Morphometric Analysis of Tungabhadra Drainage Basin in Karnataka using Geographical Information System

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ABSTRACT
The study of morphometric analysis of Tungabhadra drainage basin has been conducted based on the secondary source, the SRTM data has been downloaded from GLCF website. The downloaded data has been analyzed using ArcGIS software, the study Linear, Relief and Arial aspects of drainage basin retrieved that, total numbers of streams are 11894, in that 6058 are first orders, 3446 are second orders, 1345 are third orders and 1045 are fourth order streams. The streams have been formed in dendritic drainage pattern. The length of stream segments is maximum for first order stream and decreases as the stream order increases. The result of drainage density shows the value 0.11 per square kilo meters in study area, which suggesting that the area has highly permeable subsoil, dense vegetation cover and low relief.

Key Words: Morphometric, Watershed, Drainage Basin, Flow Accumulation, Digital Elevation Model

Introduction
The study of stream order in drainage basin helps to identify the natural environment of a place. The Geographers, Geoscientist, Hydrologist and Geologists study stream order in drainage basin to get idea of the size and strength of specific waterways within stream networks and important component to water management. Stream orders have been classified based on its relative position in the stream network, which helps us to understand the similarities and differences between them. Different types of stream order classification system has been developed, in that one of the earliest method and most commonly used method was developed by Strahler In 1952. The study of streams and waterways in general is known as surface hydrology and is a core element of environmental geography. In recent years development of Geographical Information Systems helps the researchers and scientist to study the stream order accurately and easily. The current study also has been done using GIS technique to analysis the Tungabhadra drainage basin.

STUDY AREA
The river Tungabhadra originate in Chikmagalur district of Karnataka, which formed by the convergence of the Tunga and the Bhadra River, it is flowing down the eastern slope of the Western Ghats in the Karnataka (Map: 1). Tungabhadra is the largest tributary of the river Krishna and this is the lifeline of Bellary, Koppal and Raichur districts in Karnataka. The basin is mostly rainyfed, dominated by red soils and major crops grown are paddy, jowar, sugarcane, cotton and Ragi. The geographical location of drainage basin is from 74°52’30.3’ E to 77°28’57.8’ E and 13°08’37.7’ N to 16°15’1.2’ N.

Methodology
The study is based on the secondary data. The Shuttle Radar Topographic Mission data has been downloaded from Global Land Cover Facility website. The ArcGIS software has been used to analysis the stream order of drainage basin. The contour map has been prepared from the downloaded topographic elevation data. The Triangulated Irregular Network (TIN) map has been created from the prepared contours, using TIN as an input file the output Digital Elevation Model (DEM) derived. The created DEM has been corrected using FILL tool (which removes the errors such as sinks and eliminates discontinuities) in ArcGIS Hydrology toolset. Flow Direction (Creates a raster of flow direction from each cell to its steepest downslope neighbor), Flow Accumulation (Creates a raster of accumulated flow into each cell. A weight factor can optionally be applied), Stream Order tool in Strahler method (Assigns a numeric order to segments of a raster representing branches of a linear network) and Stream to feature tools have been used to find out pattern of stream in study area. Pour points were selected to delineate the watershed boundary from the main river joining points of Tungabhadra. Number of stream orders has been calculated using raster file itself and length of each stream have been calculated using the feature (.shp) file in ArcGIS. The length, perimeter and area of drainage basin have been calculated using suitable tools in software. When the necessary data have been collected from the software the Linear, Relief and Arial properties of drainage basin have been analyzed using the method shown in table 1.
Table 1: Methods of Calculating Morphometric parameters of Drainage basin

<table>
<thead>
<tr>
<th>Morphometric Parameters</th>
<th>Methods</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stream order (U)</td>
<td>Hierarchical order</td>
<td>Strahler, 1964</td>
</tr>
<tr>
<td>Stream length (L_u)</td>
<td>Length of the stream</td>
<td>Horton, 1945</td>
</tr>
<tr>
<td>Mean stream length (L_m)</td>
<td>[L_m = \frac{L_u}{N_u}] where, (L_u)=Stream length of order ‘U’, (N_u)=Total number of stream segments of order ‘U’</td>
<td>Horton, 1945</td>
</tr>
<tr>
<td>Stream length ratio (R_L)</td>
<td>[R_L = \frac{L_u}{L_{u-1}}] where (L_u)=Total stream length of order ‘U’, (L_{u-1})=Stream length of next lower order.</td>
<td>Horton, 1945</td>
</tr>
<tr>
<td>Bifurcation ratio (R_b)</td>
<td>[R_b = \frac{N_u}{N_{u+1}}] where, (N_u)=Total number of stream segment of order ‘u’, (N_{u+1})=Number of segment of next higher order</td>
<td>Schumn, 1956</td>
</tr>
<tr>
<td>Basin relief (B_h)</td>
<td>Vertical distance between the lowest and highest points of watershed.</td>
<td>Schumn, 1956</td>
</tr>
<tr>
<td>Relief ratio (R_h)</td>
<td>[R_h = \frac{B_h}{L_b}] Where, (B_h)=Basin relief, (L_b)=Basin length</td>
<td>Schumn, 1956</td>
</tr>
<tr>
<td>Ruggedness number (R_n)</td>
<td>[R_n = B_h \times D_d] Where, (B_h)=Basin relief, (D_d)=Drainage density</td>
<td>Schumn, 1956</td>
</tr>
<tr>
<td>Drainage density (D_d)</td>
<td>[D_d = \frac{L}{A}] where, (L)=Total length of streams, (A)=Area of watershed</td>
<td>Horton, 1945</td>
</tr>
<tr>
<td>Stream frequency (F_s)</td>
<td>[F_s = \frac{N}{A}] where, (N)=Total number of streams; (A)=Area of watershed</td>
<td>Horton, 1945</td>
</tr>
<tr>
<td>Texture ratio (T)</td>
<td>[T = \frac{N1}{P}] where, (N1)=Total number of first order streams; (P)=Perimeter of watershed</td>
<td>Horton, 1945</td>
</tr>
<tr>
<td>Form factor (R_f)</td>
<td>[R_f = \frac{A}{(L_b)^2}] where, (A)=Area of watershed, (L_b)=Basin length</td>
<td>Horton, 1932</td>
</tr>
<tr>
<td>Circulatory ratio (R_c)</td>
<td>[R_c = \frac{4\pi A}{P^2}] where, (A)=Area of watershed, (\pi=3.14), (P)=Perimeter of watershed</td>
<td>Miller, 1953</td>
</tr>
<tr>
<td>Elongation ratio (R_e)</td>
<td>[R_e = 2\sqrt{\frac{(A/\pi)}{L_b}}] where, (A)=Area of watershed, (\pi=3.14), (L_b)=Basin length</td>
<td>Schumn, 1956</td>
</tr>
<tr>
<td>Length of overland flow (L_g)</td>
<td>[L_g = \frac{1}{2D_d}] where, (D_d)=Drainage density</td>
<td>Horton, 1945</td>
</tr>
<tr>
<td>Constant channel maintenance (C)</td>
<td>[C_{of} = \frac{1}{D_d}] where, (D_d)=Drainage density</td>
<td>Horton, 1945</td>
</tr>
</tbody>
</table>

Result and discussion
The result of the Linear, Relief and Arial properties of Tungabhadra drainage basin are given below.

<table>
<thead>
<tr>
<th>Morphometric Parameters</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basin Area (Km²)</td>
<td>38921.30</td>
</tr>
<tr>
<td>Perimeter (Km)</td>
<td>1499.27</td>
</tr>
<tr>
<td>Basin Order</td>
<td>4.00</td>
</tr>
</tbody>
</table>
Table: 2(a) Results of Morphometric Analysis

<table>
<thead>
<tr>
<th>Stream Order</th>
<th>Number of Stream</th>
<th>Bifurcation Ratio (Rb)</th>
<th>Stream Length (Lm) (Km)</th>
<th>Stream Length Ratio (Rl)</th>
<th>Mean Stream Length (Lsm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6058</td>
<td>1.76</td>
<td>2086.24</td>
<td>1.75</td>
<td>0.34</td>
</tr>
<tr>
<td>2</td>
<td>3446</td>
<td>2.56</td>
<td>1193.43</td>
<td>2.55</td>
<td>0.35</td>
</tr>
<tr>
<td>3</td>
<td>1345</td>
<td>1.29</td>
<td>468.00</td>
<td>1.27</td>
<td>0.35</td>
</tr>
<tr>
<td>4</td>
<td>1045</td>
<td>0.00</td>
<td>368.82</td>
<td>0.09</td>
<td>0.35</td>
</tr>
</tbody>
</table>

**Linear Aspects**

The linear aspects of morphometric analysis of drainage basin include stream order, stream length, mean stream length, stream length ratio and bifurcation ratio.

**Stream order**

Differentiate the stream orders in basin is the first step in drainage basin analysis and expresses the hierarchical relationship between stream segments, their connectivity and the discharge arising from contributing catchments. The Strahler’s method has been followed in this study; according to his definition the smallest head water tributaries are called first order streams. Where two first order streams meet, a second order stream is created. Where two second order streams meet, a third order stream is created and so on. It has been retrieved that the highest order in study area is four. The total numbers of streams are 11894, out of which 6058 are first orders, 3446 are second orders, 1345 are third orders and 1045 are fourth orders streams. The streams have been formed in dendritic drainage pattern. The calculated number of streams in number of orders retrieved that number of stream segments are decrease as the stream order is increase. Horton (1945) laws of stream numbers states that the number of stream segments of each order forms an inverse geometric sequence against plotted order. Most drainage networks show a linear relationship with small deviation from a straight line. Plotting the logarithm of number of streams against stream’s order shows a straight line which states the number of streams usually decreases as the stream order increases.

![Fig: Semi-log plots of Stream order vs Stream number](image)
Stream Length ($L_u$)
The stream length is calculated on the basis of the law proposed by Horton (1945). The length of various orders in drainage basin has been calculated using ArcGIS. The length of first orders is 2086.24 Km, second order stream is 1193.43 Km, third order stream is 468.00 Km and fourth order stream is 368.82 Km. The length of stream segments is maximum for first order stream and decreases as the stream order increases. If there is any deviation from its general behavior indicates that the terrain is characterized by high relief/moderately steep slopes, underlain by varying lithology and probable uplift across the basin. From the logarithms it can be inferred that the number of streams of a given order, when plotted against the order, the point lie on a straight line.

Mean Stream Length ($L_{mean}$)
The mean stream length of a channel is the characteristic size of drainage network components and its contributing basin surface. It is calculated by dividing the total stream length of order “u” by the number of stream of segments in the order. The mean stream length of study area is same in second, third and fourth orders (0.35) while slight change is in first order (0.34).

Stream Length Ratio ($R_L$)
The stream length ratio can be defined as the ratio of the mean stream length of a given order to the mean stream length of next lower order and having important relationship with surface flow and discharge. The ratio between orders in the study area differs from one order to another, which indicates late youth to mature stage of geomorphic development.

Bifurcation Ratio ($R_b$)
The bifurcation ratio is the ratio of the number of stream segments of given order to the number of segments of next higher order (Horton 1945) considered the bifurcation ratio as an index of relief and dissection. It is well demonstrated that Bifurcation ratio shows only a small variation for different regions on different environment except where powerful geological control dominates (Strahler 1957). The study area bifurcation ratio result shows that low in third order and high in second order ranges between 1.29 to 2.56 in which geology is reasonably homogeneous and no structural disturbances.

Relief Aspect
The relief aspects determined include relief ratio, relative relief and ruggedness number.

Relief Ratio ($R_h$)
The relief ratio is the ratio of maximum relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line is termed as relief ratio (Schumm, 1956). The $R_h$ normally decreases with the increasing area and size of sub-basin of a given drainage basin (Gottschalk, 1964). The relief ratio of study area is 5.65.

Ruggedness number ($R_n$)
It is the product of maximum basin relief (H) and drainage density (D), where both parameters are in the same unit. An extreme high value of ruggedness number occurs when both variables are large and slope is not only steep but long as well (Strahler, 1956). The result shows that the study area is extremely rugged with high relief and high stream density.

Aerial Aspect
The aerial aspects include drainage density, drainage frequency, form factor, circularity ratio, elongation ratio and length of overland flow.

Drainage density ($D_d$)
Drainage density is the total length of all the streams in the watershed to the area of watershed. It helps in determining the permeability and porosity of the watershed and an indicator of landform elements in stream eroded topography. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture. Low drainage density generally result in the area of highly resistant or permeable subsoil material and high drainage density is the resultant of weak or impermeable subsurface material. The result shows the value 0.11 per square kilometers in study area suggesting that the area has highly permeable subsoil, dense vegetation cover and low relief.

Stream Frequency ($F_s$)
The stream frequency is defined as the total number of stream segment of all order per unit area. A large basin may contain as many fingertip tributaries per unit of area as a small drainage basin, and in addition, it usually contains a larger stream or streams (Horton 1945). The stream frequency of study area is 0.31 per square km. The value of stream frequency 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.

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. The result of study shows the value of texture ratio is 4.04 which have been categorized as moderate in nature.

**Form Factor (Rf)**

Form factor is be defined as the ratio of basin area to square of the basin length (Horton 1932). The value of form factor would always be less than 0.7854 (for a perfectly circular basin). Smaller the value of form factor, more elongated will be the basin. The basins with high form factors have high peak flows of shorter duration, whereas, elongated sub-watershed with low form factors have lower peak flow of longer duration. It has been observed from the study that 0.48 is the value of form factor in study area.

**Circulatory Ratio (Rc)**

Circulatory ratio is the ratio of the basin area to the area of a circle having the same circumference perimeter as the basin, which is dimensionless and expresses the degree of circularity of the basin (Miller 1953). 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 value of circulatory ratio of present study is 0.22, which shows basin is elongated in shape, low discharge of runoff and highly permeability of the subsoil condition.

**Elongation Ratio (Re)**

It is the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin (Schumm S.A, 1956). A circular basin appear to more efficient in the discharge of run-off than that of an elongated basin (Singh and Singh, 1997). The Re values generally ranges between 0.6 and 1.0 over a wide variety of climate and geologic types. Values near to 1.0 are the characteristics of the region of very low relief, while values in the range of 0.6 - 0.8 usually occur in the areas of high relief and steep ground slope (Strahler 1964). These values are further categorized as circular (>0.9), oval (0.9-0.8) and less elongated (<0.7). The Re value of study area is 0.78, which indicates the drainage basin is high relief and steep ground slope.

**Length of overland flow (Lg)**

Length of Overland Flow It is the length of water over the ground before it gets concentrated into definite stream channels. 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. It approximately equals to half of reciprocal of drainage density (Horton 1945). The study found that Lg value of study area is 4.54, which shows high surface runoff of the study area.

**Constant Channel Maintenance (C)**

Schumm (1956) used the inverse of drainage density or the constant of channel maintenance as a property of landforms. The constant indicates the number of Kms2 of basin surface required to develop and sustain a channel 1 Km long. The constant of channel maintenance indicates the relative size of landform units in a drainage basin and has a specific genetic connotation (Strahler, 1957). Channel maintenance constant of the watershed is 9.09 Kms²/Km.

**Conclusion**

The study of morphometric analysis of Tungabhadra using GIS retrieved that, Geographical Information System helps the researchers to analysis the drainage basin easily and accurately. The study of linear aspects of drainage basin result shows that, the basin has been formed in dendritic pattern with fourth order stream, plotting the logarithm of number of streams against stream’s order shows a straight line which states the number of streams usually decreases as the stream order increases. The result of relief aspect shows the study area is high relief and high stream density, the result of arial aspect shows the texture of drainage is moderate and the result of elongation ratio indicates the drainage is high relief and steep ground slope.

**Reference**


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