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AN ANALYSIS OF MORPHOMETRIC CHARACTERISTICS OF PERUVAMBA RIVER BASIN, KANNUR DISTRICT, KERALA

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ABSTRACT

A watershed provides valuable characteristics related to river morphology, which includes linear, aerial and relief aspects of the drainage basin. The aim of the present study is to delineate and map the subwatershed of Peruvamba river basin and to carry out a morphometric analysis with the help of Geographic Information System (GIS). The Peruvamba river basin extends from 12^o 0' to 12 ^{o} 15' north latitudes and 75 ^{o} 10' to 75^o 20' east longitudes. A river originates from the Western Ghats near Pekunnu at an altitude of 356 m above MSL and has a length of 51Km. The basin has a total area of 298.15 sq.km covering 19 villages spread over 12 panchayats and 1 municipality, 3 blocks in Kannur and Kasaragod districts of Kerala State. In the present study base map, showing drainage details have been prepared from the SOI toposheets and further mathematical calculation and derived parameters were made using Micro Soft Excel Software.

KEYWORDS: *Morphometry, Watershed, GIS, Cartosat DEM, Peruvamba River Basin*

INTRODUCTION

The analytical study of drainage basin morphometry is a significant field of applied geomorphology. The need for drainage basin planning arises due to the hydrological and ecological interconnectedness of river basins, and the multiple, and at times competing, services and functions that human societies derive from these systems. A drainage basin provides valuable characteristics related to river morphology, which includes linear, aerial and relief aspects of drainage. The individual components of the basin, as well as the relationships between the characteristic form and process of a drainage basin, have to be understood in a comprehensible manner in order for watershed management to be effective. The present study is an attempt to examine the various parameters of basin morphology of Peruvamba river of Kannur in Kerala from a geomorphologic standpoint.

The morphometric analysis of a watershed provides a quantitative description of the drainage system, which is an important aspect of the characterization of watersheds (Strahler 1964). Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Clarke1996, Agarwal 1998, Obi Reddy et al. 2002). The morphometric analysis is done successfully through measurement of linear, aerial, relief, the gradient of channel network and contributing ground slope of the basin (Nautiyal 1994, Nag and Chakraborty 2003, Magesh et al. 2012b, PK Rai et al.2014). Here an attempt is made to the morphometric analysis of the Peruvamba river basin was accomplished through a study of parameters and to generate a map on subwatershed.

STUDY AREA

The Peruvamba river basin lies between 12° 0' to 12°15' north latitudes and 75°10' to 75°20' east longitudes. The river originated from the Western Ghats near Pekunnu at an altitude of 356 m above MSL and has a length of 51 km. It is bounded by Taliparambataluk of Kannur district and Hosdurgtaluk of Kasaragod district in north, Kannur, and Taliparambataluk of Kannur district in the south, Taliparambataluk of Kannur district in the east and the Arabian Sea in the west (Figure.1). The basin has a total area of 298.15 sq km covering 19 villages spread over 12 panchayats and one municipality, 3 blocks in Kannur and Kasaragod districts of Kerala state.

Table 1: Formulas, Description and References for Morphological Parameters Used in this Study

Morphometric Parameters	Formula	Description	References
Basic parameters Total Stream	∑Nu	Total order number in the basin	Strahler (1964)
Total Stream Length	∑Lu	Total length of each order was computed at basin level	Horton (1945)
Derived parameters Bifurcation Ratio (Rb**)**	Rb = Nu / Nu+1	The ratio between the number of streams of any given order to the number of streams in ratio (Rb)	Horton (1945)
Stream length Ratio (Rl)	RL=Lu / Lu-1	The ratio of mean stream length of any given segment to the mean stream length of the next lower order	Sreedevi*et al.* (2005)
RHO Co-efficient	RHO=Rl/Rb	The ratio between the stream length ratio and the Bifurcation ratio	Mesa (2006)
Stream frequency (Fs)	Fs=∑Nu/A)	The ratio between the total number of streams and area of the basin	Horton (1945)
Drainage density (Dd)	Dd=∑Lu/A	The ratio between the total stream length of all (Dd) orders to the area of the basin	Horton (1945)
Texture ratio (T)	T=∑Nu/P	The ratio between the total number of streams of all orders and perimeter of the basin	Smith (1950)
Basin relief (Bh)	$Bh=H_{max}-H_{min}$	The maximum vertical distance between the lowest and the highest points of a sub-basin	Hadley and Schumm (1961)
Relief ratio (Rr)	Rr=H/L	The ratio of the maximum vertical distance between the lowest and the highest points of a sub-basin to the basin length	Schumm (1963)
Slope angle (S)	$S=\tan^{-1}\{(H-h)/L\}$	The inverse tangent value for the ratio between the Present maximum vertical distance between the lowest and work the highest points of a sub-basin to the basin length	Ahmed *et al* (2010)
Shape Parameters Elongation ratio (Re)	Re=2p((A/π/Lb)	The ratio between the diameter of a circle with the same area as that of the basin and the maximum length of the basin	Schumm (1956)

Table 1 Contd.,			
Circularity index (Rc)	$Rc=4\pi A/P^2$	The ratio of basin area to the area of a circle having the same perimeter as the basin	Strahler (1964)
Form factor (Ff)	$Ff=A/Lb^2$	The ratio of the basin area to the square of the basin length	Horton (1945)

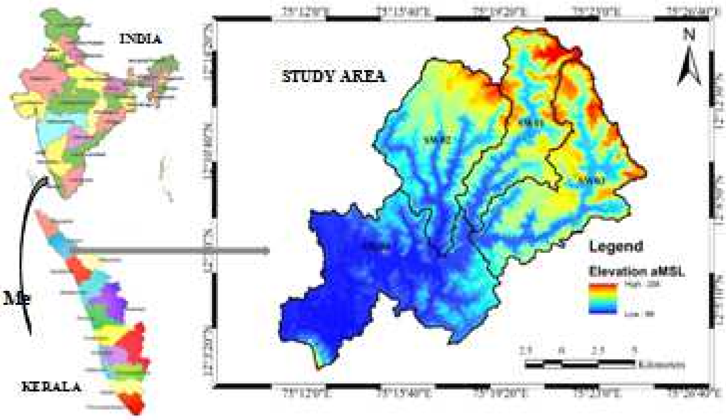

Figure 1: Location Peruvamba River Basin

METHODOLOGY

The morphometric conditions have been study with the help of Cartosat DEM and Survey of India toposheet. The base map of Peruvamba river basin is delineated from the Cartosat DEM with the help of ArcGIS 10.2 Software. Both the data are rescaled to1: 50.000 and was registered to WGS 1984, UTM projection North, Zone 43. The morphometric analysis includes the evaluation of drainage parameters through the various dimensions of drainage properties (Ahmed et al., 2010). In the research paper, an attempt has been made to analysis the morphometric parameters and delineate the sub-watershed boundary for the Peruvamba river basin. The river morphometric parameters were considered into three major divisions as basic parameters, derived parameters and shape parameters. The basic parameters include area, perimeter, basin length, stream order, stream length, maximum and minimum heights. The derived parameters include the bifurcation ratio, stream length ratio, stream frequency, drainage density, drainage texture, basin relief, and relief ratio. To study the shape characteristics, the parameters like elongation ratio, circularity index, and form factor are considered.

The preprocessing and rectified Cartosat DEM is used to extract the drainage networks and sub watershed boundary using Hydrology tool in Arc GIS software. The raw DEM data is processing to fill and sink for creating the depression less DEM. To calculate the flow of water in cells, the entire the cells in DEM data are coded with respect to the flow direction in which it will tend to flow to the adjacent cell. Depending on the flow direction, the output grid will have a cell value at the center cell ranging from 1 to 128 as per the direction, where 1 is for the east direction and 128 for the northeast direction respectively. Then the flow accumulation for each cell is determined by the flow direction and the cell elevation value. This flow accumulation is used to extract the final drainage networks with the using the threshold of accumulation and the watersheds can be delineated by giving an outlet or pour points where water flows out of an area, this is the lowest point along the boundary of the watershed. The cells in the source raster are used as pour points above which the contributing area is determined.

RESULTS AND DISCUSSIONS

Basic Parameters

Table 2: Basic Parameters of Each Sub Watershed in the Peruvamba River Basin

SW Name	Area (A)Sqkm	Perimeter (P) Km	Basin Length (L)Km
SW1	49.63	64.05	15.12
SW2	65.99	56.24	13.39
SW3	70.30	75.58	18.96
SW4	95.04	95.22	14.83

Stream Ordering

Stream ordering indicated the numbering of the stream which joins to the mainstream. The streams are ordered according to the hierarchical position of a stream within its basin. According to Strahler (1964) the first order streams are those which do not have tributaries, second-order stream those which only have the first order streams as the tributaries. Like that the third order streams have the second order steams as their tributaries and so on. In short, the term order refers to the individual streams, not the full river channel from the head to the mouth. Horton was the first one to introduce the stream ordering method. In his method, the first order streams which have no tributaries and the second streams begins at the confluence of the first order streams like that the confluence of the two lower order stream makes the next higher order streams. Horton extended the longer second order stream to its longest first order tributary and so on, this method helped to find the trunk stream. Shreve is another important geographer who proposed a modification in the stream ordering method. Through this method, the trunk stream is reflected by exactly following the first order stream (Figure 2).

Table 3: Total Number of Stream in the Peruvamba River Basin

SW Name	Number of Streams in Different Stream Order						Σnu
	1st	2nd	3rd	4th	5th	6th	
SW1	142	31	5	1	-	-	179
SW2	201	43	7	2	1	-	254
SW3	214	45	12	2	1	-	274
SW4	177	56	14	4	1	1	253

Stream Length

Length of the stream resembles the underlying rock formations. The length of the stream in hydrological measurements can be used to study the rock beneath the surface and the degree of drainage. The permeable and non-permeable rocks play a major role in the number of small streams and in the length of the stream. The permeable rock allows the water to percolate through it and the regions with permeable rock structure only have a small number of relative longer streams. Like that the surfaces which enjoy less permeable rock possess a large number of streams with a smaller length. The total number of streams and length of the stream is more in first-order streams.

Figure 2: Peruvamba River Basin- Stream Ordering

Table 4: Total length of Stream in the Peruvamba River Basin

SW Name	Stream Length of Different Order						Σlu
	1st	2nd	3rd	4^{th}	5th	6th	
SW1	56.58089	26.39445	9.76914	14.15723	-	-	106.9017
SW2	71.95385	27.66806	28.80671	9.89764	3.803809	-	142.1301
SW3	81.75982	28.38855	25.09061	5.042197	12.28266	-	152.5638
SW4	118.141	53.60047	30.35639	6.336704	4.817926	13.95581	227.2083

Derived Parameter- Bifurcation Ratio

Bifurcation ratio refers to the proportion between the numbers of streams of the segment of any given order with the number of segments in the next higher order (Schumm, 1956). Bifurcation ratio ranges between 3.0 to 5.0 for natural drainage basin, which is not influenced by the geologic structure and only reaches a higher value where the geologic structure controls the development of elongated narrow basin (Strahler, 1964).

Table 5: Bifurcation Ratio of Each Sub Watershed in the Peruvamba River Basin

SW Name	Bifurcation Ratio (Nu/Nu+1)						Mean Bifurcation Ratio (Rbm)
	1st	2nd	3rd	4th	5th	6th	
SW1	4.58	6.2	5	-	-	-	5.26
SW2	4.67	6.14	3.5	2	-	-	4.07
SW3	4.75	3.75	6	2	-	-	4.12
SW4	3.16	4	3.5	4	1	-	3.13

Stream Length Ratio

Horton (1945) proposed the stream length ratio, which is the ratio of the mean length of a stream if any given order to the mean length of a stream of the next lower order, based on the fact that mean length of a stream of any given order is always greater than the mean length of a stream of the next lower order and the law of stream length (Horton, 1945) states that mean stream length segments of each of the successive orders of a basin tends to approximate a direct geomorphic series with streams length towards higher order of streams. It is the proportion between the length of a particular stream and the lower order stream length.

Table 6: Streams Length Ratio of Each Sub Watershed in the Peruvamba River Basin

SW Name	Streams Length Ratio					
	1st	2nd	3rd	4th	5th	6^{th}
SW1	0.46	0.37	1.44	-	-	-
SW2	0.38	1.04	0.34	0.38	-	-
SW3	0.34	0.88	0.20	2.43	-	-
SW4	0.45	0.56	0.20	0.76	2.89	-

Stream Frequency

In 1932 Horton introduced channel frequency or stream frequency. Stream frequency refers to the total number of stream segments of all orders per unit area. The higher stream frequency indicates a larger surface runoff and steeper region. The values of stream frequency and drainage density for small and large river basin cannot compare directly because they usually differ with the drainage density.

Drainage Density

Drainage density is the average length of streams per unit area within the drainage basin (Horton, 1945) low drainage density is favored in the region which has high resistance or in the regions which have highly permeable subsoil, thick vegetation covers, and low relief. The drainage density is high in the areas which have low resistance or in the areas which possess the impermeable type of soil materials, a few vegetative cover, and mountainous region. Drainage density is an important component for understanding the relationship between the climate, vegetation and the resistance of the rock and the permeability of the soil material. Drainage density is a measure of the degree of fluvial dissection and is influenced by numerous factors, among which resistance to erosion, infiltration capacity, vegetation cover, surface roughness, and run-off intensity index and climatic conditions rank high (Langbein, 1947; Verstappen, 1983; Reddy *et al*., 2004). Drainage density indicates the closeness of spacing of channels.

Drainage Texture (T)

The drainage texture (T) is an expression of the relative channel spacing in a fluvial dissected terrain. It depends upon a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development of a basin (Smith, 1950). According to Horton (1945), T is the total number of stream segments of all orders per perimeter of that area. The drainage density < 2 indicates very coarse, between 2 and 4 is related to coarse, between 4 and 6 is moderate, between 6 and 8 is fine and >8 is very fine drainage texture.

The character and geometry of the drainage network are generally evaluated in terms of drainage texture, which includes the drainage density and stream frequency (Horton, 1945). Stream frequency is the total number of streams per unit area and drainage density is the sum of stream length per unit area, which expresses the closeness of spacing of stream channels. Under a given set of geological and hydroclimatic conditions, a minimum area is needed for maintaining a river channel of a given length. This has been defined as the constant of river channel maintenance (schumn, 1956). The number and density of stream in a drainage basin vary from one region to another. Rock type is an important control factor on the drainage texture and density. The areas which have granite, gneiss, quartzite, sandstone etc. as the underlying rocks shows a low drainage density because these rocks are hard and they resistance to erosion so that the river require a large area to maintain a channel. Vegetation is another important factor which has a main role in determining the drainage texture.

Vegetation protects the underlying materials and they help in increase the rate of infiltration b all these they reduce the proportion of surface runoff. The absence of vegetation will help in increase the runoff and thus channels are made.

Table 7: Drainage Density, Frequency and Texture of Each Sub Watershed

SW Name	Drainage Density (Dd)	Drainage Frequency (Fs)	Drainage Texture (T)
SW1	2.15	3.60	2.79
SW2	2.15	3.84	4.51
SW3	2.17	3.89	3.62
SW4	2.39	2.66	2.65

Shape Parameters -Elongation Ratio *(Re)*

Schumm (1956) defined elongation ratio (Re) as the ratio between the diameter of the circle of the same area as the drainage basin (D) and the maximum length of the basin (L). A circular basin is more efficient in the discharge of run-off than an elongated basin (Singh and Singh, 1997). The values of Re generally vary from 0.6 to 1.0 over a wide variety of climatic and geologic types. Values close to 1.0 are typical of regions of very low relief, whereas values in the range 0.6-0.8 are usually associated with high relief and moderate to the steep ground slope (Strahler, 1964). These values can be grouped as (a) circular (>0.9), (b) oval (0.9 - 0.8), (c) less elongated (<0.7).

Circularity Ratio *(*Rc)

It is the ratio of the area of the basin to the area of a circle having the same circumference as the perimeter of the basin (Miller, 1953) is expressed as the ratio of the basin area and the area of a circle with the same perimeter as that of the basin. The circularity ratio (Rc) is influenced by the length and frequency of streams, geological structures, land use/land cover, climate, relief, and slope of the basin. Rc 0.5 and above indicates that they are more or less circular and are characterized by high to moderate relief and drainage system is structurally controlled.

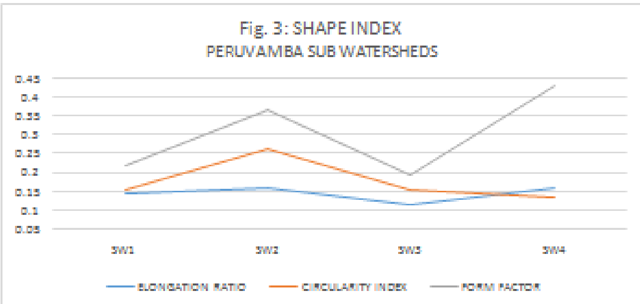

Figure 3

Form Factor *(Ff)*

The form factor is being defined as the ratio of basin area to the square of the basin length (Horton, 1932). The value of the form factor varies from 0; the value shows the highly elongated shape to 1, which shows the perfect circular shape.The basin having low Ff values indicate elongated and high Ff values indicate peaks and the river lows for a shorter duration (Figure.3).

CONCLUSIONS

Extraction of drainage networks and Delineation watershed boundary can be accomplished by using reference and standard valley and fill traditional methods from field observations, topographic maps and also the advanced and latest techniques of using remote sensing and DEMs.Remote Sensing and GIS deliver the systematic extraction and analysis of morph metric parameters and drainage network which will be great significant value in understanding the basin characteristics and hydrological modeling of the watershed.

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