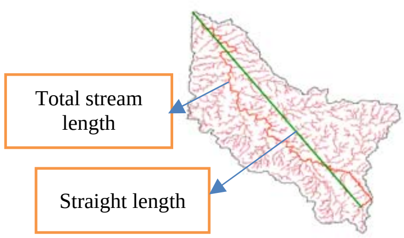

FIG. 10: Channel Sinuosity

3.5.4. Transverse topography asymmetry (T)

Transverse topographic asymmetry (T) is a reconnaissance tool for area, presenting lateral tilting (Cox et al. 2001).The cross valley asymmetry of its drainage basin for a specified sector of the stream is exemplified as a ratio of Da and Dd, where Da is the distance from stream channel to the middle of its drainage basin and Dd is the distance from the basin margin to the middle of the basin. If the value of Da = 0 and then the ratio Da/Dd is also zero, signifying asymmetrical basin, representing that the stream segment is in the middle of the drainage basin and inferring the non-tilted basin. As the value of Da/Dd will tend toward 1, the stream migrates laterally away from the centre of the basin toward the margin, representing the tilted basin. The values of transverse topography asymmetry (T) for the Upper Son river basin 0.28, which indicates that basin is less tilted with a Hypsometric integral (0 to 1 range) of 0.5 thus indicating a mature stage of development.

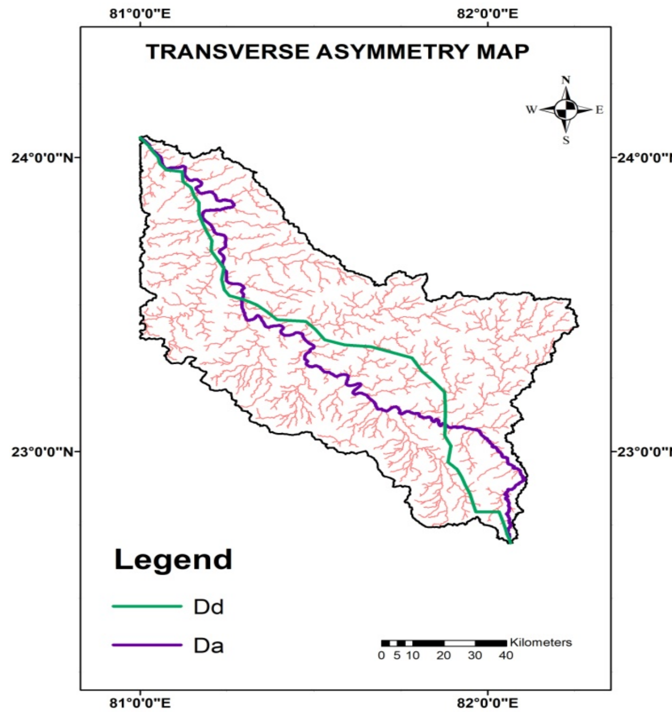

FIG. 11: Transverse asymmetry

3.6 Orientation and Lineament Density

A lineament is a linear feature in landscape which is an expression of an underlying geological structure such as fault. The orientation with respect to the direction of lineaments can be shown by using Rose diagram.

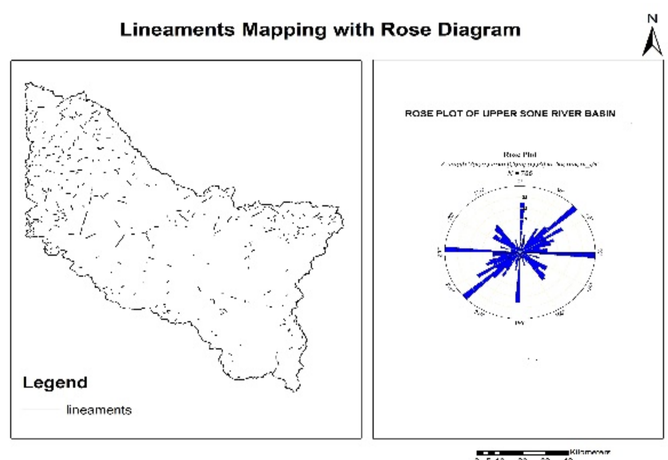

FIG. 12: Lineaments and Rose diagram

Table 2: Parameters

Parameters	Formulas	References
Linear aspects		
Perimeter (P)(km)	GIS software	Schumm (1956)
Basin length (Lb)(km)	Gis software	Schumm (1956)
Stream order (Su)	Hierarchical rank	Strahler (1952)
Stream number (Nu)	GIS software	Horton (1945)
Stream length (Lu)	GIS software	Strahler (1964)
Stream length ratio (Rl)	Lu/Lu-1	Strahler (1964)
Bifurcation ratio (Rb)	Nu/Nu+1	Strahler (1964)
Mean stream length (Lsm)(km)	Lu/Nu	Horton (1945)
Rho coefficient (*P*)	Rl/Rb	Horton (1945)
Areal aspects		
Basin area (A)(km^2)	GIS software	Schumm (1956)
Drainage density (Dd)(km/km^2)	Lu/A	Horton (1932)
Drainage texture (T)(km^{-3})	Dd*Fs	Horton (1932)
Length of overland flow(Lg)(km^2/km)	1/2*Dd	Horton (1945)
Form factor(Ff)	A/Lb^2	Horton (1932)
Circulatory ratio(Rc)	$4\pi A/P^2$	Miller (1953)
Stream frequency(Fs)(km^{-2})	Nu/A	Horton (1932)
Relief aspects		
Basin relief (R)(km)	H-h	Strahler (1952)
Relief ratio (Rr)	R/Lb	Schumm (1956)
Ruggedness number (Rn)	Dd*R	Patton (1976)
Gradient ratio (Rg)	R/Lb	Sreedevi (2004)
Shape index (Sw)	1/Ff	Horton (1956)
Tectonic aspects		
Elongation ratio (Re)	$1.128[(A)^{1/2}/Lb]$	Schumm (1956)
Asymmetry factor(AF)	Ar/At*100	Molin(1933)
Channel Sinuosity (S)	dt/dp	Muller (1968)
Transverse topography asymmetry (T)	Da/Dd	(Cox et al. 2001).
Hypsometric integral (HI)	Mean-Min/Max-Min	Strahler (1952); Mayer (1990); Keller and Pinter (2002)
Orientation and lineament density	GIS software	Nur (1982),

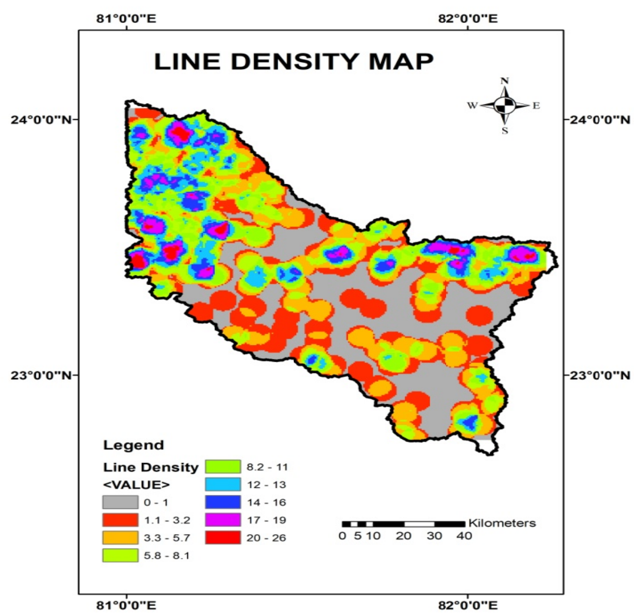

FIG. 13: Line density

3.7. Digital Elevation Model

A digital elevation model (DEM) is specialized database that represent the relief of surface between points of known elevation by interpolating known elevation data from sources such as photogrammetric data capture. It is the raster representation of a terrain surface. The following map shows DEM of SRTM data in 10 classes.

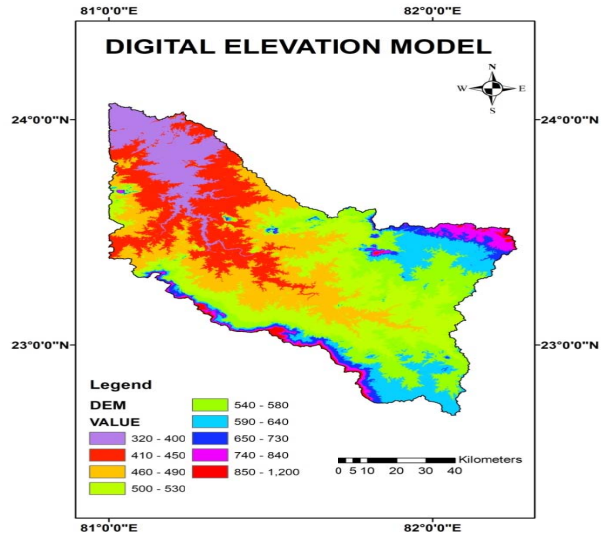

FIG. 14. Digital Elevation Model

3.8 Triangular Irregular Network

Triangular irregular networks(TIN) have been used by GIS community to represent surface morphology. TINs are a form of vector based digital geographic data and constructed by triangulating a set of vertical(points). The vertices are connected with a series of edges to form a network of triangle.

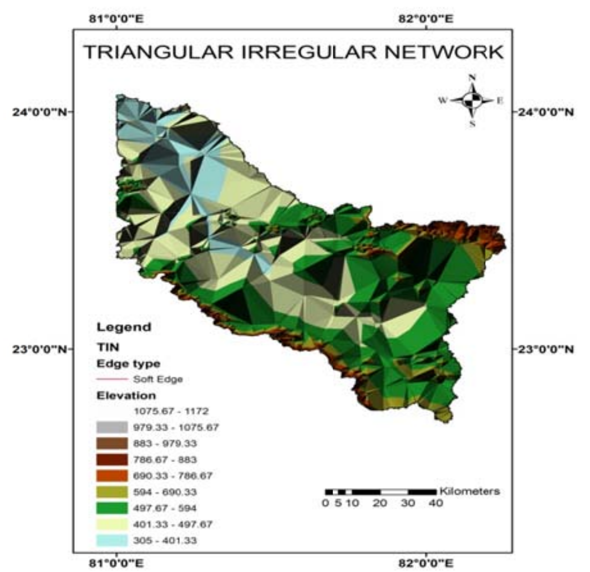

FIG. 15: Triangular Irregular Network

Table 3: Parameters for Subwatersheds

	Sw1	Sw2	Sw3	Sw4	Sw5	Sw6	Sw7	Sw8	Sw9
Linear Aspect									
Perimeter(p)(km)	136.98	138.48	125.94	194.30	96.39	80.57	155.93	195.20	168.67
Basin length(Lb)(km)	42.09	46.86	35.06	58.47	26.74	24.29	46.10	58.10	46.33
Stream order(su)	4	4	4	4	4	4	4	4	4
Stream length(Lu)	288.45	198.27	243.36	327.07	165.32	100.09	345.65	416.14	244.47
Stream number(Nu)	58	43	51	74	45	26	75	98	67
Bifurcation ratio(Rb)	3.35	3.31	3.34	3.86	3.36	2.70	3.92	4.39	3.87
Mean stream length(Lsm)(km)	4.973	4.611	4.771	4.419	3.673	3.849	4.608	4.246	3.648
Areal Aspect									
Basin area(A)(km)	581.82	540.44	578.97	825.52	377.901	276.47	759.93	1068.37	668.88
Drainage density(Dd)(km/km^2)	0.49	0.36	0.42	0.39	0.43	0.36	0.45	0.38	0.36
Drainage texture(T)(km^{-3})	0.0481	0.0284	0.0369	0.0347	0.0047	0.0338	0.0441	0.0345	0.036
Length of overland flow(Lg)(km^2/km)	1.02	1.38	1.19	1.28	1.16	1.38	1.11	1.31	1.38
Form factor(Ff)	0.33	0.24	0.47	0.24	0.52	0.47	0.35	0.31	0.31
Circulatory ratio(Rc)	0.38	0.35	0.45	0.27	0.51	0.53	0.39	0.35	0.29
Stream frequency(Fs)(km^{-3})	0.099	0.079	0.088	0.089	0.011	0.094	0.098	0.091	0.100
Relief aspects									
Basin relief(R)(km)	473	389	603	616	677	167	707	505	216
Relief ratio(Rr)	11.237	7.961	17.000	10.535	25.317	6.875	4.490	8.691	4.662
Ruggedness number(Rn)	231.77	140.04	253.26	240.24	291.11	60.12	318.15	191.90	77.76
Gradient ratio(Rg)	11.23	8.30	17.19	10.53	25.31	6.87	15.33	8.69	3.83
Shape index(Sw)	3.03	4.16	2.12	4.16	1.92	2.12	2.85	3.22	3.22
Tectonic aspect									
Elongation ratio(Re)	0.646	0.559	0.774	0.555	0.820	0.772	0.674	0.634	0.629
Hypsometric Integral(HI)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Channel sinuosity(S)	1.4	1.3	1.5	1.4	1.3	1.5	1.2	1.5	1.5

4. CONCLUSION

From the above mentioned Morphotectonic and morphometric analyses we have the influence of tectonic and erosional controls over the Upper Son basin catchment area. The morphometric parameters including Linear, Areal, Relief aspects, whereas the value of morphotectonic parameters provides valuable insight about the structure and tectonics of the area. The Upper Son Basin is a 5th order drainage basin and that is why the frequency of first order streams decreases as the stream order increases, this happens due to the presence of structures like fractures, joints, cracks etc. The value of Basin elongation ratio reveals that the Upper Son basin is elongated and tectonically active. Asymmetry factor as well as transverse topographic Symmetry factor provides a valuable information of drainage basin which is helpful in determining the tectonic lift. In case of Upper Son basin, Asymmetry factor tells that the Upper Son basin is less tilted towards the downstream left side, which may be due to the changing of subsurface structural set-up and neo-tectonic activities. The lower channel sinuosity value for the whole basin also supports the previous influence that the basin may be tectonically active. The Hypsometric Integral of the Upper Son basin indicates a mature stage of development of basin. So these all helps in management of watershed.

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