

## Morphometric Analysis of Kadvi River basin, Maharashtra Using Geospatial Techniques

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### Abstract

The present research work reflects the in detail morphometric study of Kadvi river basin, which is a part of Warna river in Shahuwadi district. Considering the geospatial techniques the study of kadvi river has further proceeded. The CARTOSAT data was used for generating DEM (digital elevation model). GIS was used for the analysis of morphometric aspects of Kadvi river basin. In the present study a variety of parameters like linear (stream number, stream order, stream length, stream length ratio, drainage density, bifurcation ratio, texture ratio, stream frequency) and shape concepts ( i.e. compactness-coefficient, circularity ratio , elongation ratio, form factors ) of the kadvi river basin has estimated. The study concludes that Kadvi river basin is having an area of 428.82 square km. The obtained number of stream order is from 1 to 7, here it is proved that 1st stream order with 1488 stream number is most dominant. The total number of streams counted in the Kadvi river basin are 1948. The drainage texture obtained in the basin is 18.07, which shows very fine texture of the river basin. The measured drainage density and stream frequency values are 3.2 km/sq.km and 4.54 respectively.



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GIS and remote  
sensing,  
Digital Elevation Model.

### Introduction

Morphometric studies are first attempted by Horton, Strahler, Smith, Schumm, and Miller<sup>1-5</sup>. Parallel work of basin morphometry has been carried out by Abrahams, Langbein, Leopold, and Maddock<sup>6-8</sup>. The morphometric analysis is done with linear, aerial, relief aspect, the slope, and a gradient of a channel by many researchers<sup>9,10</sup>. Basin morphometry gives

the signs of an influence on river hydrology and river channel. Similar work is done by Sapkale on Tarali river with an approach of hydraulic geometry and river channel processes<sup>11-13</sup>. The main aim of the attempted study is the analysis of morphometric parameters of Kadvi river watershed with an approach of GIS and remote sensing. Nowadays GIS techniques are more useful for assessment of

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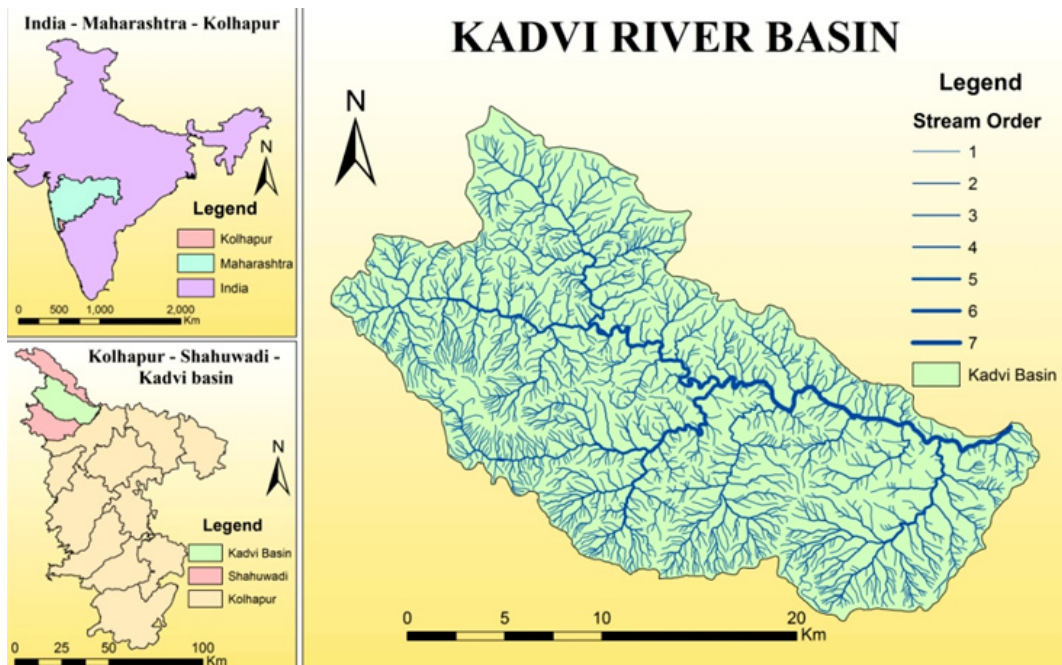
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various morphometric and terrain parameters of a watershed. GIS offer high accuracy level, flexibility in work as well as this is a user friendly tool. DEM data has used for terrain analysis of Kadvi river watershed. DEM data is employed for flow direction, flow accumulation, slope map, aspect map, contour map and other morphometric parameters like basin relief, relief ratio, absolute relief, watershed slope etc. Many researchers also used GIS and remote for evaluating morphometry of river watersheds<sup>14-22</sup>. Morphometric study of watershed gives information which is related to terrain, hydrological characteristics of the river, physiography of basin which is helpful for river water management, irrigation and site suitability for reservoirs. The deforestation, erosion of landscape due to over-exploiting of top soil and land cover changes are also the human induced impacts that is highly influenced on the morphometric characteristics of river basin. Kadvi river basin also reflects such type of human interferences, which are responsible for the changing characteristics of river basin morphometry. Fundamental morphometric parameters like drainage density, slope, run off, texture, relief ratio have also expresses hydrological characteristic of the basin, also helps to evaluate the

potential sites of ground water zones in terms of geo-hydrologic aspects. The analysis of morphometric aspects may supports for the study of hydrological models by means of remote sensing and GIS techniques.

**Study Area**

The Kadvi River basin extend between 16°48' 51.369" to 17° 3' 5.686" north latitudes and 73°45' 58.957" to 74° 05' 35.303" east longitudes. Kadvi river basin area covers 428.81 sq km with reference to SOI toposheets 47G16, 47H13 and 47L1. Kadvi river originated in western ghat near Amba village, Shahuwadi, Kolhapur, Maharashtra, India. Kadvi river is the main tributary of Warna river. Kadvi river flows western to the eastern side and meets the Warna river near Thergaon village<sup>23</sup>. Ambardi, Potphogi, and Shali rivers are sub tributaries of Kadvi river. Length of Kadvi river is 48.66 km. Kadvi river basin covers nearly 41.50% area of Shahuwadi tehsil, so Kadvi river is known as the back bone of Shahuwadi tehsil. The climate of Basin is generally temperate<sup>24</sup>. Heavy rainfall is found in this basin from June to October<sup>25</sup>.

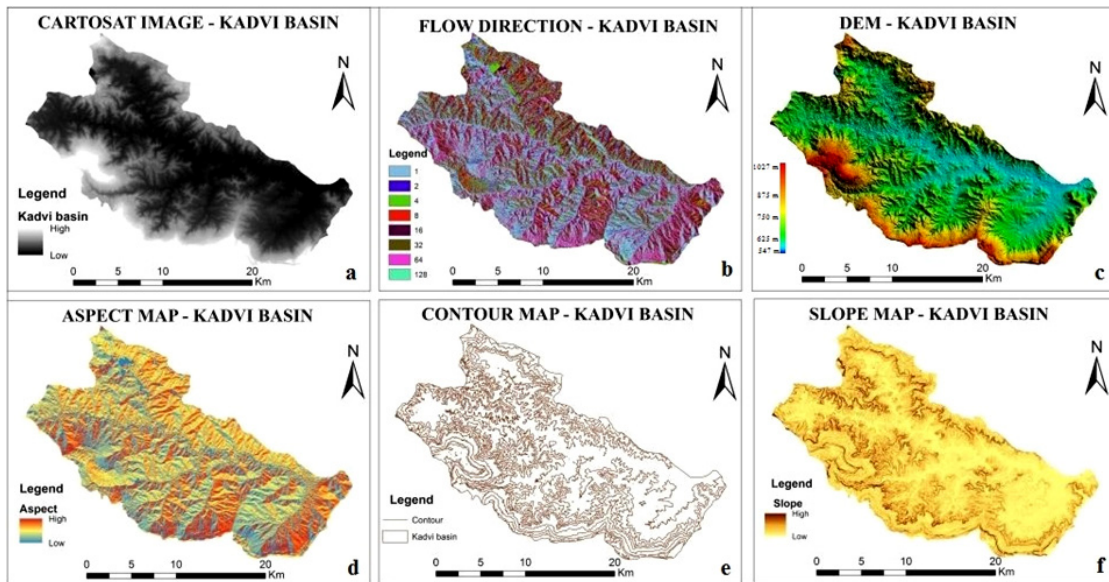


**Fig. 1: Location map and Drainage network of Kadvi River Basin (Source: Based on Survey of India Maps)**

**Materials and Methods**

Morphometric analysis of river does not possible without SOI toposheets or satellite imageries. In this present work SOI toposheets 47G16, 47H13 and 47L1 on the scale of 1:50000 were used. Georeferencing process is done by Erdas Imagin 9.1. Letter on digitization process and calculations are prepared on Arc GIS 9.3. The morphometric analysis

conveyed through linear aspects, areal aspects and relief aspects. Basin area of Kadvi river basin and drainage network has computed on the basis of SOI toposhets (Fig 1). Strahler's stream ordering method adopted for stream ordering of Kadvi river basin. Cartosat DEM images were used for flow direction map, DEM map, slope map, aspect map and contour map.



**Fig. 2: (a) Cartosat image, (b) Flow direction of Kadvi river, (c) DEM of Kadvi river, (d) Aspect map of Kadvi basin, (e) Contour map of Kadvi basin, and (f) Slope map of Kadvi basin**

**Results and Discussion**

**Stream order**

The first step of morphometric analysis of the river basin is to get the Stream order. It is identified as calculating the arrangement of a stream in the hierarchy of streams and tributaries<sup>26</sup>. Stream ordering method was first invented by Horton<sup>27</sup> in 1945, but later on in 1952 Strahler<sup>28</sup> has modified stream ordering method and published it. Strahler method is much uncomplicated so generally many researchers adopt this method for morphometry purpose. In this present work, Strahler's method is used for stream ordering. And the result is that Kadvi river is ended by 1948 streams linked with 1<sup>st</sup> to 7<sup>th</sup> stream orders.

**Number of streams (Nu)**

The number of stream segments in specific order is estimated individually and is called as stream number of that particular order. Horton<sup>27</sup> invented the number of stream segments. The number of stream decrease with increasing stream order. The negative relationship has detected between stream order and numbers of the stream to the respective order.

All the stream of the watersheds of Kadvi river basin has been designated according to the Strahler's system. As per the law of Strahler in Kadvi river basin, the first order constitutes 76.39 %, while the second is 17.97 % of the total number of streams. The 3<sup>rd</sup>, 4<sup>th</sup>, 5<sup>th</sup>, 6<sup>th</sup>, 7<sup>th</sup> streams covers 4.26 %, 0.98

%, 0.26 %, 0.10 %, 0.05 % respectively of the total number of streams. A high value of first order streams indicates that there is a possibility of serious flood after heavy rainfall in the downstream<sup>29</sup>.

### Stream Order versus log of length of stream, Kadvi River

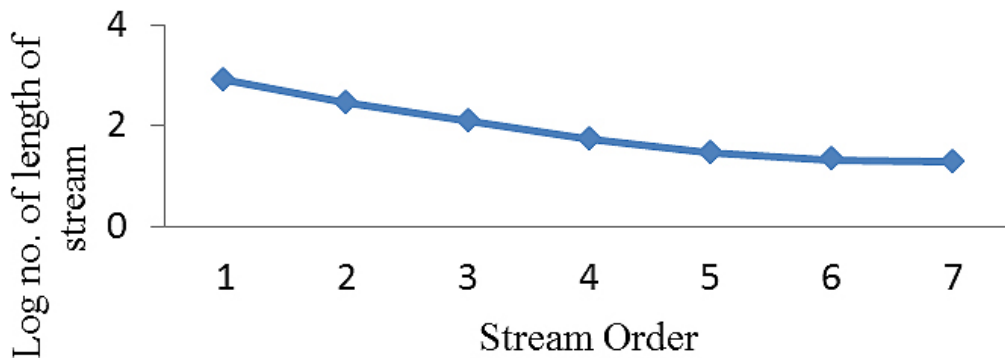


Fig. 3: Stream order versus log of stream number, Kadvi river basin

#### Stream length (lu)

Stream length means the total length of streams in each particular order is approved to as stream length of that order. In this study, the law of Horton has followed for calculating the stream length. Frequently the total length of stream sections is maximum for the first order stream and decrease with stream order increase. This may be due to the flowing of streams from high elevation, change in rock and soil type and moderately steep slopes and probably uplift across the basin<sup>30,31</sup>.

It can be measured the fact from table 1 that the length of 1st order is measured to be 60.61% of total stream length. 2<sup>nd</sup> order stream has 21.04% length. 3<sup>rd</sup> order constitutes about 9.39% length. 4<sup>th</sup> order has 3.92% length. 5<sup>th</sup> order has 2.12% length. 6<sup>th</sup> and 7<sup>th</sup> order measured 1.50% and 1.42% length respectively. The result disclosed that 1<sup>st</sup> order stream is available with a large number but short in length and basically found in an upstream area.

### Stream Order versus log of length of stream, Kadvi River

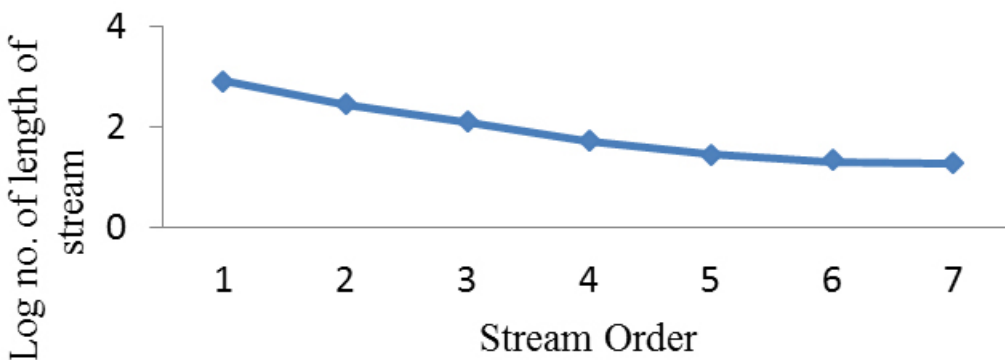


Fig. 4: Stream order versus log of length of stream, Kadvi river

**Stream length ratio (Lurm)**

Horton<sup>27</sup> has identified the concept of mean stream length. Lurm, is the ratio between any two successive orders of mean stream length. Change of Lurm, from one order to another order representing their late youth stage of geomorphic development. Variations are observed in stream length ratio between adjacent stream orders of the basin due to disparity in slope and topographic conditions. The value of stream length ratio varies arbitrarily from 1.48 to 2.05 found in Kadvi river. It reveals that hard terrain is dissected and controlled by rock structure and the streams have limited length of lower order stream.

**Mean stream length (Lum)**

Lum, is a dimensional property exhibiting the characteristic size of components of a drainage system and its contributing watershed area. Kadvi River shows 0.56 to 19.42 mean stream length value. The mean stream length of Kadvi river is 0.56 for 1<sup>st</sup> order, 0.82 for 2<sup>nd</sup> order, 1.55 for 3<sup>rd</sup> order, whereas 4th, 5th, 6th, the 7th order has 2.83, 5.81, 10.26, 19.42 respectively. The Lum of the river increases with the increase of the order it means that positive relationship is found between Lum and stream order. The average mean stream length of Kadvi River is 1.82.

**Bifurcation Ratio (Rb)**

The Rb, is the 'ratio between the numbers of streams in two successive orders'. Schumm formulates the concept of bifurcation ratio<sup>32</sup>. In conformity with Schumm 'The term bifurcation ratio is the ratio of the number of stream segments of any given

order to the number of streams in the next higher order'<sup>32</sup>. These irregularities are dependent on the geological and lithological progress of the drainage basin<sup>32</sup>. Bifurcation ratio of Kadvi river varies from 2 to 4.37. The lower values of bifurcation ratio indicate that the watersheds have undergone less structural disturbance. In this research work, it is clear that bifurcation ratio with higher values are indicative of having strong structural control on the drainage pattern, where as the bifurcation ratio with lower value shows watershed that is not affected by structural disturbance.

**Mean Bifurcation Ratio (Rbm)**

Value of mean bifurcation ratio of Kadvi river is 3.52. Higher "Rbm" of river basin means large variation in a number of stream orders because of more complex geological structure<sup>33</sup>.

**Weighted mean bifurcation ratio (Rbwm)**

Strahler in 1953 used a Rbwm, considered an outcome of bifurcation ratio for each successive pair of order and the total number of stream involved in the ratio and taking the mean of the sum of these values. The values thus determined are very close to each other. The Rbwm of Kadvi river obtained by this method is 4.24.

**Length of Main Channel (CI)**

This is the distance along the largest water source from the outlet to end of channel boundary. In this study, length of the main channel is measured by taking help of Arc-GIS software. The calculation comes to 48.66 km of Kadvi river.

**Table 1: Stream order, Number of streams, Bifurcation ratio, Total length of streams, Stream length ratio, Log of Nu and Log of Lu**

Stream Order	Number of Streams	Bifurcation Ratio	Total Length of Streams (km)	Mean Stream Length (km)	Stream Length ratio	Log Nu	Log Lu
1	1488	4.25	830.90	0.56	1.48	3.17	2.92
2	350	4.22	288.46	0.82	1.88	2.54	2.46
3	83	4.37	128.72	1.55	1.83	1.92	2.11
4	19	3.80	53.80	2.83	2.05	1.28	1.73
5	5	2.50	29.04	5.81	1.77	0.70	1.46
6	2	2.00	20.52	10.26	1.89	0.30	1.31
7	1	---	19.42	19.42	---	0.00	1.29
Total	1948	3.52	1370.85	5.89	1.82		



**Channel Index (ci) and Valley index (vi)**

Channel index of Kadvi river is calculated by dividing mean channel length of a river by minimum areal distance. The Channel Index (ci) of Kadvi river is 1.77. Estimation of valley index is performed by taking the ratio of valley length of the river to minimum areal distance, which is 1.3 obtained for Kadvi river basin.

**Rho Coefficient**

Rho coefficient parameter is strictly associated with drainage density to geologically progress of basin which evaluates the storage competence of drainage system and determinant of drainage improvement in a particular basin<sup>27</sup>. Rho coefficient value of Kadvi river is 0.52. Geological, geomorphological, climatic and biotic factors conclude the changes in Rho coefficient.

**Length of Basin**

Different meanings of basin length (lb) have been discussed by different researcher<sup>32-36</sup>. With reference to Schumm, the length of Kadvi river basin seems to be 35.86 km. Basin length of Kadvi river was measured with Arc GIS software. Length of the basin is dependent on shape of basin. Elongated basin is characteristic of high basin length.

**Sinuosity Index**

It is the property of stream that shows the divergence of the river course of a drainage line from the straight path. Sinuosity index highly signifies in verifying the effect of terrain features on the river path and vice versa. The value 1.0 shows straight river course, values involving 1.0 to 1.5 indicates the sinuous shape of the stream and the values above 1.5 shows the meandering course<sup>26</sup>. Kadvi basin has 1.36 value which shows sinuous course.

**Basin area**

It is a key parameter of morphometric analysis<sup>1-5</sup>. Basin area is any area of land where rainfall water collects and drains off into a river and other water bodies. Generally, topography of landform determined basin area of the river. Schumm had set the relation between basin area of the river and total stream length. Kadvi river basin covered 428.82 sq km. Basin area and shape of the basin are closely related to each other. Larger basin areas are more prone to flooding.

**Basin Perimeters (P)**

The perimeter of Kadvi river basin is estimated to be 107.8 km, which covers the most part of the Shahuwadi tehsil. The estimation is done using Arc GIS software (Table-2). Basin perimeter said to be the length of the watershed boundary in which catchment region is encircled when basin perimeter associated with basin area. The departure of the basin from a true circle can be calculated. Similarly, when associated with relief it gives the general steepness of the basin.

**Length area relation (Lar)**

The concept of length area relation discovered by Hack in 1957. Length area relation value is calculated with following formula<sup>37-43</sup>.

$$Lar = 1.4 * A^{0.6}$$

Lar value of Kadvi river basin is 53.15.

**Lemniscate's (K)**

To obtain the gradient of the basin, Chorley put forth the lemniscates value<sup>35,36</sup>. Kadvi River basin has K value 3. The formula is expressed as

$$K = Lb^2/4*A.$$

Here, Lb = basin length, A= Area of basin.

**Form Factor**

Horton<sup>27</sup> described form factor concept. Form factor expresses the ratio between the river basin and square of the basin length. If form factor of the basin is closer to zero is designate highly elongated shape and closer to 1 point to circular shape. Value of Rf is 0.25 indicate lower value and convey elongated shape another hand, rate of Rf is 0.78 show higher value and suggest perfect circular basin shape. The form factor of Kadvi river is 0.33. It means that Kadvi river basin having an elongated shape. Flood flows are easily spread out in an elongated basin more than the circular basin.

**Elongation Ratio**

Elongation ratio<sup>1-5</sup> means, the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin. Re, state with the following formula-

$$Re = 2 / Lb * (A / \pi)^{0.5}$$

Values of Re are classified into five classes, these are 0.9 to 0.10 is circular, 0.8 to 0.9 is oval, 0.7 to 0.8 is less elongated, 0.5 to 0.7 is elongated and below 0.5 is more elongated. Values closer to 1.0 is demonstrated region having very low relief. The value of elongation ratio of Kadvi river is 0.65 and designate low relief with an elongated shape.

#### Texture Ratio (Rt)

Texture ratio<sup>1-8</sup> is a highlighting component in the drainage morphometric analysis which is defined as the ratio of first order streams and perimeter of the basin. The present study shows 13.8 as the texture ratio of a watershed and classified as moderate in nature. It is dependent on various natural factors like climate, rainfall, vegetation, rock and soil type, infiltration capacity and developmental stage.

#### Circulatory Ratio

Miller described circularity ratio concept in 1953. According to Miller circularity ratio means the ratio of the area of basin to the perimeter of the same basin<sup>37</sup>. Rc of the basin is express with following formula -

$$Rc = 4 \pi * (A / P^2)$$

Miller has described, the basins having 0.4 to 0.5 circularity ratios specify highly elongated and homogeneous geological structures. Values of circularity ratios are between 0 (in line) to 1 (in a circle). Variations in circularity ratios found due to relief pattern, variety in a slope of the basin. A low value of circularity ratio indicates youth stage and medium and high values shows mature and old stage of river respectively. Kadvi river basin illustrates the mature stage of development with the Rc of 0.46. Kadvi River basin has a highly elongated shape as per law of Miller<sup>37</sup>.

#### Drainage Texture

Horton<sup>27</sup> invent drainage texture concept and defined drainage texture is the total number of stream numbers of all order in a basin per perimeter of the basin. Smith<sup>38</sup> has classified five classes for drainage texture i.e., below 2 for very coarse, 2 to 4 for coarse, 4 to 6 for moderate, 6 to 8 for fine and above 8 for very fine<sup>38</sup>. Drainage texture of basin is depending on rainfall, vegetation cover, climatic

condition, soil types, rock formation and relief of the basin. In this present work, the basin of Kadvi river reveals very fine drainage texture with a greater value which is 18.07 by the collective result of various geomorphological and geological processes.

#### Compactness Coefficient (Cc)

As per the law of Gravelius<sup>44</sup>, compactness coefficient of a watershed is referred as the ratio of the perimeter of a watershed to a circumference of the circular area, which equals the slope, not on the size of a watershed. Compactness coefficient is measured by considering the formula.

$$Cc = 0.2841 * P / A^{0.5}$$

The Compactness coefficient of Kadvi watershed is estimated to 1.48. For a perfect circle, Compactness coefficient is measured to be unity and is directly proportional to basin length. It direct related with elongated nature of the basin.

#### Fitness Ratio (Rf)

According to Melton<sup>47</sup>, fitness ratio is illustrated as the ratio of main channel length to the length of the watershed perimeter. For various studies fitness ratio has carried out by distinguished authors<sup>45-51</sup>. It is a measure of topographic fitness ratio, for Kadvi river basin it is 0.45.

#### Wandering Ratio (Rw)

Smart and Surkan<sup>48</sup> defined wandering ratio of main stream length to the valley length. The actual distance between the outlet of the basin and the extreme point on the ridge is the length of the valley. The wandering ratio of Kadvi river drainage basin is 1.36.

#### Stream frequency (Fs)

In 1932, Horton<sup>1-8</sup> invented the concept of stream frequency. According to him, stream frequency is a ratio of total numbers of streams of all orders of the basin divided by total area of the basin. Stream frequency and Drainage density are closely related to each other and designated if stream frequency increases, respectively drainage density also increases (Table-2). The steep slope and impervious soil and loose rock structure are causes of high stream frequency<sup>1-8</sup>. As well as stream frequency is also reliant on rainfall and geology of watershed.

Kadvi river basin frequently covered with the hilly region so moderate stream frequency is found in this basin and it is 4.54.

### **Drainage density (Dd)**

Horton has introduced the drainage density first, then later on various researchers<sup>1-8</sup> have calculated the drainage density for the river basins. Drainage density is the ratio of the length of total streams of the basin divided by total area of the basin. Dd is measured in mi/sq. mi or km/sq. km. Low drainage density indicates coarse drainage texture while high drainage density reveals the fine drainage texture<sup>1-8</sup>. Drainage density is classified in five categories<sup>39</sup>, very coarse for below 2, coarse for 2 to 4, moderate for 4 to 6, fine for 6-8 and very fine for above 8. Drainage density of Kadvi river is 3.2 km/sq. km. It is recommended coarse drainage density. High drainage density is found in a hilly region of the basin in a site of SW and S<sup>40</sup>. Dd is a very sensible parameter and closely related to rainfall, vegetation, soil structure, geology, rock formation, land use and land cover and some other morphometric parameters. Drainage density is positively correlated with stream frequency. This positive relation between drainage density and stream frequency develop the drainage capacity of the watershed.

### **Constant Channel Maintenance**

The inverse of drainage density or the constant of channel maintenance as a property of landform was given by Schumm in 1956. The constant of channel maintenance indicates the relative size of landform units in a drainage basin and has a specific genetic connotation<sup>1-8</sup>. It consist the dimensions of length and therefore shows a directly proportional relation with the scale of landform unit. The constant 'C' provides necessary data of the number of square feet of watershed surface needed to sustain one linear foot of stream<sup>1-8,19,33,49</sup>. Constant of channel maintenance is a function of ground permeability. Relatively high constant channel maintenance is seen in alluvial and the piedmont area basin. Channel maintenance for Kadvi basin is found to be 0.31 km<sup>2</sup>. Higher is the value for the constant channel, stronger the lithology control and higher the permeability<sup>8</sup>. The elements that alter the constant of maintenance other than permeability are rock type, relief, vegetation and duration of rainfall.

### **Drainage Intensity**

Drainage intensity illustrated by Faniran<sup>45</sup>, that it is a ratio of stream frequency to the drainage density. This study reflects a low drainage density of 1.42 for Kadvi watershed. Drainage density and drainage intensity are negatively co-related with each other. Higher drainage density indicates low drainage intensity and low drainage density shows higher intensity. Low drainage intensity proves that drainage density and stream frequency have very less effect on the basin surface by the denudational process<sup>45-51</sup>. Low surface runoff is the key characteristic of low drainage density, stream frequency, and drainage intensity, and effect of flood disaster, land sliding, and marsh land is occurring.

### **Infiltration Number**

The product of drainage density (Dd) and drainage frequency (fs) is termed as infiltration number. The moderate infiltration number i.e. 14.53 is shown by Kadvi river basin. When there is higher infiltration number, low infiltration and higher run off is seen, leading to the construction of higher drainage density. This also reveals the impermeable lithology and higher relief in the basin<sup>49</sup>.

### **Relief Ratio**

Schumm<sup>32</sup> has defined the relief ratio concept. According to him, the relief ratio is a ratio of total relief of basin to the basin length of the same basin. The Relief ratio of Kadvi river basin is 0.013, which indicates moderate relief basin with a moderate slope.

### **Absolute Relief (Ra)**

Absolute relief is illustrated as the elevation difference between a given location and sea level. The estimated absolute relief for the full kadvi river is 1027 mt.

### **Relative Relief (Rhp)**

Relative relief is termed as the total relief (H) divided by the perimeter (P) of the watershed. Given by expression  $Rhp = H/P$ . But Melton<sup>47</sup> estimated it by using;  $Rhp = (H*100)/P$ . The relative ratio calculated for Kadvi river is 0.44. Here low relief ratio implies gentle topography and higher relief ratio point's steep slope.



**Dissection index (Dis)**

Dissection index is computed by total basin relief divided by absolute relief with the following formula.

$$\text{Dis} = H / R_a$$

Dis value normally differs between 0 (complete lack of dissection) to 1.0 (vertical cliff at sea level). The measured Dis values for kadvi river basin it is 0.46. It expressed that Kadvi basin combines with the hilly region with a steep slope.

**Gradient Ratio (Rg)**

Gradient ratio is the ratio of total basin relief divided by basin length. It is similar to relief ratio. Sreedevi<sup>50</sup> has illustrates gradient ratio as an indicator of channel slope, which enables assessment of the runoff volume. In the study area, the computed gradient ratio for the kadvi river basin is 0.013.

**Ruggedness Number (Rn)**

According to Strahler<sup>1-8</sup> when the maximum basin relief is multiplied with drainage density the result is the ruggedness number. Based on this the estimated ruggedness number for full kadvi is 1.53.

**Melton Ruggedness Number (MRn)**

According to Melton, the MRn is a slope index that provides a specialized representation of relief ruggedness within the watershed<sup>47</sup>. The estimated MRn for the kadvi river basin is 23.03.

**Conclusion**

The present study of Kadvi river basin - morphometry has attempted by by means of Remote sensing and GIS techniques. This modern techniques offer more accuracy for the investigation of morphometric features of the river basin. Kadvi River is having 1<sup>st</sup> to 7<sup>th</sup> stream orders, but lower order streams mainly control the basin (Table-1). Form factor, elongation ratio, and circularity ratio shows an elongated shape of Kadvi river basin with moderate run off. Stream frequency and drainage density are key parameters of watershed morphometry because they are related to runoff, infiltration, sediments and other hydrological parameters. Coarse drainage density is found in Kadvi river basin which as 3.2 km/km<sup>2</sup>. Herringbone, dendritic, rectangular drainage pattern and radial pattern is shown in this basin. This study is useful for the development of the Kadvi river basin in view of watershed management. Considering the estimated morphometric data of the river basin the irrigation facilities and agricultural processes can be attempted and controlled scientifically.

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