Geo-Morphometric Assessment of Nandani River Basin, Western Maharashtra, India using Geospatial Techniques

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Abstract - *Geographic Information system (GIS) technique is appropriate tool for the identification of geomorphological features. GIS and image processing techniques can be used to define morphological characteristics and to investigate the characteristics of the basin. The present study focused on the morphometric analysis of Nandani river basin using RS and GIS techniques. The Nandani river basin has covered an area of 492 km2. For this study, all the satellite data is obtained from Bhuvan website and analyzed in ArcGIS software. Morphometric analysis of river basin was performed by determining the parameters like Linear Aspects, Basin Geometry, Drainage Texture Analysis, Relief characteristics. The drainage pattern of stream network from the basin have been observed as mainly dendritic type. Watershed boundary, flow direction, flow accumulation, flow volume flow ordering have been prepared using a hydrological tool and the slope aspect has been prepared using a surface tool in ArcGIS. These geomorphometric assessment results can be used in river basin or watershed management and hydrological studies.*

***Key Words*: ArcGIS, Geographic Information system (GIS), Morphometric analysis, Remote Sensing.**

1. INTRODUCTION

Morphometry is the measurement and mathematical analysis of the configuration of the Earth's surface, shape and dimension of its landforms (Clarke, 1966; Agarwal, 1998; Obi Reddy et al., 2002). Morphometric parameters of a drainage basin describes basin network, form, structure and extension. It is actually quantitative analysis of basin's terrain and drainage network in the basin which helps us to understand the consequent development of drainage network and thereby enable us to have an idea of the geological and geomorphological processes over time. Thus it gives us a cue of landform evolutionary phase that basin is currently going through as described in various morphometric studies (Horton, 1945; Strahler, 1952; Strahler, 1964; Shreve, 1969; Muller, 1968).

Horton is considered to be the pioneer in application of quantitative techniques in drainage basin analysis. In early days the method was very much manual which was both time taking and laborious (Horton, 1945; Strahler, 1952; Strahler,1964; Shreve, 1969; Muller,1968; Evans IS, 1972; Chorley et. al., 1984; Strahler, 1957; Schumm, 1956; Chorley and Morgan, 1962). Then J.T. Hack's Stream-profile analysis and stream-gradient index proved to be significant in the quantitative description of drainage basins (Hack, 1973). The advent of Remote Sensing and Geographical Information System (GIS) techniques began to make things much easier and computation of results more accurate. Now much advancement in RS, GIS and personal computers has made possible its widespread application in quantitative geomorphology in general and in morphotectonic analysis of drainage basins in particular (Williams, 1972; Mesa,2006; Lyew-Ayee et al., 2007; Altin and Altin, 2011; Buccolini et al., 2012). Here in India too, Quantitative techniques have been applied to study the morphometric analysis of different drainage basins (Vittala et al., 2004; Chopra et al., 2005, Vijith and Sateesh, 2006; Rudraiah et al., 2008; Bagyaraj and Gurugnanam, 2011; Malik et al., 2011; Thomas et al., 2011; Magesh et al., 2012; Singh et al., 2012; Pareta and Pareta, 2012; Rai et al., 2014; Biswas et al., 2014; Chougale and Sapkale, 2017). Various Studies concludes that morphometric properties of drainage basins as good indicators of structural influence on drainage development and neotectonic activity (Nag and Chakraborty, 2003; Das et al., 2011; Bali et al., 2012; Demoulin, 2011). There are many studies where morphometric analysis of drainage basins has been used to assess the groundwater potentiality of the basins and to locate suitable sites for construction of check dams and artificial water recharge structures (Sreedevi et al., 2005; Narendra and Rao, 2006; Avinash et al., 2011; Mishra et al., 2011; Jasmin and Mallikarjuna, 2013). Nowadays, remote sensing and GIS provide cheap, convenient and higher accuracy results in morphometric analysis of drainage basins. According to (Rao et al., 2010) the fast emerging spatial information technology, remote sensing, GIS, and GPS are effective tools to overcome most of the problems of land and water resources planning and management of basin rather than conventional methods of data process. The present study aims at using the remote sensing and GIS technology to compute various parameters of morphometric characteristics of the Nandani river basin.

2. STUDY AREA

The Nandani River is a major tributary of Yerala River. It originates from the hilly regions of Aundh, Maharashtra-India. It flows through rain shadow region of Satara and Sangli districts, which is confluence to Yerala at village Shivni near Kadepur, Sangli. The Latitude study area is 16º 55' to 17º 28' N and Longitude 74º 20' to 74º 40' E. It covers total area of 492 km^2 (Fig. 1). The watershed experiences tropical monsoon climate with normal temperature, humidity and evaporation throughout the year. The study area receives the rainfall during South-West monsoon from June to September. The distribution of rainfall is not even all over the area. During July and August rainfall is more and significant runoff takes place. The rainfall stations are Karad, Kadegaon, Vita, Palus & Vaduj. It has been observed that about 20% rainfall of total rainfall is received during post-monsoon and by thunder showers in the month of May. The temperature may rise up to 44ºC in summer and may fall down to 20ºC during winter. The climate of the region is defined as subtropical with hot and dry weather in the summer.

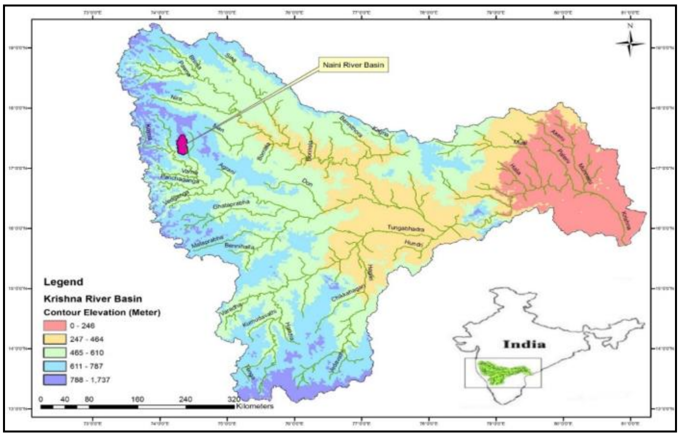

Fig - 1: Location Map of Nandani

3. METHODOLOGY

In this study Topographic information was digitized and geo-referenced in ArcMap 10.1. The watershed boundary and drainage lines were automatically extracted from the SRTM DEM using Arc hydro tools in ArcGIS 10.1 by collaborating SOI toposheets. Digital Elevation Model (DEM) and contours maps were also generated for the basin. Spatial analyst tools in ArcGIS 10.1 software were largely used for computation of aspect, relief and slope of the basin. All morphometric parameters such as linear, areal and relief have been calculated with the help of DEM in consultation with SOI topographical maps and Google Earth in GIS environment (ArcMap 10.1). To determine the morphometric parameters of a basin, two extraction techniques have been developed: extraction of the river basin boundary and extraction of the stream network using SRTM DEM from the river basin. The methodology flowchart shown in Fig. 2.

The Nandani river basin is extracted from the Bhuvan Digital Elevation Model (DEM). The contributing basin area was extracted with the help of various geoprocessing techniques in ArcGIS 10 software. The stream network of the study area is extracted from a series of geoprocessing tools in ArcGIS 10 software. The output of the stream network is smoothened using a smooth line tool in ArcGIS 10 software. Different parameters such as stream number, stream order, stream length ratio, stream length ratio, bifurcation ratio, basin length, basin area, relief ratio, elongation ratio, overland flow length, drainage density, stream frequency, drainage texture, form factor and circulatory ratio were evaluated using the standard mathematical formulas given in Table 1. Moreover, the aspect and the slope map of the study area were derived from the STRM DEM using the aspect and slope tool in ArcGIS 10 Spatial analyst module. The drainage map and drainage density map is shown in Fig. 3 and Fig. 4 respectively.

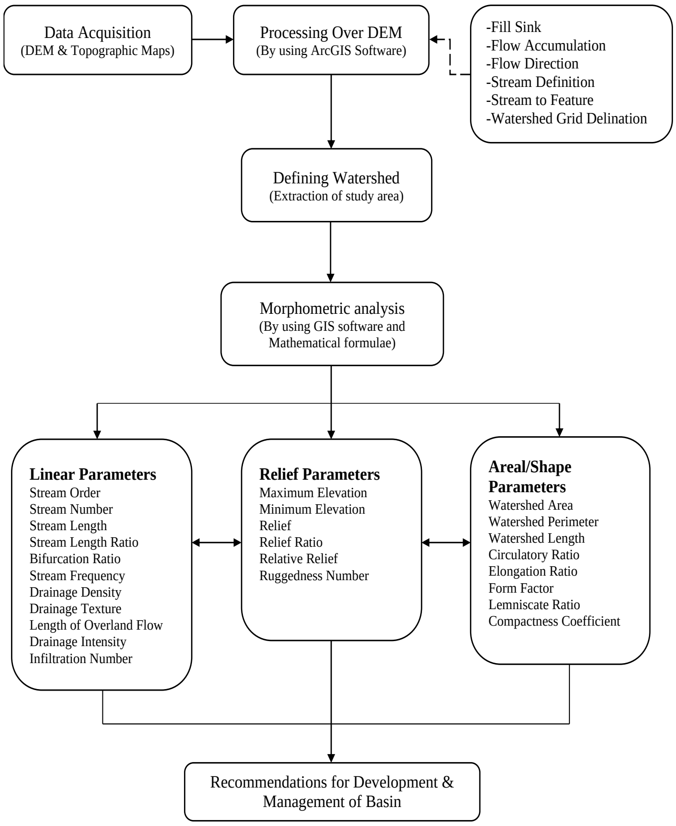

Fig - 2: Methodological flowchart for morphometric analysis

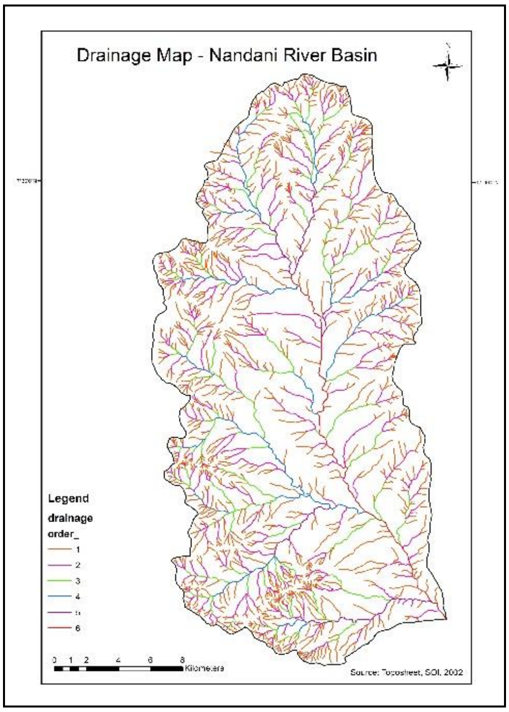

Fig - 3: Drainage Map of Study Area

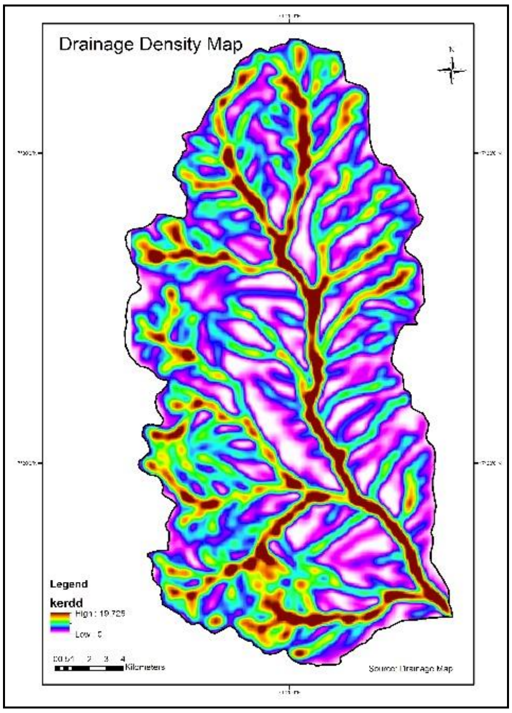

Fig - 4: Drainage Density map of study area

4. RESULTS AND DISCUSSIONS

The morphometric parameters of Nandani river basin have been examined and the results are given below (Table 2 & 3). The total drainage area of the Nandani basin is 492 km2. The drainage pattern is dendritic in nature and it is influenced by the general topography of the area.

4.1 Linear Aspects

4.1.1 Stream Order (Su)

There are four different system of ordering streams that are available (Gravelius, 1914; Horton, 1945; Strahler, 1952; Schideggar, 1970). Strahler's system, which is a slightly modified of Hortons system, has been followed because of its simplicity, where the smallest, un-branched fingertip streams are designated as 1st order, the confluence of two 1st order channels give a channels segments of 2nd order, two 2nd order streams join to form a segment of 3rd order and so on. When two channel of different order join then the higher order is maintained. The trunk stream is the highest order stream segment. It is found that Nandani river tributaries are of 7th order. In all 1655 streams were identified of which 1219 are first order, 332 are second order, 77 are third order, 18 in fourth order and 6 of the fifth order, 2 of sixth order and 1 of seventh order. Drainage patterns of stream network from the basin have been observed as mainly of dendritic type which indicates the homogeneity in texture and lack of structural control. The properties of the stream networks are very important to study basin characteristics (Strahler, 2002).

4.1.2 Stream Length (Lu)

The stream length (Lu) has been calculated on the basis of the Horton's law. Stream length is one of the most important hydrological characters of the area as it gives information about surface runoff characteristics. The river of fairly smaller length is characteristics of regions with steep slopes and better textures. Rivers having longer lengths are commonly suggestive of smoother slope. In general, the total length of river section is highest in first order stream and the length is inversely proportional to the stream order. The numbers of streams are of various orders in a watershed are counted and their lengths from mouth to drainage divide are measured with the help of GIS software. The length of first order stream is 636.012 Km, second order stream is 288.116 Km, third order stream is 159.34 Km, fourth order stream is 63.557 Km, fifth order stream 29.957 Km, sixth order stream 4.133 Km and seventh order stream is 2.779 Km. The change may indicate flowing of streams from high altitude, lithological variation and moderately steep slopes (Singh, 1997). The examination of stream order validates the Horton's law of stream number i.e. The number of the stream segments of each order forms an inverse geometric series with the order number.

Table - 1: Linear relief and areal morphometric parameters

Sr.No.	Parameters	Formulae	References
1.	Stream order (U)	Hierarchial rank	Strahler (1964)
2.	Stream length (Lu) (Km)	Length of the stream	Horton (1945)
3.	Mean stream length (Lsm) (Km)	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.	Mean stream length ratio (Rlm)	Rlm = average of stream length ratios of all order	Strahler (1964)
8.	Perimeter (P) (Km)	GIS software analysis	
9.	Length of Basin (Lb) (Km)	GIS software analysis	
10.	Area (A) (Km2)	GIS software analysis	
11.	Maximum elevation (H) (m)	GIS software analysis	
12.	Minimum elevation (h) (m)	GIS software analysis	
13.	Length Area Relation (Lar) (Km)	Lar = 1.4 x A0.6.	Nookaratnam et al. (2005)
14.	Lemniscates (K)	K = Lb2 / 4 X A	Chorely (1957)
15.	Compactness coefficient (Cc)	Cc = P/2(πA)0.5	Horton (1945)
16.	Drainage density (Dd) (Km/Km2)	Dd = Lu/A	Horton (1945)
17.	Drainage texture (T) (Km-1)	T = Dd x Fs	Smith (1950)
18.	Stream frequency (Fs) (Km-2)	Fs = Nu/A	Horton (1945)
19.	Texture Ratio (Rt)	Rt = N1 / P	Schumm (1956)
20.	Elongation ratio (Re)	$Re = Dd/L = 1.128\sqrt{A/L}$	Schumm (1956)
21.	Circularity ratio (Rc)	Rc = 4πA/P2	Strahler (1964)
22.	Form factor (Ff)	Ff = A/L2	Horton (1945)
23.	Drainage intensity (Km-1)	Di = Fs/Dd	Faniran (1968)
24.	Rho Coefficient (ρ)	ρ = Rlm/Rb	Horton (1945)
25.	Infiltration number (Km-3)	If = Fs × Dd	Faniran (1968)

26.	Length of overland flow (Km)	Lg = 1/Dd x 2	Horton (1945)
27.	Relief (R) (Km)	R = H - h	Hadley and Schumm (1961)
28.	Relief ratio	Rr = R/Lb	Schumm (1963)
29.	Relative relief	Rhp = H × 100/P	Melton (1957)
30.	Ruggedness number	Rn = R × Dd	Strahler (1952)

Table - 2 : Stream orders and numbers

Sr.No.	Parameters	Stream Orders						
		I	II	III	IV	V	VI	VII
1.	Stream order (total)	1219	332	77	18	6	2	1
2.	Stream length (Lu) (km)	636.012	288.116	159.34	63.557	29.957	4.133	2.779
3.	Mean stream length (Lsm) (km)	0.522	0.868	2.069	3.531	4.993	2.067	2.779
4.	Stream length ratio (Rl)	2.684	II/I	III/II	IV/III	V/IV	VI/V	VII/VI
			0.453	0.553	0.398	0.471	0.137	0.672
5.	Bifurcation ratio (Rb)	20.262	I/II	II/III	III/IV	IV/V	V/VI	VI/VII
			3.672	4.312	4.278	3.000	3.000	2.000

4.1.3 Mean Stream Length (Lsm)

The mean stream length is a characteristic property related to the drainage network and its associated surfaces (Strahler, 1964). The mean stream length (Lsm) has been calculated by dividing the total stream length of order by the number of stream. The mean stream length of first order stream is 0.522 Km, second order stream is 0.868 Km, third order stream is 2.069 Km, and fourth order stream is 3.531 Km, fifth order stream is 4.993 Km, sixth order stream is 2.067 Km and seventh order stream is 2.779 Km (Table 2). The mean stream length of stream increases with increase of the order of stream.

4.1.4 Stream Length Ratio (Rl)

Horton (1945, 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 (Table. 2). 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. Changes of stream length ratio from one order to the another order indicating their late youth stage of geomorphic development (Singhand Singh, 1997).

4.1.5 Bifurcation Ratio (Rb)

Bifurcation ratio (Rb) 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 (Schumn, 1956). Horton (1945) considered the bifurcation ratio as an index of relief and dissections. Strahler (1957) demonstrated that the bifurcation ratio shows a small range of variation for different regions or different environmental conditions, except where the geology dominates. It is observed that Rb is not the same from one order to its next order. In the study area mean Rb varies from 2 to 4.312; the mean Rb of the entire basin is 3.377 (Table. 2). Usually these values are common in the areas where geologic structures less disturbing the drainage pattern.

Table - 3: Results of morphometric analysis of Nandani Basin

1.	Mean stream length ratio (Rlm)	0.536
2.	Mean bifurcation ratio (Rbm)	3.377
3.	Perimeter (P) (km)	110
4.	Basin length (Lb) (km)	55.2
5.	Basin area (A) (km^2)	492
6.	Maximum elevation (H) (m)	938
7.	Minimum elevation (h) (m)	598
8.	Length Area Relation (Lar)	57.71
9.	Lemniscates (K)	1.54
10.	Compactness coefficient (Cc)	1.40
11.	Drainage density (Dd) (Km/Km2)	2.40
12.	Drainage texture (T)	8.064
13.	Drainage intensity (Km^{-1})	1.4
14.	Rho Coefficient (ρ)	0.026
15.	Infiltration number (Km^{-3})	8.064
16.	Elongation ratio (Re)	0.043
17.	Length of overland flow (Lg)	0.833
18.	Stream frequency (Fs)	3.36
19.	Texture ratio (Rt)	11.08
20.	Form factor (Ff)	0.161
21.	Circulatory ratio (Rc)	0.510
22.	Total relief (R) (Km)	0.340
23.	Relief ratio (Rr)	0.006
24.	Relative relief (Rhp)	0.852
25.	Ruggedness number (Rn)	0.816

4.2 Basin Geometry

4.2.1 Length of the Basin (Lb)

Several people defined the 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. Gregory and Walling (1973) defined the basin length as the longest length 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 any direction around the perimeter. The length of Nandani watershed in accordance with the definition of Schumm (1956) that is 55.2 Kms (Table 3).

4.2.2 Basin Area (A)

The area of the watershed is another important parameter such as length of the stream drainage. Schumm (1956) established an interesting relation between the total watershed areas and the total stream lengths, which are supported by the contributing areas in watershed. The basin area is computed by using ArcGIS-10 software, which is 492 Sq kms (Table 3).

4.2.3 Basin Perimeter (P)

Basin perimeter is the outer boundary of the watershed that enclosed its area. It is measured along the divides between watershed and may be used as an indicator of watershed size and shape. The basin perimeter is computed by using ArcGIS-10 software, which is 110 Kms (Table 3).

4.2.4 Length Area Relation (Lar)

Hack (1957) found that for a large number of basins, the stream length and basin area are related by a simple power function as follows: Lar = 1.4 x A0.6.

4.2.5 Lemniscates (k)

Chorely (1957), express the Lemniscate's value to determine the slope of the basin. In the formula k = Lb2 / 4 X A. Where, Lb is the basin length (Km) and A is the area of the basin (km2). The Lemniscates (k) value for the watershed is 1.54 which shows that the watershed occupies the maximum area in its regions of inception with large number of streams of higher order.

4.2.6 Compactness coefficient (Cc)

Compactness coefficient (Cc) is the ratio of perimeter of watershed to circumference of equivalent circular area of the watershed (Horton 1945). It is an independent of watershed size, but it depends on the slope. In the present study, value of Cc is 1.40 (Table 3). Cc is indirectly related with the elongation of the basin area. Lower values of this parameter indicate the more elongation of the basin and less erosion and vice-versa.

4.2.7 Form Factor (Ff)

According to Horton (1932), form factor is defined as the ratio of basin area to square of the basin length. The form factor value is always be less than 0.754 (for a perfectly circular watershed). The watershed will be more stretched because the value of form factor reduces. The watershed with excessive form factors have elevated crest flows of lesser period, but lengthened watershed having minimal form factor. The Nandani river basin have form factor 0.161 which is low representing the basin to be stretched out in shape and flow for longer period. Smaller the value of the form factor, more elongated will be the watershed.

4.2.8 Texture Ratio (Rt)

According to Schumm (1965), texture ratio is an important parameter in the drainage morphometric analysis of basin which is depending on the infiltration capacity, underlaying lithology and relief aspect of the terrain. The texture ratio is defined as the ratio between the first order streams and perimeter of the basin (Rt = Nl / P) and it depends on the infiltration capacity, underlaying lithology and relief aspects of the terrain. In the present study, the texture ratio of the watershed is 11.08 and categorized as moderate in nature.

4.2.9 Elongation Ratio (Re)

According to Schumm (1965, 612), elongation ratio is defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. Strahler states that this ratio lies between 0.6 and 1.0 over a wide variety of climatic and geologic types. The varying slopes of watershed area can be classified with the help of the index of elongation ratio, i.e. circular (0.9-0.10), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7), and more elongated (<0.5). The elongation ration of Nandani watershed is 0.043 which is represented the watershed is more elongated.

4.2.10 Circulatory ratio (Rc)

Circulatory ratio (Rc) is ratio of watershed area to area of a circle having the same circumference as perimeter of the watershed (Miller 1953). A circular watershed is the most susceptible to peak discharge because it will yield the shortest time of concentration. Lower, medium and higher values of Rc indicate young, mature and old stages of watershed development. Circular ratio of study area is 0.510 (Table 3). The Rc value of 0.4 and below indicates basin is elongated and values greater than 0.75 indicate circular basin. Circulatory ratio (Rc) values in between 0.4-0.75 indicate intermediate shape of basin.

4.3 Drainage Texture Analysis

4.3.1 Stream Frequency (Fs)

The drainage frequency introduced by Horton (1932, 357 and 1945, 285) means stream frequency (or channel frequency) Fs as the number of stream segments per unit area. In the present study, the stream frequency of the Nandani watershed is 3.36/km2 which lies between 2.5/km2 to 3.5/km2 which classified as moderate stream frequency. The moderate stream frequency value indicate moderate slope and moderate permeability.

4.3.2 Drainage Density (Dd)

Drainage density (Dd) is the ratio of stream length per unit area in region of watershed (Horton, 1945, 243 and 1932, 357; Strahler, 1952 and 1958; Melton, 1958) is another element of drainage analysis. Drainage density (Dd) is the expression of the closeness of spacing of channel within a basin as per Horton (1945). It is the important indicator of landform element and important parameter to determine the travel time of water in the basin. Here drainage density is calculated by using Spatial Analyst Tool in ArcGIS-10, which are 2.40 Km/Km2 indicating moderate drainage densities (Table 3). Moderate drainage density is indicative of moderate relief, moderate slope, low infiltration capacity and high water regimes throughout the basin.

4.3.3 Drainage texture (Dt)

Drainage texture (Dt) is the total number of streams per perimeter of a watershed (Horton 1945). It shows the relative spacing of drainage lines. The Dt values of < 2 indicate very coarse, 2–4 coarse, 4–6 moderate, 6–8 fine, > 8 very fine drainage texture (Smith 1950). The drainage texture of mountain–plain environment Nandani basin is 8.064, which indicates fine drainage texture (Table 3). The values indicate low infiltration capacity, less permeability of rock and high relief and sparse vegetation.

4.3.4 Constant of Channel Maintenance (1/Dd)

Schumm (1956) used the inverse of the drainage density or the constant of channel maintenance as one of the property of landforms. This constant indicates the number of Kms2 of basin surface required to develop and maintain a channel 1 Km long. The constant of channel maintenance indicates the relative size of landform units in a drainage basin and has a perticular genetic connotation (Strahler, 1957). Channel maintenance constant of the Nandani watershed is 0.416 Kms2/Km. which indicates less channel availability to drain out the excess amount of water, low infiltration capacity, moderate drainage density and mature geomorphological adjustment.

4.3.5 Drainage Intensity (Di)

Faniran (1968) defines that the drainage intensity is the ratio of the stream frequency to the drainage density. This study shows a low drainage intensity of ¬¬¬¬1.4 for the watershed. This low value of the drainage intensity concludes that drainage density and stream frequency have little effect (if any) on the extent to which the surface has been lowered by agents of denudation. With these low values of drainage density, stream frequency and drainage intensity, the surface runoff isn't removed quickly from the watershed, making it highly possible to flooding, gully erosion and landslides may takes place.

4.3.6 Rho Coefficient (ρ)

The Rho coefficient is the ratio of Mean stream length ratio to the bifurcation ratio. The Rho coefficient depends upon the climatic, geologic, biologic, geomorphologic, and anthropogenic factors. Rho values of the Nandani watershed is 0.026, (Table 3) which is very low. Lower values of Rho coefficient have lover water storage during flood periods and as such a results into the erosion effect during elevated discharge (Mesa, 2006).

4.3.7 Infiltration Number (If)

The infiltration number of a watershed is the product of drainage density and stream frequency and gives an idea about the infiltration related characteristics of the watershed. The higher the infiltration number, the lower will be the infiltration and the higher runoff. The study shows 8.064 infiltration which is high so runoff is also high. So there is a need of water retaining structure so as to overcome the runoff to help more infiltration hence groundwater table will increase.

4.3.8 Drainage Pattern (Dp)

In the watershed, the drainage pattern represents the influence of slope, lithology and structure of the basin. Finally, the study of the drainage pattern helps in identifying the stage in the cycle of erosion. Drainage pattern represents some characteristics of drainage basins through drainage intensity and drainage texture. The geology of the basin, the strike and dip of depositional rocks, the presence of faults and other geological structure details can be derived from drainage patterns. Nandani river basin has dendritic pattern. Dendritic pattern is the most common pattern formed in a drainage basin composed of fairly homogeneous rock with no or little control over the underlying geological structure.

4.3.9 Length of Overland Flow (Lg)

Horton (1945) used this term to refer to the length of the run of the rainwater on the ground surface before it is reach into definite channels. Over land area is defined as half of the reciprocal of drainage density. It is one of the most important independent variables, affecting both the hydrological and physiographical developments of the drainage basin (Horton 1945). From the morphometric analysis, the Lg value for Nandani basin is 0.833 (Table 3). This low Lg value indicates that the rainwater had to travel relatively lower distance before getting concentrated into stream channels (Chitra et al. 2011). The rainwater will enter the stream quickly.

4.4 Relief Characterizes

4.4.1 Relief Ratio (Rr)

The difference in elevation between the highest point of the watershed and the lowest point of the valley floor is known as the total relief of the river basin. The relief ratio can be defined as the ratio of the total basin relief to the longest basin dimension parallel to the main drainage line (Schumm, 1956). The probability of a close connection between the relief ratio and the hydrological characteristics of the basin suggested by Schumm, who found that sediments loose per unit area are closely associated with relief ratios. In the study area, the value of relief ratio is 0.00615 (Table 3). It has been found that areas with low to moderate relief and slope are distinguished by a moderate relief ratio. Low value of relief ratios are mainly due to the resistant basement rocks of the basin and low degree of slope.

4.4.2 Relative Relief (Rhp)

Maximum basin relief was obtained from the highest point on the perimeter of the watershed to the mouth of the stream. Using the basin relief (340m), a relief ratio was calculated as suggested by Schumm (1956), which is 0.00615 Melton's (1957) relative relief was also calculated using the formula: Rhp = (H*100) / P, where P is perimeter in meters'. This comes to 0.852 for Nandani watershed which is low and indicates flat slope.

4.4.3 Ruggedness Number (Rn)

Strahler's (1968) ruggedness number is the product of the basin relief and the drainage density and usefully combines slope steepness with its length. Calculated accordingly, the Nandani watershed has a ruggedness number of 0.816 (Table 3). The low ruggedness value of watershed implies that area is less prone to soil erosion and have intrinsic structural complexity in association with relief and drainage density.

5. CONCLUSION

The present study has proved that the Remote Sensing and GIS is an effective and reliable tool for the analysis of various morphometric parameters of the basin and helps to understand various terrain parameters. The RS data provide recent and accurate information of various landforms and update the existing data. The morphometric parameters evaluated using GIS help to understand various hydrogeological characteristics of the basin. GIS in conjunction with high resolution satellite data helps in better understanding the landforms and drainage pattern demarcations for basin planning and management The Nandani river basin is well drained in nature with stream order varying from 1 to 7. Morphometric parameters were evaluated by measurement of linear, areal and relief aspects. The bifurcation ratio and drainage density shows the normal watershed, moderate permeable soil and coarse drainage texture. The approach of this study is helpful for assessment and management of water resources too and can be applied to any drainage basin elsewhere

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