THE CONCEPT OF SPATIAL DRAINAGE DENSITY AND SPATIAL STREAM FREQUENCY IN RIVER BASIN MORPHOMETRY ANALYSIS

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Received: August 29, 2018 Accepted: October 21, 2018

ABSTRACT *The drainage basin morphometry analysis is important in understanding basin geometry and the measure of intensity of dissection in hydrological cycle of river basins. This study specifically emphasizes on the methods in calculating two morphometric parameters, Drainage density (Dd) and Stream Frequency (Fs) using the existing standard method and presenting the parameters as Spatial Drainage density (SDd) and Spatial Stream frequency (SFs) using GIS techniques which would provide spatially accurate results to understand the hydrological behaviour of a river basin. Pamba river basin in Kerala, India has been selected for this study.*

Keywords: *Basin Morphometry, Spatial Drainage density and spatial Stream Frequency.*

INTRODUCTION

The present day environmental crisis by manmade activities, the enormity of damage caused by natural hazards like flood and the cost of mitigating their effects have prompted to take up the analysis on drainage morphometry of the Pamba river basin in Kerala, India. River basin norphometric analysis provides a quantitative description of the drainage system which is an important aspect in any hydrological investigation. The morphometric characteristics of a drainage basin can be correlated with the geological, geomorphological, land use, soil properties, climatological and erosional characteristics of the basin which in turn may lead to an understanding of the physical processes and factors causing the floods in the basin.

The morphometric analysis of the Pamba basin was accomplished through a detailed study of definite morphometric parameters such as drainage pattern, stream order, bifurcation ratio, drainage density, stream frequency and other linear aspects using Geographic Information Systems (GIS) techniques by Arc Map version 10.3.

The morphometric parameters, Drainage density (Dd) and Stream frequency (Fs) measure the intensity of dissection in hydrological investigation. Drainage density is a simple expression of the length of stream channels per basin area (*Dd= L/A).*Stream frequency is the expression of number of streams per basin area (*Fs = N/A)*. It is observed that the standard values of Dd and Fs represents for entire basin and not particular area specific. Within one basin or sub basin the locations of first order streams and next higher order streams will have same value of density or frequency.

This study attempted to calculate location specific, Spatial drainage density (SDd) and Spatial stream frequency (SFs) of the basin using the GIS techniques. In this method the measure of intensity of dissection were calculated for entire basin taking the length of streams and number of streams in one square kilometer grids as analytical unit in place of total area of the basin. It is observed that this method provides more information spatially than the results from standard method. The result is vital to spatially understand the hydrological behaviour of a river basin for assessing runoff, sediment response, groundwater potential, basin management and environmental assessment. This method can also apply to other statistical analysis which has to be spatially represented.

The geo-spatial technology has provided a platform for the creation, up-gradation, storing, sharing and presenting of spatial data in a speedy and cost effective way. In this study six sub-watersheds of 6th order in Pamba river basin in Kerala, India (Figure.1) were taken for morphometry analysis.

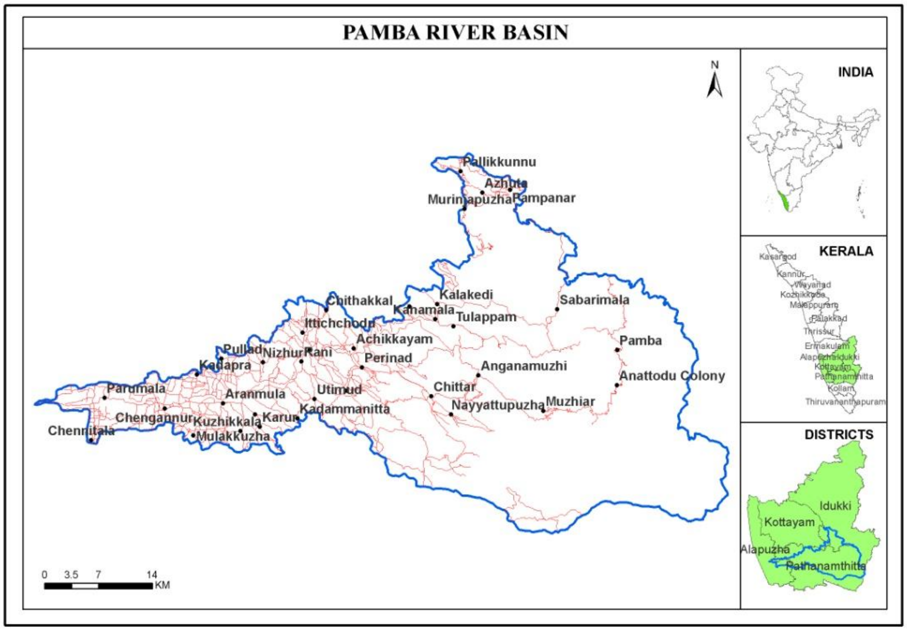

Figure.1

OBJECTIVE OF THE STUDY

The objective of this study specifically emphasizes on the methods in calculating two morphometric parameters, Drainage density (Dd) and Stream Frequency (Fs) using the existing standard method and presenting the parameters as Spatial Drainage density (SDd) and Spatial Stream frequency (SFs) using GIS techniques.

PREVIOUS WORKS

Drainage morphometry, a quantitative treatment to understand the characteristics of drainage networks, was first developed by Horton (1932, 1945) for parameters like total stream number (Nu), total stream length (lu), surface area of the basin (Au), bifurcation ratio (rb), Drainage density (Dd), stream frequency (Fs) and Length of overland flow (Lo). Later modified by Strahler (1952, 1954, 1957) , Schumm (1956), Chorley (1969), Smith (1950), Miller (1953), Melton (1957) and a host of others.

Innumerable studies have been made during the last six decades taking various river basins all over the world as example and useful conclusions were drawn on geomorphic, structural and climatic characteristics of the basins through the analysis of various morphometric parameters by Morisawa, 1958; Coates, 1958; Badgley, 1962; Carlson, 1963; Abraham, 1972 and 1980; Smart, 1972; Wilcock, 1975; Gregory and Walling, 1973; Gregory and Gardiner, 1975; Gurnell, 1978; Gardiner, 1982 and 1986; Morisawa and Hack, 1985: Bull and Knuepfer, 1987; and others.

Similar studies have been made in India as well, by several geomorphologists Banerjee,1964; Chatterjee,1945, Mukhopadhayay,1978; Niyogi,1968; Prasad,1965; Vaidhyanathan, 1962; Prasad and Varma, 1975; Dikshit, 1976; Ghose and Pandey, 1963; Singh, 1971; Nautiyal, 1994; Rao and babu, 1995: Ahmed Suleiman Mustafa1 et.al, 2016.

THE CONCEPT OF SPATIAL DRAINAGE DENSITY AND FREQUENCY

Horton (1932 and 1945) suggested that in addition to the basin area, slope and drainage density can also be correlated with rate of erosion which depends on other variable including the relief, rainfall, infiltration capacity of the terrain, and the resistance of the land to erosion. Drainage density (Dd) is a measure of total stream length in a given basin to the total area of the basin (Strahler1964). Drainage density measures basin efficiency in removing excess precipitation inputs (Patton & Baker, 1976) and it can be regarded as a factor influencing the runoff and sediment response of a drainage basin (Gregory and Gardiner, 1975). Drainage density reflects land use and affects infiltration and the basin response time between precipitation and discharge. It is also of geomorphologic interest particularly for the development of slopes, various features of landscape dissection such as valley density, channel head source area, relief, climate and vegetation (Moglen et al. 1998), soil and rock properties (Kelson and Wells 1989) and landscape evolution processes.

The Stream Frequency, the number of streams per area of the basin, reveals the character of the under lying lithology in an area along with the drainage density (Horton, 1945). As suggested by Blyth and Rodda (1973), the frequency of streams increases with total rainfall and its intensity, which in turn affects the flood/erosion peaks. The fact is apparent in this study as well, which indicates that higher frequency values are associated with high rainfall regions. Drainage density (Dd) and stream frequency (Fs) serves as a tool in establishing the erosional processes operating over an area which is calculated using the standard formula,

1. *Dd= L/A Where, L =Total length of stream, A= Area of basin.*
2. *Fs = N/A Where, L=Total number of stream, A=Area of basin*

It is observed that the Dd and Fs using this formula indicate the overall density and frequency of the entire basin which varies spatially from first order streams to higher order. Therefore here an attempt is made to generate a Spatial Drainage density (SDd) and Spatial Stream frequency (SFs) of the basin using the GIS techniques taking a grid of one square kilometre as analytical unit. The length of streams is being calculated for each square kilometre grids for Spatial Drainage density (SDd) and the number of streams per square kilometres is being calculated for Spatial Stream frequency (SFs). Therefore the standard formula has been modified as

1. *S Dd= L/ 1Km^2 Where, L =Total length of stream / 1Km^2,*
2. *S Fs = N /1Km^2 Where, L=Total number of stream / 1Km^2*

METHODS OF STUDY

The morphometric analysis of the Pamba basin was carried out with a detailed study of definite morphometric parameters (Hortan, 1945 and Strahler, 1952). The entire drainage network has been traced out from the Survey of India toposheet on 1: 50,000 scale. Morphometric analysis has been carried out for homogeneous sub-divisions of six 6th order sub basins separately to bring out more subtle variations among its density, frequency variations and comparisons among them. The sub basins are (1) Azhutha Ar, (2) Upper Pamba Ar., (3) Kakki Ar., (4) Kall Ar., (5) Kakkad Ar. And (6) Lower Pamba Ar. The drainage network ordering was done according to the Strahler's (1952) classification. Drainage density (Dd) and stream frequency (Fs) were calculated using the standard formula. Apart from this method of density and frequency calculation, one square kilometre grids were created as analytical unit. The total length and number of streams is being calculated for each grid. A point map is generated with centre point of the grid and the values were attributed. Using this point map iso-lines were generated for spatial density (SDd) and spatial frequency (SFs) in GIS platform using Triangular Irregular networks (TIN) analysis.

RESULTS AND DISCUSSION

The symbols and definitions of the morphometric parameters analysed in this study are given in Table. 1. The linear and aerial morphometric parameters like stream order, length of streams, number of streams, basin area, drainage density and stream frequency of six sub-basins of pamba river basin were calculated using the standard formula and given in Table.2.

Morphometric Parameters	Formula/Definition	References
Stream order (U)	Hierarchical order (Nu)	Strahler,1952
Stream Length (L)	Length of the stream (Lu)	Hortan, 1945
Basin Geometry	Area of the basin (Au)	Hortan, 1945
Drainage density (Dd)	Dd=L/A Where, L=Total length of stream, A= Area of basin.	Strahler,1952
Stream frequency (Fs)	Fs=N/A Where, L=Total number of stream, A=Area of basin	Strahler,1952

Table. 1

Sub Basin of Pamba	Stream Order	Area in Sq.Km (A)	Stream Length in Km (L)	No. of Streams (N)	Drainage Density (L/A)	Stream Frequency (N/A)
Azhutha Ar.	1-6	198.58	703.96	1125	3.545	5.66
Pamba Ar.	1-6	167.32	630.62	1044	3.769	6.24
Kakki Ar.	1-6	278.10	951.38	1454	3.421	5.23

Kall Ar.	1-6	291.87	989.73	1609	3.391	5.51
Kakkad Ar.	1-6	309.67	1053.80	1673	3.403	5.40
Pamba (Main)	1-7	533.89	1188.97	1595	2.227	2.98
Total		**1779.43**	**5518.46**	**8500**	**3.10**	**4.77**

Table. 2

From Table 2, it can be observed that the total basin area is 1779.43 Km^2 and the Dd and Fs of whole basin is 3.10 and 4.77 respectively. The 6th order sub basins of Pamba River with different areal extent and number of streams shows only slight difference in the drainage density which varies from 3.39 to 3.76 Km/Km^2. The value of stream frequency (Fs) for sub basins varies from 5.23 to 6.24 and exhibits positive correlation with the drainage density (Dd) value, indicating the increase in stream number with respect to increase in drainage density. Drainage density and frequency maps were generated using this values. Figure 2 (a) and 2 (b) shows the maps depicting drainage density and frequency of respective sub basins derived using standard formula.

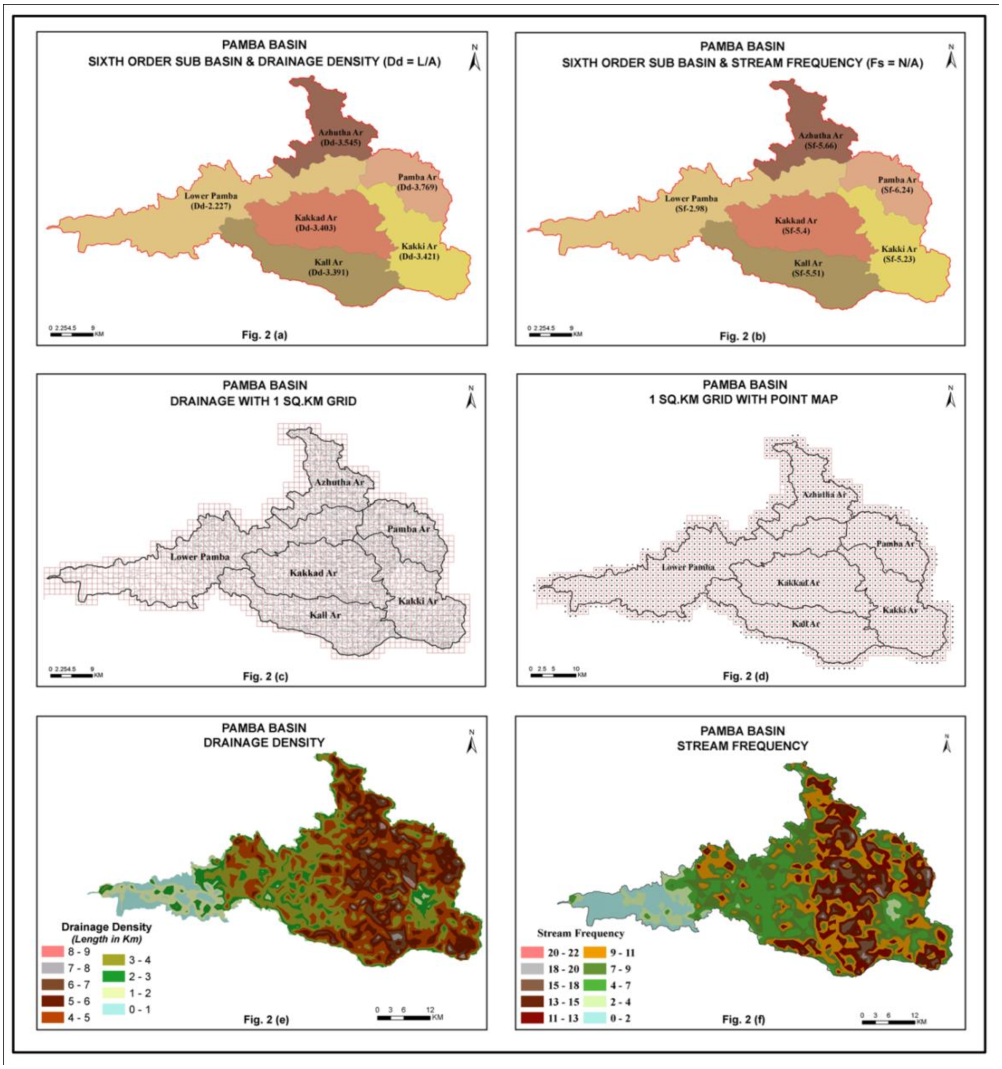

Figure. 2

Figure 2 (c) shows the drainage pattern of the basin with grids of 1 Km^2 . Figure 2 (d) shows the point map generated taking the centre of the grid. Figure 2 (e) shows the output map of Spatial Drainage density (SDd) and Figure 2 (f) shows the output map of Spatial stream frequency (SFs) using Triangular Irregular networks (TIN) analysis in GIS platform.

The value of Spatial Drainage density (SDd) range from 1 to 9 Km/ Km^2 and Spatial stream frequency (SFs), number of streams/ Km^2 range from 1 to 22. The higher values are associated with locations of 1st and 2nd order stream and low values with higher order locations. This shows significant difference between the two methods in representing length of streams and number of streams within a basin. In the first method, the values were calculated with basin area as analytical unit, resulting a single value of Dd and Fs for one basin. The second method provides a range of values with location specific or spatial Dd and Fs for entire basin.

CONCLUSIONS

The study indicates that the spatial representation of basin morphometry parameters using geographic information system (GIS) provide more accurate results to understand the hydrological behaviour of a river basin. The study correlates the results of two methods in calculating Drainage density (Dd) and Stream Frequency (Fs).The results from the standard method and the present one is different in terms of spatial representation. It is observed that the second method provides more spatial specific information than the first one which is an important factor while correlating the Dd and Fs with geological, geomorphological, land use, climatological, erosion intensity and flood characteristics of the basin which in turn may lead to an understanding of the physical processes with more spatial accuracy. This method can also apply to other statistical analysis which has to be spatially represented.

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