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Morphometric Analysis of the Berne River Basin, Tributary of Ken River, Part of Rajnagar Block, Chhatarpur, M.P, India

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***Abstract*: The morphometric analysis of Drainage Basin and Terrain is widely used now for various evaluations related to different fields such as river processes, engineering planning, environmental impact assessment studies etc. for last few decades. The morphometric study involves numeric transformation by measurements of linear, aerial and slope aspects of various geomorphic forms of the drainage basin in question.**

***Keywords*: Morphometric analysis, geomorphic process, aspects: - linear, areal and relief, GIS.**

1. Introduction

The Berne River is a perennial stream which is a tributary of Ken River, a tributary of Yamuna River which in turn is part of the Ganges system. The study area is extended between latitude 24º 45’- 25º 0’ N and longitude 79º 30’ – 79º 45’E. The area is a granitic terrain.

2. Methods and materials

The study on Berne River was made on Survey of India topographic sheet No. 54P/9, 54P/10, 54P/13, 54P/14 on scale (1:50000) and digital satellite data SRTM with 30m spatial resolution covering the drainage basin of the Berne River. The set of toposheets was taken in the ArcGIS environment to construct mosaic and rectified and projected to the world space coordinate system, UTM 1984. The area was digitized for the fifth order drainage that produced three sub-basins. In the attribute table all the geometry was calculated which was further taken for the computation of different parameters of morphometric analysis to study the drainage behavior.

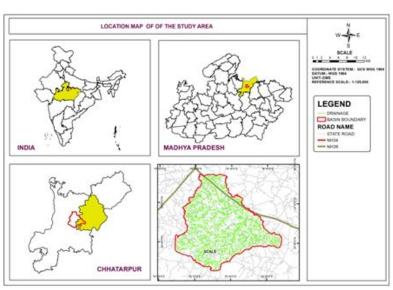

Fig. 1. Location map of the study area.

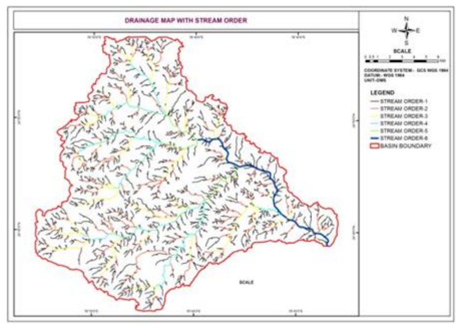

Fig. 2. Drainage map of the study area.

3. Observations

On the following parameters and formula’s (Table 1), the present work was carried out for the detailed study of the watershed. By this computation the drainage characteristics and geological behavior of the watershed can be studied.

4. Results and discussions

From the above observation it is found that the drainage of the study is of dendritic pattern and in some part it shows parallel to sub-parallel pattern.

A. Linear aspect of the drainage basin

1) Drainage network

2) Stream Order (u)

The first step in geomorphologic analysis of a drainage basin is the designation of stream order, based on the hierarchic making of stream proposed by A.N Strahler (1964). According to him each finger –tip channel are defined as first order streams. When two streams of first order join, a second order stream is produced. When two stream of second order join, a third order stream produced whereupon a stream of third order results a forth and so on (Strahler 1969).These streams may have additional stream segments of lower order than their own order and thus these do not affect the classification. The order of a basin is the order of the highest stream. For the present study the total number of stream order of all 3 sub basins is of fifth order.

Table 1
Different Morphometric Parameters of Three Fifth order sub-basins

S. No.	Morphometric Parameters	Symbols /Formulae	Values			References
	Name of the sub -basins		A	B	C	
1	Area	A5	62.184	58.657	107.327	Schumm (1956)
2	No.of 1st order stream	N1	158	170	270	Strahler (1964)
	No.of 2nd order stream	N2	37	40	61	
	No.of 3rd order stream	N3	9	7	12	
	No. of 4th order stream	N4	2	2	2	
	No. of 5th order stream	N5	1	1	1	
3	Total no.of streams	Nu	207	220	346	
4	Length of 1st order stream	L1	81	93.38	139.52	Horton (1945)
	Length of 2nd order stream	L2	34.1	35.22	45.87	
	Length of 3rd order stream	L3	17.44	14.41	29.51	
	Length of 4th order stream	L4	12.29	15.53	24.58	
	Length of 5th order stream	L5	3.68	3.69	4.52	
5	Total length of the streams	Lu	148.51	162.23	244	
6	Mean Stream Length	Lm= Lu / Nu	0.717	0.737	0.705	
7	Length of the sub -basins	Lb	11.995	18.084	11.941	Schumm (1956)
8	Width of the sub-basins	Wb	7.91	5.903	9.39	Horton, R. (1932)
9	Maximum height of the sub-basins	H	364	382	384	
10	Minimum height of the sub-basins	H	277	278	268	
11	Perimeter of the sub-basins	P	43.972	33.827	54.627	Schumm (1956)
12	Form Factor	Ff=A/Lb^2	0.432	0.1793	0.752	Horton (1932)
13	Circulatory ratio	Rc=12.57*(A/P^2)	0.404	0.644	0.452	Miller (1953)
14	Drainage Density	Dd=Lu/A	2.388	2.7657	2.273	Horton (1932)
15	Drainage texture	Dt=Nu/P	4.707	6.503	6.334	Horton (1945)
16	Stream Frequency	Fs=Nu/A	3.328	3.750	3.224	Horton (1932)
17	Bifurcation ratio Rb=Nu/Nu+1	Rb1&2	4.270	4.25	4.426	Schumm (1956)
		Rb2&3	4.111	5.714	5.083	
		Rb 3&4	4.5	3.5	6	
		Rb 4&5	2	2	2	
18	Elongation Ratio	Re=2/Lb*√(A/π)	0.742	0.477	0.979	Schumm (1956)
19	Compactness coefficient	Cc=0.2841*P/A^0.5	1.584	1.254	1.498	Gravelius (1914)
20	Texture ratio	Tr=Dd*Fs	7.950	10.372	7.329	Smith (1950)
21	Drainage intensity	Di=Fs/Dd	1.393	1.356	1.418	Faniran, A. (1968)
22	Infiltration Number	In=Fs*Dd	7.950	10.372	7.329	Faniran, A. (1968)
23	Constant channel maintenance	Cm=1/Dd	0.418	0.361	0.439	Schumm, S. (1956)
24	Length of over Land Flow	Lo=1/2 Dd	0.209	0.180	0.219	Horton, R. (1945)
25	Stream Length ratio SLR=Lu/Lu-1	SLR 2&1	0.420	0.377	0.328	Horton, R. (1945)
		SLR 3&2	0.511	0.409	0.643	
		SLR 4&3	0.704	1.077	0.832	
		SLR 5&4	0.299	0.237	0.183	
26	Lemniscate's ratio	Lmt R (k)= Lb^2/4.A	2236.749	4795.734	3825.871	Chorley et.al (1957)
27	Rho Coefficient	(ρ)=SLR 2&1/Rb1&2	0.098	0.088	0.074	Horton (1945)
		(ρ)=SLR 3&2/Rb2&3	0.124	0.0716	0.126	
		(ρ)=SLR 4&3/Rb3&4	0.156	0.307	0.138	
		(ρ)=SLR 5&4/Rb4&5	0.149	0.118	0.091	
28	Total Basin relief	Bh=H-h	87	104	116	Schumm (1956)
29	Relief ratio	Rhl=Bh/Lb	7.253	5.750	9.714	Schumm (1956)
30	Ruggedness Number	Rn=Dd*(Bh/1000)	0.207	0.287	0.263	Melton (1957), Strahler (1968)

3) Stream Number (Nu)

R.E Horton’s (1945) defines the relationship between the order of the basins and stream numbers. After assigning stream orders, the segments of each order are counted to get the number of segments of the given order (u). It is the number of stream segment of various orders and is inversely proportional to the stream order. The number of streams at each order denoted as N1, N2, N3…Nu and total number of streams up to a particular of order Σ(N)u. The stream numbers of the Berne River sub-basins are (207, 220, and 346).

4) Bifurcation Ratio (Rb)

Bifurcation Ratio is the ratio of the number of streams of a given order (Nu) to the number streams of the next higher order (Nu+1), (Horton 1945, Strahler 1964). Rb=Nu/Nu+1.

Bifurcation ratio is related to the branching pattern of the drainage network. When it varies between 3 and 5, the rock type is homogenous and the geological structure does not exercise a dominance influence on the drainage pattern. According to Strahler (1975), when the bifurcation ratio more than 5, the basin is elongated and geological structure controls the basin. In well-developed drainage network the bifurcation ratio is generally between 2 to 5, (Horton, 1945; Strahler, 1964). The values for the study area are hereunder.

5) Mean bifurcation ratio (Rbm)

Mean bifurcation ratio is the average of bifurcation ratio of Strahler all orders (Rbm). The mean bifurcation ratio of the sub-

Table 2
Bifurcation ratio

Rb1&2	4.270	4.25	4.426
Rb2&3	4.111	5.714	5.083
Rb 3&4	4.5	3.5	6
Rb 4&5	2	2	2

basins is (3.720, 3.866, and 4.377), which shows that the rock type is homogeneous.

6) Stream Length (Lu)

Horton's law (Horton, 1932) of stream length supports the theory that geometrical similarity is preserved generally in the basins of increasing order (Strahler, 1964). The stream length is represented as L1, L2, L3 ...Lu. The mean length of channel Lu of order U is the ratio of the length to the number of streams of a given order is greater than that of the next lower order but less than that of the next higher order. The total length of the stream Lu for the study area is (148.51, 162.23, and 244).

7) Mean Stream Length (Lm)

It is the ratio of the length of all the streams having order U and the number of streams of segments of order U. Lm=Lu/Nu. The mean stream length is the characteristics property related to the drainage network and its associated surfaces. The (Lm) for the study area sub-basins is (0.717, 0.737, and 0.705).

8) Stream length ratio (SLR)

The proportion of increase of mean lengths (Lu) of stream segments of two successive basin orders is defined as stream length ratio (SLR). SLR=Lu/Lu-1. The value for the study area sub-basins are hereunder.

Table 3
Stream length ratio

SLR 2&1	0.420988	0.377169	0.32877
SLR 3&2	0.511437	0.409143	0.64334
SLR 4&3	0.704702	1.077724	0.832938
SLR 5&4	0.29943	0.237605	0.183889

B. Aerial Aspect of Drainage

1) Basin geometry

2) Basin Area

Plan area of the watershed is called as basin area (sq.km). The area of the sub basins are (A=62.184, B= 58.657, C=107.327) sq.km. The smaller the area of the basin, it is likely that the rainwater will reach the main stream more rapidly than the larger basin.

3) Basin Length (Lb)

According to Schumm (1956), the basin length (Lb) of a watershed is the longitudinal distance between the watershed outlet and the farthest point in the watershed (km). The length of the study area sub-basin is (11.995, 18.084, and 11.941) (km).

4) Basin width (Wb)

Basin width is the lateral distances between the two parallel sides the watershed (km). The width of the sub basins are (7.91, 5.903, 9.39) (km).

5) Basin Perimeter (P)

The perimeter of the basin is the length of outer boundary of the watershed that encloses its area (km). The perimeter of fifth order sub-basins A, B, C is (43.972, 33.827, and 54.627)(km).

6) Form Factor

Form factor is the ratio of a basin area (A) to the square of the basin length (Lb), (Horton,1932). Ff= A / Lb^2. For the perfect circular shape of the basin the value would always be less than 0.7854. Smaller the value of factor form, more elongated will be shape of the basin and the value that is closer to 1 indicates circular shape. The form factor of the study area sub-basins are (0.432, 0.179, and 0.752).

7) Circulatory Ratio (Rc)

It is defined as the ratio of basin area (A) to the area of circle of watershed perimeter (P), (Miller 1953). Rc= 12.57 A/ P^2. It is influenced more by the length, frequency of streams, gradients of streams of various orders rather than slope conditions and drainage pattern of the basin. The circulatory ratio of the sub-basins for the study area is (0.404, 0.644, and 0.452).

8) Elongation Ratio (Re)

It is the ratio of the diameter of a circle of the same area that of the basin to the maximum length of the basin, (Schumm's 1956). Re=2/Lb*√A/π. It is a very significant index in the analysis of basin shape which helps to give an idea about the hydrological character of a drainage basin. Values near 1.0 are typical of regions of very low relief (Strahler,1964), whereas value ranges between 0.6 to 0.8 are generally associated with strong relief and steep ground slope. The value of elongation ratio for the sub-basins is (0.742, 0.477, and 0.979).

9) Compactness Coefficient (Cc)

It is the ratio of perimeter of watershed to circumference of circular area, which equals the area of the watershed (Gravelius,1914). Cc = 0.2841*P/A^0.5. The values for sub-basins of study area are (1.584, 1.254, and 1.498).

10) Drainage Texture (Dt)

It is the ratio of total number of stream segment of all orders upon perimeter of the area. Dt = Nu /P The drainage texture of the study area sub-basins are (4.707, 6.503, and 6.334).

11) Texture ratio (Tr)

The drainage texture may be defined as the relative spacing of drainage lines. The drainage density and drainage frequency have been collectively defined as drainage texture. Tr=Dd*Fs. Based on the value of Tr it is classified as (Smith 1950).

0-4 = coarse
4-10 = intermediate
10-15 = fine
>15 =ultra fine (bad 1 and topography).

The texture ratio of the study area sub-basins are (7.950, 10.372, and 7.329) which falls under intermediate to fine texture.

12) Rho Coefficient (ρ)

It is the ratio between stream length ratio to the bifurcation ratio, (Horton, 1945).

Rho Coefficient (ρ) = stream length ratio (SLR) / bifurcation ratio. The values for the study area are given in the table.

Table 4
Rho Coefficient (ρ)

(ρ)=SLR 2&1/Rb1&2	0.0985	0.088	0.074
(ρ)=SLR 3&2/Rb2&3	0.124	0.071	0.126
(ρ)=SLR 4&3/Rb3&4	0.156	0.307	0.138
(ρ)=SLR 5&4/Rb4&5	0.149	0.118	0.091

C. *Drainage texture analysis*

1) *Stream Frequency (Fs)*

Stream frequency of the basin is defined as the ratio of the total numbers of stream segments of all orders to the area of the basin (Horton, 1945). It is mainly depends upon the lithology of the basin and reflects the texture of the drainage network. High drainage density and stream frequency indicate larger run off from a basin. Fs= Nu/A. The stream frequency of all the sub-basins of study area is (3.328, 3.750 and 3.224).

2) *Drainage density (Dd)*

The drainage density is define as the ratio of the total length of the streams of all orders of basin to the area of the basin. It is expressed as km/km2. (Horton 1932). It indicates closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channel for the whole basin.
Dd= Lu/A. The Drainage density of the study area sub-basins are (3.388, 2.765 and 2.273) (km/sq.km).

3) *Drainage Intensity (Di)*

According to Franiran (1968) the drainage density is a ratio of the stream frequency to the drainage density. Di =Fs / Dd. The drainage intensity of the study area sub-basins are (1.393, 1.356 and 1.418).

4) *Constant Channel Maintenance*

According to Schumm (1956) it is an inverse of drainage density (1/Dd). It may be defines as the area of the basin surface needed to sustain a unit length of stream channel. It is expressed as: (Cm= 1/Dd) sq.km per km. The (Cm) of the study area is (0.418, 0.361 and 0.439).

5) *Length of Overland Flow (Lo)*

Length of overland flow is the length of water over the ground before it gets concentrated into definite stream channel (Horton 1945). It is defined as the half and reciprocal of the drainage density. Lo=½*1/Dd. The (Lo) of the study area sub-basins are (0.209, 0.180 and 0.219).

6) *Infiltration Number (In)*

The infiltration number of a watershed is defined as the product of drainage density and stream frequency and gives an idea about the infiltration characteristics of the watershed(Faniran,1968). In=Fs*Dd. The (In) of the study area sub basin are (7.950, 10.372, and 7.329).

D. *Relief Aspect of the River Basin*

E. *Relief characteristics*

- *Maximum height of the basin (H)*: It is the maximum elevation of the basin (m). The maximum elevation of the sub-basins of study area is (364, 382, and 384).
- *Minimum height of the basin (h)* It is the minimum elevation of the basin (m). The minimum elevation of the sub-basins of the study area is (277, 278 and 268) m.
- *Total Basin Relief (m)* It is the difference between the maximum height and the minimum height of the basin (m), (Schumm, 1956). Bh=H-h. The value for (Bh) of the study area sub-basins are (87, 104 and 116) (m).
- *Relief Ratio (Rhl)*: The relief ratio may be defined as the ratio between the total relief of a basin and the longest dimension of the basin parallel to the main drainage line (Schumm,1956). Rhl=Bh/Lb. The (Rhl) of the study area sub-basins is (7.253, 5.750 and 9.714).
- *Ruggedness Number (Rn)* Strahler's (1968) defines it as the product of the maximum watershed relief and its drainage density gives an idea of overall roughness of a watershed. It is expressed as: Rn = Dd*Bh / 1000. The values of the sub-basins of the study area are (0.207, 0.287, and 0.263).
- *Lemniscate's ratio (Lmt R)*: Chorley et.al.(1957), express the Lemniscate's value to determine the slope of the basin. It is expressed as: (LmtR)(k)=Lb^2/4. A, where Lb is the basin length (km) and A is the area of the basin (km2). The values for (Lmt R) of the study area sub-basins are (2236.749, 4795.734 and 3825.871).

5. Interpretation

A. *Area and number parameters*

The stream number parameters of N1, N2, N3, N4, N5 and Nu show strong and very significant correlation with area (N1=98.678, N2=98.384, N3=94.153 and Nu=98.880). The N4 however is equal for all basins therefore it does not show any correlation. It concludes that the larger the basin the greater is the number of streams.

B. *Area and length parameters*

Similar to number parameters the length parameters also show very high degree of significance in correlation (L1= 96.454, L2=98.857, L3=99.209, L4=94.855, L5=99.716, Lu=98.040, Lb= -56.154, Lw= 85.480). The basin length parameter is negatively correlated whereas width parameter is strongly positively correlated. It shows that the basins of larger area do not increase in basin length and the increase in area is compensated by increase in width.

C. *Area and relief parameters*

The total basin relief and relief ratio are showing good and very significant correlations (Bh=77.263, Rhl=94.931). However, the total basin relief has somehow come to a stage where it is not significantly changing. The ruggedness number has very poor or no correlation (16.18). It shows that the ruggedness of the terrain is nearly uniform and is not showing any sign of drainage dependent development.

D. Drainage density, drainage frequency, and drainage intensity

Drainage density is generally a rigid parameter and normally does not show variations but in the present case it is showing negatively good relation with area and same is true with the drainage frequency (Dd= -72.662, Fs= -70.195). The negative value is indicating here that the larger the basin the less is drainage frequency or stream length per unit area and similarly for drainage frequency it holds for the basin that the larger the basin less is the number of streams per unit area. However, the drainage intensity has a strong correlation ship (83.40).

6. Conclusion

Streams are mainly governed by joint systems, weathered tracts, and lineation of the granites, however, in general the organization resembles a dendritic pattern and in some part it also shows the parallel to sub-parallel pattern. The drainage parameters were statistically correlated by pair-wise Pearson correlation coefficient. The drainage is well organized up to 3rd order level but as we can consider the greater basin of the 6th order the streams of lower order find less organizational opportunity therefore negative relations of high significance are found. The positive parameters are related to lower order basins. Mismanagement in land use/landcover may lead to formation of soil erosive system as there is lot of space available for the gully-streams system to develop.

References

[1] Chorely, R. (1971) The Drainage Basin as the Fundamental Geomorphic Unit. In: Chorely, R., Ed., Introduction to Fluvial Processes, Methuen and Co. Ltd., London, 30-32. 2.

[2] Chorely, R., Donald, M. and Pogrzelsk, H. (1957) A New Standard for Estimating Drainage Basin Shape. American Journal of Science, 255, 138-141.

[3] Doornkamp, J.C. and King, C. A.M (1971), "Numerical Analysis in Geomorphology" Edward Arnold, London, p. 372.

[4] Faniran, A. (1968) The Index of Drainage Intensity-A Provisional New Drainage Factor. Australian Journal of Science, 31, 328-330.

[5] Horton, R. (1945) Erosional Development of Streams and Their Drainage Basins: Hydrological Approach to Quantitative Morphology. Geological Society of America Bulletin, 56, 275-370.

[6] Horton, R. (1932) Drainage Basin Characteristics. Transactions, American Geophysical Union, 13, 350-367.

[7] Magesh, N.S., Jitheshlal, K.V. and Chandrasekar, N. (2013) Geographical Information System-Based Morphometric Analysis of Bharathapuzha River Basin, Kerala, India. Applied Water Science, 3, 467-477.

[8] Miller, J.R., Ritter, D.F. and Kochel, R.C. (1990) Morphometric Assessment of Lithologic Controls on Drainage Basin Evolution in the Graford Uplands, South-Central Indiana. American Journal of Science, 290, 569-599.

[9] Schumm, S. (1956) Evolution of Drainage Systems and Slopes in Badlands at Perth Amboy, New Jersey. Geological Society of America Bulletin, 64, 597-646.

[10] Shamistha Nagal, Sanjay Tignath, Anupam Pandey (2014), Morphometric Analysis of the Adwa River Basin, Tributary of Balen River, India. IJATER, Volume 4, 39-45.

[11] S.K Nage, D.K Deolia, Sanjay Tignath, and N. Damle, GIS Based Morphometric Analysis of Sub-Watershed, Jabalpur District, M. P, India. Sci-front, Frontiers of Science, A Journal of multiple science, vol. 8, 43-56.

[12] Sharma, S.K., Gajbhiye, S. and Tignath, S. (2015) Application of Principal Component Analysis in Grouping Parame ters of a Watershed for Hydrological Modeling. Applied Water Science, 5,89-96.

[13] Strahler, A.N. (1952) Dynamic Basis of Geomorphology. Geological Society of America Bulletin, 63, 923-938.

[14] Strahler, A. N. (1957) Quantitative Analysis of Watershed Geomorphology. Transactions, American Geophysical Union, 138,913-938.

[15] Strahler, A.N. (1964) Quantitative Geomorphology of Drainage Basins and Channel Networks. In: Chow, V.T., Ed., Handbook of Applied Hydrology, McGraw-Hill, New York, 4-39/4-76.

[16] Reddy, G.P.O., Maji, A.K. and Gaibhiya, K.S. (2004) Drainage Morphometry and Its Influence on Landform Characteristicsin Basaltic Terrain, Central India—A Remote Sensing and GIS Approach. International Journal of Applied Earth Observation and Geoinformation, 6, 1-16.