The evaluation of Morphometric characteristics of Upper Subarnarekha Watershed drainage basin using Geoinformatics as a tool, Ranchi, Jharkhand
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ABSTRACT

The development of Morphometric techniques was a major advance in the quantitative description of the geometry of the drainage basins and its network which helps in characterizing the drainage network, comparing the characteristic of several drainage networks and examining the effect of variables such as lithology, rock structure, rainfall etc. The geographical position of watershed is 85°10’0” to 85°40’0”E and 23°10’0” to 23°40’0” N. The elevation of the watershed ranges from 300m to 700m within Ranchi district. The study was carried out using the method of Horton and Strahler, to rank the stream segments using ArcGIS 9.2. The relevant numbers of the streams were entered into the attribute table and all other analyses based on the mathematical formulas. The results indicated that the watershed area was 594.68 km², perimeter 159.26km, mean slope 32.21, axial length 54.70 km, basin width 23.61 km, form factor 0.20, compactness factor 1.40, circulatory ratio 0.29, elongation ratio 0.50, number of segments was 935 of each order those varied 1 to 6th. The stream frequency and drainage density were 1.57 (No./km²) and 1.12(km/km²). Bifurcation ratio and length of overland flow were 3.94 and 0.56 km. The results of this analysis would be useful in determining the effect of watershed characteristics such as size, shape, slope of the watershed & distribution of stream net work within the watershed.

Keywords: Morphometry, Upper Subarnarekha watershed, GIS and Remote Sensing

1. Introduction

The basin morphometric characteristics of the various basins have been studied by many scientists using conventional (Horton, 1945; Smith, 1950; Strahler, 1957) and remote sensing and GIS methods (Krishnamurthy and Srinivas, 1995; Srivastava and Mitra, 1995; Agarwal, 1998; Biswas et al., 1999; Narendra and Nageswara Rao, 2006).

The Upper Subarnarekha watershed lies in the Ranchi District of Jharkhand State. The geographical position of study area is 23010’0” to 23040’0” N and 85010’0” to 85040’0” E with an area of 594.68 km2. The elevation of the watershed ranges from 300m to 700m within Ranchi district. The main objective of this study, using advanced remote sensing and GIS technology is to compute basin morphometric characteristics for various parameters.
2. Physiography of Study Area

The study area lies in the Ranchi District of Jharkhand State. The geographical position of study area is $23^010'0"$ to $23^040'0"$ N and $85^010'0"$ to $85^040'0"$ E with an area of 594.68 km$^2$. The Subarnarekha is the main river passing through the block, which originates south of village Nagri, 15 km west and south-west of Ranchi town. It contains treacherous quicksand, which is dangerous to cross. The name means streak of gold and gold is found in its bed in minute quantities.

The physiographic position determines the pedogenetic stage of soil development within an area. Ranchi District is representative of massive granitized genesis and exposed earth’s surface due to removal of superincumbent load of overlaying rocks through continued erosion, become interesting landforms. In the regions covering the Sadar Sub-Division of Ranchi District Dharwar rocks, gneisses; granite and pegmatite are extensively exposed.

The soil and climatic conditions of an area largely determine the cropping pattern and crop yields. The area receives rainfall almost throughout the year, though the concentration is during the monsoon months from June to September. During the monsoon months the area receives about 82 per cent of the annual rainfall. July and August are the rainiest months. Rocks of Archean era both Dharwars and post Dharwars, dominate the geological formation of this region. The western tract above 3000 ft. elevation has valuable deposits of bauxite, laterite and Kaolin. The Eastern and Southern zones have epidirite and home blend but patches of volcanic agglomerates are also found. The Northern zone has lower Gondwana formation. They consist of shales, sandstones and agglomerates.

![Figure 1: Location map of the study area](image)

3. Materials and Method
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The Morphometric analysis of Upper Subanarekha river watershed have been carried out on the basis of a topographic map of study area, Ranchi district, Jharkhand followed by relevant field checks supported by high resolution satellite data. Based on topographical map on 1:50,000 scales (Survey of India, toposheet No.-73E/2, 73E/3, 73E/6, 73E/7, and 73E/11) the drainage map of Upper Subanarekha river basin has been prepared. Digitization work has been carried out for entire analysis of basin morphometry using GIS software (ArcGIS 9.2). The order was given to each stream by following Strahler (1964) stream ordering technique. The attributes were assigned to create the digital data base for drainage layer of the river basin.

Various morphometric parameters such as linear aspects of the drainage network: stream order (Nu), bifurcation ratio (Rb), stream length (Lu) and areal aspects of the drainage basin: drainage density (D), stream frequency (Fs), texture ratio (T), elongation ratio (Re), circularity ratio (Rc), form factor ratio (Rf) of the basin were computed.

4. Results and Discussions

The various morphometric parameters of the Upper Subarnarekha area were determined and are summarized in Tables 1 and 2.

4.1 Linear Aspects of the Channel System

The linear aspects of drainage network such as stream order (Nu), bifurcation ratio (Rb), Stream length (Lu) results have been presented in Table 1.

4.1.1 Stream Order (Na)

Order is directly proportional to channel dimension and to stream of discharge in a basin. In present study Strahler’s (1957) system of stream ordering, which is modification of Horton’s (1945) system has been used. In it the smallest unbranched stream segment was designated as the first order stream, the one formed by merging of two such order streams, the second order stream and so on. When low order stream meets high order streams, the result is the same high order stream. The study area is a 6th order drainage basin (Figure 2).
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**Figure 2:** Drainage pattern and their order identified from the study area

**Table 1:** Linear aspects of the drainage network of the study area

<table>
<thead>
<tr>
<th>River basin</th>
<th>Stream Order u</th>
<th>Number of Streams $N_u$</th>
<th>Total length of streams in km $L_u$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Subarnarekha</td>
<td>1</td>
<td>698</td>
<td>403.96</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>178</td>
<td>127.09</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>48</td>
<td>73.46</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>8</td>
<td>22.58</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>2</td>
<td>10.42</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>1</td>
<td>30.29</td>
</tr>
</tbody>
</table>

**Bifurcation ratio $R_b$**

<table>
<thead>
<tr>
<th>$1^{st}$ order/ $2^{nd}$ order</th>
<th>$2^{nd}$ order/ $3^{rd}$ order</th>
<th>$3^{rd}$ order/ $4^{th}$ order</th>
<th>$4^{th}$ order/ $5^{th}$ order</th>
<th>$5^{th}$ order/ $6^{th}$ order</th>
<th>Mean Bifurcation ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.92</td>
<td>3.7</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>3.92</td>
</tr>
</tbody>
</table>

**Table 2:** Aerial aspects of the study area

<table>
<thead>
<tr>
<th>Morphometric parameters</th>
<th>Symbol/formula</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (sq. km)</td>
<td>$A$</td>
<td>594.68</td>
</tr>
<tr>
<td>Perimeter (km)</td>
<td>$P$</td>
<td>159.26</td>
</tr>
<tr>
<td>Drainage density (km/sq. km)</td>
<td>$D_d = L_u / A$</td>
<td>1.12</td>
</tr>
<tr>
<td>Stream frequency</td>
<td>$F_s = N_s / A$</td>
<td>1.57</td>
</tr>
<tr>
<td>Texture ratio</td>
<td>$T = N_s / P$</td>
<td>5.87</td>
</tr>
<tr>
<td>Basin length (km)</td>
<td>$L_b$</td>
<td>54.70</td>
</tr>
<tr>
<td>Elongation ratio</td>
<td>$R_e = 2 * \sqrt{A / \pi}$ / $L_b$</td>
<td>0.50</td>
</tr>
<tr>
<td>Circularity ratio</td>
<td>$R_c = 4 \pi A / P^2$</td>
<td>0.29</td>
</tr>
<tr>
<td>Form factor ratio</td>
<td>$F_f = A / L_b^2$</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Where

$L_u = \text{Total stream length of all orders}$

$N_u = \text{Total no. of streams of all orders}$

$N_1 = \text{Total no. of 1st order streams}$

$\pi = 3.14$

4.1.2. Bifurcation ratio ($R_b$)

The term bifurcation ratio ($R_b$) is used to express the ratio of the number of streams of any given order to the number of streams in next higher order (Schumnn, 1956). Bifurcation ratios characteristically range between 3.0 and 5.0 for basins in which the geologic structures do not distort the drainage pattern (Strahler, 1964). Strahler (1957) demonstrated that bifurcation ratio shows a small range of variation for different regions or for different environment dominates. The mean bifurcation ratio value is 3.92 for the
study area (Table 1) which indicates that the geological structures are less disturbing the drainage pattern.

4.2. Area Aspects of the Drainage Basin

Area of a basin (A) and perimeter (P) are the important parameters in quantitative morphology. The area of the basin is defined as the total area projected upon a horizontal plane contributing to cumulate of all order of basins. Perimeter is the length of the boundary of the basin which can be drawn from topographical maps. It is interesting that the maximum flood discharge per unit area is inversely related to size (Chorley, et al., 1957). The aerial aspects of the drainage basin such as drainage density (D), stream frequency (Fs), texture ratio (T), elongation ratio (Re), circularity ratio (Rc) and form factor ratio (Rf) were calculated and results have been given in Table 2.

4.2.1. Drainage Density (D)

Horton (1932), introduced the drainage density (D) is an important indicator of the linear Scale of land­form elements in stream­eroded topography. It is the ratio of total channel segment lengths cumulated for all orders within a basin to the basin area, which is expressed in terms of mi/sq. mi or km/sq. km. The drainage density indicates the closeness of spacing of channels, providing a quantitative measure of the average length of stream channel for the whole basin. It has been observed from drainage density measurements made over a wide range of geologic and climatic types that a low drainage density is more likely to occur in regions of highly resistant of highly permeable subsoil material under dense vegetative cover, and where relief is low. High drainage density is the resultant of weak or impermeable subsurface material, sparse vegetation and mountainous relief. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture (Strahaler, 1964).

The drainage density (D) of the study area is 1.12 km/sq. km indicating low drainage density. The type of rock also affects the drainage density. It is suggested that the low drainage density indicates the basin is highly permeable subsoil and thick vegetative cover (Nag, 1998). Smith (1950) and Strahler (1957) have described drainage density values less than 5.00 as course, between 5 – 13.7 as medium, between 13.7 – 155.3 as fine, and greater than 155.3 as ultra fine.

4.2.2. Stream frequency (Fs)

The stream frequency or channel frequency has been defined as the number of streams per unit of area. It directly depends on the size of the drainage area. According to Horton (1945), A large basin may contain as many finger tip tributaries per unit of area as a small drainage basin, and in addition, it usually contains a larger stream or streams. The stream frequency value of the basin is 1.57. The value of stream frequency (Fs) for the basin exhibit positive correlation with the drainage density value of the area indicating the increase in stream population with respect to increase in drainage density

4.2.3. Texture Ratio (T)
Texture ratio (T) is an important factor in the drainage morphometric analysis which is depending on the underlying lithology, infiltration capacity and relief aspect of the terrain. In the present study the texture ratio of the basin is 5.87 and categorized as moderate in nature

4.2.4. Elongation Ratio (Re)

Schumm (1956) used an elongation ratio (Re) defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. 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 to 1.0 are typical of regions of very low relief (Strahler, 1964). The value Re of the study area is 0.50 indicates that the low relief of the terrain and elongated in shape.

4.2.5. Circularity Ratio (Rc)

Miller (1953) defined a dimensionless circularity ratio (Rc) as the ratio of basin area to the area of circle having the same perimeter as the basin. He described the basin of the circularity ratios range 0.4 to 0.5 which indicates strongly elongated and highly permeable homogenous geologic materials. The circularity ratio value of the basin is 0.29 corroborates the Miller’s range which indicating that the basin is elongated in shape, low discharge of runoff and highly permeability of the subsoil condition

4.2.6. Form Factor Ratio (Rf)

Quantitative expression of drainage basin outline form was made by Horton (1932) through a form factor ratio (Rf), which is the dimensionless ratio of basin area to the square of basin length. Basin shape may be indexed by simple dimensionless ratios of the basic measurements of area, perimeter and length (Singh, 1998). The form factor value of the basin is 0.20 which indicate lower value of form factor and thus represents elongated in shape. The elongated basin with low form factor indicates that the basin will have a flatter peak of flow for longer duration. Flood flows of such elongated basins are easier to manage than of the circular basin.

5. Conclusion

It is easy to analyze the Morphometric features of the basin using GIS and Remote Sensing. Size, shape, slope of the watershed basin& distribution of stream network within the watershed indicated the watershed characteristics. The morphometric analysis carried out in the Upper Subarnarekha shows that the basin is having low relief of the terrain and elongated in shape. This is useful to conserve reservoirs and apply proper watershed management practices. The morphometric parameters evaluated using GIS helped us to understand various terrain parameters such as nature of the bedrock, infiltration capacity, runoff, etc

5. References


