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Drainage morphometry of the Dhasan river basin, Bundelkhand craton, central India using remote sensing and GIS techniques

K. Prakash, T. Mohanty, S. Singh, K. Chaubey and P. Prakash
Centre of Advanced Study, Department of Geology
Banaras Hindu University, Varanasi-221005
Email: kuldeep_prakash@yahoo.com, tanuja.mohanty@gmail.com, geosaurabh@gmail.com, kanchichaubey2011@gmail.com, premprakash102d@gmail.com

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Abstract: The Dhasan river is one of the major NE flowing tributaries of the Yamuna river in rain-deficient part of central India. The basin is divided into five subwatersheds viz. Rohni, Bila, Sukhnai, Lakheri and Ur. The morphometric parameters (linear, aerial and relief) of Dhasan river basin were measured using remote sensing and GIS (geographic information system) techniques for future development and planning of the watershed. The quantitative analysis of watershed development of the Dhasan river basin and its five sixth order sub watersheds (SW1- SW5), was carried out using Landsat 7 ETM+, ASTER (GDEM) data and Survey of India toposheets (parts of 54I, 54K, 54L, 54O and 54P). The drainage orientation data suggests a polymodal distribution (NE-SW, NW-SE and E-W). The relief disposition and tectonic control of Dhasan watershed are manifested by trellis drainage pattern. The bifurcation ratio and high gradient ratio indicate an undulatory topography with steeper stream gradient in some parts of the basin. In other parts, the basin is characterized by high infiltration rate having fewer channels. The bifurcation ratio indicates limited relationship amongst the hydrographic networks that are considered diagnostic of tectonic (and/or neotectonic) imprints on the drainage network in the study area. The elongated nature of Dhasan watershed, characterized by the shape parameters, reflects a dominant control of regional linear tectonic elements pervasively present in the entire Bundelkhand craton.

Keywords: Dhasan river, Morphometry, Remote sensing and GIS technique, Bundelkhand craton, Central India

1. Introduction

Morphometric analysis of river basin deals with the quantitative assessment of the topographic pattern of the Earth's surface, the shape and dimensions of its landforms, and it is also an imperative technique to assess and comprehend the role of watershed dynamics (Clarke, 1966). The progression of fluvial landforms with the degree of lithological and structural controls is well established by the drainage basin analysis (Horton, 1945). The study of drainage basins strengthens basic understanding of geometric characteristics of the fluvial landscape (Pophare and Balpande, 2014). In addition, the drainage pattern observed on Earth has a tremendous bearing on subsurface geology and operative processes (Ritter, 1986; Pati et al., 2006; Pati et al., 2008). Recent studies have demonstrated strong structural anisotropy in Bundelkhand craton basement and the subsurface faults and fractures control the overall topography in the overlying sedimentary sequences (Pati et al., 2006; Godin and Harris, 2014).

In Indian scenario, the morphometric analysis was adopted to resolve issues related to watershed analysis (Vijith and Satheesh 2006; Thomas et al., 2010; Mishra et al., 2011; Singh, 2014; Prabu and Baskaran, 2013; Withanage et al., 2014; Prakash et al., 2016) and for analysis and prioritization of micro-watersheds (Pankaj and Kumar, 2009; Sarmah et al., 2012; Vandana, 2013).

The Dhasan river drains through the hard rock terrain of the Bundelkhand craton, Bijawar group, Vindhyan supergroup and the Deccan trap. These terrains comprise granitoids, Banded Iron Formations, sandstones and basaltic rocks, respectively, which does not permit sufficient groundwater recharge owing to their very low porosity and permeability including mildly metamorphosed sandstones. Hence, the entire Dhasan basin faces ground water scarcity due to deficient recharge. The ground water, which is available for drinking and irrigation purposes, is either surface rain water or from shallow dug wells which are mainly concentrated in small patches of alluvium or highly fractured/ jointed rocks. The present study comprises a quantitative approach of drainage management and advancement of groundwater potential for watershed development of the Dhasan river basin with the help of remote sensing and GIS techniques.

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2. Geology of the area

The study area is spread over parts of Bundelkhand craton, Bijawar group, Vindhyan supergroup and Deccan trap in central India. The Bundelkhand craton is surrounded by Vindhyan supergroup on its eastern, southern and western margins, while northern part is covered by the Indo-Gangetic alluvium. Mappable outcrops of Bijawar group of rocks occur in its south-western fringe (Fig. 1). The Bundelkhand craton comprises mainly granitoids and in addition, syenites, amphibolites, Banded Iron Formation, tonalite-trondhjemite-granodiorite (Pati et al., 2007), gneisses, calc-silicate rocks, quartzites, pillow lavas (Pati and Raju, 2001), basaltic komatiites of boninitic affinity-volcaniclasticmeta sediments (Malviya et al., 2006), Giant Quartz Veins (Pati et al., 2007) and volcanics (rhyolites). PGE-bearing mafic-ultramafic rocks are also exposed in southern margin of the craton (Pati et al., 2005). Most of quartz veins of varied size with mainly NNE-SSW and NE-SW trends are observed in parts of the Bundelkhand craton representing an episodic tectonic controlled hydrothermal activity (Pati et al., 2007) which are later on intruded by mafic dykes in some places. Mafic dykes represent the youngest intrusive phase (Pati et al., 2005) with mainly NW-SE trend.

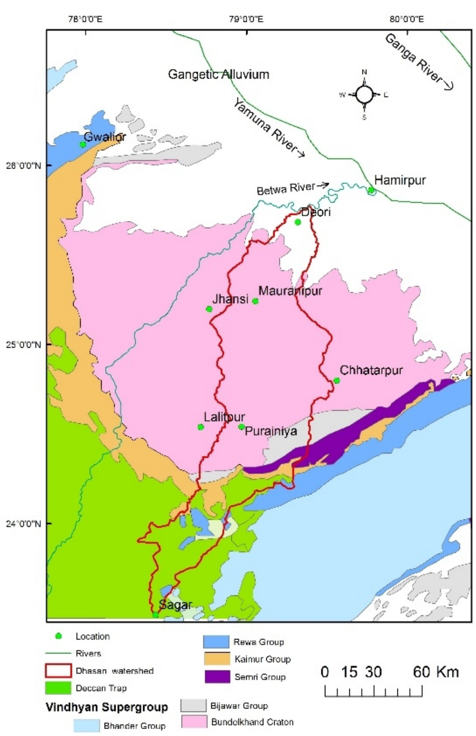

Figure 1: Map showing the Dhasan river basin in a simplified geological map of central India

The Bijawar group is considered to be of Mesoproterozoic age and overlies the Archean Bundelkhand granitoids. The Bijawar group of rocks are exposed along its southeastern (Hirapur and Sonarai basins) and northwestern (Gwalior basin) margins. The Bijawar group consists of a basal conglomerate and quartzite, overlain by hornstone breccias, limestone, phyllitic shales, jaspers and diorites. These rocks are also well exposed along the southeastern edges of the Vindhyan basin where they dip under the Semri group (Vindhyan supergroup; Ray, 2006).

The Vindhyan supergroup, is one of the biggest and widest Precambrian sedimentary successions of the world, occupying an area of 104,000 km^2 in central peninsular India. The basin spreads over the states of Rajasthan, Madhya Pradesh, Uttar Pradesh, Jharkhand and Bihar. The southern boundary of Vindhyan basin is marked by the ENE-WSW trending Narmada-Son lineament. The western margin is delimited by the NE-SW trending Great Boundary Fault closest to the northwest trending Aravalli-Delhi Fold Belt (Venkatachala et al., 1996) and it is bound by Indo-Gangetic alluvium to its north and east. However, the basin is deemed to persist underneath of the Gangetic alluvial (Chakraborty, 2006). The Vindhyan supergroup is subdivided into the Upper Vindhyan (Kaimur, Rewa, and Bhander groups) and the Lower Vindhyan (Semri group). The rocks of Vindhyan supergroup are well-exposed in three diverse regions: the Rajasthan, the Bundelkhand and the Son valley. The study area extends over the Bundelkhand region where, the Semri, Kaimur and Rewa group of rocks are exposed.

The Deccan traps occur in peninsular India between longitudes 69°–79°E and latitudes 16°–22°N and comprise one of the largest volcanic provinces of Earth (Mahoney et al., 2002; Courtillot et al., 1988; Bose, 1995; Ghosh et al., 2006). The Deccan traps also have severe problem in ground water abundance (Limaye, 2010). Lithology, degree of deformation and intensity of precipitation are controlling factor of hydrological potential of this volcanic province.

3. Methodology

Advanced Space borne Thermal Emission and Reflection (ASTER G-DEM) (date of acquisition - 2006-09-30), data is used for delineation of drainage map. The ASTER included elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth. The ASTER data of WRS-2 satellite with capture resolution of 3 arc second and pixel resolution of 30 meter was used for this study.

The ASTER data were used to delineate the drainage network through digital elevation model technique (Fig. 2 & 3). Thematic Mapper (ETM+) data and SOI (Survey of India) topographic maps (1:50000) are used for delineation of the drainage network, lineaments and demarcation of subwatershed of the study area. The ASTER and ETM+ data were obtained from Global Land Cover Facility (http://www.landcover.org). The ETM+ is a cross-track scanner providing seven multispectral channels (3 visible, 1 near-infrared, 2 mid-infrared, 1 thermal-infrared) at 30-meter resolution while 15 meter spatial resolution in panchromatic mode (120-meter resolution for the thermal-infrared band) and orthorectified data with moderate resolution 30-90 meter of Date 2000/11/20. The LANDSAT data is used for lineament identification of the basin (Fig. 4).

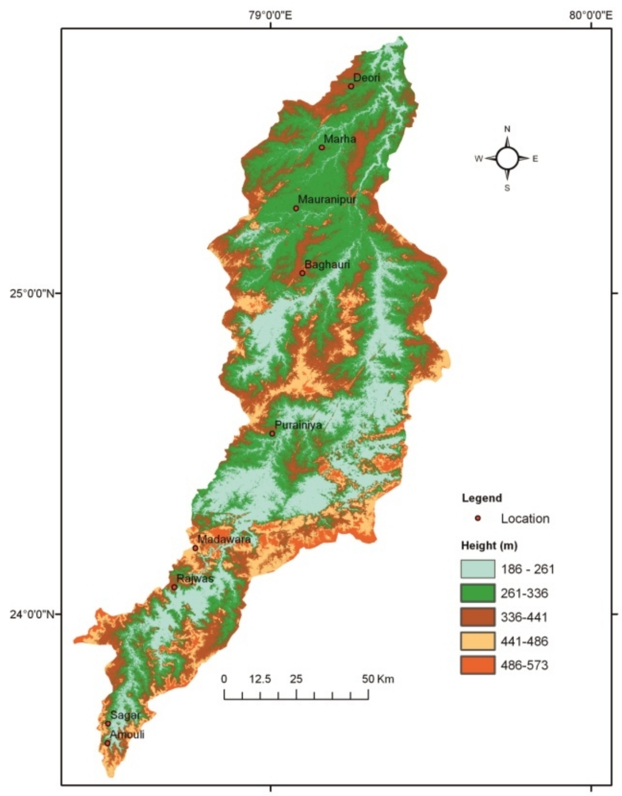

Figure 2: Digital Elevation Model (DEM) based on ASTER elevation data of the study area. The DEM is used to extract the drainages and to demarcate the five subwatershed of the Dhasan watershed

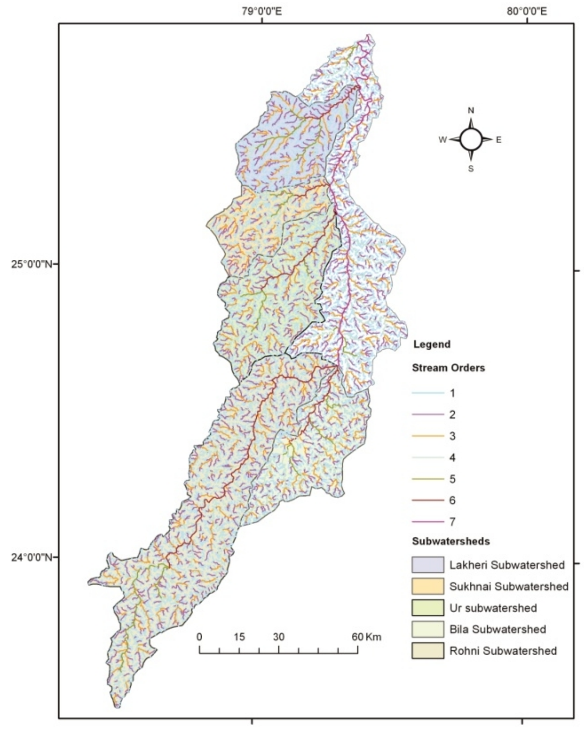

Figure 3: Drainage with subwatersheds in which the main watershed is divided into five subwatersheds (Rohni, Bila, Ur, Sukhnai and Lakheri) on the basis of 6th order stream

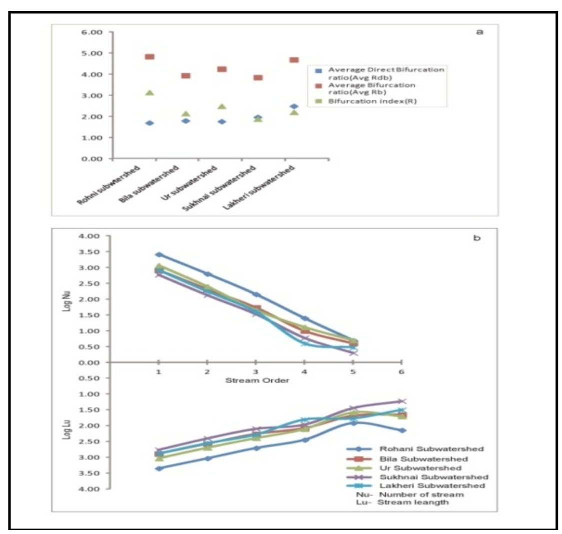

Figure 4: (a) Scatter diagram of bifurcation index, average bifurcation ratio and average direct bifurcation ratio of the five subwatersheds of the Dhasan river basin; (b) Scatter diagram with smooth line and marks between stream order verses logarithm of number of stream and logarithm of stream length

Watershed and drainage network was analyzed using Horton's (1954) scheme while in stream ordering Strahler (1964) methods was adopted. The basic parameter like length of individual stream, basin area and perimeter of the basin were extracted from the Arc GIS-10 geodatabase and further used for calculating morphometric parameter such as linear, areal, relief and tectonic aspects by means of various equations (Table 1).

4. Results and discussion

The morphometric investigation incorporates measurement and mathematical analysis of the area, altitude, volume, slope, profiles of the land and drainage basin characteristics of the catchment area concerned (Clark, 1966).

The catchment area of the Dhasan river with stream network and 5 sixth order subwatersheds viz. Rohni, Bila, Ur, Sukhnai and Lakheri are shown in figure 3. The parameters of linear, areal, relief and tectonic aspects have been examined and described in the following section along with their highlights.

Drainage pattern

The drainage orientations of the Dhasan watershed (DW) show polymodal distribution (NE-SW, NW-SE, N-S and E-W). The NE-SW trend of the streams is most conspicuous. The drainage patterns are trellised in general; while rectangular, dendritic and parallel pattern also observed. The trellis drainage pattern is formed by the network of tributaries and consequent the Dhasan river, which follows the regional slope and is well adjusted to the different geological structures. Dendritic or tree- shaped drainage pattern is the most common and widespread pattern to be found in the study area. The dendritic drainage pattern is characteristic of area having homogeneous lithologies and horizontal to gently dipping strata. Some parts of the study area are characterized by centripetal drainage pattern, which may be caused by the localized exhumation due to erosional and tectonic activities of intrusive granitoids.

Linear aspects

Perimeter (P)

The Dhasan watershed with perimeter 683.172 km is divided into five 6^{th} order subwatersheds and the details are given in Table 2. Among the 6 subwatersheds, the Rohini subwatershed has largest perimeter (424.17 km) and Sukhnai subwatershed has smallest perimeter (151.5 km).

Table 1: Different morphometric parameters used for morphometric analysis

	Parameters	Definition
Linear aspects	Perimeter (P) (km)	
	Basin length (Lb) (km)	
	Stream order(Nu)	Strahler (1957)
	Stream length(Lu) (km)	Horton (1945)
	Bifurcation ratio(Rb)	Rb=Nu/N(u+1), Horton (1945)
	Stream lengthratio (Rl)	Rl=Lu/L(u-1), Horton (1945)
	Rho coefficient(R)	R=Rl/Rb, Horton (1945)
Areal aspects	Area (A) (km2)	
	Drainage density(Dd) (km km^{-2})	Dd=∑Lt/A, Horton (1945)
	Stream frequency(Fs) (km^{-2})	Fs=Nt/A, Horton (1945)
	Drainage texture(T) (km km^{-4})	T=Dd×Fs, Smith (1950)
	Length ofoverland flow(Lg) (km)	Lg=1/2Dd, Horton (1945)
	Constant of Channel maintenance(C) (km)	C=1/Dd, Schumm(1956)
	Form factor (Ff)	$Ff=A/Lb^2$, Horton (1945)
	Circularity ratio (Rc)	$Rc=4\pi A/P^2$, Miller (1953)
	Elongation ratio (Re)	Re=1.128√A/Lb, Schumm(1956)
Relief aspects	Basin relief (r) (km)	R= H-h, Schumm (1956)
	Relief ratio (Rr)	Rr= R/Lb, Schumm (1956)
	Ruggedness number (Rn)	Rn=R*Dd, Strahler (1958)
	Gradient ratio (Rg)	Rg=Es-Em/Lb, Sreedevi et al. (2004)
	Meltonruggedness ratio (MRn	$MRn=H-h/A^{0.5}$, Melton (1965)

Table 2: Linear aspects, areal aspects, relief aspects and tectonic parameters of Dhasan river basin and its five subwatersheds

Subwatersheds -----→		Rohni	Bila	Ur	Sukhnai	Lakheri	Main
Linear Parameters	Perimeter (P, km)	424.17	207.79	209.79	151.5	157.99	760.29
	Basin Length (Lb, km)	149.1	69.31	76.27	50.64	57.43	271.73
	Average stream length ratio (AvgRl)	0.7	0.59	0.62	0.52	0.56	0.55
	Average Bifurcation ratio (AvgRb)	4.84	3.94	4.25	3.85	4.69	4.58
	Rho coefficient (R)	0.14	0.15	0.15	0.13	0.12	0.12
Areal Parameters	Area (A, km^2)	3495.45	1277.36	1617.81	865.82	1148.41	10992.58
	Drainage density (Dd)	1.26	1.23	1.27	1.28	1.3	1.26
	Stream frequency (Fs)	0.97	0.85	0.91	0.89	0.92	0.93
	Drainage Texture (T)	1.22	1.05	1.16	1.14	1.2	1.18
	Length of overland flow (Lg)	0.4	0.41	0.39	0.39	0.38	0.4
	Constant of channel maintenance (C)	0.8	0.81	0.78	0.78	0.77	0.79
	Form factor(Ff)	0.16	0.27	0.28	0.34	0.35	0.15
	Circulaory Ratio (Rc)	0.24	0.37	0.46	0.47	0.58	0.24
	Elongation ratio (Re)	0.45	0.58	0.59	0.66	0.67	0.44
	Shape index (Sw)	6.36	3.76	3.6	2.96	2.87	6.72
Relief and Tectonic Parameters	Basin Relief(r)	0.31	0.21	0.18	0.16	0.15	0.49
	Relief Ratio (Rr)	0.0021	0.003	0.0024	0.0032	0.0026	0.0017
	Ruggedness number (Rn)	0.39	0.26	0.23	0.2	0.2	0.62
	Gradient ratio (Rg)	0.0021	0.0029	0.0024	0.0032	0.0024	0.0017
	Melton ruggedness ratio (MRn)	0.0052	0.0059	0.0045	0.0054	0.0044	0.0046
	Average Direct Bifurcation ratio (AvgRdb)	1.7	1.8	1.76	1.97	2.49	
	Bifurcation index (R)	3.14	2.14	2.49	1.88	2.2	
	Asymmetry factor (AF)	53.97	83.43	56.66	15.97	64.03	

Stream Order (Nu)
A measure of the position of a stream in the hierarchy of tributaries is defined as stream order (Leopold et al., 1969). The classification of streams based on the number and type of tributary junctions has proven to be a useful indicator of stream size, discharge and drainage area (Strahler, 1957). The DW is allocated as seventh order stream. The subwatersheds are divided on the basis of sixth order stream.

Stream length (Lu)
Stream length is an important hydrological feature of the basin as it reveals surface runoff character and streams of relatively smaller lengths are characteristic of the steeper slope and finer texture of the area. The streams having relatively long channel lengths are suggestive of flat topography with gentle gradients. In general, the total length of stream segments is maximum in first order streams and decreases as the stream order increases, according to the law of stream length after Horton (1945). The mean and total stream lengths of each stream order are given in Table 2. The relationship between watershed area and stream length is characterized by Hack (1957) as the head-ward erosion is the predominant driver for the drainage network development and expansion. The rapid boost up from average stream length ratio is observed in the Rohni subwatershed (0.70), symptomatic of the influence of rock types and structures in the development of drainage networks.

Bifurcation ratio (Rb)
According to Strahler (1964), the bifurcation ratio is defined as a ratio of the number of streams of a given order (Nu) to the number of streams of the next higher order (Nu+1). The values of the bifurcation ratio vary from 3.85 to 4.84. The bifurcation ratio varying between 3.0 and 5.0 for sub-watersheds suggests that the geological structures control the drainage pattern of the DW. The elongated basin of the Rohni subwatershed with high Rb value would yield a low but extended peak flow and the rotund basin of Sukhani subwatershed with low Rb value would produce a squat peak discharge (Strahler, 1964).

Stream length ratio (Rl)
The stream length ratio, among 5 subwatersheds, varies from 0.52 to 0.70. The variability in Rl is an indication of differences between slope and topography and hence it has an important control on discharge and different erosion stages of the watershed (Sreedevi et al., 2004). Higher stream length ratio indicates higherosion activity. The increase of Rl from lower to higher orders is exemplified by the attainment of geomorphic maturity (Thomas et al., 2010).

Rho coefficient (R)
The Rho coefficient varies between 0.12 and 0.15 for these subwatersheds. The R is an important parameter relating drainage density to physiographic development of a watershed. It also assists in the evaluation of storage capacity of drainage network and hence, a determinant of critical degree of drainage development in a given watershed (Horton, 1945).

Areal aspects

Area (A)
The Dhasan watershed occupies 10992.58 km^2 area in central India. The areas of other sub-watersheds are tabulated (Table 2).

Drainage density (Dd)
Drainage density (Dd) is described as an expression of the closeness of spacing of channels and quantitatively obtained by the ratio of total channel segment lengths within a basin over the basin area (Horton, 1945; Strahler, 1964). The Dd of the Dhasan watersheds is 1.26 (Table 2). Low drainage density of the Bila subwatershed is favored of resistant lithology or highly permeable subsoil materials, under dense vegetations while high drainage density of the Lakheri subwatershed is favored in regions of weak or impermeable materials with sparse vegetation cover (Strahler, 1964).

Drainage texture (T)
Smith (1950) suggested that drainage texture is a measure of relative channel spacing in a fluvial-dissected terrain, which is greatly influenced by climate, vegetation, lithology, soil type, relief, and stage of development of a watershed. According to Smith (1950) classification, the study area comes under very coarse drainage texture because of the low drainage density (<2).

Length of overland flow (Lg)
Horton (1945) defined length of overland flow (Lg) as the length of flow path, projected to the horizontal of non-channel flow from a point on the drainage divide to a point on the adjacent stream channel. Length of overland flow is also affected by other factors viz. rainfall intensity, infiltration rate, soils, vegetations covers etc. In the study area Lg varies from 0.38 and 0.41 (Table 2). Early stage is marked with maximum length of overland flow and old stages spottedas reduction in Lg.

Constant of channel maintenance (C)
Schumm (1956) used the inverse of drainage density as a property termed constant of channel maintenance. The C of DW is 0.79 (Table 2). Large valueof C signifies higher infiltration rate and mature to old stage of the river.

Form factor (Ff)
Form factor is used to predict the flow intensity of a watershed of a defined area (Horton, 1945; Gregory and Walling, 1973). The index of Ff also illustrates the inverse relationship with the square of the axial length and a direct relationship with peak discharge (Magesh et al., 2012). Ff of DW is 0.16. The Ff of other subwatersheds is given in the table 2. Relatively larger values of Ff (>0.30) for Sukhnai and Lakheri subwatersheds are indicating higher flow peak for shorter duration.

Circulatory ratio (Rc)
Miller (1958) used a dimensionless circulatory ratio Rc, defined as, the ratio of basin area to the area of a circle having the same perimeter as the basin. Rc of DW is 0.24 (Table 2). Low (Rohni subwatershed) i.e. 0.24 and high (Lakheri subwatershed) i.e. 0.58 value of Rc corresponds to youth and mature stages of watershed development.

Elongation ratio (Re)
Schumm (1956) used an elongation ratio Re, defined as the ratio of diameter of a circle of the same area as the basin to a maximum basin length. The ratio in general varies between 0.40 and 1.0 over an ample diversity of climate and geology. Values close to1.0 is distinctive of the regions characterized by very low relief, whereas values in the range 0.6 to 0.8 are generally associated with strong relief and steep ground slant.

Shape index (Sw)
The shape index of DW is 6.72, while the values of the sub-watersheds range between 2.87 and 6.36 (Table 2). The shape index refers to elongated basin with high peak discharge.

Relief aspects

Basin Relief (R)
Basin relief is a parameter that determines the stream gradient and influences flood pattern and volume of sediment that can be transported (Hadley and Schumm, 1961). It is also an important factor to understand denudational characteristics of the basin (Sreedevi et al., 2004). The basin relief values are given in table 2.

Relief Ratio (Rr)
Relief ratio is a dimensionless ratio between basin relief and basin length and widely accepted as an effective measure of gradient aspects of the watershed (Schumm,1956; Vittala et al., 2004). The maximum Rr values of Sukhnai subwatershed is 3.2 (Table 2), signifying the presence of steeper slope and higher relief underlain by resistant rocks.

Ruggedness number (Rn)
The ruggedness number is expressed as the product of basin relief and drainage density (Strahler, 1958; Vijith and Satheesh, 2006). The high ruggedness value (Table 2) of the Dhasan watershed implies that the tract is more prone to soil erosion and have structural deformation in association with relief and drainage density.

Gradient Ratio (Rg)
Gradient ratio is a marker of channel undulation which assists the assessment of the runoff volume (Sreedevi et al., 2004; Thomas et al., 2010). The large Rg values of Bila subwatershed reflect the elevated and rugged nature of the terrain.

Tectonic parameters

Asymmetry Factor (AF)
The Asymmetry factor permits to establish the lateral tilting of a basin with respect to the main water course (Hare and Gardner, 1985; Cox, 1994; Cuong and Zuchiewicz, 2001; Mohan et al., 2007; Singh and Srivastava, 2011; Raj, 2012). This index also includes directions of possible differential tectonic (neo) activity and is also sensitive to uplift and subsidence of discrete blocks versus broad tilting (Pinter, 2005). The asymmetric factor (AF) is defined as AF= 100 (Ar/At) where, Ar= Area of the right (facing downstream) of the trunk stream, and At= Total area of the drainage basin. According to Molin et al. (2004), when AF is greater than 50 the channel has shifted towards the left side of the drainage basin whereas a value less than 50 is indicative of channel shift towards the downstream right side of the drainage basin. Sukhnai subwatershed shows value less than 50 pointing towards their shift in the right side of the drainage basin.

Direct Bifurcation Ratio
The bifurcation ratio is the measure of the degree of branching within the hydrographic network (Horton, 1945; Strahler, 1952). Direct bifurcation ratio Rdb = Ndu/Nu+1 where Ndu represents the number of fluvial segments of a given order that flows in segments of the next higher order (Guarnieri and

Pirrotta, 2008); Nu+1 is the number of segments of next higher order. This ratio describes the structure of the hydrographic network without considering hierarchical anomalies. Bifurcation index R = Rb - Rdb. It can give useful information on the erosive processes and on the degree of evolution of the basin (Guarnieri and Pirrotta, 2008). The parameters relative to this analysis demonstrated that Rohni subwatershed had an inadequate association of the hydrographic network due to active tectonics. Sukhnai subwatershed shows low bifurcation index which are sure indicators of notable tectonic imprint on the drainage network.

Lineament Study

According to Nur (1982), the lineaments are one of the important components of the Earth's surface morphology and the lineament density is relative to the intensity of deformation. The linear structural elements (lineament) traced out in Betwa basin consist of fractures (joints and faults) and shear zones etc. The giant quartz veins and basic dykes are genetically associated by these structural elements and so are their spatial and temporal distributions. These lineaments are of tectonic origin (Senthiappan, 1981; Basu, 1986; Pati et al., 2015) and are easily deciphered on LANDSAT (ETM+) imageries and based on tonal contrast, shape, change in relief, texture and pattern (hill and drainage) etc. Many of these linear structures are verified with the help of field observations and evidences of shear displacements. The orientations of linear structures have been shown in the form of a rose diagram (Fig. 5) with a total number of 566 linear structures. It is remarkable to note that the maximum lineament density (Fig. 6) is found in the upper part of the Betwa river which is mainly the central part of Bundelkhand craton. The linear structures indicate three main azimuthal frequenciesin NE-SW, E-W, and NW-SE directions representing the three major deformation trend viz. giant quartz veins, shear zone and basic dykes respectively. The azimuthal frequency of NW-SE trending lineaments is comparatively low. In general, all these fractures can be formed either due to shear rupture or tensile failure. Shear failure (Hodgson, 1961) can very well explain the origin of lineament but rarely supported by in situ observations (Nur, 1982). Most of the drainages of the Dhasan river basin follow the NE-SW trend. The present work can be extended to various ventures in the Betwa basin (semi-arid region) like ground water surveys by locating the zones of higher secondary porosity through fracture density data generated in the present study.

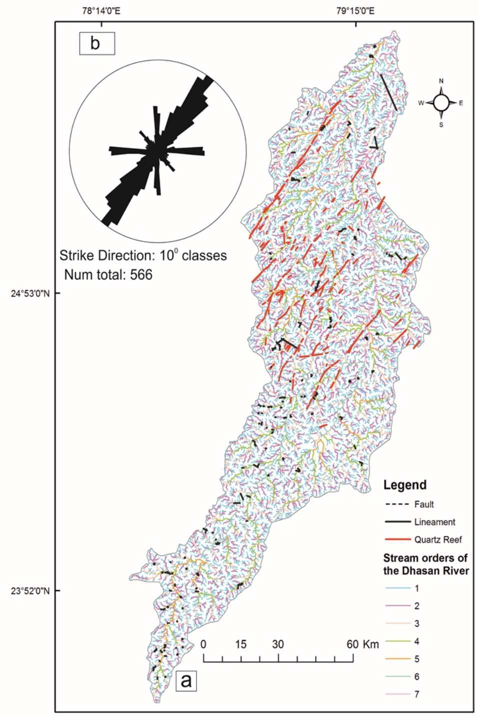

Figure 5: (a) Spatial distribution of lineaments in the study area; (b) Trends of 566 lineaments are shown in a Rose diagram

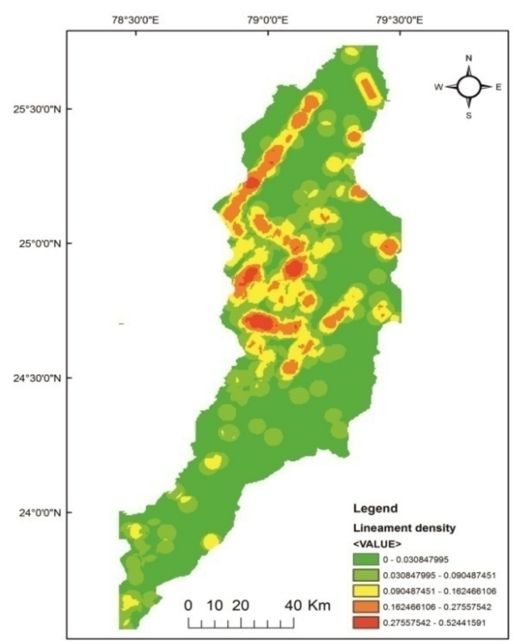

Figure 6: Lineament density map of the Dhasan river

The study shows that GIS techniques provide efficient tools for the assessment of drainage characteristics of the Dhasan watershed and its five sixth order subwatersheds, to comprehend the significance of morphometric studies in terrain characterization and expansion of the river basin.

Systematically organized and well developed drainage network with large number of first and second order streams in the Dhasan basin is validated through the homogeneous weathering and head-ward erosion. The area exhibits dendritic drainage pattern on the whole however sporadic trellis and centripetal pattern are also notice in some region. Very high fraction of first and second order streams point out the structural deformation, mainly as fractures, lineaments and folded litho units. The elongated shape of watersheds is characterized by lower flood peaks but longer duration flood flows, advocating flood management. The values of bifurcation ratio (Rb) for the DW illustrate dissected mountainous nature of watersheds having high drainage integration and mature topography. The tectonic (neo) activities on drainage expansion are supported by higher bifurcation ratios, along with drainage density and low elongation ratios.

The high drainage density in the Dhasan river basin is described as the impermeable subsurface lithology present in the area. Linear relationship between drainage density (Dd) and drainage texture (T) is expressed by the mature nature of basins and structural control on drainage expansion. Rohni subwatershed has longer basin length among the 5 sub-watersheds describing that water is surging to a larger distance with extended time- span.

A scatter diagram of bifurcation index, average bifurcation ration and average direct bifurcation ratio is showing (Fig. 4a) linear likeness, demonstrating the control of the lithology and geological structures on distorted trellis and dendritic drainage pattern. A scatter diagram with smooth line and marks (Fig. 4b) of stream order (on abscissa) and logarithm of number of streams and logarithm of stream length is constant throughout the successive order of basin and advocating the preserved geometrical similarity in ascending order.

Consequently, the morphometric analysis provides a better understanding for the status of land form and their processes, drainage management and evolution of groundwater potential for watershed planning and their management in water-deficient areas.

5. Conclusion

The study demonstrates that morphometric analysis of a river basin can be performed using remote sensing and GIS techniques. This provides an alternate and efficient way to understand the status of land form and their processes. Such analysis is useful in development and planning of watersheds.

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