Morphometric and Terrain analysis of Payaswani River Basin of Kerala and Karnataka States using GIS

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ABSTRACT

Morphometry and terrain analyses are important in geomorphology where quantitative measurements are made on physical characteristics of landforms. It is done mainly to understand the structure, processes and evolution of landscape. In this paper, an attempt is made to study the morphometric aspects of streams and terrain characteristics of landforms of Payaswani river basin of Kerala and Karnataka states using GIS. It has an area of 1342 km². Of which, 42.02 per cent of the total area is in Kasaragod district of Kerala state and 57.08 per cent in Karnataka state. Survey of India Topographic maps and SRTM data were used for the study. ArcGIS and Spatial Analyst Module were used for the study. Payaswani River is the 6th order stream in which there are 5643 streams available in the basin. Relief is varying between mean sea level west and 1100 meters in the south east. There are two planation surfaces at 100m and 200m height. Hundred meter surface occupy 52.7 per cent of the total area. Three to six degrees slope category is the predominant slope with 19.7 per cent. North direction slope occupy 17.7 per cent. Most of the area comes under erosional landforms. Bifurcation ratio indicates that there was neotectonic activity in the lower region of the basin. In general the landscape indicates structural control over the landform development.

Keywords: Morphometry, planation surface, structural control, tectonic, neotectonics.

1. Introduction

Morphometry and terrain analysis are important in geomorphology where quantitative measurements are made on physical characteristics of land forms. It is done mainly to understand the structure, processes and evolution of landscape. Terrain analysis is defined as the representation and investigation of information relating to the shape of the earth. Various dimensions of a landscape or of individual landforms can be measured, and any relationships between them can be investigated. This branch of geomorphology is called morphometry (Hart, 1986). Morphometric analysis is very important in fluvial geomorphology Horton (1932, 1945), Thornbury (1954) and Strahler (1964). Drainage pattern analysis is important in characterizing geomorphic features and inferring the degree of structural and lithological controls in the evolution of fluvial landforms. Geology, relief, and climate play important roles to understand running water ecosystems at basin level. Morphometric characteristics represent relatively simple approaches to describe basin processes and to compare basin characteristics (Mesa 2006) and enable an enhanced understanding of the geological and geomorphic history of a drainage basin (Strahler 1964). The hydrological characteristics of a river basin can be interrelated with the physiographic characteristics of the drainage basin, such as size, shape, slope, drainage density and length of the streams, etc. (Lobeck, 1939, Thornbury, 1954, Chorley 1969). Hence, morphometric analysis of a basin is a first step, towards understanding of watershed dynamics. In this paper an attempt is made to study the morphometric aspect of
streams and terrain characteristics of landforms of Payaswani River basin of Kerala and Karnataka states using GIS.

Pioneering work on the drainage basin morphometry has been carried out by Horton (1932, 1945), Miller (1953), Smith (1950), Morisawa (1962), Leopold et al, (1964), Strahler (1964) and others. Terrain analysis principles and methods were explained by Burrough et al, (1998), Wilson and Gallent (2000), Corripio (2003), Quinn et al (1991), Jenson and Domingue (1991), Moore (1996), Jenson (1997) used digital terrain model for hydrological modeling. In India, morphometric analyses were carried out by numerous authors. In Kerala, morphometric analysis is carried out in the river basins of Karamana (Sinha Roy, 1979), Neyyar (Samsuddin, 1980), Pamba (Rajendran,1982), Kuttiyadi (James et al 1983), Valapattanam (Mahamaya Chattopadhyay, 1984), Kuppam (Mahamaya Chattopadhyay et al 1986), Chalakudy (Maya,1997), Meenachil (Vijith et al 2006) Achankovil Manu et al (2008) and Muthirapuzha (Thomas, 2010).

2. Material and methodology

Survey of India topographic maps on scale 1:50,000 are used for delineation of streams and river basin. Streams were digitised for stream ordering by Strahler method. Relief map was prepared based on topographic maps and SRTM data. Based on relief map, slope, aspect and areas of erosion and deposition analysis were carried out. ArcGIS software and Spatial Analyst module were used for the study.

2.1 Study area

Payaswani River is situated in the northern part of Kerala in Kasaragod District (Fig.1). It has an area of 1342 km², of which, 42.02 per cent of the total area is in Kasaragod district of Kerala state and 57.98 per cent in Karnataka state. It occupies 28.31 per cent of the total area of Kasaragod district. It is a sixth order basin. Chandragiri River is an important tributary and a fifth order basin. Payaswani River originates from south eastern part of Dakshin Kannada district and western part of Coorg district of Karnataka state and discharge their waters into Lakshadweep Sea in Kerala. Though Payaswani River is bigger and longer than Chandragiri River, the name Chandragiri is given at the mouth of the river. It is considered as one of the 41 west flowing rivers in Kerala.

3. Analysis

Payaswani River basin is a sixth order stream. There are 5643 streams in the basin. It has 10 fifth order streams. Among the 10 fifth order sub-basins, Chandragiri is the biggest basin. It has an area of 368.5 km².

3.1 Frequency of streams

The classification of streams based on the number and type of tributary junctions, has proven to be a useful indicator of stream size, discharge, and drainage area (Strahler 1957). According to Strahler’s stream ordering method, Payaswani River is a sixth order stream. Number of streams per order is given in the Table 2. Figure 2 shows stream orders of Payaswani River Basin.
3.2 Bifurcation Ratio (Rb)

Bifurcation ratio, a measure of the degree of ramification of drainage network (Mesa 2006), exercises a significant control over the ‘peakedness’ of runoff (Chorley 1969). The Rb values usually fall in the range of 3.0 and 5.0 for networks formed on homogeneous rocks (with least/minimum structural disturbances), on the one hand and hits values higher than 10.0, where structural controls play dominant roles on the other. The shape of watersheds also exerts a significant control on Rb. The variations in Rb values are a reflection of the differences in the shape of stream network. In Payaswani River basin 5th and 6th order streams show bifurcation...
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ratio more than 5. From this, it is inferred that neotectonic activity might have played a role in the lower region of the basin. Table.4 shows the bifurcation ratio of Payaswani River basin.

![Figure 2: Map showing stream order of Payaswani River basin](image)

Table 4: Payaswani river basin- Bifurcation ratio

<table>
<thead>
<tr>
<th>Stream Order</th>
<th>Number of streams</th>
<th>Bifurcation Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st order stream</td>
<td>4365</td>
<td></td>
</tr>
<tr>
<td>2nd order stream</td>
<td>982</td>
<td>4.44</td>
</tr>
<tr>
<td>3rd order stream</td>
<td>230</td>
<td>4.26</td>
</tr>
<tr>
<td>4th order stream</td>
<td>55</td>
<td>4.18</td>
</tr>
<tr>
<td>5th order stream</td>
<td>10</td>
<td>5.50</td>
</tr>
<tr>
<td>6th order stream</td>
<td>1</td>
<td>10.0</td>
</tr>
<tr>
<td>Total streams</td>
<td>5643</td>
<td></td>
</tr>
</tbody>
</table>

Stream length is very high in the 1st order stream. Stream lengths by stream order are given in Table.5.

Table 5: Payaswani river basin - Total stream length by stream order

<table>
<thead>
<tr>
<th></th>
<th>Length in km 1st Order</th>
<th>Length in km 2nd Order</th>
<th>Length in km 3rd Order</th>
<th>Length in km 4th Order</th>
<th>Length in km 5th Order</th>
<th>Length in km 6th Order</th>
<th>Total length in km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payaswani River basin</td>
<td>4232.2</td>
<td>1172.6</td>
<td>644.5</td>
<td>341.6</td>
<td>268.4</td>
<td>93.6</td>
<td>6752.9</td>
</tr>
</tbody>
</table>
Form factor, drainage texture and Drainage density are the other morphometric parameters derived using GIS techniques and they are shown in Table 6.

**Table 6: Payaswani River basin – Other morphometric parameters**

<table>
<thead>
<tr>
<th></th>
<th>Circularity ratio</th>
<th>Elangation ratio</th>
<th>Form factor</th>
<th>Drainage Texture</th>
<th>Drainage Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Basin</td>
<td>0.16</td>
<td>1.35</td>
<td>0.02</td>
<td>70.63</td>
<td>2.87</td>
</tr>
</tbody>
</table>

### 3.3 Relief

Relief height varies from mean sea level in the west to 1100 meters in the South East. High relief is found in the east, south east and south. High relief in the east is mainly due to the presence of Western Ghafts, especially Brahmagiri hills of Coorg district of Karnataka state. Undulating low plateau at an elevation of 100m covers most of the western part of the basin, mainly in the Kasaragod district of Kerala. In the west, the terrain is dissected by incised meandering rivers and streams. Most part of this low level plateau is covered by hard laterite duricrust, mainly ferricrete type. Fig 3 shows relief of Payaswani river basin. There are two erosional surfaces found at 100m and 200m height. They occupy 52.7 per cent and 14.5 per cent of the total basin area respectively.

*Figure 3: Map showing Relief of Payaswani River Basin*
3.4 Slope

Slope of the basin is classified into ten classes. Of which, 3 to 6 degrees category covers 19.7 per cent of the total area of the basin followed by 6 to 9 degrees category with 15.5 per cent. Slope 0 to 3 degrees category occupies 14.6 per cent of the total basin area. Steep slopes are found in the east and south east and south along the Western Ghats margin. Fig. 4 shows the distribution of slope in the basin.

![Figure 4: Map showing Slope categories of Payaswani River Basin](image)

3.5 Aspect

Aspect is classified into 10 categories. Of which north direction slope occupies about 17.7 per cent of the basin, followed by south west and south with 14.7 and 14.6 per cent respectively. Fig. 5 shows distribution of aspect (slope direction) in the basin.

3.6 Areas of erosion and deposition

Payaswani river basin shows mostly of erosional landforms. About 53.5 per cent of the total area comes under moderate erosion. Most of the areas are under laterite chemical weathering where sheet erosion is common. Only 27.8 per cent of the basin comes under low deposition. Fig. 6 shows the areas of erosion and deposition of the basin.
**Figure 5**: Map showing Aspect (Slope direction)

**Figure 6**: Map showing areas of erosion and deposition
4. Conclusion

Study of morphometric and terrain analysis is much easier by using GIS technique. Calculation of morphometric parameters are convenient than conventional calculation. First order streams were found distributed above 100 meters above mean sea level. Second and third order streams were found between 100 and 200 meters above mean sea level. Fourth order streams are found above 60 meters and fifth order streams are found between 60 and 100 meters above mean sea level. Sixth order stream is found from mean sea level to 100 meters above mean sea level. From the fluvial morphometric study, it is understood that there is structural control over the development of land forms. Tectonic forces have played a role in shaping the land forms in the geologic history. Planation or erosional surface at 100m and 200 meters above mean sea level indicates polycyclic evolution of the basin. More than 52 per cent of the area occupied between 100 m and 200 m. High bi-furcation ratio in the lower order indicates neotectonic activity in the coastal region of the district. From the curvature analysis, it is found that the Payaswani river basin dominated by erosional features than depositional. Outcome of the study would be useful for applications.

5. References


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