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The morphometric Evaluation through GIS Technique of Dangriand Bengna watersheds, North-Eastern part of Haryana, India

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Abstract

The GIS techniques have been use for the identification of morphometric properties, which was carried out in two watersheds in the Dangri and Bengna in Haryana, India. These watersheds are the parts of Markanda River basin which flow from north-eastern to south- west in Haryana and which are occurrence devastating flood in monsoon season. Quantitative Geomorphometric analysis was carried out for the Dangri and Bengna watersheds independently by estimating their aerial aspects like circulatory ratio, elongation ratio, drainage density; linear aspects like stream number, stream order, stream length, mean stream length, stream length ratio, bifurcation ratio, length of overland flow, drainage pattern and relief aspects like basin relief, relief ratio, relative relief and ruggedness number. The drainage areas of Dangri and Bengna watersheds are 814 and 274 km^2 respectively and show nearly patterns of dendritic to sub-dendritic drainage. The both drainage was classified as a sixth order drainage basin. The stream order of the basin was predominantly controlled by physiographic and structural conditions. Although, the stream length ratio increasing from lower to higher order evident that the study area going to became a mature geomorphic stage. these studies are useful for planning rain water harvesting and watershed management.

Keywords GIS, Morphometric analysis, Dangri and Bengna watersheds, GIS and Remote Sensing.

Introduction

The Remote sensing and Geographic Information System (GIS) has become very significantfor morphometric analysis of a basin. Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms

(Agarwal 1998; Reddy et al. 2002). The watershed is defined as surface area drained by a part of the totality of one or several given water cources and can be taken as a basic erosional landscape element where land and water resources intract in a perceptible manner (Biswas et al. 1999). The quantitative analysis of the morphometric characteristics of a drainage basin has been useful in many application studies which include estimation of runoff, flood discharge, ground recharge, sediment yield, soil and water conservation, environmental analysis and so on (Gopalakrishan 1997). The quantification of river networks was introduced by Horton (1932, 1945) who studied the origin of river networks. Morphometric analysis of a watershed provides a quantative description of the drainage system which is an important aspect of characterization of watersheds (Strahler 1964). The subject of quantitative morphometrical analysis got enriched considerable by the work of many researchers like Strahler (1950, 1952, 1957, 1964), Schumm (1954, 1956,) Romshoo (2012),
Hack (1957), Melton (1958), Morisawa (1957) etc.

The nature of hydrograph and Hydrological variables of a basin is influence by Morphometric features such as basin shape and basin relief. Drainage system provides information on the topography and underlying geological structure. Drainage density found varies with relative age, differing geology, drainage area etc. and enables comparisons of basins and streams the emerging trends in the applications of computers especially in mapping, development of information systems made the quantitative approach for surface characterization and the mechanism for the interpretation and manipulation of the quantitative data sets easy. Moreover, the advantages of this digital earth concept over the conventional methods are its ability to create, manipulate, store, and use spatial data much faster and at a rapid rate. The present study employed the same concept on a watershed level and this paper primarily focuses on the description and nature of spatial variations of physical characteristics of the drainage systems of the Dangri and Bengna watersheds, for describe and evaluate the areal, linear, and relief characteristics, using data aggregated from Survey of India (SOI) toposheets (1:50000) and corresponding Cartosat data.

The morphometric parameters were extracted for the Bengna and Dangri watersheds of tributaries of Markanda River, Haryana. The Morphometric values were calculated, mapped and analysed using statistical methods. The GIS has to characterize the stream networks and drainage basin systems. The results found on the basis of drainage basin analysis provide information for an improved understanding of the hydrological characteristics of the Dangri and Bengna watershed.

Study Area

The study area, Dangri and Bengna watersheds the part of Markanda located in north-eastern side of Haryana. Dangri watershed geographically extend between 76° 30′ and 77° 8′ E longitudes and 30° 04′ and 30° 44′N Latitudes and covers an of 914 km^2 while Bengna extend between 77° 03′ and 77° 11′ E longitudes and 30° 16′ and 30° 40′N Latitudes and cover 274 km^2 (Fig. 1). The study area has high relief and steep slopes in northern side but mostly area in south-western side found plain in both watersheds. The Drainage pattern is

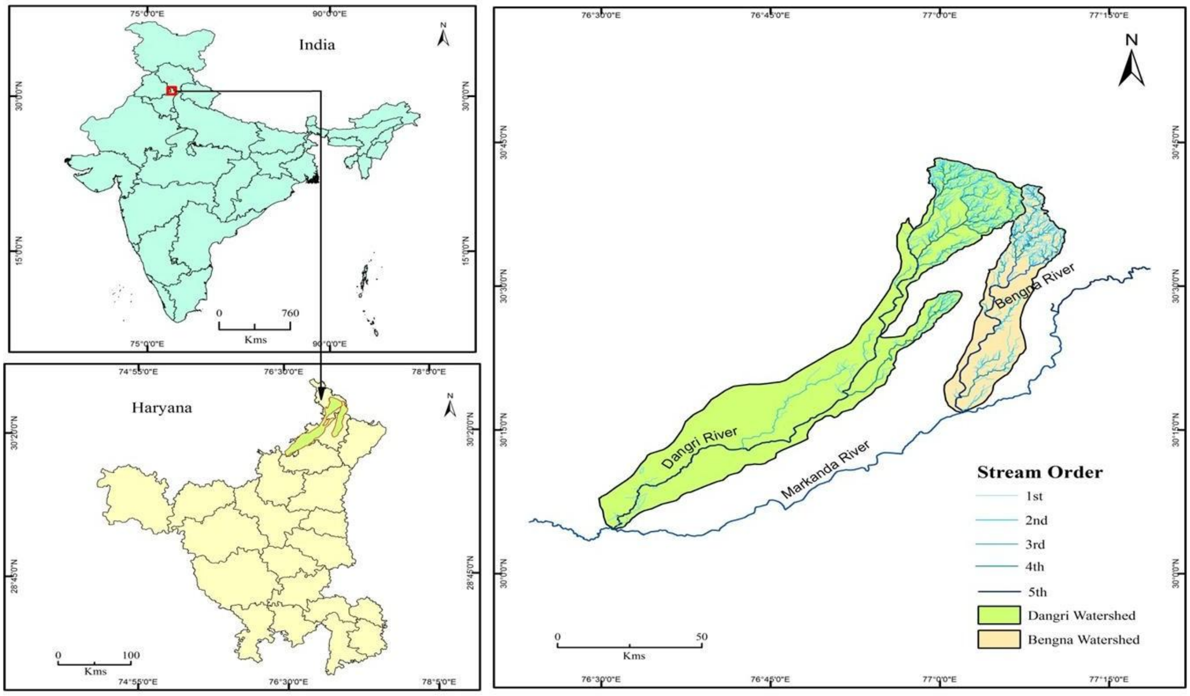

Figure 1 Location of Dangri and Bengna Catchment.

dendritic to sub-dendritic, which is characterized by irregular branching of tributary system in many directions joining the main channel. The study area experiences typical tropical climate for the better part of the year and characterized by wet type of climate and four types of seasons are identified. The hot summer season from April to May, the southwest monsoon season from June to September, the northeast monsoon season from October to December, and a general cool and salubrious climate period during January to February. More than 75 % of the total rainfall in the

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study area occurs during period of June to September (SW monsoon), 16 % during October to December (NE monsoon), 9 % is received during March to May and the remaining 1 % is accounted for January and February months. The average annual rainfall in the study area ranges between approximately 2,000 and 3,000 mm. The temperature of the area varies from 22° to 36° C. The most of the study area is covered by tropical wet evergreen and tropical moist deciduous forest.

Methodology

For the appropriate and adequate information adopt a systematic way towards determining the morphometric parameters, the topographic maps were collected and used as the basis for the creation of several GIS thematic layers. The base maps of the Dangri and Bengna watersheds were prepared based on Survey of India topographic maps on a 1:50000 scale and also with Cartosat data. The drainage networks were traced and it digitized from topographic maps. The second principal component derived from the processing of a DEM data of the study area, with a spatial resolution 90m (Figure 2). This data was downloading from the Bhuvan site. The Cartosat DEM data was then imported to ArcGIS 10. As a result, significant

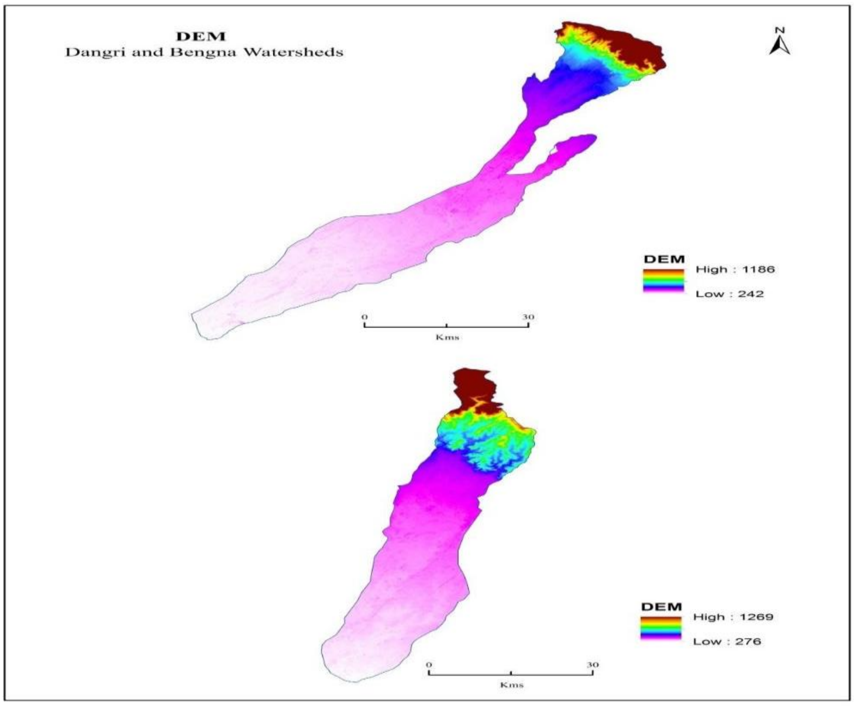

Figure 2 Cartosat DEM of Dangari and Bengna Catchment.

geomorphological parameters such as contours, slope gradient and aspect have been quantified. The Drainage networks of the watersheds were scanned from the Survey of India (SOI) Toposheets No. 53 B/11/12/13/14/15 and 53 F/2/3 (1:50000) and digitized in ArcGIS

10. The drainage order digitized streams was performed in GIS according to Strahler's system (Strahler 1957, 1964). The Drainage network of the basin is analysed as per the Laws of Horton (1945). The basic watershed characteristics (basin area, perimeter, cumulative

length of streams and basin length) were measured in the GIS environment. Morphometric parameters such as stream frequency, drainage density, texture ratio, form factor, bifurcation ratio, length of over land flow, elongation and circulatory ratios were evaluated with mathematical equations (Strahler 1964). The extracted values and the formulae used to calculate them are shown in Table 1.

Table 1 Linear relief and areal morphometric parameters

S. No	Parameters	Formulae	References
1	Stream Order (U)	Hierarchial rank	Strahler (1964)
2	Stream Length (Lu)	Length of the stream	Horton (1945)
3	Mean Stream Length (Lsm)	Lsm = Lu/Nu	Strahler (1964)
4	Stream Length Ratio (RL)	RL = Lu/(Lu-1)	Horton (1945)
5	Bifurcation Ratio (Rb)	Rb =Nu/Nu + 1	Schumm (1956)
6	Mean Bifurcation Ratio (Rbm)	Rbm = average of bifurcation ratios of all order	Strahler (1957)
7	Drainage density (Dd)	Dd = Lu/A	Horton (1945)
8	Drainage texture (T)	T = Dd × Fs	Smith (1950)
9	Stream Frequency (Fs)	Fs = Nu/A	Horton (1945)
10	Elongation ratio (Re)	Re =D L=1.218	Schumm (1956)
11	Circularity ratio (Rc)	Rc = 4πA/P2	Strahler 1964
12	Form factor (Ff)	Ff = A/L2	Horton (1945)
13	Length of overland flow (Lg)	Ff = A/L2	Horton (1945)
14	Relief	R = H-h	Hadley and Schumm (1961)
15	Relief Ratio	Rr = R/L	Schumm (1963)

Result and Discussion

Morphometry of a basin is the way to understand its hydraulic behaviour because it is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimensions of its landform (Clarke 1996). The present study emphasizes the use of GIS and remote sensing for morphometric analysis. The DEM has been used to calculate slope, contour

and aspect maps. The development of drainage networks depends on geology, and precipitation apart from exogenic and endogenic influences. The drainage pattern of the basin is dendritic to sub-dendritic. Based on the drainage order, Dangri and Bengna watersheds are classified as sixth order basins in order to interpret the morphodynamic parameters listed in Table 1. (Horton 1932, 1945; Smith 1950; Schumm 1956, 1963; Hadley and Schumm 1961;
Strahler 1964; Sreedevi et al. 2005; Mesa 2006).

Aspect

Aspect of a surface defines as the direction to which a mountain slope faces. The aspect of slope aspects duration of sun-light exposition, precipitation intensity, moisture retention, vegetation covers which subsequently stimulate the erosion process. This can have major effects on the distribution of vegetation and bio-diversity in the study area (Magesh et al. 2010). The given output raster data set represents the compass direction of the aspect. "0 is true north; a 90 degree aspect is to the east, and so forth. The aspect map of Dangri and Bengna watersheds are revealed in (Fig. 3). The visual interpretation revealed clearly shown that north-eastern side facing slope occur in the Dangri and also in Bengna watershed. So

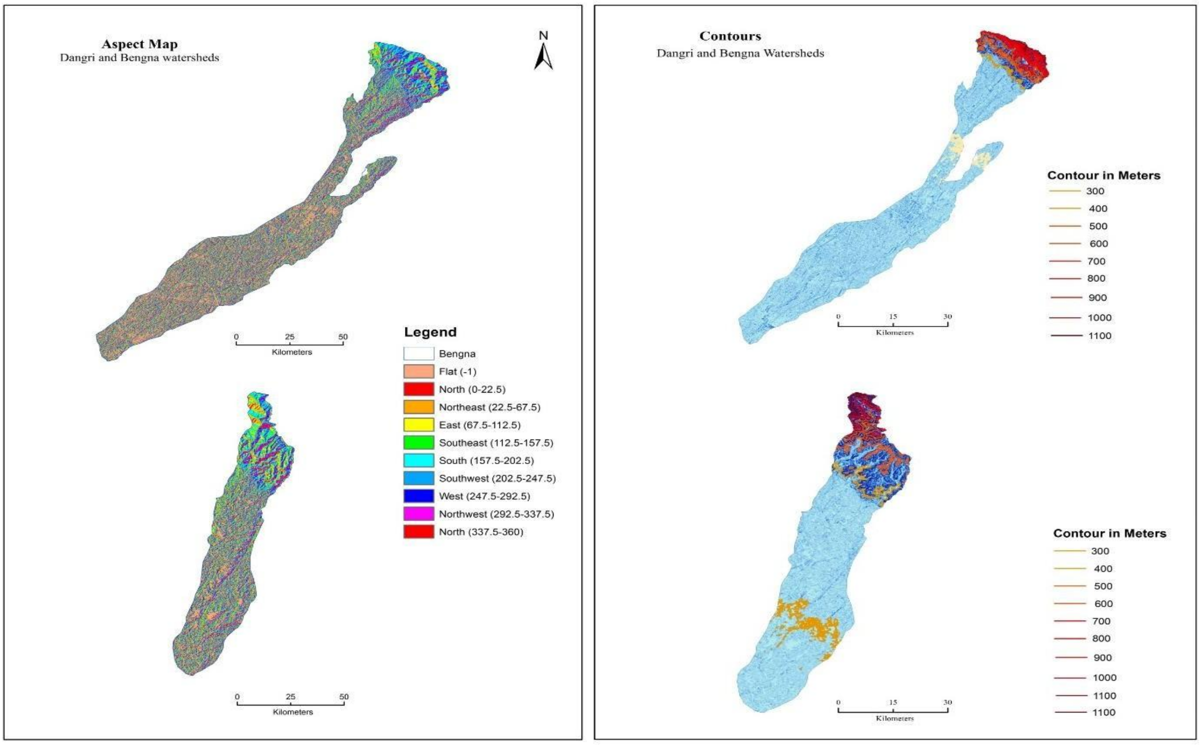

Figure 3. Aspect and Contours Map of Dangari and Bengna Catchment.

north eastern side slopes have higher moisture content and lower evaporation rate then the south-western side of both watershed, because here slopes are more common. This indicates that the low slopes area of the Dangri and Bengna watersheds is drier, and has a higher evaporation rate. As a result, the vegetation index is higher in north eastern side in Dangri and Bengna watershed.

The Slope

The amount of inclination of a physical feature, topographic landform, refers as slope that is surface to the horizontal and it is an important parameter in geomorphic studies. The slope elements, in turn are controlled by the climatomorphogenic processes in areas having rock of varying resistance. Slope grid is identified as "the maximum rate of change in value from each cell to its neighbors (Burrough 1986). The slope map of Dangr and Bengna watersheds are shown in Fig. 4. The degree of slope exhibited by Dangri watershed varies from 0° to 60°

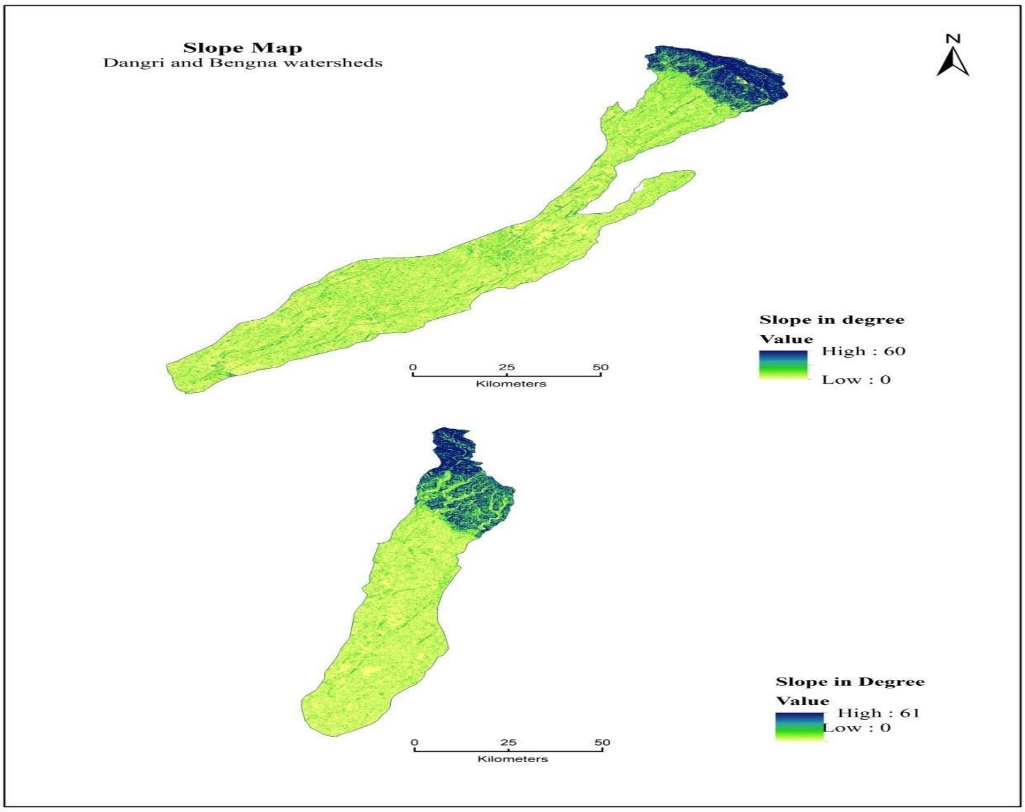

Figure 4. Slope Map of Dangari and Bengna Catchment.

whereas Bengna watershed slope varies from 0° to 61°. Higher degree of slope results in rapid runoff and increased erosion rate with feeble recharge potential.

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Stream Order

The streams ordering are very important in the analysis and it has been ranked according to Strahler's classification. In the given table 2 represent order wise stream length and stream numbers of Dangri and Bengna watersheds. The variation in stream order and the basin area are largely due to physiographic and structural conditions of the region. It is revealed by the Strahler's method of ordering, the both watershed Dangri and Bengna designated as sixth order watershed. (Fig. 1).

Stream number (Nu)

The Number of streams of various orders and the total number of streams in the watersheds are counted independently with the help of GIS software (Table 2). It is obvious that the total number of streams gradually decreases as the stream order increases.

Stream length (Lu)

The stream numbers at various orders in both the watersheds are counted individually on the topographic maps using Arc GIS software and also their lengths from mouth to drainage

Table 2 Results of morphometric analysis of Dangri and Bengna watersheds

S.No	Parameters	Dangri Watershed						Bengna Watershed					
		Stream Order						Stream Order					
1	Stream Order (U)	I	II	III	IV	V	VI	I	II	III	IV	V	VI
		613	160	36	9	2	1	339	89	23	5	2	1
2	Stream Length (Lu)	363.7	126.2	63.7	37.8	21.1	98.0	219.1	76.0	38.0	39.2	14.4	35.0
3	Mean Stream Length (Lsm)	0.59	0.78	1.77	4.2	10.5	98	0.64	0.85	1.65	7.8	7.1	35
			II/I	III/II	IV/III	V/IV	VI/V		II/I	III/II	IV/III	V/IV	VI/V
4	Stream Length Ratio (RL)		1.32	2.27	2.37	2.5	9.33		1.32	1.94	4.73	0.92	4.93
			I/II	II/III	III/IV	IV/V	V/VI		I/II	II/III	III/IV	IV/V	V/VI
5	Bifurcation Ratio (Rb)		3.8	4.4	4.0	4.5	2.00		3.8	3.9	4.6	2.5	2.00
6	Mean Bifurcation Ratio (Rbm)				3.74						3.36		
7	Perimeter (P) (km)				246						105		
8	Basin length (Lb) (km)				95.42						46.68		
9	Basin area (Sq. Km)				814						274		
10	Total relief (R) (Mtrs)				944						993		
11	Relief ratio (Rh)				0.01						0.02		
12	Elongation ratio (Re)				0.33						0.38		
13	Length of overland flow (Lg)				2.29						1.29		
14	Drainage density (D)(kms/km2)				0.87						1.54		
15	Stream Frequency (Fs)				1.01						1.68		
16	Texture ratio (Rt)				3.34						4.37		
17	Form factor (Rf)				0.09						0.13		
18	Circulatory ratio (Rc)				0.17						0.31		

divide are measured in the same platform. The length of stream segments is maximum for first order streams and decreases as the stream order increases. The regression plot for stream order and logarithmic stream length were computed and it gives a straight line fit (Fig. 5). The straight-line fit indicates that the ratio between stream length and stream order is constant

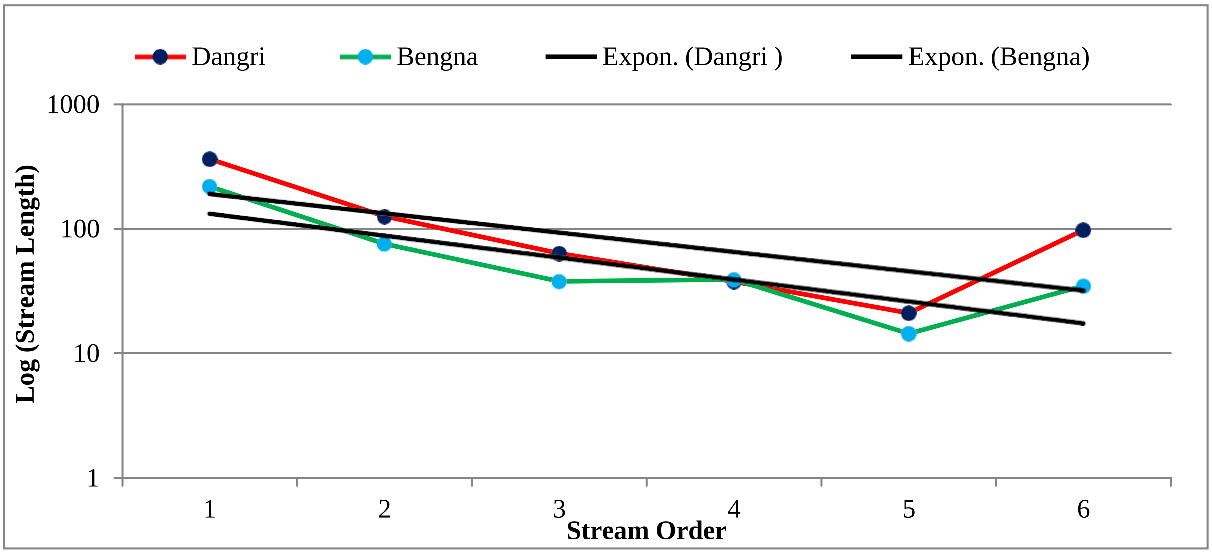

Figure 5. Regression of Stream length on stream order of Dangri and Bengna.

throughout the successive order of a basin and suggest that the geometrical similarity is preserved in both watersheds of increasing order.

Mean stream length (Lsm)

The mean stream length (Lsm) is very important morphometric parameter which has been computed by dividing the total stream length of order ‘u’ by the number of streams of segments in the order (Table 2). It is a characteristic property related to the size of drainage network components and its associated surfaces (Strahler 1964). From the analysis it is revealed that the Lsm values of the Dangri vary from 0.59 to 98 while in the case of Bengna Lsm values varies from 0.64 to 35

Stream length ratio (RL)

Stream length ratio (RL) is the ratio of the mean length of the one order to the next lower order of the stream segments (Horton 1945) that is sown in Table 2. There is found variation in Stream Length ratio which is might be attributed to variation in slope and topography, indicating the late youth stage. The Bengna watershed exhibits an increasing trend in the length ratio from lower order to higher order indicating their mature geomorphic stage.

Bifurcation ratio (Rb)

Bifurcation ratio (Rb) is elaborated by Horton as an index of relief and dissections. It may be defined as the ratio of the number of stream segments of given order to the number of segments of the next higher order (Schumm 1956) (Table 1). The Rb is also an indicative tool of the shape of the basin. Elongated basins have low Rb value, while circular basins have high Rb values (Morisawa 1985). It is observed from the Table 2; the Rb is not same from one order to its next order. These irregularities depend upon the geological and lithological development of the drainage basin (Strahler 1964). The mean bifurcation ratio of Dangri and Bengna watersheds are 3.74 and 3.36 respectively, that is indicate both watersheds do not exercise a dominant influence on the drainage pattern.

Relief (R)

Relief is the maximum vertical difference between the lowest and the highest point of a basin. Basin relief is an important factor in understanding the denudational characteristics of the basin. It plays a significant role in landforms development, drainage development, surface and sub-surface water flow, permeability and erosional properties of the terrain. The total reliefs of the Dangri and Bengna watersheds are 944 and 993 m respectively. The high relief value indicates the gravity of water flow, low infiltration and high runoff conditions. Figure 3 present the relief maps for both watersheds.

Relief ratio

The Relief ratio defined as the measure of overall steepness of the catchment. It is appropriate indicator of the intensity of water flows from a catchment slope. The Rh is the Horizontal distance along the longest dimension of the basin parallel to the principal drainage line (Schumm 1956). The high Rh implies on shorter lag time and attains higher peak discharge and flow velocities. With increasing relief, steeper hill slopes and higher stream gradients, Tc of runoff decreases, thereby increasing flood peaks (Patton 1988).In the present study, it should be noted that the relief ratios of Dangri and Bengna watersheds are 0.01 and 0.02 respectively, corresponding to steep slopes and medium relief**.**

Drainage density (Dd)

Drainage density indicates the closeness of spacing of channels (Horton 1932). Drainage density is defined as the total length of streams of all order per drainage area. According to Strahler

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(1964), low drainage density values occur where basin relief is low while high Dd is favoured where basin relief is high. The Dd is a significant factor in controlling over the landscape runoff, and it influences on the flood peak discharges (Yildiz 2004; Pallard et.al. 2009). The Dd values are normally high in the regions of impermeable subsurface material, sparse vegetation and mountainous relief that implies on high flood volumes (Pallard et al. 2009). The Dd values for Dangri and Bengna watersheds are 0.87 and 1.54 km/km^2 respectively. The Dd of the both watersheds reveals that the nature of subsurface strata is permeable, which is a characteristic feature of coarse drainage as the density values are less than 5.0.

Stream frequency (Fs)

Stream frequency is an interlinking factor in predicting peak flood discharge (Patton & Baker 1976; Eze & Efiong 2010). The stream frequency (Fs) is the ratio of the total number of stream segments of all the orders in the basin to the total area of the basin Horton (1932). Generally, high Fs is related to impermeable sub-surface material, sparse vegetation, high relief conditions and low infiltration capacity (Reddy et al. 2004; Shaban et al. 2005).The stream frequency values for the Dangri and Bengna watersheds are 1.01 and 1.68 km/km^2 respectively (Table 2). Stream frequency dependant more or less on the rainfall, temperature and lithology of the basin and reflect the texture of the drainage network. It is noted that the Fs values of both watersheds exhibits positive correlation.

Drainage texture ratio (T)

The drainage texture influence by a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development (Smith 1950). The soft and weak rocks unprotected by vegetation produce a fine texture, whereas, massive and resistant rocks cause coarse texture (Sreedevi et al. 2009). Smith (1950) classified the drainage texture, which is shown in Table 2. It's come out that the Dangri watershed has a fine drainage texture as the value is 3.34 while the Bengna watershed having T value between 4.37, therefore exhibits intermediate drainage texture.

Form factor (Ff)

The form factor represents the shape or outlines of a basin and is useful in predicting the flow intensity of a catchment and has a direct link to peak discharge (Horton 1945; Gregory & walling 1973). The Smaller the value of the form factor, the basin will be more elongated with lower peak flows of longer duration. Circular basins have intermediate form factors, which are close to one. Basins with high form factors experience larger peak flows of shorter duration, whereas elongated watersheds with low form factors experience lower peak flows of longer duration. The index of Ff shows the inverse relationship with the square of the axial length and a direct relationship with peak discharge. The Ff values Dangri and Bengna are 0.09 and 0.13 respectively, representing both watersheds comprise elongated basin with lower peak flows of longer duration than the average.

Circularity ratio (Rc)

Circularity ratio (Rc) refers to the ratio of watershed area to the area of circle having the same circumference as the perimeter of the catchment. Circularity ratio (Rc) is the ratio of the area of a basin to the area of a circle having the same circumference as the perimeter of the basin (Miller 1953). Rc is controlled by the length and frequency of the streams, geological structures, landuse, land cover, climate, relief and slope steepness of the catchment. Rc is a significant ratio that indicates the dendritic stage of a watershed. Low, medium and high values of Rc indicate the young, mature, and old stages of the life cycle of the tributary watershed. The both watershed Dangri (0.17) and Bengna (0.31) have less than 0.5 values indicating that these are elongated and both watersheds reached the topographical maturity.

Elongation ratio (Re)

Elongation ratio (Re) is a significant index in the analysis of the basin shape and hydrological characters of drainage. It may be defined as the ratio between the diameter of a circle of the same area as the drainage basin and the maximum basin length (Schumm 1956). Re values close to unity correspond typically to regions of low relief, whereas values in the range 0.6 to 0.8 are usually associated with high relief and steep ground slope (Strahler 1964). In the case of Dangri and Bengna watersheds the elongation ratio is less than 0.6 indicating that both the watersheds are elongated and having high relief and gentle slopes Table 2.

Length of overland flow (Lg)

The length of the overland flow (Lg) indicates the length of the longest drainage path that water takes before it gets concentrated (Horton 1945) (Table 1). The length of overland flow (Lg) approximately equals half the reciprocal of the drainage density (Horton 1945). The Length of overland flow relates inversely to the average slope of the channel and is quite synonymous with

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the length of sheet flow. It is revealed that the Dangri and Bengna watersheds are 2.29 and 1.29 respectively (Table 2). The present study is valuable for rainwater harvesting, watershed and ecosystem management.

Conclusion

The present technique of GIS and Remote Sensing provides more reliable and accurate estimation and prove to be an ideal application for the hydrological investigation of similar parameters of a watershed. The drainage basin is a major landform unit in fluvial terrain and is of particular relevance to morphometric analysis. Landscape morphology is a function of drainage, climate, and structure of a given basin. The study has describe morphometric analysis of the Dangri and Bengna watersheds based on numerous of drainage parameters, by which the watersheds have been classified as fifth order basins. Each basin is mainly dominated by lower order streams. The drainage areas of Dangri and Bengna watersheds are 814 and 274 km^2 respectively and show patterns of dendritic to sub-dendritic drainage. The variation in the stream length ratio may be due to changes in slope and topography. The drainage network of the watershed is effective to provide a sufficient superficial draining with a high number of streams of low order that flow directly in the principal collector or in upper order steams. The bifurcation ratio indicates that the watershed areas do not exercise a governing influence on drainage patterns. The drainage density values of the Dangri and Bengna watersheds have values below 5 revealing that the sub-surface strata is permeable, a characteristic feature of coarse drainage. The study areas experience intermediate to fine drainage textures. Rainfall may affect the development of stream segments in the watersheds. The aspect of Bengna watershed is dominated by east facing slopes indicative of high moisture content, whereas the Dangri watershed is dominated by west facing slopes and correspondingly lower moisture content. This is because the sun’s radiation intensity is greater on west facing slopes, causing increased evaporation. The elongation ratio indicates that both watersheds have maximum plain high relief, gentle slopes and elongated (than average) the latter, mainly due to the guiding effect of thrusting and forcing. The relief ratio indicates that the discharge capability of these watersheds is very high and the potential groundwater resource is meagre. Usually, morphometric analysis of drainage system is prerequisite to any hydrological study. Thus, determination of stream networks’ behaviourand their interrelation with each other is of great importance in many water resources studies. This study includes a comprehensive morphometric analysis that can be useful and applicable for any drainage system elsewhere to understand the drainage characteristics with respect to the fluvial ecosystem.

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