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Original Research Paper

Remote Sensing Cum GIS Based Assessment of Morphometric Characteristics of Chittar Basin in District Thiruvananthapuram, Kerala, South India

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ABSTRACT

The use of the drainage morphometric characteristics for the investigations relating to hydrology has been amply discussed in various studies. The realization of its importance has made the analysis of drainage morphometric characteristics studies related to hydrological studies. The morphometric analysis of Chittar River Basin (CRB), a fifth order sub basin of Vamanapuram River on the south west coast, has been studied using Arc Info GIS software. The drainage patterns of the basin are delineated using IRS IC LISS III data and SOI toposheets on 1:25,000 scale as reference. The drainage pattern of the study area is dendritic with stream orders ranging from I to V. The different drainage parameters studied include drainage pattern, stream order, stream number, stream length ratio, relief ratio, bifurcation ratio, constant of channel maintenance, frequency of source head, frequency of confluence points, slope and DEM. The drainage density of the Chittar basin varies from 1 km/km^2 to > 4 km/km^2. Stream length ratios for different stream orders vary between 0.30 and 0.64, which are low to moderate and suggest the moderately resistant hard rock terrain. The bifurcation ratio of streams of different order of the basin varies from 3.21 to 5.00. The average bifurcation ratio for the Chittar basin is 3.94, which is near to 4, suggesting some structural control over the development of drainage basin. The relative relief of the basin varies from place to place and most of the basin comes under the category of 30-60 m. At some places relative relief is very high and it suggests rugged topography. It is concluded that Remote Sensing and GIS have been proved to be efficient tools in drainage delineation and updation.

INTRODUCTION

Morphometry has a considerable bearing on the movement of groundwater in any area. Configuration of surface features has a significant effect on hydrogeological set up and infiltration. It also plays a vital role in the formation of residual soils and its effects on the overall drainage system of the basin. River characteristics are reasonably understood by the morphometric analysis of that particular river basin. The morphometric studies on river basins were first introduced by Horton (1932), and the idea was later developed in detail by Miller (1953), Schumm (1956), Coates (1958), Melton (1958), Smith (1958), Brosco (1959), Morisawa (1959), Chorley (1962), Strahler (1964), Guisty & Schneider (1965) and Muller (1968). The morphometric studies were carried out in India by James & Padmini (1983) on Kuttiyadi river basin in the Malabar coast, and Chattopadhay et al. (1996) on Vamanapuram River Basin (VRB), southern Kerala. The main objective of the present study is to compute basin morphometric parameters of the Chittar basin (CRB), a fifth order sub-basin of Vamanapuram River basin (VRB) by using advanced high resolution data and GIS technology .

STUDY AREA

The CRB with a catchment area of 102.77 sq.km lies between north latitude 8°44'00'-8°52'00' and east longitude 76°52'00'-76°56'00' falling in the Survey of India toposheets numbers of 58 D/13 and 58 D/14 (1:50,000) and shown in Fig. 1. This river length of 14.35 km originates from Madamukalil Kunnu at about 4 km north west of Kadakkal village in Chadayamangalam block of Kollam district and drains through, Kilimanoor block of Thiruvana-nthapuram district in southern direction and joins the Vamanapuram river at Munnumukku in Kallara panchayat. The monsoon commences in June and extends up to September. The area receives an average annual rainfall of 2283.19 mm. Cold weather prevails during December and January months. Geologically the Chittar basin is composed mainly of precambrian crystalline rocks. A large part of the crystalline rocks is of meta sedimentary in origin, and is referred to in early literature as Khondalite group. It shows much variation, ranging from nearly massive to well banded and foliated rocks. This group includes garnet-biotite- sillimanite gneiss, garnet-biotite with graphite gneiss, pyroxene granulites, and quartzo-feldspathic gneiss and patches of charnockite/charnockite gneiss.

MATERIALS AND METHODS

The drainage patterns of the basin are delineated using IRS IC LISS III data and SOI topographic numbers 58D/13 SW,58 D/13 SE, 58D/14 NE and 58 D/14 NW on 1:25,000 scale as reference. The measurement of various morphometric parameters such as stream order, bifurcation ratio (Rb), stream length and stream length ratio, relief ratio, basin area, basin perimeter, basin length, stream frequency, drainage density (D), drainage intensity (Di), weighed mean bifurcation ratio (Rbw), constant of channel maintenance, frequency of source head, frequency of confluence points, length of overland flow, slope and DEM were worked out. For digitization, computation and output generation, the GIS software was used.

Basin delineation: From the topographic data conjunction with satellite data the drainage network of the study area were drawn and CRB has been subdivided into I, II, III and IV order basins, based on the stream order.

Linear aspects: Linear aspects of the basins are related to the channel patterns of the drainage network wherein the topological characteristics of the stream segments in terms of open links of the network system are analysed. The linear aspects include the stream orders, stream length, bifurcation ratio, stream length and stream length ratio. For the study area linear aspects were derived and discussed.

RESULTS AND DISCUSSION

Stream order: Stream order is a measure of the relative size of the streams, the size ranges from first to twelfth order. The usefulness of the stream order depends on the premise that on the average, if a large sample is treated, order number is directly proportional to size of the contributing watershed, to channel dimensions and to stream discharge at that place in the system. The first order streams are those that do not have any tributary, the smallest recognizable channels (streams) are called first order and these channels normally flow during wet weather. A second order stream forms when two first order streams join and a third order when two second order streams are joined and so on (Strahler 1964). Where a channel of lower order joins a channel of higher order, the channel downstream retains the higher of the of the two orders and the order of the river basin is the order of the stream draining its outlet, the highest stream order in the basin. Chittar river is a fifth order perennial stream, the channel systems of different magnitudes of the drainage have been subdivided into hierarchical order (Strahler 1952) and shown in Fig. 2 and the details are given in Table 1.

The first order streams (218) can be identified only during monsoon period and stream ordering indicates discharge from a network. It is noticed that the maximum frequency is in case of first order streams. It is also observed that there is a decrease in stream frequency as the stream order increases.

Table 1: Stream orders of the study area.

Stream order	Number of Stream segments	Percentage to total number of segments	Stream length (km)	Stream length percentage
I order	218	71.01	107.46	49.00
II order	68	22.15	52.58	23.98
III order	15	4.89	23.71	10.81
IV order	5	1.63	21.20	9.67
V order	1	0.33	14.36	6.54
Total	307	100%	219.29	100

Table 2: Aerial parameters of the watershed.

S. No.	Parameters	Values
1	Basin area (sq:km)	102.77
2	Basin perimeter (km)	68.26
3	Basin length (km)	14.32
4	Basin width (km)	12.11
5	Stream frequency (Sf)	2.987
6	Drainage density (Dd)	2.133
7	Drainage intensity (Di)	1.40
8	Weighted Mean bifurcation ratio (Rbw)	3.50

Table 3: The drainage density and the area of the basin.

S.No.	Drainage Density	Area sq.km	Area in %
1.	< 1	18.92	18.41
2.	1-2	27.52	26.78
3.	2-3	34.21	33.29
4.	> 3	22.12	21.52

Stream Length

Stream length is measured from mouth of a river to drainage divide with the help of GIS software. This has been computed based on the law proposed by Horton (1945) for all the sub-orders of the study area. The total length of stream segments is maximum in first order streams and decreases as the stream order increases in the present study area (Fig. 3). This may be due to flowing of streams from high altitude, change in rock type and moderately steep slopes and probable uplift across the basin (Vittala et al. 2004).

Stream Length Ratio

Stream length ratio (RL) is the ratio of the mean length of the one order to the next lower order of the stream segments. The study area stream length ratios for different stream orders are worked out and shown in Fig. 4. It varies between 0.3 and 0.64 and found that, this is low to moderate and suggesting the moderately resistant hard rock terrain.

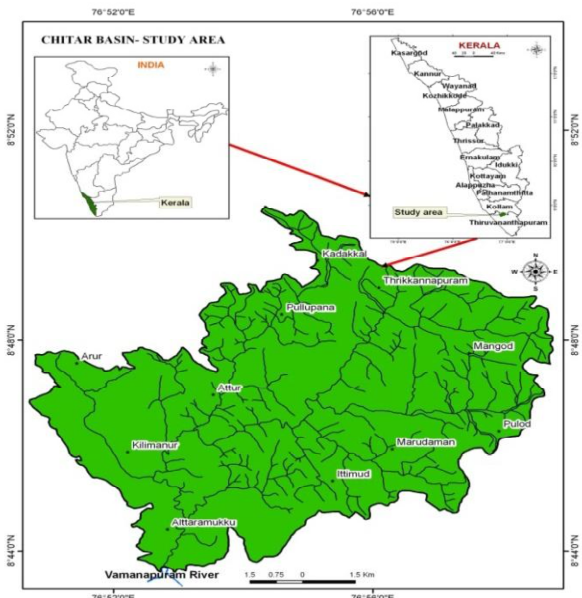

Fig. 1: Key map.

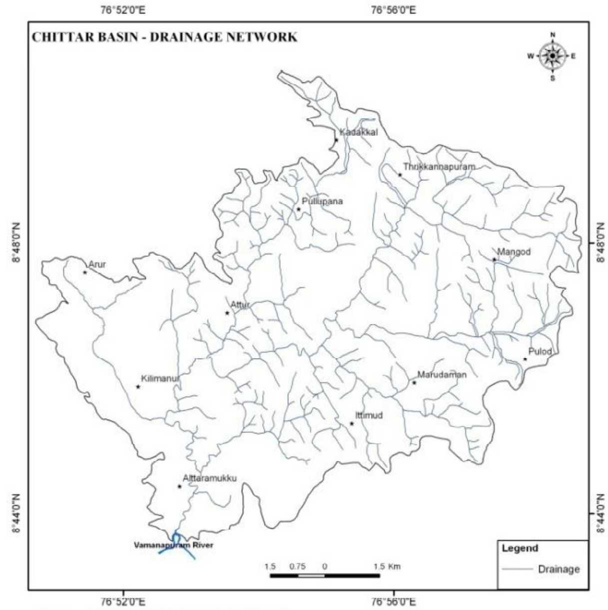

Fig. 2: Drainage network of Chittar basin.

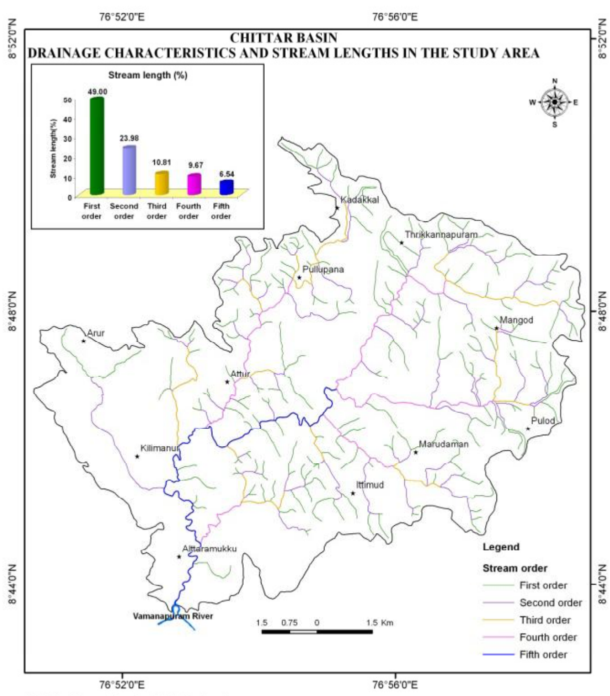

Fig. 3: Stream length of Chittar basin.

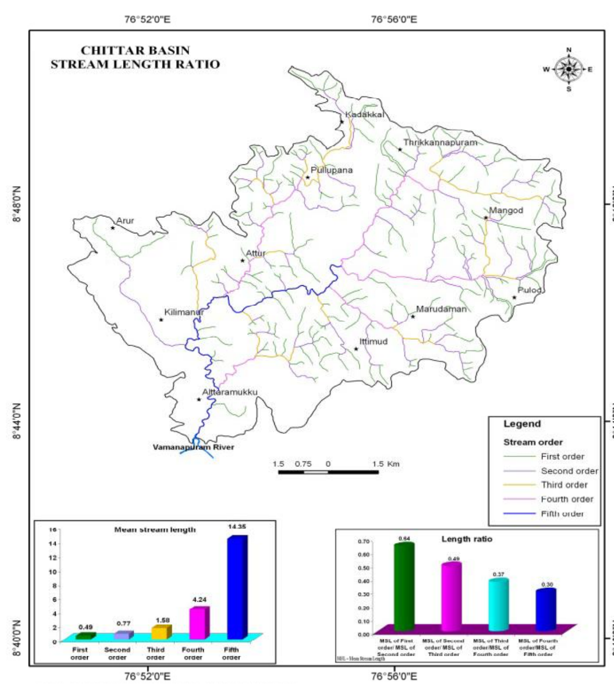

Fig. 4: Stream length ratio of Chittar basin.

Bifurcation Ratio

According to Schumn (1956), the term Bifurcation ratio (Rb) is defined as the ratio of the numbers of stream segments in one order (Nu) to the number of stream segments of next higher order. It is determined from the ratio of the number of streams of a given order to the number of the next higher order. The bifurcation ratio of the stream order for the study area have been worked out and shown in Fig. 5, and range from 3-5, indicating that the basin falls under normal basin category.

Weighed Mean Bifurcation Ratio

Strahler suggested a new concept of weighed mean bifurca-

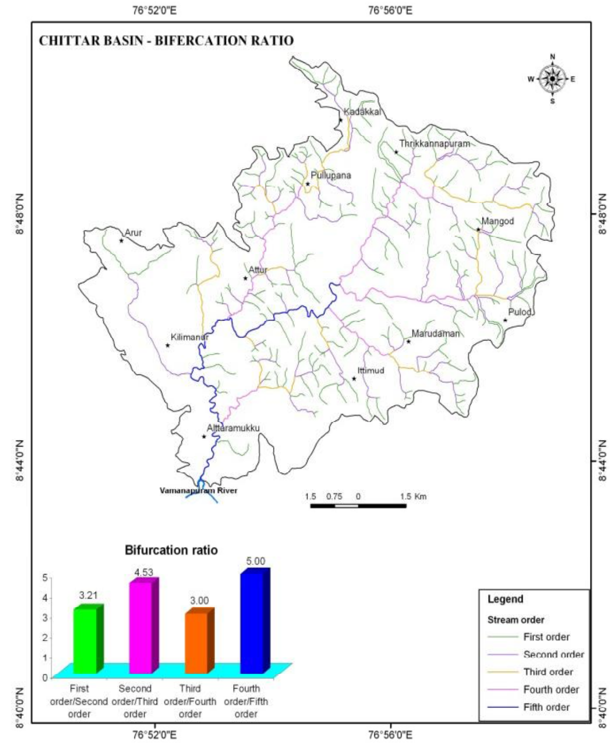

Fig. 5: Bifurcation ratio of Chittar basin.

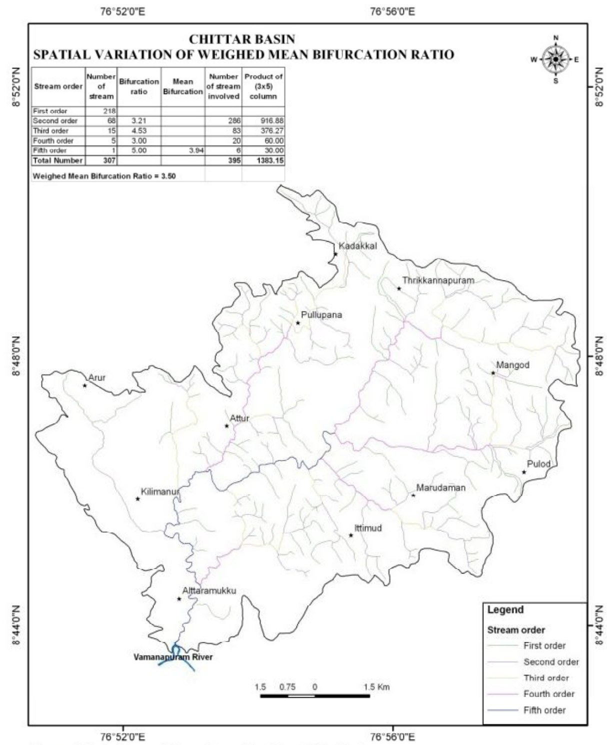

Fig. 6: Weighed mean bifurcation ratio of the Chittar basin.

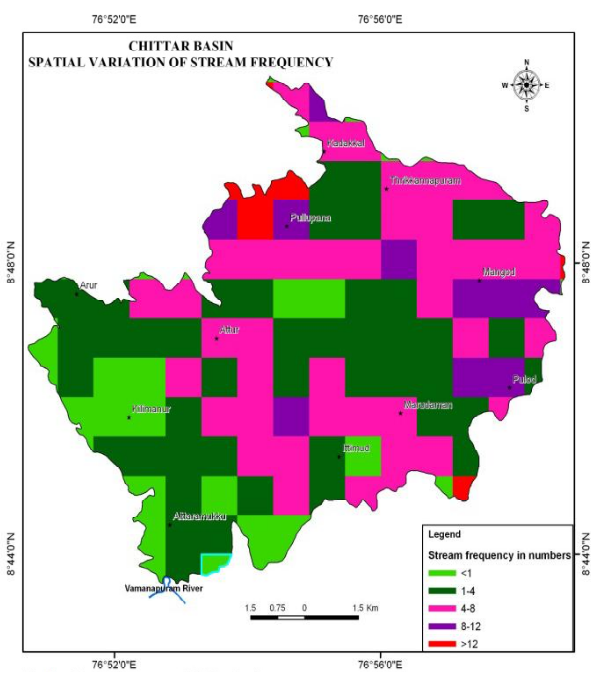

Fig. 7: Stream frequency of Chittar basin.

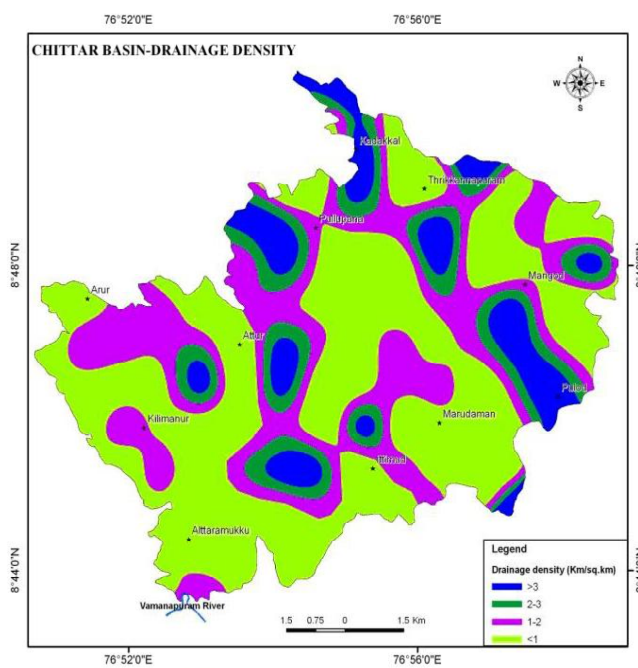

Fig. 8: Drainage density of Chittar basin.

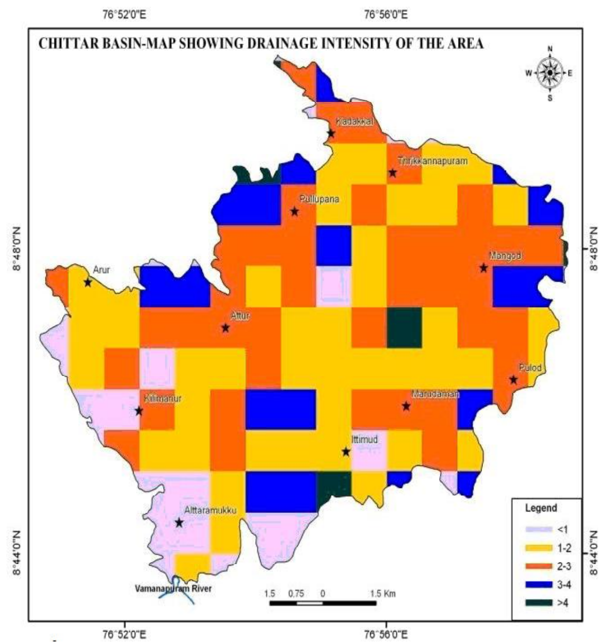

Fig. 9: Map showing drainage intensity of Chittar basin.

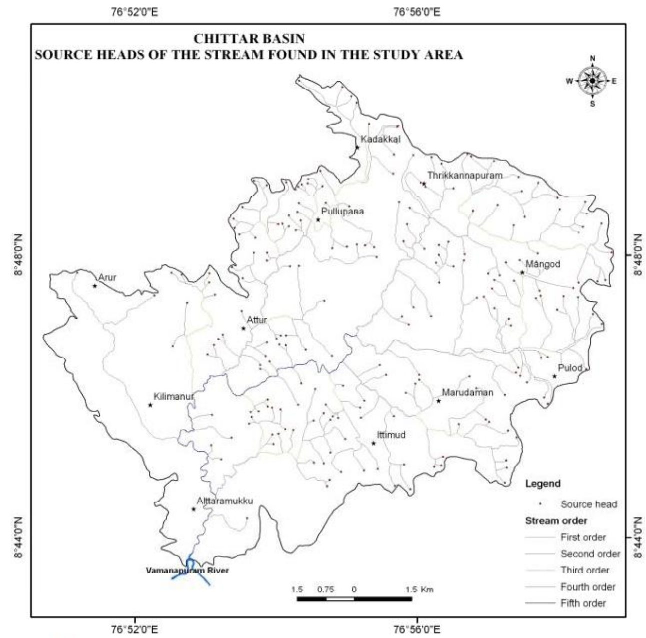

Fig. 10: Source head of the streams of Chittar basin.

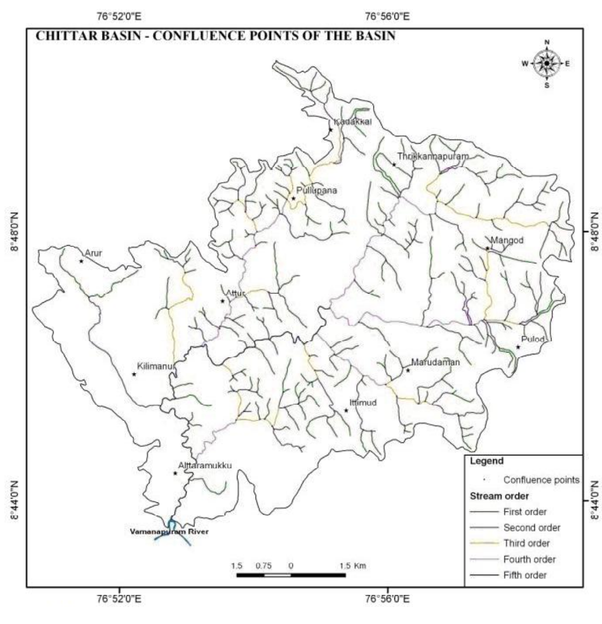

Fig. 11: Confluene points of Chittar basin.

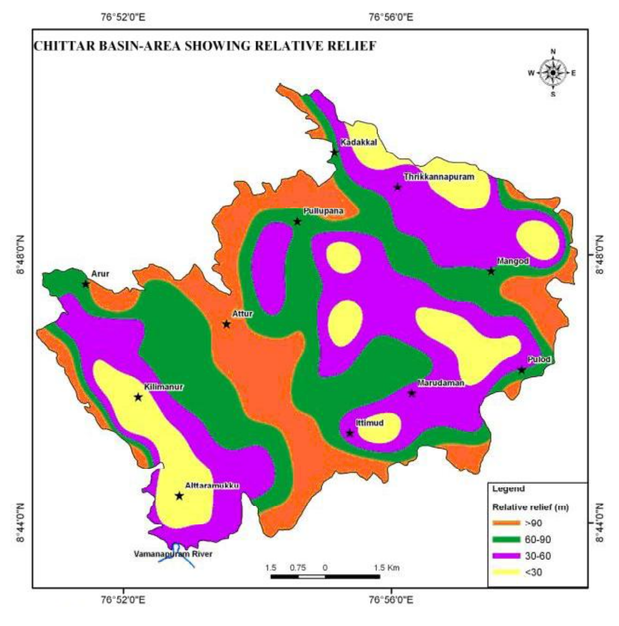

Fig. 12: Area of relative relief of Chittar basin.

tion ratio (Rbw) for the variations in the bifurcation ratio between streams of different order. Same way the average bifurcation ratio for the Chittar basin has been worked out and graphical representations are shown in Fig. 6. It has been shown that the ratio is 3.94, which is near to 4, suggesting some structural control over the development of drainage basin.

Aerial Parameters

Aerial parameters of the watershed are associated with the slope and size of the surface area. The aerial parameters include basin area (A), basin perimeter (P), basin length (L), drainage density (DD), drainage intensity (DI) and stream frequency (SF). The aerial parameters of the basin have been

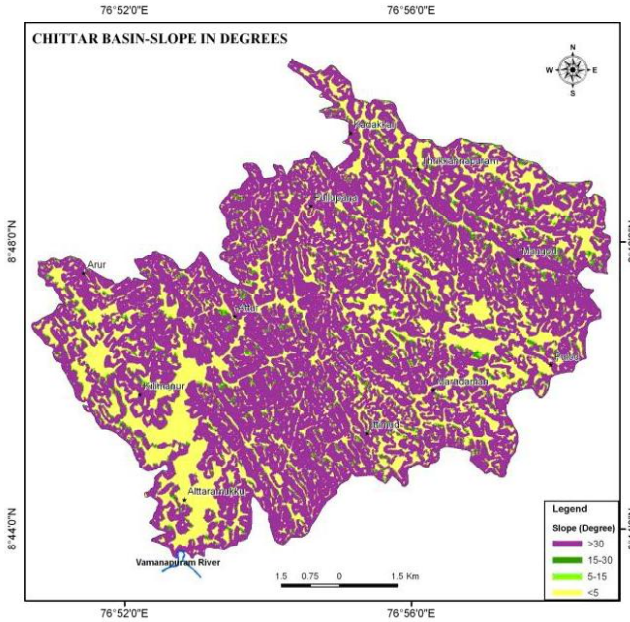

Fig. 13: Slop of Chittar basin.

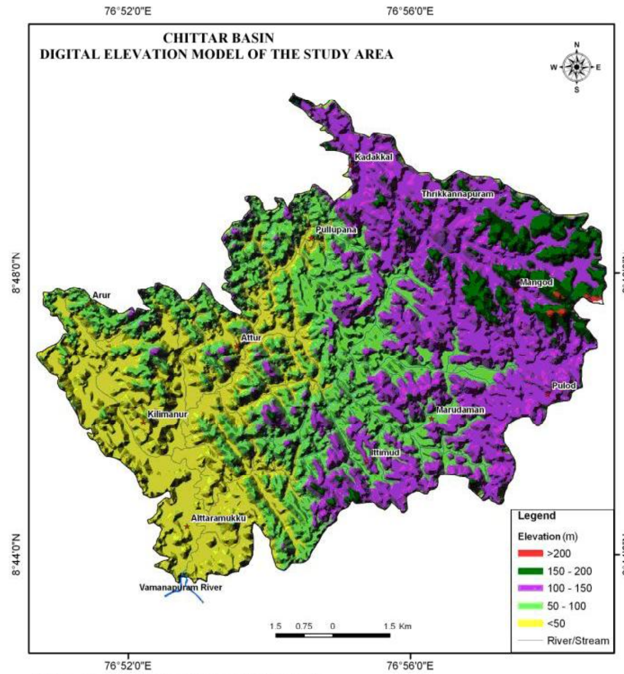

Fig. 14: Digital elevation model of Chittar basin.

calculated using GIS and given in Table 2.

Basin area: The total basin areas are measured as 102.77 sq.km, the first order occupies 39.89 sq.km, second order stream occupies 57.09 sq.km and third and fourth order streams occupy 44.23 and 72.92 sq.km respectively. The comparison of number of streams and basin areas of the basin indicates that the basin areas of fourth order stream number are greater.

Basin perimeter: It is the total length along the water divide of the basin as projected on the horizontal plain of the map. It is the linear measure of the basin and largely dependent on the texture of the topography. The perimeter of the watershed as a whole is 68.26 km.

Basin length: The basin length is defined as the largest length of the basin where the one end being the mouth of the stream. The measured length of the basin as a whole is 14.32 km.

Basin width: Basin width is nothing but maximum width of the basin. The Chittar basin width has been calculated as 12.11 km.

Stream frequency: Horton (1945) has defined stream frequency as a number of stream segments per unit area within a drainage basin. Shortly, it is the ratio of stream numbers to the basin area. The average stream frequency of the Chittar basin was worked out as 2.99. The spatial stream frequency is prepared and shown in Fig. 7. In the study area higher stream frequency indicates hard formations and greater surface run off.

Drainage density: Drainage density is expressed as the length of stream channels per unit area in the drainage basin (Horton 1945). It is a measure of the sum of the stream length per unit area and is obtained by dividing the total lengths of stream by the basin area. Vegetation, climate, permeability and rocks resistance to weathering controls drainage density. It also affects the run-off. The higher the density, the greater the run-off and vice versa (Fig. 8). Lower drainage density indicates the presence of permeable formations in the sub-surface. The drainage density indicates the closeness of spacing of channels (Horton 1932). The drainage density and the area associated in the basin are given in Table 3. The drainage density of the entire basin has been calculated as 2.133 km/km^2.

Drainage Intensity

The drainage intensity is defined as the ratio of stream frequency (SF) to the drainage density (DD). Drainage intensity contours were drawn from the drainages. The intensity contours were also drawn based on the area of influence and buffered out and shown in Fig. 9.

Constant of Channel Maintenance

The inverse of the drainage density gives the constant of channel maintenance (Schumm 1956). Generally, this constant varies directly with the size of the drainage basin. The drainage density of the area under study is 2.133 km/km^2. The constant of channel maintenance is 0.46 km/km^2. The low value for the constant of channel maintenance indicates

Table 4: Relative relief Data of chittar basin.

Relative relief(m)	Area (sq.km)	Area (%)
< 30	13.97	13.59
30-60	38.65	37.60
60-90	31.29	30.44
90-120	11.34	11.04
> 120	7.53	7.33
Total	102.77	100.00

Table 5: Slope catogories.

Slope	Area (sq.km)	Area (%)
> 30	69.55	67.68
15-30	6.17	6.00
5-15	4.32	4.21
< 5	22.73	22.11
Total	102.77	100.00

the permeable nature of sub-surface formation of the basin.

Length of Overland Flow (Lf)

The length of overland flow was introduced by Horton (1945) to describe the length of flow of water over the ground before it becomes concentrated in dendritic stream channels. Length of overland flow is approximately equal to half of the reciprocal of drainage density (Dd). The length of the overland flow (Lf) for the Chittar basin as a whole is 0.234.

Source Heads and Confluence Points of Chittar Basin

Source head is the point from where a first order stream starts. A low source head frequency implies a higher permeability of the surface and vice versa. High density of source heads and confluence points occur along the north eastern part and middle part of the basin i.e., along the high contour lines, whereas low and medium density zones occupy along the south western part of Chittar basin. High density of source heads and confluence points shows high relief (Fig. 10 and Fig. 11).

Relief Parameters

Relative relief: The relative relief contours were drawn from topographic data prepared, from the isolines the area of frequency of relative relief was drawn and shown in Fig. 12. The relative relief of the basin are worked out in Table 4. It varies from place to place, and it has been observed that the most of the basin comes under the category of 30-60 m. At some places relative relief is very high and it suggests rugged topography.

Slope Analysis

Slope has a dominant effect on the contribution of rainfall to stream flow and to the groundwater. Slope controls the duration of overland flow, infiltration and sub-surface flow. The slope conditions also control the depth to water table and distribution of head. The slope has a marked influence on the distribution of vegetation and pattern of land use and the slope information plays an important role in the evaluation of suitable sites for artificial recharge structures and it has direct influence on the morphometry of the basin. The slope was worked out using Wentworth's formula and calculated for the study area and shown in Fig. 13 and Table 5. The slope of the study area varies from < 5° to > 30°. Higher the slope areas, higher the runoff and lower the recharge.

Digital Elevation Model

Terrain analysis is defined as the representation and investigation of information relating to the shape of the earth. Geospatial terrain analysis is the digital representation of the physical features of the earth. These surfaces are often referred to as terrain models using GIS, the Digital Elevation Model (DEM) of the Chittar basin has been prepared and shown in Fig. 14. The DEM can be used for various common applications of the watershed viz., surface and groundwater hydrological modelling, overland flow modelling, forest resource modelling, land use classification and cartographic enhancement. In the present study, the prepared DEM is used to determine the direction of movement of flow through terrain model.

CONCLUSION

Remote sensing and GIS techniques have proved to be sufficient tools in drainage delineation and their updation. These updated drainages have been used for the morphometric analysis. The morphometric analysis of the Chittar basin has been carried out by measuring linear, aerial and relief aspects of the basin to bring out the form and processes of the study area. The drainage network of the basin is dendritic and the variation in stream length ratio might be due to change in slope and topography. The presence of high drainage density suggests low permeable sub-soil. The bifurcation ratio indicates normal basin category. The analysis of the relative relief of the area comes under the category of 30-60 m and at some places relative relief is very high and it suggests rugged topography. The drainage density indicates that the permeability of the terrain is high. The stream frequencies are inferred that the degree of dissection of the basin is higher. The analysis of the slope of the basin comes under the > 30° slope category.

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