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MORPHOMETRIC ANALYSIS OF DRAINAGE BASIN USING AERIAL PHOTOGRAPHS: A CASE OF KARUN WATERSHED OF SEONATH SUB-BASIN OF CHHATTISGARH

[a]Nigam, G.K., [b]Tripathi, M.P., [c]Ambast, S.K., [d]Love Kumar and [e]Dhiraj Khalkho
[a&b&d& e]Department of Soil & Water Engineering, SV College of Agricultural Engineering and Technology & Research Station, Indira Gandhi Krishi Vishwavidyalaya, Raipur - 492012, Chhattisgarh, India.
[c]Director, Indian Institute of Water Management -ICAR, Bhubaneswar, Odisha

ABSTRACT
The term morphometery senses the measurements and analysis of form and its properties. In context of geomorphology which is science of landforms it is concerned with the various geometrical aspects of the landforms. Geographical information system and remote sensing are proven to be an efficient tool for morphometric analysis as well as for delineation of drainage pattern and water resources management and it's planning. Morphometric analysis of a Kharun watershed of Seonath sub-basin was carried out in the Department of Soil and water engineering, Faculty of Agricultural Engineering, Indira Gandhi KrishiVishwavidyalaya Raipur. The watershed morphometric parameters such as linear, relief and aerial aspects of the watershed were determined and computed. Database has been prepared in ArcGIS 10.4 desktop application for certain significant of morphometric parameters analysis. The Shuttle Radar Topography Mission (SRTM) 30 meter data were used for preparation of DEM, and drainage network. The Kharun watershed covers an area of about 4143.25 km^2 and has V^{th} order streams were calculated by using GIS environment. The low values of bifurcation ratio indicate that the drainage of the basin has suffered less structural disturbances and drainage pattern has been distorted. The basin has low drainage density and elongated in shape. Stream length decreases with the order increases. Logarithm of number of stream vs stream order and length of stream segment vs stream order were computed in the watershed area. These studies are significant for soil erosion prevention and land and soil management practices.

KEYWORDS - Morphometric; GIS; Watershed; Remote Sensing.

INTRODUCTION
Watershed is a natural hydrological boundary which allows the surface runoff drain to a defined stream or river at a single particular point (Chaudhary et al., 1998). The morphometric analysis of the drainage basin and channel network play a vital role in understanding the geo-hydrological behavior of drainage basin and expresses the prevailing climate, geology, geomorphology, structural, etc. antecedents of the catchment. Watershed management process implies appropriate use of land and water resources for optimum production with minimum hazard to natural resources (Nag, 1998; Kanth et al., 2012). The morphometric parameters of the watershed are evaluated through the measurement of linear, areal and relief parameters of the watersheds. Remote sensing techniques using satellite images are convenient tools for morphometric analysis. The satellite remote sensing has the ability to provide synoptic view of large area and is very useful in analyzing drainage morphometry. The image interpretation techniques are less time consuming than the ground surveys, which coupled with limited field checks yield valuable results. The quantitative analysis of drainage system is an important aspect of characteristics of taluk (Strahler, 1964). Drainage pattern refers to spatial relationship among streams or rivers, which may be influenced in their erosion by inequalities of slope, soils, rock resistance, structure and geological history of a region. As the main objectives of this work was to carried out to detailed morphometric analysis of Kharun watershed of Seonath river of Chhattisgarh and discusses their feature and characteristic with the help of different morphometric parameter viz., streams order, streams number, streams length, mean streams length, bifurcation ratios, elongation ration, circularity ratio, shape factor, drainage density, stream frequency, texture ratio, relief ratio, length of overland flow, constant channel maintenance, etc. using the remote sensing and GIS.

MATERIALS & METHODS
Description of Study area
The study area of Kharun watershed in Seonath sub basin was selected for research work it is situated between 20^0 33' 30" - 21^0 33' 38" N latitude and 81^0 17' 51" E - 81^0 55' 25" E longitude. Location map of Kharun watershed was shown in the Figure 1.

Database and Methodology
The topographic characteristics of the study area were analyzed by using the topographic sheet of survey of India on 1:50,000 scale (survey of India, Raipur Division). It is covered by the toposheet no. 64G6, 64G7, 64G8, 64G10, 64G11, 64G12, 64G14, 64G15, 64G16, 64H5, 64H6, 64H9, 64H10. The topographical maps were georeferenced in Arc GIS 10.4 software. The Shuttle Radar Topography Mission (SRTM 30m) data were used

to derive the Digital elevation model (DEM) Figure 2. Hydrology tool under Spatial Analyst Tools in ArcGIS10.4 software was used to extract drainage channels that followed a series of steps *i.e*. DEM, fill, flow accumulation, stream order and drainage network. The definition of different morphometric parameters used in the study and empirical formulas are presented in Table 1.

TABLE 1: Empirical Relationships Used in Analysis of Morpho-Metric Parameters and Formula

Morphometric parameter	**Formula**	**Reference**
Linear Aspects		
Stream order	Hierarchial rank	Strahler (1964)
Stream length (L_u)	Length of stream	Horton (1945)
Mean stream length (L_{sm})	$L_{sm} = L_u/N_u$ where, L_{sm} = mean stream length L_u = Total stream length of order 'u' N_u = Total no. of stream segments of order 'u'	Strahler, 1964)
Stream length ratio (L_{ur})	$L_{ur} = L_u / L_{u-1}$ where, L_{ur} = stream length ratio L_u = mean of stream length of order 'u' L_{u-1} = mean of stream length of its next lower order	Horton (1945)
Bifurcation ratio (R_b)	$R_b = N_u / N_{u+1}$ R_b = Bifurcation ratio N_u = Total no. of stream segments of order 'u' N_{u+1} = no. of stream segments of the next higher order	Schumn (1956)
Mean bifurcation ratio (R_{bm})	R_{bm} = Average of bifurcation ratios of all orders	Strahler (1957)
Length of overland flow (L_g)	$Lg = 1/2D_d$ where, L_g = Length of overland flow D_d = Drainage density	Horton (1945)
Basin length (L_b)	$L_b = 1.321A^{0.568}$ where, A= Area of the basin	Nookaratnam (2005)
Basin Perimeter (P)	Outer boundary of drainage basin measured in kilometers. (GIS software analysis)	Schumn(1956)
Areal Aspects		
Drainage density (D_d)	$D_d = L_u /A$ where, D_d = Drainage density L_u = Total stream length of all orders A = Area of basin (km^2)	Horton (1945)
Basin Area (A)	Area from which water drains to a common stream. (GIS software analysis)	Strahler (1964)
Stream frequency (F_s)	$F_s = N_u / A$ where F_s = Stream frequency N_u = Total no. of streams of all orders A = Area of basin (km^2)	Horton (1932)
Texture ratio (R_t)	$R_t = N_u / p$ where, R_t = Texture ratio N_u = Total no. of streams of all orders P = Perimeter (km)	Horton (1945)
Infiltration Number (I_f)	$D_d \times F_s$ Where, D_d= Drainage density (Km/Km^2) and F_s = Drainage frequency.	Zavoiance(1985)
Form factor (R_f)	$R_f = A/L_b^2$ where, A = Area of basin (km^2) L_b^2 = Square of basin length	Horton (1932)
Shape factor (B_s)	$B_s = L_b^2/A$ where, L_b = Square of basin length A= Area of basin (km^2)	Nookaratnam (2005)
Circulatory ratio (R_c)	$R_c = 4 \times \pi \times A / P^2$ where, R_c = circulatory ratio A = Area of basin (km^2) P = Square of the perimeter (km)	Miller (1953)
Elongation ratio (R_e)	$R_e = (4 \times A / \pi)^{0.5} / L_b$	Schumn (1956)

	where, Re = Elongation Ratio A = Area of basin (km^2) L_b = Basin length	
Compactness constant (C_c)	$C_c = 0.2821P/A^{0.5}$ where, A = Area of basin (km^2) P = Perimeter (km)	Horton (1945)
Constant channel maintenance (C)	$C = 1 / D_d$ where, D_d Drainage density	Schumn (1956)
Relief Aspects		
Ruggedness Number (R_n)	$R_n = D_d * H$ R_n = Ruggedness number where, D_d Drainage density and Basin relief (m)	Strahler (1956)
Relief Ratio	$R_{hl} = H / L_b$ R_{hl} = Relief ratio where, Basin relief (m) and	Schumn (1956)

RESULTS & DISCUSSIONS

The various morphometric parameters such as stream length, bifurcation ratio, drainage density, stream frequency, form factor, texture ratio, elongation ratio, circularity ratio, compactness constant etc. were computed.

Stream order

The stream order and the total number of stream segments in watershed are shown in Table 2. Based on the Strahler (1964) system of stream ordering, the watershed has been designated as a 5th order watershed in Figure 3. The calculated result matched with Strahler (1964), it was observed that the maximum frequency is in the case of first order streams and number of streams gradually decreases as the stream order increases. The presence of large number of streams in the watershed indicates that the topography is still undergoing erosion, and at the same time, less number of streams indicates mature topography.

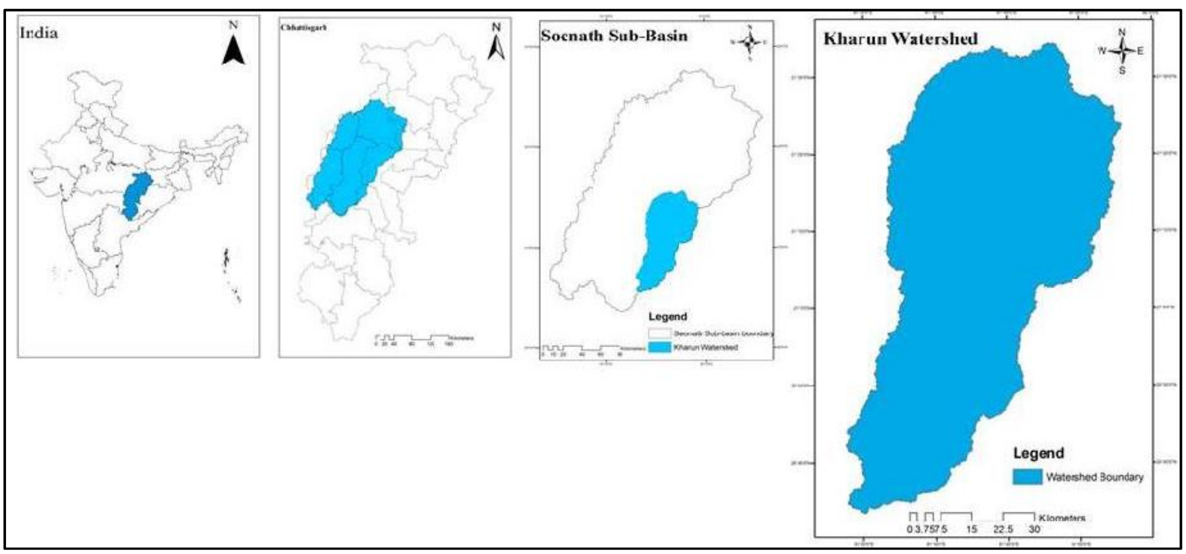


FIGURE 1: Location Map of Study Area

Stream Number (N_u)

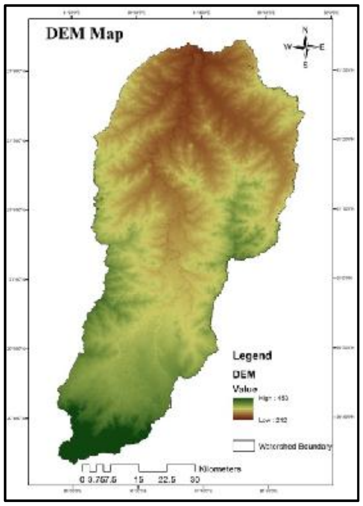
Horton (1945) states that the numbers of stream segments of each order form an inverse geometric sequence with order number. Stream number of the watershed was found out by using ArcGIS10.4. Total no of 755 streams were identified in the study area, out of which 450 was first order, 206 was in second order, 79 was in third order, 17 was in fourth order and 03 was in fifth order (Table 2).

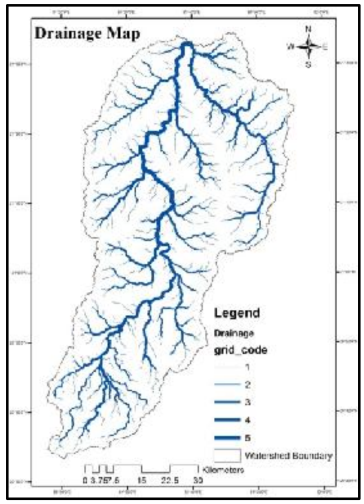
Bifurcation ratio (R_b)

The bifurcation ratio is dimensionless property, defined as ratio of number of streams in Nth order to (N+1)th order (Horton, 1945). It is an important parameter to describing stages of a river development. Bifurcation ratio is an important characteristic feature of drainage basin as it controls the rate of discharge after a sudden heavy rainfall. Potential flood damage increases as the value of bifurcation ratio increases (McCullagh, 1978). From the Table 2, clearly the bifurcation ratio values for the Kharun watershed vary from 2.2 to 5.7 with the mean bifurcation ratio of 3.7 and the highest R_b was in stream order 5th. Weighted mean bifurcation ratio was 2.6 of the steady area. The value of the weighted mean bifurcation ratio was observed that very close to the mean value of bifurcation ratio (Table 2).

Stream Length (L_u)

The length of the stream channel is a dimensional property, which reveals the size of the component of drainage lines. It is the total length of stream in a particular order. The total stream lengths of the Kharun watershed was computed with the help of Survey of India topographical sheets and ArcGIS 10.4 software tool. The stream length of different order wise was computed based on the law proposed by Horton (1945). The stream length of study area varies from 999.9 km to 78.5 km (Table 3.)





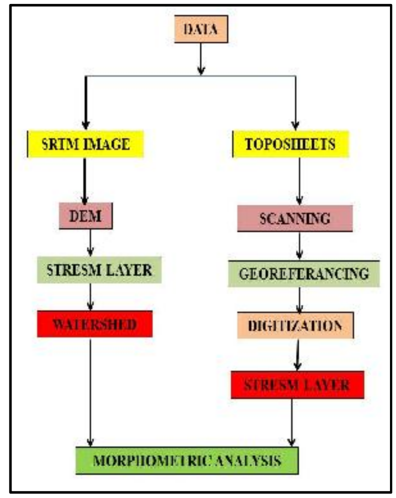


FIGURE 2: DEM of Study Area **FIGURE. 3:** Drainage Map of Study Area **FIGURE. 4:** Flow Chart of Methodology

TABLE 2: Stream Order, Streams Number, and Bifurcation Ratios in Kharun Watershed

S_u	N_u	R_b	N_{u-r}	R_b*N_{u-r}	R_{bwm}
1	450				
2	206	2.2	656.0	1433.0	
3	79	2.6	285.0	743.2	
4	17	4.6	96.0	446.1	2.6
5	3	5.7	20.0	113.3	
Total	755	15.1	1057	2735.6	
Mean	151	*3.8			

S_u: Stream order, Nu: Number of Streams
R_b: Bifurcation ratios, Rbm: Mean bifurcation ratio*,
N_{u-r}: Number of stream used in the ratio,
R_{bwm}: Weighted mean bifurcation ratio

TABLE 3: Stream Length, and Stream Length Ratio in Kharun Watershed

S_u	L_u	N_u	L_u/S_u	L_{ur}	L_{ur-r}	L_{ur}*(L_{ur-r})	L_{uwm}
1	999.9	450	2.2				
2	531.2	206	2.6	1.1	1531.1	1711.2	
3	247.7	79	3.1	0.8	778.9	659.7	
4	116.7	17	6.9	1.0	364.4	362.7	1.02
5	78.5	3	26.2	1.0	195.1	185.7	
Total	1973.9	755	40.9	3.9	2869.5	2919.2	
Mean				0.98*			

Su: Stream Order, Lu: Stream Length
L_{ur}: Stream Length ratio, L_{urm}: Mean Stream Length ratio*
L_{ur-r}: Stream Length used in the ratio,
L_{uwm}: Weighted mean Length ratio Stream.

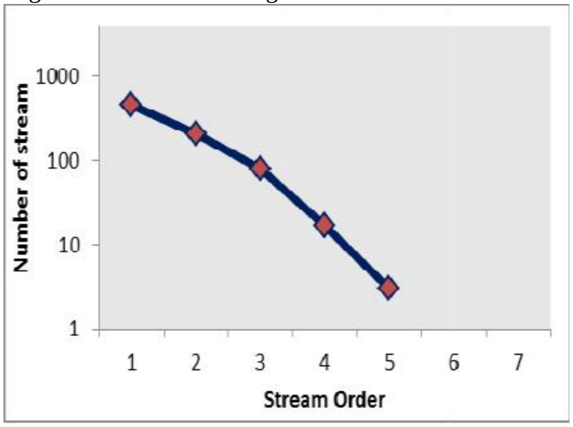
Mean Stream Length (L_{sm})

Mean Stream length is a dimensional property revealing the characteristic size of components of a drainage network and its contributing watershed surfaces (Strahler, 1964). It is computed by dividing the total length of stream of an order by total number of segments in the order, the result of mean stream length shown in (Table 3).

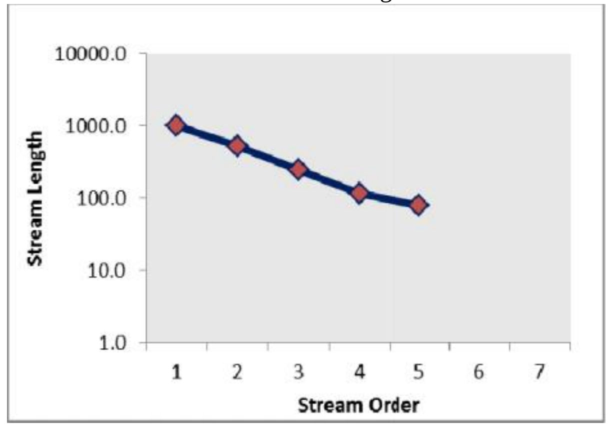
Length of overland flow (Lo)

This term refers to the length of the runoff rain water on the ground surface before it gets concentrated into definite stream channels (Horton, 1945). This factor relates inversely to the average slope of the channel and is quite synonymous with the length of sheet flow to a large degree. The length of overland flow of the Kharun watershed was found to be 0.24 kilometers, (Table 4).

Higher the values of Length of overland flow lower will be the relief and lower the values higher will be the relief.



(a)



(b)

FIGURE 5: (a) Relation of Logarithm of Number of Streams vs Stream Order (b) Relation of Logarithm of Length of Stream versus Stream Order

Drainage density (D_d)

The drainage density determines the time travel by water (Schumm, 1957). The measurement of Dd is a useful numerical measure of landscape dissection and runoff potential (Chorley et al., 1957). Drainage density is calculated as the total length of the stream of all orders divided by the area of the basin (Horton, 1932). In general, low values of Dd indicate that the regions underlain by highly permeable material with vegetative cover and low relief and vice versa (Nautiyal, 1994). The drainage density of the Kharun watershed was 0.48 km/km^2 (Table 4).

Stream frequency (F_u)

Stream frequency factor is the ratio of total number of streams in a basin to the basin area (Horton, 1945). In general, low stream frequency indicates maximum area of watershed is covered with forest and high frequency indicates maximum area is covered with agricultural land (Pandey, 2007). The stream frequency (Fu) of the Kharun watershed was found 0.18. The result having low Fu values which indicate low runoff and low flood may occur (Table 4).

Texture ratio (T)

It is the total number of stream segment of all orders per perimeter of that area (Horton, 1945). Horton recognized infiltration capacity as the single important factor which influences Texture ratio (T). Tables 4 indicate that in Texture ratio (T) of the study area was found to be 0.55.

Infiltration number (I_f)

Infiltration number plays a significant role in observing the infiltration characteristics of the basin. It is inversely proportional to the infiltration capacity of the basin. The infiltration number of the study area was 0.09 very low. It indicates that runoff will be low and the infiltration capacity high.

Circularity ratio (R_c)

It is ratio of the area of the basin to the area of circle having the same circumference as the perimeter of the watershed (Thornbury, 1969). High circularity ratio reflects rapid discharge from the watershed and watershed of low circularity ratio have high channel storage and low sediment yield–delivery ratio (Singh, 1992). It was found to be 0.03 in Kharun watershed. The Circularity ratio of the study area indicates that the drainage basin is more or less elongated and is characterized by medium to low relief.

Form factor (R_f)

It is defined as the ratio of basin area to square of the basin length (Horton, 1932). The form factor ratio value of the basin was low, 0.19 that represents elongated shape.

Shape factor (B_s)

It is the inverse of the form factor and shape factor of the Kharun watershed was found to be 5.34.

Elongation ratio (R_e)

Elongation ratio is the ratio of the diameter of a circle of the same area as that of the watershed to the maximum length of the watershed (Schumm, 1956). The value of R_e for the Kharun watershed was found to be 0.49 (Table 4). The R_e values can be grouped into three categories, namely circular (>0.9), oval (0.8-0.9), less elongated (<0.7) (Chopra, et al., 2005). The results indicate that basin is elongated. Values near to 1.0 are typical of regions of very low relief (Strahler, 1964).

Compactness constant (C_c)

The C_c is independent of size of basin and dependent only on the shape. The compactness coefficient for study area was found to be 5.99.

Constant of channel maintenance (C)

Schumn (1956) used the inverse of drainage density as a property termed as constant of channel maintenance. It decreases with increasing erodibility (Schumn, 1956). Constant of channel maintenance (C) value for Kharun watershed was found to be 2.10 (Table 4.) Higher

Ruggedness Number (R_n)

Strahler's (1968) ruggedness number is the product of the basin relief and the drainage density and usefully combines slope steepness with its length. The Ruggedness Number of the study area was 0.12 to be indicating that low value of ruggedness and basin implies that area is less prone to soil erosion and have intrinsic structural complexity in association with relief and drainage density.

Relief Ratio

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 (Schumn, 1956). The possibility of a close correlation between relief ratio and hydrologic characteristics of a basin suggested by Schumn who found that sediments loose per unit area is closely correlated with relief ratios. In the study area, the value of relief ratio was 1.62 (Table 4).

Lemniscate (k)

Chorely et.al.,(1957), express the lemniscate value to determine the slope of the basin. In the formula k= $Lb^2/4*A$ where, Lb is the basin length (km) and A is the area of the basin (km2). The lemniscate (k) value for the watershed is 1.34 respectively.

TABLE 4: Morphometric Analysis of the Study Area

Morphometric parameters	Kharun watershed
Basin Area (sq. Km)	4143.25
Total Number of Stream (Nu)	755
Perimeter(P), (Km.)	1367.61
Basin Length (L_b), (Km.)	148.79
Elongation Ratio (Re)	0.49
Texture Ratio (R_t)	0.55
Mean Bifurcation Ratio (R_{bm})	3.78
Drainage density (D), (Km/Km^2)	0.48
Stream frequency(F_s)	0.18
Infiltration number (I_f)	0.09
Form factor(R_f)	0.19
Circulatory ratio(R_c)	0.03
Length of overland flow (L_g), (Km.)	0.24
Constant channel maintenance(C)	2.10
Compactness constant (C_c)	5.99
Shape factor (B_s)	5.34
Ruggedness Number (R_n)	0.115
Basin Relief (H), (m.)	241
Relief Ratio (R_h)	1.62
Lemniscate (k)	1.34

CONCLUSION

The integrated Remote Sensing and GIS based approach is more appropriate and useful than conventional methods. The study seeks to utilize the interpretation capabilities of GIS to find out the morphometric parameters of Kharun watershed. Further, the Remote Sensing techniques have been found to be suitable for the preparation of updated drainage map in a timely and cost-effective manner and should be preferred in soil erosion studies for deriving input data. The detailed quantitative morphometric analysis enables to understand the relationships among the different aspects of the drainage patterns and their influence on landform processes, drainage, and land erosion properties. Drainage density and stream frequency are the most useful criterion for morphometric classification of drainage basins. These are controllers of the runoff pattern, sediment yield and other hydrological parameters of the drainage basin. The highest order of stream is fifth order. The numbers of lower order streams are more than the higher order streams. The low value of bifurcation ratio (3.78) indicates that the drainage of the watershed is not affected by structural disturbances. Drainage network of the basin exhibits as mainly dendritic type which indicates the homogeneity in texture and lack of structural control.

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