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Periodic Research

Morphometric Analysis of River Beas Watershed, Himachal Pardesh

Abstract

The focus of the present study is to analyse the base river basin morphometrically. The study has been conducted using remote sensing and GIS. Demarcation, watershed and other parameters required for this study are extracted from Cartosat DEM. Geospatial technology has proved itself as an efficient tool in the analysis of morphometric parameters of a watershed. The parameters of the study for Beas basin like linear and aerial aspects of the river basin were determined and computed. This river performs 5th order drainage basin and drainage pattern mainly in sub-dendritic to sub-trellis type with coarse drainage texture. The basin has high bifurcation ratio which indicates its strong structural control on the drainage. It is also observed that the drainage density value is low which indicates the basin is highly resistant subsoil material. The circularity ratio value reveals that the basin is strongly elongated. This study (would be helpful for the administration to) help the administration to utilize the watershed for sustainable development of the basin area.

Keyword: Morphometric Analysis, River Beas, remote sensing, GIS

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Introduction

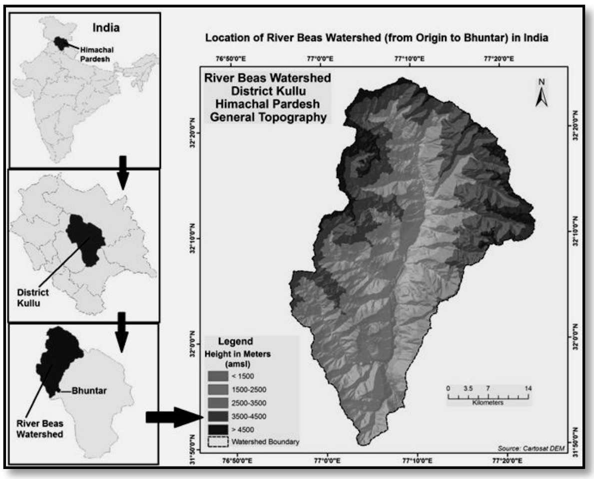
The drainage system and river pattern is highly influenced by geomorphology, geology, structural components, soil, and vegetation of the area form where the river passes (Rekha et al. 2011). These hydrologic systems can be better understood by studying these parameters. A drainage basin which is considered as the basic units of water supply brings surface run-off to a well defined stream or river at a point. Its size varies from few hectares to thousands of km² (Chopra et al. 2005). Morphometric analysis plays a crucial role in understanding a particular drainage basin. This is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimensions of its landforms which provides quantitative description of the basin geometry to evaluate initial slope or inequalities in the recent diastrophism, rock hardness, structural controls, geomorphic and geological history of drainage basin (Strahler 1964; Clarke 1966).

Geographical Information System (GIS) and remote sensing techniques are widely(extensively) used for the investigation of various morphometric and terrain parameters of the watersheds and drainage basins as they provide a digital environment (which is powerful)and a powerful tool for handling and analysis of the geographical information for better understanding (Vijith 2006). Several scientists like Horton (1945) ; Smith (1950) ; Strahler (1957) ; Krishnamurthy and Srinivas (1995) ; Srivastava and Mitra (1995) ; Agarwal (1998) ; Biswas et al. (1999) ; Narendra and Nageswara Rao (2006), Brar (2014) etc. have conducted morphometric analysis using conventional as well as remote sensing and GIS methods. In the present study, morphometric analysis has been carried out in Beas river watershed (Himachal Pardesh), which is a major river of Indo-Gangetic river system.

Study Area

River Beas from its origin to Bhutar is chosen for the analysis of morphometric analysis. It is an important river of Indus river system, which originates from Beas Kund in Kullu district of Himachal Pardesh. It flows from north to south direction. After a journey of about 70 kilometer, River Parbati joins it at the place of Bhuntar. The river is fed by several Himalayan glaciers. River Beas's watershed has an area of 1416.7 km² and its areal extent is 31°50'08"N to 32°25'02"N latitudes and 76°56'02" E to 77°23'45"E longitudes. The study area is characterized by undulating mountainous topography and steep slopes. Mountains are generally composed of metamorphic rocks.

Map 1: Location Map of River Beas Catchment



Materials and Methods

The delineation of River Beas watershed and drainage network is done from Catrosat DEM using ArcGIS 9.3 software. Morphometric analysis has been carried out of the following parameters: stream order(U), stream length(Lu), mean stream length (Lsm), stream length ratio (RL), bifurcation ratio (Rb), mean bifurcation ratio (Rbm), relief ratio (Rh), drainage density (Dd), stream frequency (Fs), drainage texture (Rt), form factor (Rf), circulatory Ratio (Rc), elongation ratio (Re) and length of overland flow(Lg). The methodology for the calculation of above mentioned parameters is given in Table

Table 1: Morphometric parameters with formula

Morphometric Parameters	Formula	Reference
Stream Order (U)	Hierarchical Rank	Strahler (1964)
Stream Length (Lu)	Length of Stream	Horton (1945)
Mean Stream Length (Lsm)	Lsm= Lu/Nu Where, Lsm = Mean Stream Length Lu = Total stream length of order 'u' Nu= Total no. of stream segments of order 'u'	Strahler (1964)
Stream Length Ratio (RL)	RL= lu/Lu-1 Where, RL = Stream Length Ratio Lu = The total stream length of order 'u' Lu-1= The total stream length of its next lower order	Horton (1945)
Bifurcation Ratio (Rb)	Rb= Nu/Nu+1 Where, Rb = Bifucation Ratio Nu = Total no. of stream segments of order 'u' Nu+l= Number of segments of the next higher order	Schumm (1956)
Mean Bifurcation Ratio (Rbm)	Rbm= average bifurcation ration of all orders	Strahler (1957)
Relief Ratio (Rh)	Rh= H/Lb Where, Rh=Relief Ratio H=Total relief (Relative relief) of the basin in Kilometer Lb= Basin length	Schumm (1956)
Drainage Density (Dd)	Dd=Lu/A Where, Dd=Drainage Density Lu=Total stream length of all orders A= Area of the Basin (km 2)	Horton (1932)
Stream Frequency (Fs)	Fs= Nu/A Where, Fs=Stream Frequency Nu=Total no. of streams of all orders A= Area of the Basin (km^2)	Horton (1932)
Drainage Texture (Rt)	Rt= Nu/P Where, Rt = Drainage Texture Nu=Total no. of streams of all orders P=Perimeter (km)	Horton (1945)
Form Factor (Rf)	Rg= A/Lb^2 Where, Rf=Form Factor A=Area of the Basin (km 2) Lb^2=Square of Basin length	Horton (1932)
Circularity Ratio (Rc)	Rc= $4 \times \pi \times A/P^2$ Where, Rc=Circularity Ratio π = 3.14 A=Area of the Basin (km 2) P = Perimeter (km)	Miller (1953)
Elongation Ratio (Re)	Re= $2(\sqrt{A/\pi})/Lb$ Where, Re= Elongation Ratio π = 3.14 Lb=Basin Length	Schumm (1956)
Length of Overland Flow (Lg)	Lg= ½*D Where, Lg=Length of overland flow D=Drainage Density	Horton (1945)

Results and Discussion

The various morphometric parameters of the River Beas watershed area were determined and are summarized in Tables 2 and 2(a).

Table 2

Results of Morphometric Analysis

Parameter	Results
Basin Area (KM²)	1416.7
Perimeter (KM)	202.2
Basin Order	5
Basin Length (Lb)	68.17 KM
Basin Relief (M)	4885
Relief Ratio (Rh)	0.072
Mean Bifurcation Ration (Rbm)	4.503
Drainage Density (Dd)	0.62
Stream Frequency (Fs)	0.352
Drainage Texture (Rt)	2.46
Circularity Ratio (Rc)	0.44
Length of Overland Flow	0.801
Form Factor (Rf)	0.305
Elongation Ratio	0.62

Table 2(a)

Results of Morphometric Analysis

Stream Order (U)	Stream Number (Nu)	Bifurcation Ratio (Rb)		Stream Length (Lu) (KM)	Mean Stream Length (Lsm)	Stream Length Ratio (RL)	
1	396	I/II	5.08	447.674	1.130	II/I	0.458
2	78	II/III	4.33	205.149	2.630	III/II	0.642
3	18	III/IV	3.60	131.725	7.318	IV/III	0.356
4	5	IV/V	5.0	46.944	9.389	V/IV	1.121
5	1			52.638	52.638		

Stream Order (U)

First step to analyze drainage basin is designation of stream into various orders based on hierarchical ranking. In the present study, a method suggested by Strahler (1964) is adopted for stream ordering. The number of streams in each order and their length is given Table 2(a). The River Beas watershed is designated as 5th order watershed having a total number of 498 streams of different orders (Map 2).

Stream Length (Lu)

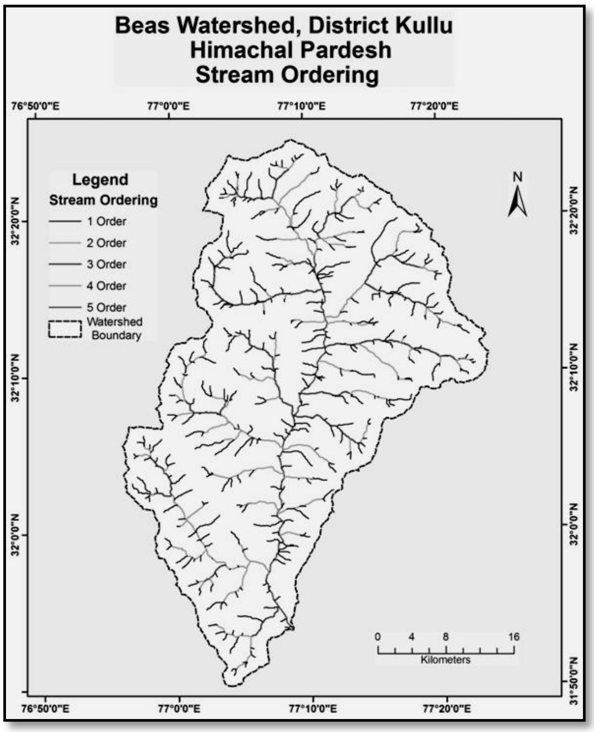
Total stream length in a particular order is represented by stream length (Lu). The numbers of streams of all six orders in the watershed are counted and their length is measured with the help of ArcGIS 9.3 and shown in table 2(a). In general, the length of streams decreases as the stream orders increase. In River Beas watershed, the length of streams from 1st order to 5th decreases except 4th order which is against the general behavior and indicates that the terrain is characterized by high relief/moderately steep slopes, underlain by varying lithology and there is probability of upliftment across the basin.

Mean Stream Length (Lsm)

The mean stream length (Lsm) is calculated by dividing the total stream length of order 'u' and number of streams of segment of order 'u' (Table 1). It is a characteristic property related to the drainage network and its associated surfaces of the watershed. From the table 2(a), it can be noted that the mean stream length varies from 1.13 KM to 52.64 KM. In River Beas watershed, as the stream order increases mean stream length also increases. This might be changes in slope and topography of the watershed.

Map 2

Different Stream Orders in River Beas Watershed



Stream Length Ratio (RL)

The stream length ratio (RL) is the ratio of the mean stream length (Lsm) of a given order to the mean stream length (Lsm) of next lower order. According to Horton's law of stream length (1945), the mean stream length segments of each of the successive orders a basin tends to approximate a direct geometric series with streams length increasing towards higher order of streams. The stream length ratio between successive streams orders depends on slope and topographic conditions and it has an important relationship with the surface flow discharge and erosional stage of the basin. In River Beas watershed it varies from 0.36 to 1.12 (Table 2(a)).

Bifurcation Ratio (Rb)

The bifurcation ratio is the ratio of the number of stream segments of given order to the number of segments of next higher order (Schumn, 1956). Horton (1945) considered it as an index of relief and dissection. Bifurcation ratio shows only a small variation for different regions on different environment except where powerful geological control dominates (Strahler 1957). The value of bifurcation ratio for River Beas watershed varies from 3.6 to 5.08 (Table 2(a)).

Mean Bifurcation Ratio (Rbm)

Mean bifurcation ratio (Rbm) was suggested by Strahler in 1957. It is the average of bifurcation ratios of all orders used to investigate the influence of structural control in the development of drainage system. In the study area, mean bifurcation ratio of 4.50 indicates that there is strong structural control over the drainage development (Table 2).

Relief Ratio (Rh)

The difference in the elevation of the highest and lowest points in a watershed is its total relief, whereas the ratio of basin relief to basin length (horizontal distance along the longest dimension of the basin parallel to the principal drainage line) is Relief Ratio (Rh) (Schunm, 1956). It is used to measure the overall steepness of a river basin and is an indicator of intensity of erosion processes operating on the slopes of the basin. Normally, it has inverse correlation with drainage area and size of drainage basin. For the present study, it is 0.07 (Table 2).

Drainage density (Dd)

According to the drainage density (Dd) is defined as the total length of streams per unit area divided by the area of drainage basin (Horton 1945). It is helpful in determining the permeability and porosity of the watershed. It is also a good indicator of landform elements in stream eroded topography. Low drainage density leads to coarse drainage texture and vice versa. Generally, low drainage density results in the area of highly resistant subsoil material and high drainage density is the resultant of weak subsurface material. In River Beas watershed with drainage density value of 0.62, confirms

the recognition the basin is highly resistant subsoil material and hilly relief.

Stream Frequency (Fs)

The stream frequency is the total number of stream segment of all order per unit area (Horton 1945). The stream frequency of study area is 0.352 per square km.

Drainage Texture (Rt)

Horton (1945) defined drainage texture as the total number of stream segments of all order in a river basin to the perimeter of the basin. It is important to understand geomorphology which means that the relative spacing of drainage lines. Drainage texture can be classified into 5 different textures i.e., very coarse (<2), coarse (2 to 4), moderate (4 to 6), fine (6 to 8) and very fine (>8) (Smith 1950). In the present study the watershed has a drainage texture of 2.5.

Form Factor (Rf)

Form factor is the numerical index which is commonly used to represent different basin shapes (Horton 1932). Its value is varies between 0.1-0.8. Smaller the value of form factor, more elongated will be the basin. A perfect circular basin has a form factor of 0.7854. The basins with high form factors have high peak flows of shorter duration, whereas, elongated watershed with low form factors have lower peak flow of longer duration. In River Beas watershed, Rf value is 0.305 indicating it to be elongated in shape and suggesting flatter peak flow for longer duration.

Circularity Ratio (Rc)

Miller (1953) defined circularity ratio as the ratio of the area of the basin to the area of the circle having same circumference as the basin perimeter. Its value ranges between 0 (in line) to 1 (in a circle). Circularity ratio is dimensionless and expresses the degree of circularity of the basin (Miller 1953). The basin of the circularity ratios range 0.4 to 0.5 which indicates strongly elongated and highly permeable homogenous geologic materials. The Beas watershed has a circularity ratio of 0.435 indicating that the area is highly elongated.

Elongation Ratio (Re)

Schumm (1956) defined elongation ratio (as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. The value of elongation ratio ranges from 0 (in highly elongated shape) to unity i.e. 1.0 (in the circular shape). Values close to 1.0 represent regions of very low relief, whereas values of 0.6 to 0.8 are usually associated with high relief and steep ground slope (Strahler 1964). The Re for the Beas watershed is 0.623 which indicates watershed to be more elongated with high relief and steep slope.

Length of Overland Flow (Lg)

Horton (1945) described length of overland flow (Lg) as the length of water over the ground before it gets concentrated into definite stream channels. It is expressed as equal to half of the reciprocal of Drainage Density. It is an important independent variable, which greatly affects the quantity of water required to exceed a certain threshold of erosion. This factor related inversely to the average slope of the channel and is quite similar with the length of sheet flow to a large degree. The study area has length of overland flow value 0.801 which indicates a well developed drainage network.

Conclusion

The morphometric analysis of River Beas watershed using GIS and remote sensing retrieved that this tool is extremely supportive to the researchers to analyze drainage basin pattern in short succession of time. The analysis of linear aspects of drainage basin result shows that the basin has a Sub-dendritic to sub-trellis pattern with 5^{th} order stream. High bifurcation ratio in the study area indicates a strong structural control on the drainage. The inference of relief aspect shows the study area is characterized by high relief and high stream density. The results of aerial aspect show that the texture of drainage is coarse. The investigation of elongation ratio indicates the drainage basin is elongated in nature with high relief and steep slopes.

References

1. Agarwal, C. S. (Oct. 1998), Study of drainage pattern through aerial data in Naugarh area of Varanasi district, UP, Journal of the Indian Society of Remote Sensing, vol. 26, no. 4. pp. 169-175.
2. Biswas, S, Sudhakar, S. and Desai, V. R. (Nov. 1999), Prioritisation of subwatersheds based on morphometric analysis of drainage basin: A remote sensing and GIS approach, Journal of the Indian Society of Remote Sensing, vol. 27, no. 3, pp. 155-166.
3. Brar, G. S. (May 2014), Morphometric analysis of Siswan drainage basin, Punjab (India) using

Geographical Information System, International Journal of IT, Engineering and Applied Sciences Research, vol. 3, no. 5, pp. 11-16.
4. Chopra, R., Dhiman, R. D. and Sharma, P. K. (Sept. 2005), Morphometric analysis of sub-watersheds in Gurdaspur District, Punjab using remote sensing and GIS techniques, Journal of the Indian Society of Remote Sensing, vol. 33, no. 4, pp. 531-539.
5. Clarke, J. I. (1966), Morphometry from maps, Essays in Geomorphology, G.H. Dury (Ed) American Elsevier Publ. Co., New York.
6. Horton, R. E. (1932). Drainage basin characteristics, Transactions American Geophysical Union, vol. 13, no. 1, pp. 350-361.
7. Horton, R. E. (March 1945), Erosional development of streams and their drainage basins: Hydrophysical approach to quantitative morphology, Geological Society of America Bulletin, vol. 56, no. 3, pp. 275-370.
8. Krishnamurthy, J. and Srinivas, G. (1995) Role of geological and geomorphological factors in groundwater exploration – a study through remote sensing techniques, International Journal of Remote Sensing, vol. 16, no. 14, pp. 2595–2618.
9. Miller, V. C. (1953), A Quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain area, Virginia and Tennessee, Project NR 389-042 , Tech Report 3, Columbia University, Department of Geology, ONR, New York.
10. Narendra, K and Rao, K. N. (June 2006), Morphometry of the Meghadrigedda watershed, Visakhapatnam district, Andhra Pradesh using GIS and Resourcesat data, Journal of the Indian Society of Remote Sensing, vol. 34, no. 2, pp. 101-110.
11. Rekha, V. B., George, A. V. and Rita, M., (Sept. 2011) ,Morphometric analysis and micro-watershed prioritization of Peruvanthanam sub-watershed, the Manimala river basin, Kerala, South India, Environmental Research, Engineering and Management, vol. 3, no. 57, pp. 6-14.
12. Schumn, S. A. (May 1956), Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. Geol. Soc. Am. Bull., vol. 67, no. 5, pp. 597-646.
13. Smith, K. G. (Sept. 1950), Standards for grading textures of erosional topography, American Journal of Science, vol. 248, no.9, pp. 655-668.
14. Srivastava, V. K. and Mitra, D. (Dec. 1995), Study of drainage pattern of Raniganj Coalfield (Burdwan District) as observed on Landsat TM / IRS LISS II imagery, Journal of the Indian Society of Remote Sensing, vol. 23, pp. 225-235.
15. Strahler, A. N. (Dec. 1957), Quantitative analysis of watershed geomorphology, Transactions American Geophysical Union, vol 38, no. 6, pp. 913-920.
16. Strahler, A. N. (1964) Quantitative geomorphology of drainage basins and channel networks, Handbook of Applied Hydrology, McGraw Hill Book Company, New York.
17. Vijith, H. and Satheesh, R. (Jan. 2006), GIS based morphometric analysis of two major upland sub-watersheds of Meenachil river in Kerala, Journal of the Indian Society of Remote Sensing, vol. 34, no. 2, pp. 181-185