ISSN: 2456-043X

IJESAR

International Journal of Engineering Science and Generic Research (IJESAR)

Available Online at www.ijesar.in

Volume 3; Issue 6; November-December; 2017; Page No. 52-59

Geoinformatics based Morphometric analysis of Dumar Kocha Watershed of Angara block in Ranchi District, Jharkhand, India

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Abstract

Remote Sensing and Geographic Information System techniques are successfully being second-hand in recent times as a significant device in influential the quantitative explanation of morphometry of a basin. This technique characterizes very high precision of mapping and dimension of the morphometric investigation. The mean of the present learn is consequently to evaluate the GIS-based morphometric activities of the Dumar Kocha watershed of Angara block in Ranchi district, Jharkhand. Morphometric factor detail preserves assist in the enhanced supervision of the watershed. This study aimed to evaluate morphometric characteristics of the Dumar Kocha watershed for its prioritization towards planning and development. The watershed is located in Ranchi district close to Ranchi, the state capital of Jharkhand state in India and lies between 23º21'35"N to 23º26'10"N latitudes and 85º30'30"E to 85º36'38"E longitudes. Methods of Strahler, Horton, and Schuman were useful which helped in assessing the fluvial character of the watershed. The watersheds of the study are found is third order. The various values of a different parameter such as drainage density vis of 1.528 km/km^2, bifurcation ratio ranging from 1.736 to 3, the circular ratio are 0.712, relief ratio is 24.038, these values gives a measurement of the basin condition which can be utilized for proper planning of the watershed development.

Keywords: Watershed, Morphometric analysis, Drainage density, Stream orders, GIS, Remote Sensing.

INTRODUCTION

An advanced geoinformatics tool has a greater advantage over the traditional method for planning and management of watersheds. Drainage morphometry study using Geospatial technology by virtue of its ability to assess cost-effective manner for a larger area with lesser time (Rudraiah *et al* 2008). Proper development and conservation of natural resources like land and water are closely associated with the future of human beings necessitating the sustainable development of natural resource (Panhalkar *et al* 2012). Drainage basin are the essential unit of the fluvial scenery and a huge quantity of explore has fixed on their numerical description, counting the topology of the tributary networks, and quantitative explanation of drainage texture, model, profile, and relief description (Abrahams 1984). Morphometry is definite as the dimension of the figure and the morphometric study in the field of hydrology were first initiated by R.E. Horton and A.E. Strahler in the 1940s and 1950s. Morphometry is the amount and arithmetical investigation of the arrangement of the earth's surface, shape, and measurement of its landforms (Agarwal, 1998).

REVIEW OF LITERATURE

Ramu, B.Mahalingam, and P.Jayashree, (2013) this is esteemed for morphometric study of Tungabhadra drainage basin based on minor source i.e. the SRTM data.

Rao, L.A.K et al., (2009) it is recognized the vigorous constancy that has been achieved due to announcement between material and control to understand the present geo-hydrological character of the drainage basins. Additional investigation has been approved out with remote sensing and Geographical Information System (GIS) techniques to review the geo-hydrological uniqueness of four sub-watersheds of Agra district, Uttar Pradesh.

R.K. Somashekar and P.Ravikumar.,(2011) It is accepted for quantitative morphometric examination for Hesaraghatta watershed, and the four sub-

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watersheds, Bangalore separately by estimate their various aerial, linear, relief aspects.

M.L.Waikar and Ajay Chavadekar., (2014) carried out investigation on spatial and temporal land use/land cover (LULC) changes at provincial scales. A case study related to Chandpur reservoir area in Maharashtra state is presented.

M.D Gajul et al., (2016) the morphometric psychiatry of the drainage basin and channel system contribute a important accountability in tolerant the geo-hydrological performance of the drainage basin and is a expression of the recognized climate, geology, geomorphology, hydrology, creation and land cover of the catchment area. It has been carried out using Geographical Information System (GIS) techniques to assess the geo-hydrological characteristic of Baltra drainage basin.

DIFFERENT MORPHOMETRIC PARAMETER

Morphometric parameters of drainage networks are evaluated with established mathematical equations. Holistic stream and fluvial properties are found out from the measurement of various stream attributes of the watershed. Drainage texture, pattern, shape, and relief characteristics (Abrahams 1984). Morphometric parameters of drainage networks are evaluated with established mathematical equations. The morphometric analysis is carried out through measurement of linear, areal, and relief aspects of the basin and slope contribution (Nag and Chakraborty, 2003). Holistic stream and fluvial properties are found from the measurement of various stream attributes of the watershed.

STUDY AREA

Dumar Kocha watershed lies between 23º21'35"N to 23º26'10"N latitudes and 85º30'30"E to 85º36'38"E longitudes (Fig. 1). This area falls within the Ranchi district, close to the Ranchi city, the capital of Jharkhand state in India. Average high temperature of the region varies from 21ºC to 38ºC during the summer and it ranges from 10ºC to 24ºC during the winter. The annual rainfall received in this area varies between 1100 mm to about 1400 mm. This watershed covers an approximate area of 48.21 square kilometers falling within the Angara administrative block. The watershed is drained by the Dumar Kocha stream, which is a tributary of the system of streams within the Subarnarekha river basin. This is primarily an agrarian watershed with crop and vegetable cultivations requiring suitable land and water management for long-term sustainability of these activities.

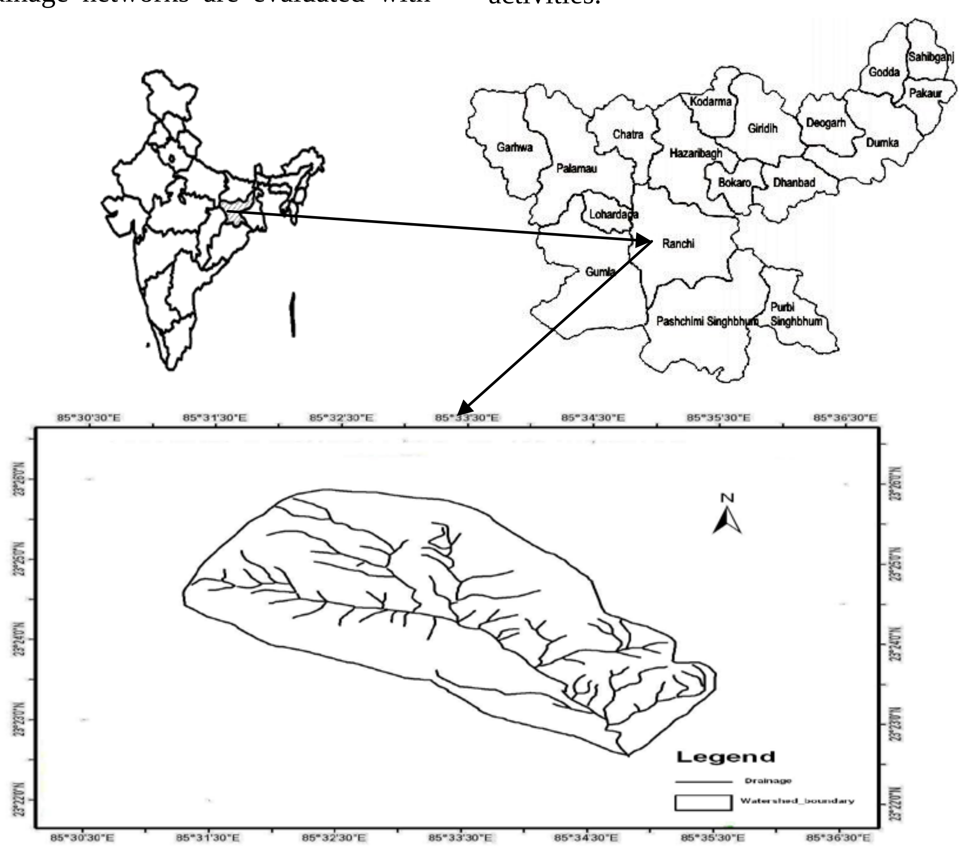

Figure 1: Dumar Kocha watershed of Angara block, Ranchi district, Jharkhand

MATERIALS AND METHODS

In current observation, morphometric analysis of basin is based on the included use of remote sensing and GIS technique. The remotely sensed data is geometrically rectified with respect to Survey of India (SOI) topographical maps at 1:50000.The digitization of dendritic drainage pattern is carried out in Arc GIS 10.3 software. (Fig.2). the various steps employed in the study are given in Fig. 2.

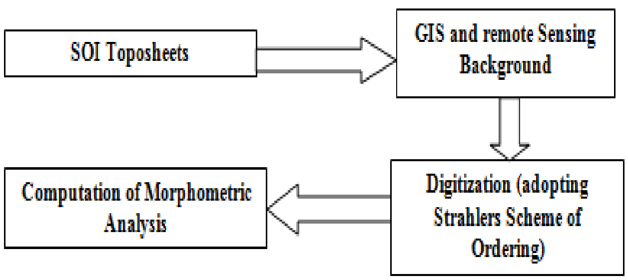

Figure 2: Steps of Methodology

MORPHOMETRIC ANALYSIS OF BASIN

The subsequent paragraphs explain the physical importance of different morphometric parameters. Further values of these parameters are obtained as per methods proposed by various researchers for the study area and indicated in respective descriptions.

RESULTS AND DISCUSSION

The drainage map of the study area was prepared using the Survey of India topographical map no 73E/11 on 1:50000 scale and updated with IRS LISS-III satellite data. ASTER Digital Elevation Model (DEM) supplemented the derivations of further topographic related aspects of the watershed. Extraction of the drainage information was accomplished by Strahler's (1957) method. These were digitized through suitable data automation techniques of GIS. Digital image processing part was carried out using ERDAS IMAGINE software and GIS operations were performed over Arc GIS software. The Morphometric parameter will be calculated using the formula given by Strahler, Horton, and Schuman. Relevant morphometric parameters were derived for this watershed as the drainage morphometric details are important components of characterization for a particular watershed area. The morphometric analysis carried out led to the details of the Dumar Kocha watershed as enumerated in table 1. Different parameters measured therein are discussed as follows:

Table 1: Method of Calculating Morphometric parameters of Drainage Basin

	Morphometric parameters	Formula/Definition	References
LINEAR	Stream order (U)	Hierarchical order	Strahler,1964
	Stream Numbers	Total Numbers of the stream	Horton, 1945
	Stream Length (LU)	Length of the stream	Horton, 1945
	Mean stream length (Lsm)	Lsm=Lu/Nu; Where, Lu=Mean stream length of a given order (km), Nu=Number of stream segment.	Horton, 1945
	Stream length ratio (RL)	RL= Lu / Lu-1 Where, Lu= 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, Nu=Number of stream segments present in the given order Nu+1= Number of segments of the next higher order	Schumn,1956
RELIEF	Basin relief (Bh)	The vertical distance between the lowest and highest points of the basin.	Schuman,1956
	Relief Ratio (Rh)	Rh = Bh / Lb Where, Bh=Basin relief, Lb=Basin length	Schumn,1956
AERIAL	Drainage density (Dd)	Dd=L/A Where, L=Total length of the stream, A= Area of the basin.	Horton, 1945
	Stream frequency (Fs)	Fs=N/A Where, L=Total number of stream, A=Area of basin	Horton, 1945
	DrainageTexture (Rt)	T=N1/P Where, N1=Total number of first order stream, P=Perimeter of the basin.	Horton, 1945
	Form factor (Rf)	Rf=A/(Lb)2 Where, A=Area of basin, Lb=Basin length	Horton, 1945
	Circulatory Ratio (Rc)	Rc = 4 * Pi * A / P^2, A = Area of the basin (km2), P^2 =Square of the perimeter (km)	Hortan, 1945
	Elongation ratio (Re)	Re=√(Au/π)/ Lb Where, A=Area of basin, π=3.14, Lb=Basin length	Schumn 1956

Source: M.L.Waikar et al, Morphometric Analysis of a Drainage Basin Using Geographical Information System: A Case study (2014)

LINEAR ASPECTS OF THE CHANNEL SYSTEM

Linear aspects include drainage parameters such as stream order (Nu), Stream Numbers, stream length (Lu), Mean Stream Length (Lsm), Stream Length Ratio (Rl), and Bifurcation Ratio (Rb).

Stream Order (u)

As a first step of the analysis of drainage of this watershed, stream ordering was undertaken. One of the first attributes quantified was the hierarchy of stream segments according to an ordering classification system. Streams are categorized according to their position depicted by order of magnitude within a drainage network. The order is calculated based on the Strahler's method. Using this method, channel segments were ordered numerically from a stream's headwaters to the down-stream points. Numerical ordering began with assigning the value of 1 to the tributary streams at the headwaters. A stream segment that resulted from joining of two first order segments was given an order of 2. Two-second order streams formed a 3rd order stream, and so on. Thus, the drainage order map of the streams of this watershed was generated (figure 2). This shows that the first order streams have zero tributaries; the second order streams have tributaries of only first order, the third order streams have first and second order tributaries and so on. The number of first order streams in a basin of a given size is dependent on the climatic, geologic and hydrologic factors etc (Bagyaraj, M et al., 2011).

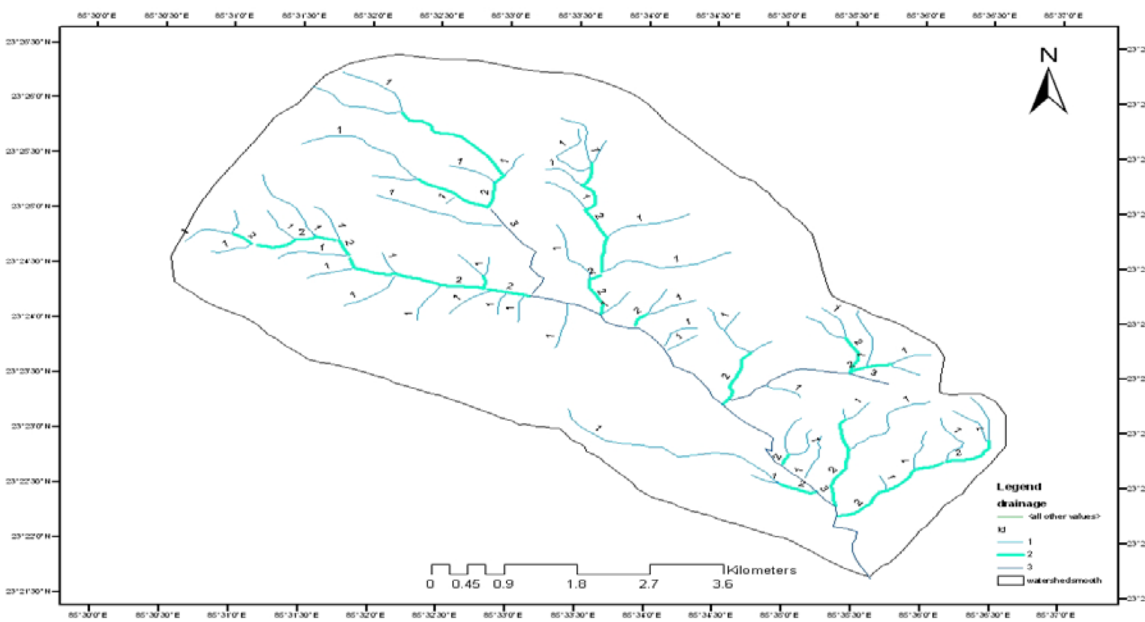

Figure 3: Stream order map of the study area

Stream Numbers

Horton introduced the concept of stream numbers in the year 1945 which is one of the most extensively used relationships in river basin hydrology. The total number of streams of a single type is known as stream number. It shows that the increase of stream order implies the decrease in the stream segments. This study area was found to be a third order stream watershed with a total number of 115 stream segments of different orders. The number of segments of the first order streams of this watershed was found to be 66, a number of second order stream segments found was 38 and that of third order stream was found to be 11. This was worked upon using Arc GIS software through the process of drainage network extraction and generation of attribute table of the drainage network analysis (Coskun., et al 2009).

Stream Length (Lu)

The total length of the stream segments is maximum for the first order streams and decreases as the stream order increases as per the Horton's rule. For this watershed, the first order stream length found was 45.091 km, second-order stream length was found to be 17.531 km and that of the third order stream was 11.088 km. Higher to lower stream lengths with the increasing order of streams of this watershed was found to be matching with the Horton's rule.

Mean Stream Length (Lsm)

The mean stream length can be computed by dividing the total length of the stream of an order by the number of stream segments of the same order. Mean stream length (Lsm) is expressed as Lu/Nu Where, Lu = total stream length of the order 'u', Nu = total number of stream segments of order 'u'. The calculated mean stream length showed a range of variation from 0.683 to 1.008 km in this watershed in the different orders. Slope and elevation of any area largely affect the Lsm values of different orders of the stream (Gavrilă., et al., 2012).

Stream Length Ratio (RL)

The ratio of the length of the one order to the next lower order of the stream segments is termed stream length ratio.The stream length ratio was observed to be varying between the sub-basins of streams of different orders. This may be due to the variation in slope and topography resulting from the geomorphic developments (Sarala.C., 2013).

Bifurcation Ratio (Rb)

It can be computed by using the ratio of the number of the stream segments of given order to the number of segments of the next higher orders. It is expressed as Rb = Nu / Nu + 1, Where, Rb = Bifurcation ratio, Nu = Total no. of stream segments of order 'u' and Nu + 1 = Number of segments of the next higher order. The result indicates an increase from one order to next order (M.L.Waikar et al., 2014).

RELIEF ASPECTS OF THE CHANNEL SYSTEM

Aerial Aspect includes drainage parameters such as Basin Relief (Bh), Relief Ratio (Rh)

Basin relief (Bh)

It can be computed from the elevation difference between the highest and lowest point on the valley floor of the region. The relief valve is for the study area 252 meter derived from the Digital elevation model of the study area.

Relief Ratio (Rh)

It can be computed from the maximum relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line is termed as relief ratio.The relief ratio for the study area is 23.028.

AREAL ASPECTS OF THE DRAINAGE CATCHMENT

Aerial Aspect includes drainage parameters such as Drainage Density (Dd), Stream Frequency (Fs), Drainage Texture (Dt), Form Factor (Rf), Circulatory Ratio (Rc), Elongation Ratio (Re).

Drainage Density (Dd)

It can be calculated by using radio of total length of streams of all orders to the area of drainage. It can be denoted as D = Lu / A, Where, D = Drainage density, Lu = Total stream length of all orders, A = Area of the basin (km2). (Ahmed Ali et al., 2016).The drainage density in the study area 1.528 per km2, which is shown in figure 4.

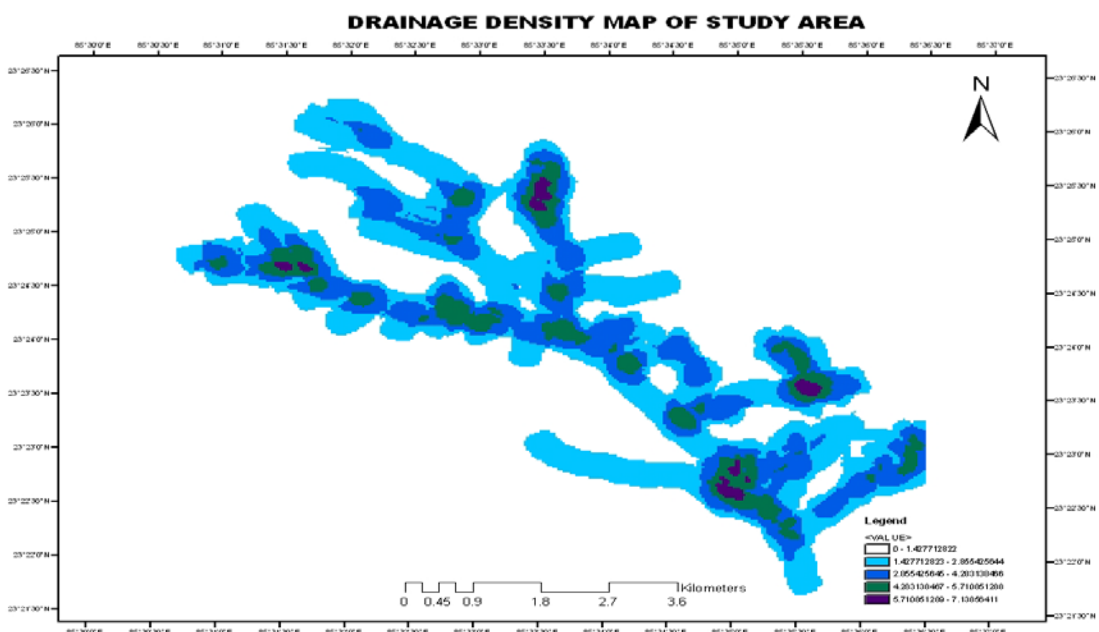

Figure 4: Drainage density map of the study area

Stream Frequency / Channel Frequency (Fs)

It can be computed as by using the formula Fs = Nu / A, Where, Fs = Stream frequency Nu = Total no. of streams of all orders, A = Area of the basin (km2). The Fs values of the study area are 2.385 (Nag et al., 2003).

Drainage Texture (Rt)

Drainage texture is the total number of stream segments of all orders per perimeter of that area Rt = Nu / P, Where, Rt = Drainage texture, Nu = Total no. of streams of all orders, P = Perimeter (km). The value of drainage texture ratio of the study area is 3.943 (Nishant Vaidya et al., 2013).

Form Factor (R_f)

It can be calculated by using formula Rf = A / Lb², Where, Rf = Form factor, A = Area of the basin (km2), Lb² = Square of basin length value of form factor computed here is 0.438, Which suggest the oval shape for the watershed area (Subudhi et al., 1989).

Circulatory Ratio (R_c)

It can be compute by using Hortons formula Rc = 4 * Pi * A / P², Where, Rc = Circularity ratio, Pi = 'Pi' value i.e., 3.14, A = Area of the basin (km2), P² =Square of the perimeter (km) ,the Rc value is 0.72

Elongation Ratio (Re)

It can be calculated as using the Hortons formula $Re = 2\sqrt{(A / Pi)} \; / Lb$, Where, Re represents Elongation ratio, A represents Area of the basin (km2) and =3.141, Lb represents the Basin length (Gajul.M.D. et al., 2016). The elongation ratio value of the watershed is 0.373.

Table 2: Morphometric characteristics of the Dumar Kocha watershed

Stream Order	***Stream Segments***	***Stream Length (km)***	***Basin Area (km2)***	***Perimeter (km)***	***Basin Length (km)***	***Mean Stream Length (km)***	***Stream Length ratio***	***Bifurcation Ratio***	***Mean Bifurcation Ratio***
First	66	45.091	48.21	29.16	10.48	0.683	Second Order/First Order = 0.388	1.736	2.595
Second	38	17.531				0.461	Third order/Second Order = 0.632	3.454	
Third	11	11.088				1.008			
Total	115	73.71							
	Drainage density (km/km2)	***Stream frequency***	***drainage texture***	***Form factor***	***Circulatory ratio***	***Relief ratio***	***Elongation ratio***	***Relief aspect in mtr***	
	1.528	2.385	3.943	0.438	0.712	24.038	0.373	252	

CONCLUSION/ SUGGESTIONS/ FINDINGS

The geoinformatics tool is widely used for calculating the drainage morphometry variables which is essential for the estimation of soil erosion condition and planning for the development of the watershed, The results show it is 3rd order drainage basin and the highest drainage density value varies between 5 to7.13 which is shown in figure-3it means in that particular area the erosion is more as compared to lower drainage density area, Similarly the bifurcation ratio is under 3 so it is not highly vulnerable to the erosion but is moderately expose to soil erosion. The Circularly ratio is less than the value of 3.141 which is 0.72 so the shape of the basin is elliptical.

ACKNOWLEDGMENT

The authors are thankful to Professor A.P.Krishna, Birla Institute of Technology Mesra, Ranchi Department of Remote Sensing is thanked for fast forward support during the GIS and Remote Sensing applications.

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