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RESEARCH ARTICLE

MORPHOMETRIC ANALYSIS OF JATAYU GANGA WATERSHED KUMAUN HIMALAYA, UTTARAKHAND USING REMOTE SENSING AND GIS TECHNIQUES

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ABSTRACT

Morphometric properties represent a measurement of earth's surface and processed according to the principles of quantitative analysis through the application of mathematics equation and statical methods to data from topographic maps and satellite. Morphometric analysis of watershed is an important aspect of watershed characterization. It usually consists of dimensional, aerial and relief aspects. Watershed development and management plans are very important for surface and ground water conservation. To prepare a watershed development plan, it becomes important to know the topography, lithology, erosional status and drainage pattern of the area. This study attempts to study the morphometric characteristics of Jatayu Ganga Watershed by using Geographical information system (GIS). The ArcGIS 10.4.1 has been accustomed to extrapolating various necessary parameters. The watershed delineated using SRTM data and on 1:50000 scale and Survey of India Toposheet as reference. In the present investigation various morphometric parameters of the Jatayu ganga watershed are outlined. Various morphometric characteristics of the Jatayu Ganga watershed have been assessed by applying GIS techniques and using SRTM data. Strahler's, Horton's and Schumm's methods have been employed to assess the fluvial characteristics of the study area. Jatayu Ganga one of the major tributaries of Saryu River flows on eastern part of Almora district, Uttarakhand that occupies an area of 78.64Km2. The river amasses the water all over from 545 Perennial and non-perennial Streams which together forms the Jatayu Ganga watershed. Total length of all tributaries is 311.26 km. This analysis has shown that the relation of stream order (U) and stream number (Nu)which gives negative linear pattern that order increases with a decreasing number of stream segment of a particular order. Different morphometric parameters such as stream length (Lu), bifurcation ratio (Rb), drainage density (D), stream frequency (Fs), texture ratio (Rt), elongation ratio (Re), circularity ratio (Rc) and form factor ratio (Rf), relief ratio (Rh) have revealed the basin has dendritic pattern of drainage, indicating high relief and steep ground slope with less elongated young and mature landforms in which geological structures don't have a dominant influence on watershed. Dendritic drainage pattern in the area shows that the area consists of homogeneous rock material, which is structurally undisturbed. The elongation and circulatory ratio reveal that the Jatayu Ganga watershed is highly elongated and flood flows are easier to manage than that of circulatory basins. The results clearly indicate relations among various morphometric attributes of the basin and help to understand their role in sculpturing the surface of the region.

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INTRODUCTION

Drainage morphometry is defined as a measurement of linear, areal and relief characteristics of any drainage basin (Clarke 1966). It is measurement and mathematical analysis of the configuration of the earth's surface, as well as the shape and dimensions of its landforms. It is the measurement of the geometry or shape of any natural form, whether it is a plant, an animal or relief features (Strahler, 1969). Drainage morphometry was first initiated by Horton (1932). The drainage morphometric characteristics are important to understanding the underlain structure, geomorphological formations and hydrological characteristics of any basin (Morisawa 1985). The relationship between drainage morphometric parameters to its underlain geology, geomorphology and hydrological characteristics is established through the work of different geologist and geomorphologist (Strahler 1952; Chorley *et al*. 1985). It also plays an important role to characterise the soil erosion, food condition and geomorphological processes (Chavare and Potdar 2014). The evolutionary history of any basin can be best understood through the implication of different relief morphometric measures of drainage basin (Sharma and Sarma 2013). Morphometry is the approximation and mathematical interpretation of the configuration of the surface, shape, dimension of its landforms. Morphometric properties represent a measurement of earth's surface and processed according to the principles of quantitative analysis through the application of mathematics equation and statical methods to data from topographic maps and satellite.

The different morphometric characteristics like linear parameters (stream order, stream number, bifurcation ratio, strength length, mean stream length), areal or basin parameters (circularity ratio, elongation ratio, drainage density, drainage frequency) and relief parameters (dissection index, ruggedness index, hypsometric characteristics) are important for any river basin management. The hydrological and morphological behavior of any basin can be best understood through the areal and relief morphometric parameters, respectively. The geomorphological stages of evolution with its erosional characteristics can also be best understood through the different drainage morphometric parameters (Strahler 1952). The study of the morphometric analysis of the watershed indicates the important factors for estimating the possible groundwater areas, controlling water supplies, conveniently identifying the place for the drainage system's water storage systems, runoff and geographic character. This analysis could also be functional in fields like regional planning, agriculture and forestry. Keeping the above in sight, it is also conducted to properly characterize watershed for its morphological properties, in order on the premise of suitable watershed management plan. Watershed development and management plans are very important for surface and ground water conservation. To prepare a watershed development plan, it becomes important to know the topography, lithology, erosional status and drainage pattern of the area. A number of morphometric studies have been carried out in different Indian watersheds and subsequently used for water resources development and management projects as well as for watershed characterization and prioritization (Chalam *et al*., 1996; Chaudhary *et al*., 1998; Srinivasan *et al*., 1999; Kumar *et al*., 2001; Ali *et al*., 2002; Singh *et al*., 2003; Pandey *et al*., 2004).

Nowadays, integration of Remote Sensing and GIS is helpful in planning and management of land and water resources for adoption of location specific technologies. A Geographic Information System (GIS) is a software-based approach for monitoring and analysing instances of earthly features. GIS technology incorporates maps with common operations like query and statistical analysis. GIS improves calculations for watershed characteristics by using Digital Elevation Models (DEMs). Remote sensing is the science of obtaining information from either a distance on objects or regions, generally from aircraft or satellites. Remote sensed imagery is incorporated within GIS. Recently several workers have used remote sensing data and GIS on morphometric parameter and have concluded that remote sensing has emerged as a powerful tool in analysing the drainage morphometry(Vittala *et al*., 2004;Sreedevi *et al*., 2005;Thomas *et al*., 2010; Ansari *et al*. ,2012; Pandey, R.K., 1990). The evaluation of the morphometric watershed model provides the valuable metrics for evaluating groundwater potential areas, defining sites for water harvesting systems, controlling water quality, runoff and drainage system geo-graphic features. In present study, Morphological characteristics of the Jatayu Ganga watershed in Almora district, Uttarakhand, were described and their inter-relationship was established.

OBJECTIVES

The prime Aim of the present study is to analyses the morphometric characteristics of Jatayu Ganga watershed with the following objectives:

- To describe and discuss quantitatively the linear, areal and relief aspect of Jatayu Ganga watershed.
- To study the relationship among the morphometric properties of watershed.
- Understanding the morphometric behaviour of the area.

METHODOLOGY

The Survey of India Toposheet numbers 53 O/14, on the scale of 1: 50,000 were used for the present study. In the study, SRTM DEM, grid resolution of 90 m was used as fundamental data source for the morphometric analysis.

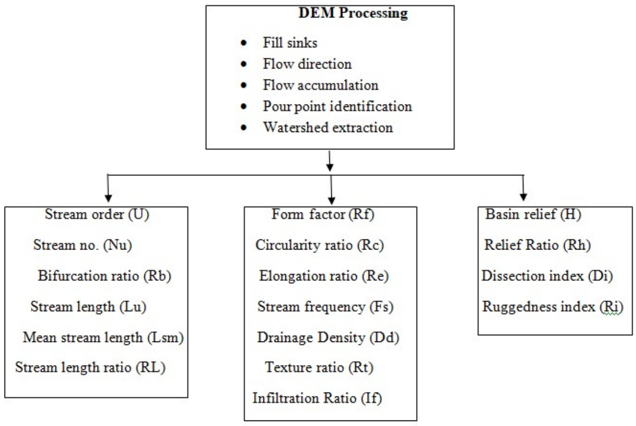


Fig. 1. Flow Chart of methodology for watershed morphometric analysis

DEM derived from SRTM data using ArcGIS software 10.4.1. The different morphometric parameters have been calculated by using following formulae with the help of GIS techniques (fig.1 and table1).

STUDY AREA

The study area viz; The Jatayu Ganga watershed (fig.1.0) is located in between 29° 34'-29°44' North latitude and 79°49'-79°58' East longitude and has a geographical area of about 78.81 km^2 in district Almora of the Uttarakhand state. It is situated at southern edge of Kumaun Lesser Himalaya Region of Central Himalaya.The whole region is mountainous with successive mountain range and river valleys.The altitude of the watershed varies in between 620 m to 2344 m above the mean sea level.The study area is bounded by Bageshwar block of district Bageshwar in the north, Gangolihat development block of district Pithoragarh in the east, Bhasiyachana development block of district Almora in the west and Pati development block of district Champawat in the south. The watershed lies 48 km east of the Almora town and 412 km from Delhi. The watershed includes area of two development blocks of i.e., Bhasiyachana and Dhauladevi have total 54 revenue villages and 27 village Panchayats (fig. 2.0). The watershed is religious and historical impression as one of the 12 jyotirlinga, viz. Jageshwar Temple lies in the watershed (fig 2.0). Jageshwar temples also referred to as Jageshwar Valley Temples, are the group of 124 ancient Hindu temples dated between 7^{th} and 14^{th} century near Almora in the Himalayan state of Uttarakhand. It is located 36km northeast of Almora town. It is Hindu pilgrimage town and one of the Dham in the Shaivism Tradition.

RESULT AND DISCUSSION

Linear Aspect: The linear aspect includes stream order, stream length, mean stream length, stream length ratio and bifurcation ratio and the results of analysis are given in Table 2 and are discussed below.

Stream Order (U): The designated stream order is the first step in the drainage basin analysis. In the present study, ranking of streams has carried out based on method proposed by Strahler (1964). After analysis of the drainage network, it was found that Jatayu ganga watershed is of 5th order and drainage pattern is dendrite (fig.3).

Stream Number (Nu): After assigning stream orders, the segments of each order are counted to get the number of segments of the given order (u). Individual counting of the streams in the watershed reveals the total number of the streams Jatayu ganga watershed has 545 streams, of which 75.22% are the first order streams having 410 segments. The second order stream segments are 102and account for 18.71%, third order stream segments are 28 and accounted 5.13%, fourth order stream segments are 4 and account for 0.73% and fifth order stream segment is 1 and account for 0.18%. (Table 2).

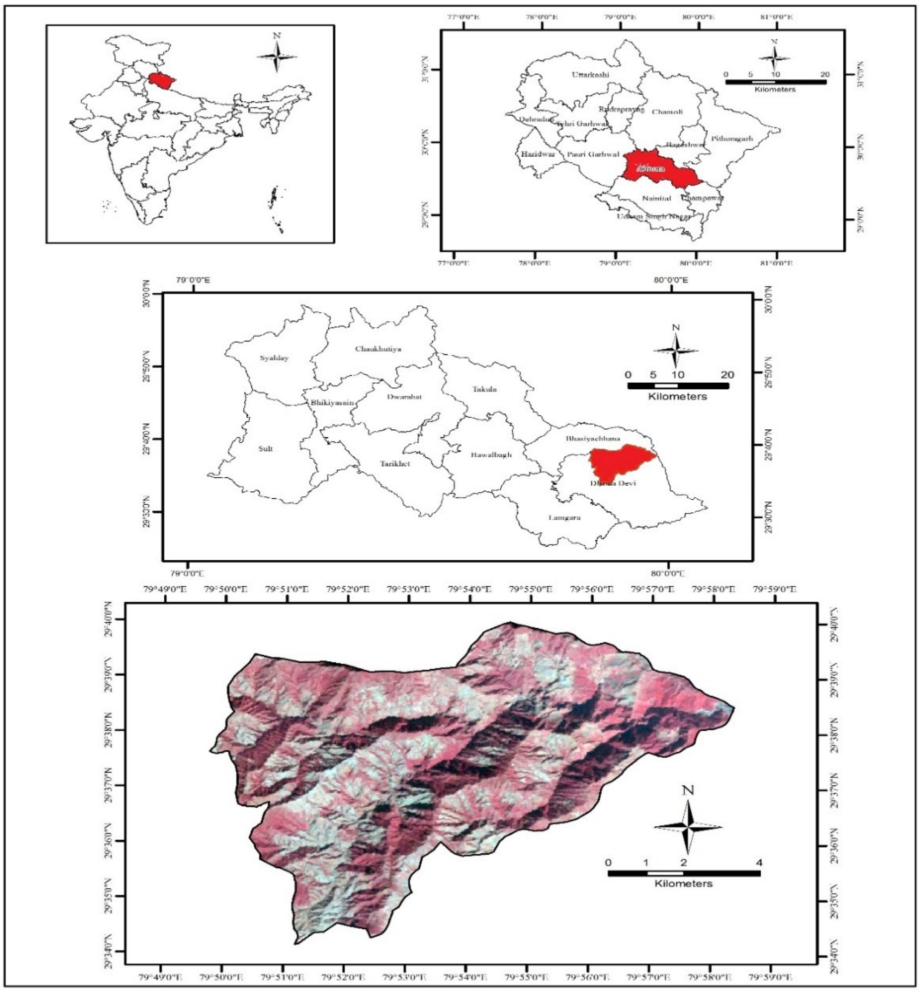


Fig. 2. Location map of the Jatayu Ganga watershed, Kumaun Himalaya, Uttarakhand

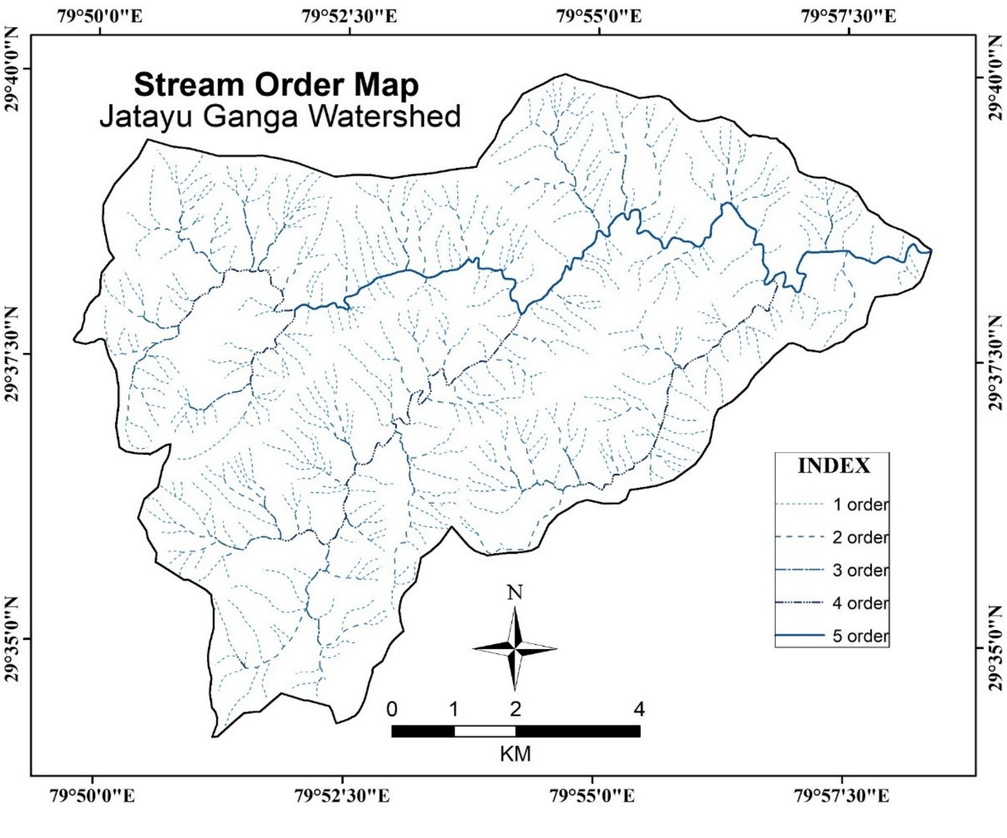
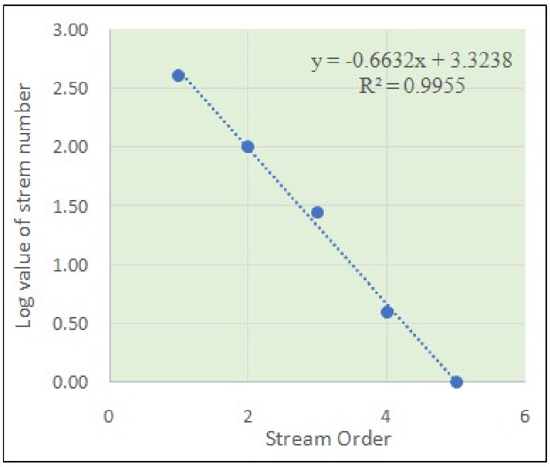


Fig 2.0. Stream ordering map of the Jatayu Ganga watershed, Kumaun Himalaya, Uttarakhand



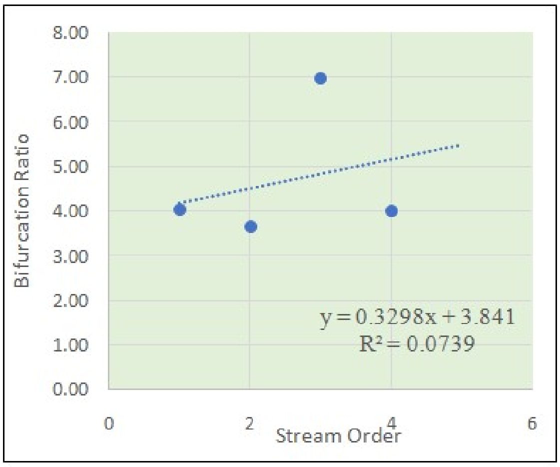


Fig 3 (A)- Relationship between stream order and number of streams in the Jatayu Ganga watershed, Kumaun Himalaya, Uttrakhand. (B) -The scatter plot of bifurcation ratio and stream order in the Jatayu Ganga watershed, Kumaun Himalaya, Uttrakhand.

Table 1.0. Methodology adopted for the computation of morphometric parameters

Morphometric aspects	Parameters	Formulae	References
Linear aspect	Stream order (U)	Hierarchical rank	Strahler (1964)
	Stream no. (Nu)	Nu=number of streams of a particular order 'u'	Strahler (1964
	Bifurcation ratio (Rb)	Rb=(Nu/Nu+1), Where, Nu=Number of stream segments, present in the given order, Nu+1= Number of segments of the next higher order.	Horton (1945)
	Stream length (Lu)	Lu=total length of streams (km) of a particular order 'u'	Horton (1945)
	Mean stream length (Lsm)	Lsm = Lu/Nu; where, Lu=total length of streams (km) of a particular order 'u', Nu=Total number of streams of a particular order 'u'	Horton (1945)
	Stream length ratio (RL)	RL= Lu / Lu-1 Where, Lu= Total stream length of order (u), Lu1=The total stream length of its next lower order	Horton (1945)
Areal aspect	Form factor (Rf)	Rf =A/(Lb)² Where, A=Area of basin, Lb=Basin length	Horton (1932)
	Circularity ratio (Rc)	Rc = 4πA/P²Where A= Area of basin, π=3.14, P= Perimeter of basin.	Miller,1953
	Elongation ratio (Re)	Re=√(Au/π)/ Lb Where, A=Area of basin, π=3.14, Lb=Basin length	Strahler (1964)
	Stream frequency (Fs)	Fs= N/A; where, N =total number of streams of a given basin, A =total area of basin (km2)	Horton (1945)
	Drainage Density (Dd)	Dd=L/A; where, L =length of streams (km), A =Basin area (km2)	Horton (1945)
	Texture Ratio (Rt)	Rt= ∑Nu / P, Where, Rt is the texture Ratio ∑Nu is the total number of streams of the catchment and P is the perimeter of the catchment.	Horton (1945)
	Infiltration Ratio (If)	If= Rt * Fs, Where Rt = Drainage Texture, Fs = Stream Frequency	Zavoiance (1985)
Relief Aspect	Basin relief (H)	H = Z - z where, Z =highest relief, z =lowest relief	Schumm (1956)
	Relief Ratio (Rh)	Rh = H / Lb Where, Bh=Basin relief, Lb=Basin length	Schumm, (1954)
	Dissection index (Di)	Di= H/R; H =relative relief (m), R =absolute relief (m)	DovNir(1957)

Table 2.0 Linear morphometric aspects of river basins

Morphometric Parameters	Jatayu Ganga Watershed				
Stream order (U)	I	II	III	IV	V
Total Streams number (Nu)	410	102	28	4	1
Bifurcation Ratio (Rb)	4.02	3.64	7.00	4.00	-
Total Streams Length (Lu)	206.86	49.35	19.77	18.37	16.91
Mean stream length (Lum)	0.50	0.48	0.71	4.59	16.91
Stream Length Ratio (Rl)	-	0.96	1.47	6.4	3.68

Table 3.0. Areal morphometric aspects of river basins

Area (km2)	78.64
Perimeter (kilometre)	44.05
Basin length (kilometre)	14.02
Drainage density (per square kilometre)	3.96
Stream frequency	6.93
Drainage texture	12.37
Elongation ratio	0.71
Circularity ratio	0.51
Form factor ratio	0.40
Infiltration Ratio	27.43

R.E. Horton prepared the low of stream number in 1932. According to him the number of stream segments in each order forms an inverse geometric sequence with the stream order number. The given statement regarding the Jatayu Ganga watershed is plotted in a semilogarithmic graph between log value of stream number and stream order number (fig4, A). The relationship between stream order and stream number in the study area comprises Horton's low of stream number (fig 4, A). The fig.4, (A) reveals that there is negative correlation (r2 = -0.09955) between stream order and stream number.

Bifurcation Ratio (Rb): The bifurcation ratio computed for different order streams of the study area are presented in table 2.0 and are diagrammatically illustration in figure 4 (B). The bifurcations ratio in the study area of the first, second, third and fourth order stream stand at 4.02, 3.64, 7.00 and 4.00 (Table-2). Figure 4 (B) illustrates that the relationship between stream order and bifurcation ratio is constant (r2 =0.0739). The bifurcation ratios in the study area are moderate except 3rd order stream. The higher values of bifurcation ratio show strong structural control in the drainage pattern whereas the lower values indicate that the watersheds are less affected by structural disturbances (Strahler, 1964; Vittala *et al*., 2004).

Stream Length (Lu): The stream length (Lu) was measured using topographic data and Arc GIS 10.4 software. The total stream length in the study area stands at 311.26 km. The total stream length of the first, second, third, fourth and fifth order streams stand at 206.86 km, 49.35 km, 19.77 km, 18.37 km and 16.91 km respectively (Table-2).

Mean stream Length (Lsm): Mean Stream Length (L) is a parameter associated with drainage network components and their associated basin surface (Strahler 1964). This has been calculated by dividing the total stream length of order by the number of streams of segment in the order. The mean stream length of the first, second, third, fourth and fifth order streams in the watershed stands at 0.50km, 0.58 km, 0.71km, 4.59 km and 16.91 km (Table-2).

Stream Length Ratio (RL): The stream length ratio of the study area is presented in table-2.0 which reveals that the stream length ratio of the second, third, fourth and fifth order streams stand at 0.96, 1.47, 6.4 and 3.68 respectively.

Areal Aspect: The areal aspect includes Basin Area, Drainage density, Stream frequency, Drainage texture, Form factor ratio, Circularity ratio, Elongation ratio, Infiltration Ratio and the results of analysis are given in Table 3 and are discussed below.

Basin Area: Basin area is the direct outcome of the drainage development in a particular basin. The area of Jatayu Ganga watershedis about 78.64 sq. km.

Perimeter (P) and Basin length (L): The perimeter and basin length of the Jatayu Ganga watershed was found to be 44.05 km and 14.02 km, respectively (Table 3).

Form factor (Rf): Quantitative expression of drainage basin outline form was made by Horton (1932) through a form factor, which is the dimensionless ratio of basin area to the square of basin length. Mathematical representations of form factor are below:

$F= A/L^2$

Where, F = form factor, A = basin Area, L = basin length

The value of the form factor varies between o (zero) to 1(one). The value of zero is indicated highly elongated shape and one indicated perfect circular shape. Table 3 shows a form factor of Jatayu Ganga Watershed. The form factor value of the entire Jatayu Ganga catchment is 0.40, which indicate lower value of form factor and thus represents elongated in shape (Reddy *et al*., 2004; Prasanna Kumar *et al*., 2011). The elongated basin with low form factor indicates that the basin will have a flatter peak of flow for longer duration. Flood flows of such elongated basins are easier to manage than of the circular basin.

Circularity ratio (Rc): To measure the shape or outline from of a drainage basin Miller (1953) has used a parameter known as basin circulatory ratio. It is the ratio of the drainage basin area of a circle with that of the basin perimeter. The basin's relief and slope, drainage density and frequency, lithology, land use/land cover and meteorological all influence the circularity ratio (Rc) (Ahmed *et al*., 2010). Basin circularity ratio is calculated with the help of following formula (Miller, 1953).

$Cr = 4\ \pi Ab/P^2$

Where Rc is basin circularity ratio, Ab is the area of the basin, Bp is perimeter of the basin. When the basin circularity ratio is equal to unity, it indicates a perfect circular basin. This ratio can be unity or less than one but never exceed one. Following above formula, the circularity ratio of the Jatayu Ganga watershed stands at 0.51.

Elongation ratio (Re): Drainage basin shape can be expressed also by an elongation ratio (Re), which is the "ratio between the diameter of a circle with the same area as the basin and maximum length of the basin as measured for the relief ratio". Schumm (1956). According to Strahler's the mathematical representation of the elongation ration (Re) is given bellow:

$Re=\sqrt{(Au/\pi)}/ Lb$

Where, A=Area of basin, π=3.14, Lb=Basin length

The value of Re varies from 0 to 1. The value of the 0 is show highly elongated shape and 1 is circular shape. The Re of the Jatayu Ganga (0.71) indicates that the basin is Less elongation in shape.

Stream frequency (Fs): The total number of streams per unit area has been defined as stream frequency (Horton, 1932, 1945). The phrase "Stream Frequency" some term also known as "Channel Frequency" was coined by Horton (1932). The stream Frequency is related with permeability, infiltration capacity and relief of a basin (Vijith& Sateesh 2006). Stream Frequency refers to the total number of stream segments of all orders per unit area. The following formula was used to calculate the stream frequency of the study area (Horton, 1945).

$Fs=\sum Nu/Ab$

Where, Sf= Stream frequency, ∑Nu= total number of stream segments of all orders, Ab=area of the unit. Following above formula, the average drainage frequency of the area stands at 6.93 N/ km2 which indicate high stream frequency. High drainage stream frequency in the watershed indicates larger runoff from the basin.

Drainage Density (Dd): The drainage density is a measure used in drainage systems to define the degree of fineness or coarseness of the drainage pattern (Strahler, 1963). The drainage density can be defined as the total stream length per unit area or as the total channel length divided by the area of the basin. Total stream length per unit drainage area is expressed by drainage density (Dd). The drainage density is generally determined by the stage of evolution. It develops significantly as the area progress from youth to maturity, but it decreases as the area get older. Drainage density was defined by R.E. Horton in 1945 as the ratio of the total length of all stream segments in a drainage catchment to the entire area of that catchment and it can be calculated as follows:

$Dd = \sum Lu / Ab$

Where, Dd = drainage density, ∑Lu = total length of all stream segment of the catchment, Ab = total area of the catchment. Using above formula, the drainage density of the area stands at 3.96 km/ km^2which shows low drainage density. It indicates region having highly resistant rock or highly permeable subsoil material and area with low relief.

Texture Ratio (Rt): To measure the relative spacing between stream lines of a drainage basin Horton (1945) has used a parameter known as drainage texture (Dt). The drainage texture is defined as the ratio of the basin's perimeter to the total number of streams in the catchment. Drainage texture is calculated with the help of following formula (Horton, 1945).

$Rt= \sum Nu / P$

Where, Rt is the texture Ratio, ∑Nu is the total number of streams of the catchment and P is the perimeter of the catchment. Smith (1950) has classified drainage density into five different textures i.e., very coarse (<2), Coarse (2-4), moderate (4-6), fine (6-8) and very fine (>8). In the present study texture ratio of the Jatayu Ganga is 12.37, which indicate very fine texture and area under high relief and steep slopes.

Infiltration Ratio (If): The product of drainage density and stream frequency per unit basin area is the infiltration number (If). The infiltration number of the Jatayu Ganga catchment was calculated using the following formula:

$If= Dd * Fs$

Where, If is the infiltration ratio, Dd is the Drainage density and Fs is the Drainage frequency. It gives an idea of the basin's infiltration characteristics. Low infiltration and high runoff are indicated by a greater Infiltration value and vice versa. Following above formula, the infiltration ratio of the Jatayu Ganga watershed stands at 27.43.

Relief Aspect

Basin relief (Bh): The basin relief (Bh) is defined as the difference in elevation between the highest and the lowest points on the valley floor of a basin. Relief is measured by subtracting the elevation of the mouth of the basin from the highest point within the basin. It is an important factor in understanding the denudational characteristics of the basin and plays a significant role in landform development, drainage development, surface and sub surface water flow, permeability, and erosional properties of the terrain. In the study, Bh is obtained as 1724.

Relief Ratio (Rh): Relief ratio is defined as the ratio between the total relief of a basin i.e., elevation difference of lowest and highest points of a basin, and the longest dimension of the basin parallel to the principal drainage line (Schumm, 1954). It is a dimensionless ratio. The value of Rh in the basin is 122.96 indicating moderate relative relief. The high values of Rh indicate steep slope and high relief and vice-versa. Run-off is generally faster in steeper basins, producing more peaked basin discharges and greater erosive power (Palaka & Sankar, 2016).

Dissection index (Di): Dissection index, expressing a ratio of the maximum relative relief to the maximum absolute relief, is an important morphometric indicator of the nature and magnitude of dissection of terrain. According to Nir (1957), the dissection index is a ratio of relative relief to absolute relief. He suggested the following formula for the derivation of dissection index as follows;

$DI = RR / AR$

Where RR is relative relief and AR is absolute relief, The dissection index is calculated using the relative and absolute relief of the Jatayu Ganga catchment. The dissection index of the study area stands at 0.30 which shows mature stage of cycle of erosion according to Nir (1957).

Conclusion

The morphometric study of Jatayu Ganga Riverindicates that the watershed is fifth order basin and is passing through an early mature stage to old stage of the fluvial geomorphic cycle. The basin shows dendritic type drainage pattern. Mean length of channel segments of a given order is greater than that of the next lower order but less than that of the next higher order. The logarithm of stream length of each order as a function of order is plotted and relation between stream order and mean stream length, yields a set of points lying generally along a straight line, that indicates no strong structural control in the area. The average bifurcation ratio of the basin reveals that there appears to be no strong geological control in the development of the drainage, homogeneous nature of lithology and drainage network in study area is well developed stage. The northern upper part of the basin is under high relief which shows steep slopes with high drainage density, high stream frequency and less permeable subsurface lithology. The elongation ratio, circulatory ratio and form factor reveals that the Jatayu Ganga watershed is highly elongated and flood flows are easier to manage than that of circulatory basins. The study also reveals that the texture of the watershed very fine and basin is highly elongated. The drainage basin size analysis reveals that the flooding is lesser.

REFERENCES

Agarwal, R.P. andBho, R. (1992): Evolution of Kosi River fan, India; structural implications and geomorphic significance. International Journal Remote Sensing, Vol.13(10), pp.1891–1901.

Ahmed, S. A., Chandrashekar Appa, K. N., Raj, S. K., Nischitha, V. and Kavitha, G. (2010): Evaluation of morphometric parameters derived from ASTER and SRTM DEM –A study on Bandihole sub watershed basin in Karnataka, Journal of the Indian Society Remote Sensing, Vol. 38, pp. 227–238.

Ali, S. and Singh, R. (2002): Morphological and Hydrological investigation in Hirakund catchment for watershed management planning, Journal of Soil and Water Conservation (India), Vol.1(4), pp 246-256.

Ansari, Z.R., Rao, L.A., Yusuf, A. (2012): GIS based morphometric analysis of yamuna drainage network in parts of Fatehabad area of Agra District, Uttar Pradesh. Journal of Geological Society India, Vol. 79, Pp.505–514.

Chalam, B.N.S., Krishnaveni, M. and Karmegam, M. (1996): Correlation of runoff with geomorphic parameters, Journal of Applied Hydrology, Vol. 9(3-4), pp. 24-31.

Chaudhary, R. S. and Sharma, P. D. (1998): Erosion hazard assessment and treatment

prioritization of Giri river catchment, North Western Himalaya, Indian Journal of Soil

Conservation, Vol.26 (1), pp. 6-11.

Chavare, S. and Potdar, M. (2014): Drainage morphometry of Yerla River Basin using geoinformatics techniques, Neo Geography, Vol. 3(3), pp.40–45.

Chorley, R.J., Schumm, S.A. and Sugden, D.E. (1985): Geomorphology, Methuen and Co., Ltd., London.

Clarke, J. I. (1966): Morphometry from maps, In Essays in Geomorphology (edited by G.H. Dury), Heinmann, London, pp. 235- 274.

Horton, R.E. (1932): Drainage Basin Characteristics, Transactions of American Geophysics, Union, Vol.13, pp. 350-361.

Horton, R.E. (1945): Erosional development of streams and their drainage basins: hydro physical approach to quantitative morphology, Bull Geol Soc Am, Vol. 56(3), pp. 275–370

Kumar, R., Lohani, A. K., Kumar, S., Chatterjee, C.and Nema, R. K. (2001): GIS based morphometric analysis of Ajay River basin uptoSarth gauging site of South Bihar, Journal of Applied Hydrology, Vol.15(4), pp 45-54.

Miller, V.C. (1953): A quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain area, Virginia and Tennessee, Columbia University, New York, Vol.3.

Morisawa, M. (1985): Rivers-forms and process. Longman Group, London.

Nir, D. (1957): The ratio of relative and absolute altitude of Mount Carmel, Bulletin of the Geological Society America, Vol. 56, pp. 564-569.

Palaka, R., & Sankar, G. J. (2016). Study of watershed characteristics using Google

Elevation ServicePande, R.K. (1990): Quantitative Geomorphology of a Himalayan Drainage Basin, 1990, Almora (Uttarakhand).

Pandey, A., Chowdary, V.M. and Mal, B. C. (2004): Morphological analysis and watershed management using GIS, Hydrology Journal, Vol.27(3-4), pp 71-84.

Prasannakumar, V., Vijith, H. and Geetha, N. (2011): Terrain evaluation through the assessment of geomorphometric parameters using DEM and GIS: case study of two major sub-watersheds in Attapady, South India, Arabian Journal of Geoscience, doi:10.1007/s12517-011-0408-2.

Reddy, G. P. O., Maji, A. K. and Gajbhiye, K. S. (2004): Drainage morphometry and its influence on landform characteristics in a basaltic terrain, Central India, a remote sensing and GIS approach, Inter J Applied Earth Observation Geoinformatics, Vol. 6, pp. 1–16.

Schumm, S. A. (1954): The relation of drainage basin relief to sediment loss, Pub. International Association of Hydrology, IUGG, Tenth Gen. Assembly, Rome, 1, 1954, 216-219.

Schumm, S.A. (1956): The evolution of drainage system and slopes in Badlands at Perth Amboy, New Jersey. Bull Geol Soc Am, Vol. 67, pp. 214–236.

Sharma, S. and Sharma, J.N. (2013): Drainage analysis in a part of the Brahmaputra Valley in Sivasagar District, Assam, India, to detect the role of nontectonic activity. J Ind Soc Rem Sens, Vol. 41(4), pp. 895–904.

Singh, R. K., Bhatt, C. M. and Prasad, V. H. (2003): Morphological Study of a watershed using remote sensing and GIS techniques, Hydrology Journal Indian association of hydrologists, Vol. 26(1-2), pp 55-66.

Smith, K. G. (1950): Standards for grading textures of erosional topography, American Journal of Science, Vol. 248(9), pp 655-668.

Sreedevi, P.D., Subrahmanyam, K. and Ahmed, S. (2005): The significance of morphometric analysis for obtaining groundwater potential zones in a structurally controlled terrain. Environ Geol,Vol.47(3), pp. 412–420.

Srinavasan, P. R. and Subramanian, V. (1999): Ground water targeting through morphometric analysis in Mamundiyar river basin, Tamilnadu, The Deccan Geographer, Vol. 37 (1), pp 22-30.

Strahler, A.N. (1952): Hypsometric analysis (area-altitude) of erosional topography. Geological Soc Am Bull, Vol. 63, pp. 117–142.

Strahler, A.N. (1964): Quantitative Geomorphology of Drainage basins and Channel Networks, Handbook of applied hydrology, (McGraw- Hill Book Cooperation, New York. 1964, pp. 4-76.

Strahler, A.N. (1963): The earth Sciences, New York, p-507.

Strahler, A. N. (1969): Physical Geography, third edition, John Willey and Sons, Inc. New York.

Thomas, J., Joseph, S. and Thrivikramaji, K.P. (2010): Morphometric aspects of a small tropical mountain river system, the southern Western Ghats, India. Int J Digit Earth, Vol. 3(2), pp. 135–156.

Vijith, H. and Sateesh, R. (2006): GIS based morphometric analysis of two major upland sub-watershed of Meenachil river in Kerala, Journal of the Indian Society Remote Sensing, Vol. 34, No. 2, pp. 181-185.

Vittala, S.S., Govindaiah, S. and Gowda, H.H. (2004): Morphometric analysis of sub-watersheds in the Pavagada area of Tumkur District, South India using remote sensing and GIS techniques. J Ind Soc Remote Sens, Vol. 32(4), pp.351–362.

Zävoiance, I., (1985): Developments in water science, Elsevier, Chapter XI Hypsometric Curves and Longitudinal Stream Profiles, Vol.20, pp.185-200.

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