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Morphometric Analysis of the Ver Watershed in Gujarat's Tapi River Basin Using Spatial Information Technology

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Abstract:- It has been demonstrated that spatial information technology (SIT) is effective tool for determining drainage patterns and organizing the management of water resources. This covers application of Geographic Information Systems (GIS), GPS, and Remote Sensing Information (RS). Morphological characteristics in Ver Watershed in Lower Tapi River Basin (LTRB) region of Gujarat state, India, have been identified and their parameters examined using Geographic Information Systems (GIS) and image processing techniques. Other morphometric parameters of river basin were also determined, along with its linear and aerial dimensions. It is basin of fifth order with a drainage pattern that ranges from subdendritic to dendritic. The basin in question has a significant vegetative cover and a very permeable subsurface, as indicated by low drainage density number that was measured. The strong elongation, high permeability, and homogeneity of geological materials in basin are all suggested by high circularity ratio value. The study's conclusions will enable locals to make better use of basin's resources going forward.

Keywords:- *Morphometry; Tapi River Basin; Spatial Information Technology.*

I. INTRODUCTION

Integrated remote sensing and GIS approaches are used to analyse soil erosion and prioritize watershed investigations. For example, map of land usage in a watershed, remote sensing can provide input parameters for modeling soil erosion. A geographic information system contributes to creation of a watershed data base, which is particularly useful for performing spatial analysis and helping decision-makers come up with best solutions for worst-affected areas. Recently, numerous researchers have used GIS and remote sensing technology to study sediment yield and soil erosion. Desmet and Govers (1996) employed GIS approach to automatically determine USLE LS factor for topographically complex landscape units.

Geographic information systems were employed by Kothyari and Jain (1997) to calculate sediment yield. Jasrotia et al. (2002) employed remote sensing and GIS techniques to estimate rainfall-runoff and soil erosion for Tonnes watershed. Morphometric analysis is crucial tool for selecting micro-watersheds, even without taking into account soil map (Biswas et al. 1999). For morphometric analysis, it is required to measure linear characteristics, channel network gradient, and ground slopes that contribute to drainage basins. Numerous studies have been published that analyse morphology using GIS and remote sensing methods. Shrimali et al. (2001) presented case study of 43 km2 Sukhana lake catchment in Shiwalik highlands for delineation and prioritising of soil erosion sites. They used remote sensing and GIS techniques. Using remote sensing and GIS techniques, Srinivasa et al. (2004) performed a morphometric analysis of subwatersheds in Pawagada area of Tumkur district of Karnataka. Chopra et al. conducted morphometric research on Panjab, Bhagra-Phungotri, and Hara Maja sub-watersheds in Gurdaspur district. Khan et al. (2001) employed remote sensing and GIS techniques to prioritise watersheds in Guhiya basin in India.

II. PHYSIOGRAPHY OF STUDY AREA

The Ver watershed is a section of LTB and is located in eastern part of Gujarat between longitudes 73° 15" and 78° 16" and latitudes 21° 00" and 21° 43". Its total area is 92.51 km2. The study zone is situated immediately downstream of Ukai reservoir, main reservoir of LTB, with an LS factor that can stretch to 65 km. The Ver watershed is traversed by canal on left bank of Ukai Reservoir. The right bank canal and other watersheds are accessible via Kakrapar weir on river Tapi, which is situated 25 kilometers after Ukai reservoir. For their 2000–2001 report, Central Water Commission discovered a small valley and gently sloping land in LTB. In area under consideration, maximum daily average temperature varies from 45 degrees Celsius in summer to 9 degrees Celsius in winter. In LTB, relative humidity ranges from 41% to 79% and there is average annual rainfall of 1379 mm. The Kakrapar left bank and right bank canal, which is mostly utilized for cotton and sugarcane, provides most of water required for irrigation.

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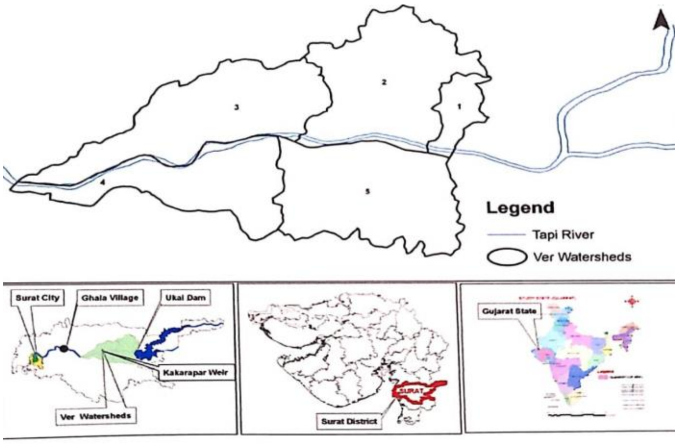

Fig. 1: Location Map of Study Area

III. MATERIALS AND METHODS

The combined use of remote sensing and GIS methods forms basis for morphometric analysis and prioritization of mini watersheds in Ver watershed in current study. Theme classification uses satellite images at a scale of 1:50,000 from IRS-P6 PAN+ folded LISS-III combined geocoded products. Utilizing satellite data from 20.4.2005, drainage layer was created. We geometrically corrected remotely sensed data using topographic maps from Survey of India (SOI) with a resolution of 1:50,000. The legibility of drainage images was improved using image-enhancing techniques. The dendritic drainage pattern may be computationally recorded thanks to GIS setup. To create order, stream flow was subjected to Horton's law. The length, area, and circumference of basin as well as number of streams were determined using drainage layer. Utilizing formulas provided by Horton (1945), Strahler (1964), Schumn (1956), Nookaratnam et al. (2005), and Miller (1953), morphometric parameters for watershed's defined size were determined. The length of stream, bifurcation ratio, drainage density, frequency of streams, shape factor, texture ratio, elongation ratio, circularity ratio, and compactness constant were all identified as morphometric properties.

IV. RESULTS AND DISCUSSION

Tables 1 & 2 provide summary of various morphometric parameters for Ver Watershed in lower Tapi river basin.

A. Linear Aspects of Channel System

Results for linear drainage network characteristics of stream order (Nu), bifurcation ratio (Rb), and stream length (Lu) are shown in Table 1.

➢ *Stream Order (Nu)*

Ranking streams in a drainage basin is first step in analysis. Strahler's stream ordering approach has been used to arrange channel segments inside drainage basins. The smallest tributaries are those that start at tips of fingers, according to Strahler (1964). A second-order channel segment is created when two first-order channel segments merge; a third-order channel segment is created when two second-order channel segments merge. The main routes by which water and debris are removed from watersheds are trunk streams. A fifth-order drainage basin makes up study region (Figure 3). Out of a total of 3908 streams detected, 2120 are first-order streams, 979 are second-order streams, 505 are third-order streams, 291 are fourth-order streams, and 13 are fifth-order streams. The vast majority of stream network's drainage patterns are dendritic, indicating textural homogeneity and lack of structural control. With its primary junctures at right angles to one another, limbs of this shape most nearly resemble a tree or fern. In contrast to other regions of basin, which have radial and parallel pattern types, hilly terrains contain topographic characteristics that are dipping, folded, and heavily jointed. A parallel drainage pattern is created when all of tributaries enter main river at almost same angle. The existence of parallel drainage indicates a place with gentle, regular slopes and softer bedrock. Water flowing outward or downward from hill or dome creates radial drainage pattern. With circular network of parallel channels flowing away from central high point, radial drainage pattern of channels resembles shape of wheel (Jensen, 2006). Understanding creation of landforms requires understanding of stream network features (Strahler and Strahler, 2002).

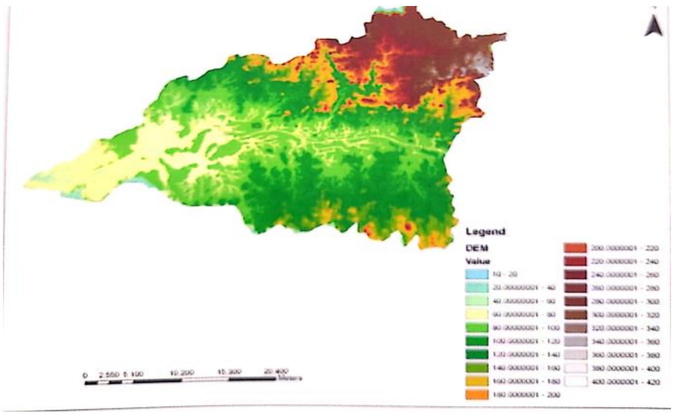

Fig. 2: False color composite of IRS LISS III data

Table 1: Linear aspects of drainage network of study area

River basin	Stream order u	Number of streams Nu	Total length of streams Nu	Log Nu	Log Nu
Ver Watershed	1	2119	142.62	3.35	2.12
	2	980	720.86	2.96	2.76
	3	503	545.24	2.72	2.64
	4	290	295.12	2.47	2.37
	5	14	490.55	1.13	2.67
Bifurcation ratio Rb				**Mean bifurcation ratio**	
1st order/	2nd order/	3rd order/	4th order/		

2^{nd}order	3^{rd}order	4^{th}order	5^{th}order	
1.04	0.93	0.20	4.70	1.70

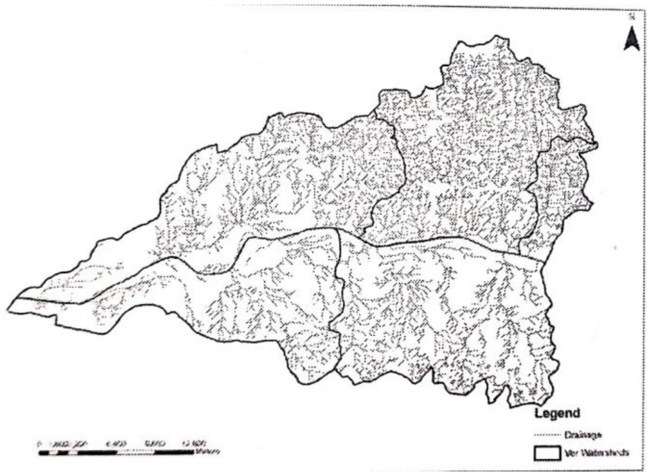

Fig 3: Drainage pattern and their order identified from study area

Table 2: Aerial aspects of study area

Morphometric parameters	Symbol/formula	
Area (sq. km)	A	92.51
Perimeter (km)	P	106
Drainage density (km/sq. km)	$D = \frac{L_u}{A}$	23.74
Stream frequency	$F_s = \frac{N_u}{A}$	42.24
Texture ratio	$T = \frac{N_1}{P}$	99.86
Basin length (km)	Lb	34.16
Elongation ratio	$R_e = \frac{2\sqrt{A/\Pi}}{L_b}$	0.3177
Circularity ratio	$R_c = \frac{4\Pi A}{P^2}$	0.103
Form factor ratio	$R_f = \frac{A}{L_b^2}$	0.079

Where,
Lu = Total stream length of all orders
Nu = Total no. of streams of all orders
N1 = Total no. of 1 st order streams
Π = 3.14

The entire number of arranged stream segments makes up stream number. When plotted versus order, most drainage networks show linear connection with little departure from straight line, according to Horton's (1945) laws of stream numbers. It is claimed that number of stream segments in each order forms inverse geometric sequence. The logarithm of number of streams against order of streams is represented in Figure 4(a) as straight line in accordance with Horton's law. This indicates that number of streams often decreases geometrically as stream order is raised.

➢ *Bifurcation Ratio (Rb)*

The bifurcation ratio (Rb) is defined as difference between number of streams in any given order and number of streams in next higher order (Schumn, 1956). Bifurcation ratios often go below 3.0 for basins where geologic formations do not change drainage pattern (Strahler, 1964). Strahler (1957) found that bifurcation ratio very slightly varies between regions or when certain environment predominates. The mean bifurcation ratio for research area is 1.72, which indicates that geological formations don't significantly affect drainage pattern.

➢ *Stream Length (Lu)*

Stream length is one of most significant hydrological properties of basin since it provides information about surface runoff characteristics. Streams that are relatively shorter in length tend to have larger slopes and finer textures. Longer streams often have gradients that are flatter. The basin's homogenous rock material is vulnerable to weathering and erosion, as seen by linear pattern in Figure 4(b)'s plot of logarithm of stream length versus stream order. The terrain differs from its regular behaviour, which indicates that lithology and topography are variable.

B. Areal Aspects of Drainage Basin

The two most crucial variables in quantitative morphology are basin area (A) and perimeter (P). The total area of basin, when projected onto horizontal plane, adds to combined area of all basins. The perimeter also referred to as boundary, of basin can be measured using topographic maps. The size of storm hydrographs and magnitudes of peak and mean runoff are both influenced by basin area, which is important in terms of hydrology. It's fascinating to think about that size is inversely proportional to maximum flood discharge per unit area (Chorley et al., 1957). Aerial metrics of drainage basin determined and shown in Table 2 include drainage density (D), stream frequency (Fs), texture ratio (T), elongation ratio (Re), circularity ratio (Re), and form factor ratio (Rf).

➢ *Drainage Density (D)*

Drainage density (D), first described by Horton (1932), is crucial indicator of linear scale of landform's constituent parts in stream-eroded topography. It is ratio of surface area of basin to total length of all channels inside basin, regardless of order. Drainage density gives number representing average length of stream channel for entire basin and indicates how far apart streams are from one another. A high drainage density is influenced by weak or impermeable subsurface material, lack of vegetation, and steep topography. High drainage densities provide fine drainage textures, and low drainage densities produce coarse drainage textures (Strahaler, 1964).

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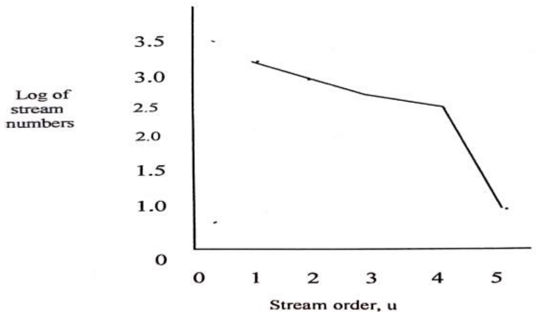
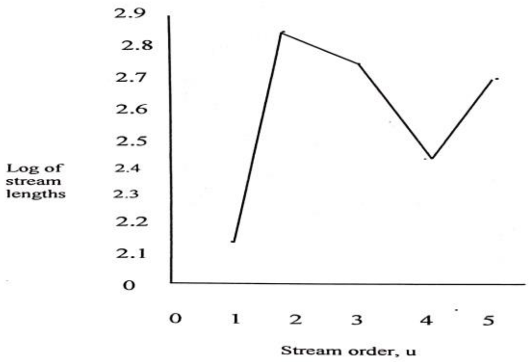


(a)



(b)

Fig 4. A) Regression of logarithm of number of streams versus stream order,
b) Regression of logarithm of stream length versus stream order

The drainage density (D) of study area, which is 23.70 km/sq km, is low. An explanation for basin's low drainage density (Nag, 1998) is that it has a very permeable subsoil and a substantial vegetative cover. The type of rock also has an impact on drainage density. Regions rich in granite, gneiss, and schist often have lower D values. The primary rock type in studied region is khondalite, which belongs to gneissic group of rocks. This confirms observations about poor drainage density in drainage basins.

➢ *Stream Frequency (Fs)*

Stream frequency, also known as channel frequency (Fs), is total number of stream segments for all orders inside a given region (Horton, 1932).

➢ *Texture Ratio (T)*

Texture ratio (T), which depends on underlying lithology, infiltration capability, and relief aspect of terrain, is significant factor in drainage morphometric analysis. The texture ratio of basin in current study is 99.90 and is characterized as moderate in nature.

➢ *Elongation Ratio (Re)*

Schumm (1956) defined elongation ratio (Re) as ratio of a circle's diameter to its maximum practicable basin length. It is a crucial index in basin shape analysis that helps shed light on hydrological composition of drainage basin. Values that are close to 0.9 are typical in areas with limited relief (Strahler, 1964). The study area's Re value of 0.30 indicates that topography has little relief and an elongated shape.

➢ *Circularity Ratio (Re)*

A dimensionless circularity ratio (Re) was defined by Miller (1953) as ratio of basin area to area of circle with same perimeter as basin. He described basin as having circularity ratios ranging from 0.1 to 0.4, indicating highly elongated and permeable homogeneous geologic materials. The basin's circularity ratio value (0.103) confirms Miller's range, indicating that basin is elongated in shape, has low discharge of runoff, and has high permeability of subsoil condition.

➢ *Form Factor Ratio (Rf)*

In order to quantitatively express outline form of drainage basin, Horton (1932) employed form factor ratio (R), which is dimensionless ratio of basin area to square of basin length. Basin shape can be indexed by simple. ratios of basic dimensionless length, area, and perimeter measurements (Singh, 1998). The basin has elongated shape due to its form factor value of 0.080, which indicates lower value. The low form factor of elongated basin indicates that peak of flow will be flatter and last longer. Compared to circular basins, these long basins make it easier to control flood flows.

V. CONCLUSIONS

It has been demonstrated that quantitative analysis of morphometric traits is helpful for evaluating river basins, prioritizing watersheds for soil and water conservation, and managing local natural resources. The lower Tapi river basin's Ver Watershed was subjected to morphometric analysis, which revealed that basin is long and flat. The basin's predominance of dendritic drainage systems suggests lack of structural control and homogeneous texture. The topography of basin dips and joins in several locations in parallel and radial pattern. The diagram's linear pattern draws attention to area's vulnerability to weathering and erosion. In order to understand type of bedrock, infiltration rate, runoff, and other features of landscape, we used GIS to examine morphometric data. These understandings can all be improved with aid of related research augmented with high resolution satellite data.

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