ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, *Vol 10(11), DOI: 10.17485/ijst/2017/v10i11/109695, March 2017* ISSN (Online) : 0974-5645

A Quantitative Morphometric Analysis of Barhar River Watershed of Mahoba district, U.P., India using Remote Sensing and GIS

D. Sen Gupta[1*], P. Ghosh[1] and S. K. Tripathi[2]

[1]Department of Geology, CAS, Institute of Science, Banaras Hindu University, Varanasi – 221005, Uttar Pradesh, India; devsengupta.28@gmail.com, partho_ghosh@yahoo.com
[2]Department of Energy and Environment, M.G.C.G.V., Chitrakoot, Satna - 485334, Madhya Pradesh, India; tripathi.shashikant@gmail.com

Abstract

Objectives: The quantitative morphometric analysis is found to be vital study in understanding hydrological aspects and its interaction with the environment of any watershed system. The main objective of the study is to calculate the morphometric parameters of the Barhar river watershed. Methods/Statistical Analysis: The study area lies between 79° 32′ E to 79° 37′ E longitude and 25° 22′ N to 25° 30′ 30′′ N latitude covering an area of about 48.75 km^2 belonging to Bundelkhand region. The drainage of the region has been prepared using Survey of India (SOI) toposheet (No.54O/11), Landsat TM and Digital Elevation Model (DEM) of the area. Remote Sensing (RS), Geographical Information System (GIS) and Global Positioning System (GPS) have been used in the study as efficient tools in our various modern geographical and geological studies. **Findings:** Barhar river watershed belonging to the northern part of Mahoba district is a hard rock terrain consisting mostly granite and granitoids. Rivers flowing in such terrains are mostly found to follow the fractures and lineaments. The watershed is of forth order drainage having drainage density and stream frequency of 2.281 and 2.481 respectively. The watershed shows elongated in nature. The method applied to the river basin gave a recent calculation of the morphometric parameters of the region. **Application/Improvements:** The drainage morphometric analysis is important in selection of water recharge sites, watershed modelling and groundwater prospect mapping. The study would provide an important information collection regarding future watershed prospects of the area.

Keywords: Barhar, GIS, Groundwater, Landsat TM, Morphometry, Remote Sensing

1. Introduction

The morphometric detection, calculation and assessment of any watershed helps in understanding the details of hydrologic aspects that reveals the geomorphology and geology of the area. During early and late nineties various drainage parameters were investigated by eminent workers like Horton, Thornbury and Strahler which proves to be important in understanding the structural, lithological, geomorphological and other aspects.

Various studies have been conducted regarding morphometric analysis in different basins of India. In present times computer based analysis are proving easier, time- efficient and most reliable results where software plays great role in analysing the huge data. In the present study software based analysis was carried out that was later verified in field study.

2. Study Area

The study area lies between 79° 32′ E to 79° 37′ E longitude and 25° 22′ N to 25° 30′ 30″ N latitude covering an area of about 48.75 km^2 belonging to Bundelkhand region. The region experiences subtropical climate where summers are long and intense. It receives moderate rainfall during rainy season and winters are short and cold.

* *Author for correspondence*

It is a hard rock terrain consisting of granites and granitoids as lithology of the region. The river in its path crosses agricultural lands and sparsely populated villages having some barren lands due to uneven distribution of rock exposure.

3. Methodology

The stream networks were previously digitised using toposheet and satellite imagery of the respected area using Arc GIS version 10.1 software. The major and minor stream networks of the watershed were analysed using parameters of previous workers[1–7]. The calculation was operated using mathematical equations and different required parameters were calculated, Table 1, which later on were verified in the field.

4. Result

The digitisation of the watershed has been done and various parameters of morphometry were calculated under major heads of linear, areal and relief aspects.

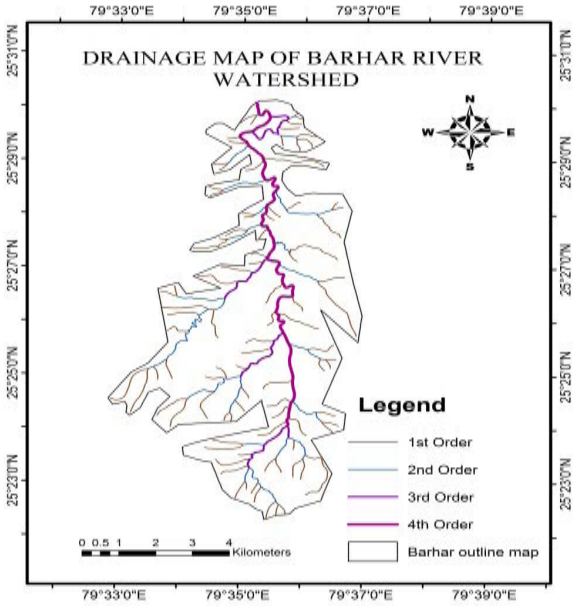

Figure 1. The drainage map of Barhar river watershed.

Table 1. Morphometric parameters

S.No.	Mophometric Parameters	Formula
		Linear Aspect
1.	Perimeter (P)	Length of the drainage basin boundary
2.	Basin length(Lb)	Maximum length of the basin measured parallel to the main drainage line
3.	Stream length (Lu)	Length of the Major stream
4.	Mean stream length (Lsm)	Lsm = Lu / Nu , Lu = Total stream length of order 'u' Nu = Total no. of stream segments of order 'u'
5.	Bifurcation ratio (Rb)	Rb = Nu / Nu + 1, Nu = Total no. of stream segments of order 'u' Nu + 1 = Number of segments of the next higher order
6.	Mean bifurcation ratio (Rbm)	Rbm = Average of bifurcation ratios of all orders
7.	Stream length ratio (Rl)	Rl = Lu / Lu – 1, Lu = The total stream length of the order 'u' Lu – 1 = The total stream length of its next lower order
		Aerial Aspect
8.	Total Area (A)	Total area of river basin
9.	Drainage density (Dd)	Dd = ∑Lu / A
10.	Stream frequency (Fs)	Fs = ∑Nu / A
11.	Form factor (Rf)	$Rf = A / Lb^2$
12.	Circularity ratio (Rc)	$Rc = 4 \pi A / P^2$
13.	Drainage texture (T)	T= Dd × Fs
14.	Elongation ratio (Re)	$Re = 1.128\sqrt{A} / Lb$
15.	Length of overland flow (Lg)	Lg = 1/2Dd
		Relief Aspects
16.	Basin Relief (R)	R = H– h, H is maximum elevation and h is minimum elevation within the basin.
17.	Relief Ratio (Rr)	Rr = R/Lb
18.	Ruggedness number (Rn)	Rn = R × Dd R is the basin relief and Dd is the drainage density

1. Perimeter (P)

The P of Barhar river watershed is 66.062 km.

2. Basin Length (Lb)

Lb measures geometrical size and shape of a drainage basin. Barhar river watershed has a Lb of 14.305 km.

3. Length of the Main Stream

In general the length implies of the main stream. During the digitisation ArcGIS-10.1 software was used for digitising main channel length. The analysis gave the value of about 14.686 km.

4. Stream Order (Nu)

The first step towards drainage basin analysis is the designation of stream order which shows the relative and hierarchical relationship between stream segments, their connectivity and the discharge having contributions of the main watershed and its sub-watersheds as shown in Figure 1.

5. Stream Number (u)

Horton[2] stated that the numbers of stream segments of each order eventually form an inverse geometric sequence with the order number. The total number of streams in the study area is 121 as mentioned above.

6. Stream Length (Lu)

The stream network of Bagain River basin was previously categorized into several orders, which were then computed using Arc GIS software version 10.1 using Survey of India toposheets as primary data. The stream length according to the law proposed by Horton[2] has been computed. The total length of streams (Lt) in Barhar river watershed is 111.225 km.

7. Bifurcation Ratio (Rb)

The bifurcation ratio can be defined as a ratio of the number of stream segments of given order to the number of segments of next higher order. Bifurcation ratio is a good index of relief and dissection[2]. For the study area mean bifurcation ratio is 4.558 indicating geologic structures controlled drainage network.

8. Rho coefficient

It is an important parameter showing relation between drainage density and physiographic development of any watershed for the storage capacity evaluation of the related drainage network.

9. Area (A)

The A of Barhar river watershed is 48.756km^2.

10. Drainage Density (Dd)

The drainage density has been found to be an important parameter which can be defined as total length of the streams of all orders/drainage area[5]. It is linear scale type parameter of landform element in stream which is topographically eroded. The low drainage density is often found to be favoured by highly permeable subsoil region bearing dense vegetation cover whose relief is low, whereas high drainage density always favoured in regions having weak or impermeable sub-surface materials, sparse vegetation and high mountain relief.

11. Drainage Texture (T)

Drainage texture has been categorised as:

- less than 2 shows very coarse,
- value between 2 and 4 shows coarse,
- value between 4 and 6 shows moderate,
- value between 6 and 8 hows fine and
- rest greater than 8 shows very fine drainage texture[11].

In the present study shows the drainage texture value of Barhar river watershed to be 5.659 which indicates texture pattern of Barhar river watershed to be moderate drainage texture.

12. Stream Frequency (Fs)

The stream frequency of the watershed found to be 2.481. Thus, the stream frequency falls under moderate frequency class in the study area. The stream frequency found in the study area shows a positive correlation with its calculated drainage density, indicating an increase in the stream population with the increase in drainage density.

13. Form Factor (Rf)

The value of form factor of the watershed is 0.238 indicating lower form factor values showing the watershed to be of elongated shape. The elongated basin having low form factor value indicates basin having a longer duration flatter peak of flow.

14. Length of Overland Flow (Lg)

The computed value in this study of length of overland flow is about 1.140 which indicates low surface runoff.

15. Relief Ratio (Rr)

The Rr of Barhar river watershed is 0.006.

16. Ruggedness Number (Rn)

The Rn of Barhar river watershed is 0.200 given in Table 2. The ruggedness number of the basin indicates lower soil erosion susceptibility.

17. Basin Relief (R)

Slope analysis is a significant parameter. It is generally controlled by the region's climate morphogenic processes. The Sb of Barhar river watershed is 0.088 km (Table 2), revealing gentle sloppy characteristic of the terrain.

5. Discussion

The watershed was found to have gentle slope as shown by dendritic drainage pattern which generally implies massive crystalline hard rock found as country rock in the terrain. The bifurcation ratios which have been calculated found to be good indicators of structurally controlled drainage pattern development in the region[12]. The values calculated in drainage density clearly indicates the presence of impervious rocks as lithology holding very less soil cover in the area that has also been aided by the calculation of its drainage texture. Geomorphology in general is often studied based on the systematic study in relation to nature, development, origin, geological features of present day landforms and their relationship with other various underlying structures[13–16]. The technology has always been effectively and economically used in analysis and inventory for basin area development and management[17–20].

Table 2. Morphometric parameter's calculation

S. No.	Parameters	References	1st Order	2nd Order	3rd Order	4th Order	Total
			Linear aspect				
1.	Perimeter						66.062 km
2.	Basin length						14.305 km
3.	Stream length	2	63.460 km	24.317 km	8.762 km	14.686 km	111.225 km
4.	Number of streams	2	94	21	5	1	121
5.	Bifurcation ratio	2	4.476	4.2	5		4.558 (Mean)
6.	Stream Length ratio	2		0.383	0.360	1.676	0.806 (Mean)
7.	Rho coefficient	2		0.091	0.072		
			Areal aspect				
8.	Area						48.756 sq km
9.	Drainage density	5,2					2.281
10.	Stream frequency	2					2.481
11.	Drainage texture	6					5.659
12.	Length of overland flow	2					1.140
13.	Constant of channel maintenance	3					0.438
14.	Form factor	2					0.238
15.	Elongation ratio	3					0.550
16.	Shape index	2					4.201
			Relief aspect				
17.	Basin relief	3					0.088 km
18.	Relief ratio	3					0.006
19.	Ruggedness number	7					0.200

6. Conclusion

The groundwater occurrence in the study area is mainly found in the top weathered parts of hard crystalline rocks as fissures and fractures showing secondary porosities. For sustainable development groundwater exploitation has to be done from the above mentioned water bearing zones. The study also reveals that DEM could be useful in studying the topography within GIS environment. The investigation done can be used for Barhar river watershed management and protection of the region's natural environment.

7. Acknowledgement

Authors are thankful to Head, Department of Geology, BHU for providing the lab facility for the present study.

8. References

1. Strahler AN. Quantitative geomorphology of drainage basin and channel networks. Chow VT, editor. Handbook of applied hydrology. New York, McGraw Hill Book; 1964. p. 4–76.
2. Horton RE. Erosional development of streams and their drainage basins: Hydrophysical approach to quantitative morphology. Bulletin of the Geological Society of America. 1945; 5:275–370. Crossref
3. Schumm SA. Evolution of drainage system and slope in badlands of Perth Amboy, New Jersey. Bulletin of the Geological Society of America. 1956; 67:597–46. Crossref
4. Strahler AN. Quantitative analysis of watershed geomorphology. Transactions, American Geophysical Union. 1957; 38:913–20. Crossref
5. Horton RE. Drainage basin characteristics. Transactions, American Geophysical Union. 1932; 13:350–61. Crossref
6. Miller VC. A quantitative geomorphic study of drainage basin characteristic in the clinch, Mountain area, Verdinia and Tennesser, Project NR 389-042, Technical Report 3 Columbia University, Department of Geology, ONR, Geography Branch, New York; 1953.
7. Singh S, Dubey A. Geo environmental planning of watersheds in India. Allahabad, India. Chugh Publications; 1994. p. 28–69.
8. Strahler AN. Dimensional analysis applied to fluvially eroded landforms. Geological Society of America Bulletin. 1958; 69:279–300. Crossref
9. Verstappen H. Th. Applied geomorphology-geomorphological surveys for environmental development. New York, Elsevier; 1983. p. 57–83.
10. Chorley RJ, Donald EGM, Pogorzelski HA. A new standard for estimating drainage basin shape. American Journal of Science. 1957; 255:138–41. Crossref
11. Smith KG. Standards for grading texture of erosional topography. American Journal of Science. 1950; 248:655–68. Crossref
12. Chottopadhyay N, Hasmi S. The sung valley alkaline ultramafic carbonalite complex, East Khasi Hills and Jaintia Hills district, Meghalaya. G.S.I. Record. 1984; 113(4):24–33.
13. Agarwal CS. Study of drainage pattern through aerial data in Naugarh area of Varanasi district, U.P. Journal of the Indian Society of Remote Sensing. 1998; 26:169–75. Crossref
14. Rudraiah M, Govindaiah S, Vittala SS. Morphometry using remote sensing and GIS techniques in the sub-basins of Kagna River basin, Gulburga District, Karnataka. Journal of the Indian Society of Remote Sensing. 2008; 36:351–60. Crossref
15. Mayilvaganan MK, Mohana P, Naidu KB. Delineating groundwater potential zones in Thurinjapuram watershed using geospatial techniques. Indian Journal of Science and Technology. 2011 Nov; 4(11):1470–6.
16. Gupta DS, Dwivedi L, Tripathi SK, Ghosh P, Awasthi A. Groundwater potential mapping of Sihu river watershed area of Mahoba district, U.P. using remote sensing and GIS. International Journal of Applied Research. 2015; 1(10):241–8.
17. Dwivedi L, Gupta DS, Tripathi S. Groundwater potential mapping of Ukmeh river watershed area of Upper Vindhyan region using remote sensing and GIS. Indian Journal of Science and Technology. 2016 Sept; 9(36):1–7. Crossref
18. SK Nag. Morphometric analysis using remote sensing techniques in the chaka sub-basin, Purulia district, West Bengal. Journal of Indian Society of Remote Sensing. 1998; 26(1–2):69–76.
19. Patel RS, Gupta DS, Tiwari SK, Dwivedi SB. Morphometric aspects of a small river system of Mirzapur district, Uttar Pradesh, India: A case study of Barhi river system. International journal of Multidisciplinary Research and Development. 2016 Mar; 3(3):250–5.
20. Singh S, Singh MC. Morphomertric analysis of Kanhar river basin. National Geographical Journal of India. 1997; 43(1):31–43.