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Morphometric analysis of different irrigation drainage parameters of a Pravara river basin, Maharashtra, India

Shubham R Supekar, Dr. Mohd. Aftab Alam, Tushar Rathod, Dr. Vikram Singh and Akshay V Chavan

Abstract
The described study of the Morphometric analysis based on several drainage parameters, by which the watershed streams have been classified up to fifth order streams of Pravara River Basin, Maharashtra using GIS and Remote Sensing technique. Topographical maps and ASTER DEM data at 30m spatial resolution have been used for the analysis. Stream networks, different linear, areal, and relief aspects of the basin were analyzed using QGIS 3.16 software. The linear aspects of watershed was carried out *i.e.*, Stream order (625), Bifurcation ratio (6.24), Stream length (1873Km) and aerial aspects such as Drainage density (D_d = 0.71), Stream frequency (F_s=0.24), Form factor (F_f = 0.10), Circulatory ratio (R_c = 0.13) and Elongation ratio (R_e=0.36) has been carried out on the basis of soil erosion. The study of the data revealed that the total no of streams were 625 in that 475.00 in first order, 117.00 in second, 30.00 in third, 2.0 in fourth and 1.0 in fifth simultaneously. The low Bifurcation ratio (R_b) value reveals that a lower peak flow would result from the watershed and it can be more risk of flooding. The low Drainage density (D_d) value indicates that the basin has moderately low permeable soil (Black soil) and sparse vegetative cover. The low Circulatory ratio (R_c) value also indicates as the watershed basin is almost elongated in shape, it has a high discharge rate of runoff and poorly permeable soil condition.
As the both low Drainage density (D_d) and Circulatory ratio (R_c) values indicating low permeable sub soil conditions, accompanied with the low Bifurcation ratio (R_b) values and all the low values of Elongation ratio (R_e), Form factor (F_f), and Stream frequency (F_s) indicating a flatter peak of flow for a longer duration thus the basin is not well capable of absorbing water into the soil and less groundwater recharging whereas more risk of flooding. If such floods would be emerged, those could be managed easily from this type of elongated watershed basins than from circular basins by adopting suitable precautionary measures.

Keywords: GIS, areal aspects, relief aspects, Pravara river basin etc.

Introduction
On Earth water and soil are limited natural resources and their wide utilization with increasing population is a major area of interest of most countries. The natural resources management in a country where 70% population is based on agriculture and it also balance the economics of the country (Biswajit Mondal, *et al*., 2016) [3].
To conserve water during drought period is a main goal by government and NGOs and to increase watershed conservation and to this lots of efforts were taken into drainage development and characterizations of a watershed (Ashok S Sangle, *et al*., 2015) [2].
The term ‘Morphometry’ literally means measurement of forms Morphometric analysis of the drainage basin and channel network play a vital role in understanding the hydro-geological behavior of drainage basin. Drainage basins, catchments and sub catchments are the fundamental units for administrative purposes to conserve natural resources.
A watershed is a hydrological unit which generates runoff itself as resulting of precipitation. However the runoff water is depends upon morphology of the watershed morphometric is the measurement and mathematical analysis of the configuration of the earth surface, shape and dimension of land forms (Agarwal, 1998; Rudraiah *et al*, 2008) [1, 12].
In morphometric analysis of a drainage basin and its stream channel arrangement can better understand through the measurement of linear aspects (one dimension) of the drainage networks, areal aspects (two dimension) of the drainage basins and relief aspects (three dimension) of channel networks and contributing ground slopes (Nag and Chakraborty, 2003) [11]. The parameters worked out include bifurcation ratio, stream length, form factor,

circulatory ratio, elongation ratio, drainage density, constant of channel maintenance, and stream frequency.

Developmental planning and sustainable use of land and water resources should be based on scientific evaluation of various static and dynamic properties pertaining to various physical sciences methods, models and modern tools have been used in the past, watershed properties have to be analyzed to serve a limited objective, usually pertaining to a particular scientific discipline. The aim of this study was to be analysis of different irrigation drainage parameters of a pravara river basin watershed and to infer hydrological characterizations of the river basin watershed area.

Material And Methods

Study Area

The area selected for the study is the Pravara River Basin from watershed of Ahmednagar District in Maharashtra State the location is 70 km away from Ahmednagar main. The taluka is situated at 19°34′51″ North Latitude and 74°12′18″ East Longitude with an Elevation above sea level 549 m. The watershed falls under semi critical zone Based on the Thornthwaite system of climatic classification, Ahmednagar (R) is classified under the category of Tropical Dry-sub-humid climate.

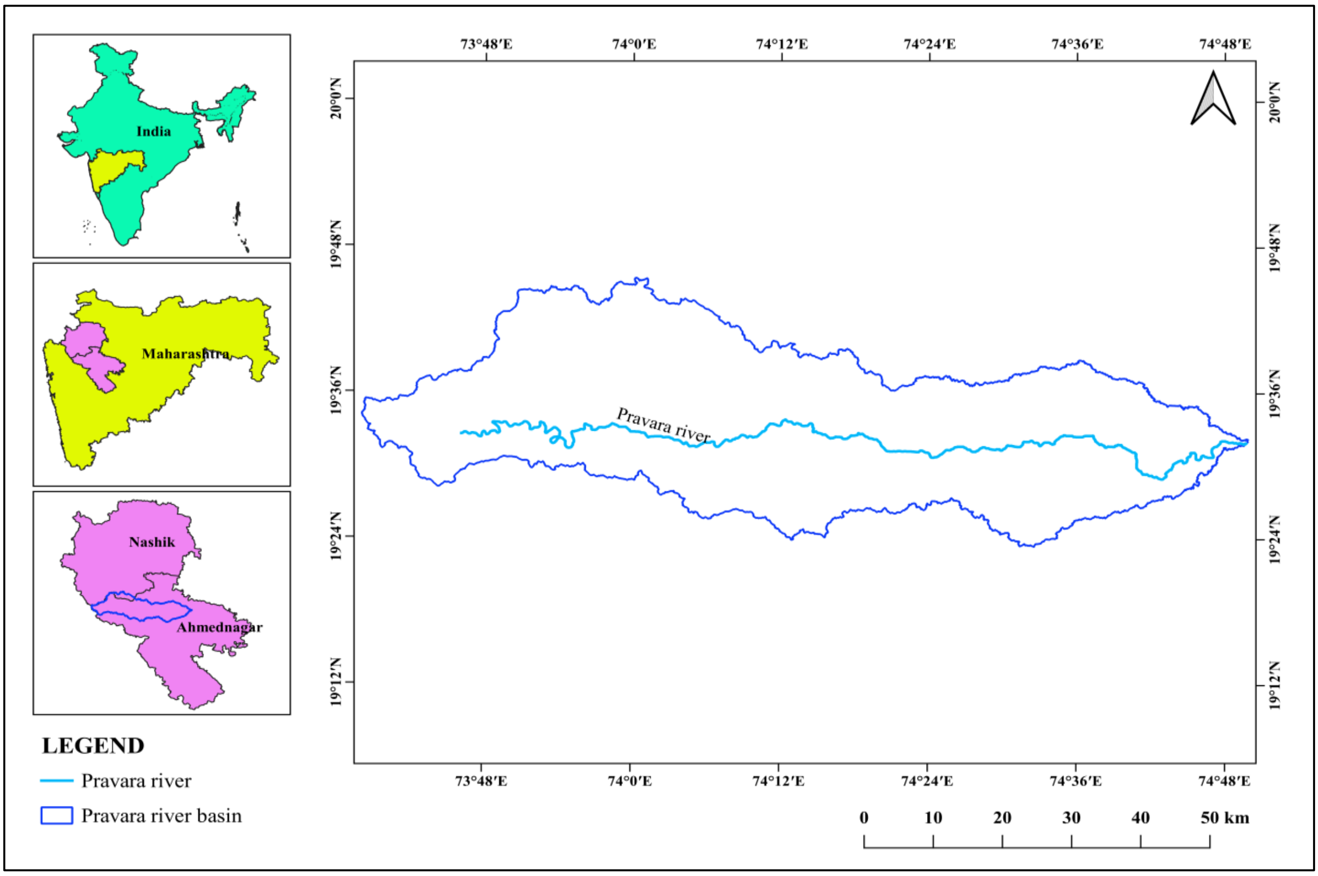

Fig 1: Location map of study Area

The morphometric parameters were computed using the formulae developed by different researchers as presented in Table:

Table 1: Methods of calculating morphometric parameters

Morphometric Parameters		Formula	Reference
Linear	Stream order	Hierarchical rank	Strahler (1964) [4]
	Stream length (L_u)	Length of the stream	Horton (1945) [7]
	Mean stream length (L_{sm})	$L_{sm} = L_u / N_u$ Where, L_u= Total stream length of order 'u' N_u= Total number of stream segments of order 'u'	Strahler (1964) [4]
	Stream length ratio (R_l)	$R_l = L_u / L_{u-1}$ Where, L_u= Total stream length of order 'u' L_{u-1}= Total stream length of its next lower order	Horton (1945) [7]
	Bifurcation ratio (R_b)	$R_b = N_u / N_{u+1}$ Where, N_u= Total no. of stream segments of order 'u' N_{u+1}= Number of segments of the next higher order	Schumm (1956) [13]
Relief	Relief ratio (R_h)	$R_h = H / L_b$ Where, H= Relative relief of the basin, km	Schumm (1956) [13]

		L_b= Basin length, km	
	Basin relief (B_h)	Vertical distance between the lowest and highest points of Watershed	Schumm (1956) [13]
	Ruggedness number (R_n)	$R_n = B_h \times D_d$ Where, B_h =Basin relief D_d=Drainage density	Schumm (1956) [13]
Areal	Drainage density (D_d)	$D_d = L_u / A$ Where, L_u= Total stream length of all orders A= Area of the basin, km^2	Horton (1945) [7]
	Stream frequency (F_s)	$F_s = N_u / A$ Where, N_u= Total no. of streams of all orders A= Area of the basin, km^2	Horton (1945) [7]
	Texture ratio (R_T)	$R_T = N_u / P$ Where, N_u= Total no. of streams of all orders P= Perimeter of the basin, km	Horton (1945) [7]
	Form factor (F_f)	$F_f = A / L_b^2$ Where, A= Area of the basin, km^2 L_b^2= Square of basin length	Schumm (1956) [13]
	Circulatory ratio (R_c)	$R_c = 4 \times \pi \times A / P^2$ Where, A= Area of the basin, km^2 P= Square of the perimeter, km	Miller (1953) [10]
	Elongation ratio (R_e)	$R_e = (4 \times A / \pi)^{0.5} / L_b$ Where, A= Area of the basin, km^2 L_b= Basin length, km	Schumm (1956) [13]
	Length of the overland flow (L_o)	$L_o = 1 / 2D_d$	Horton (1945) [7]
	Compactness constant (C_c)	$C_c = 0.2821 \times P / A^{0.5}$ Where, A= Area of the basin, km^2 P= Basin perimeter, km	Horton (1945) [7]

Morphometric Analysis of Watershed

The morphometric analysis is refers to quantitative evaluation of hydrological unit. This is the most common approach which is used for basin analysis, morphometric associated with interpretation and analysis of fluvially originated landforms.

Stream order: Estimated runoff contribution from different order streams varies according to watershed characteristics.

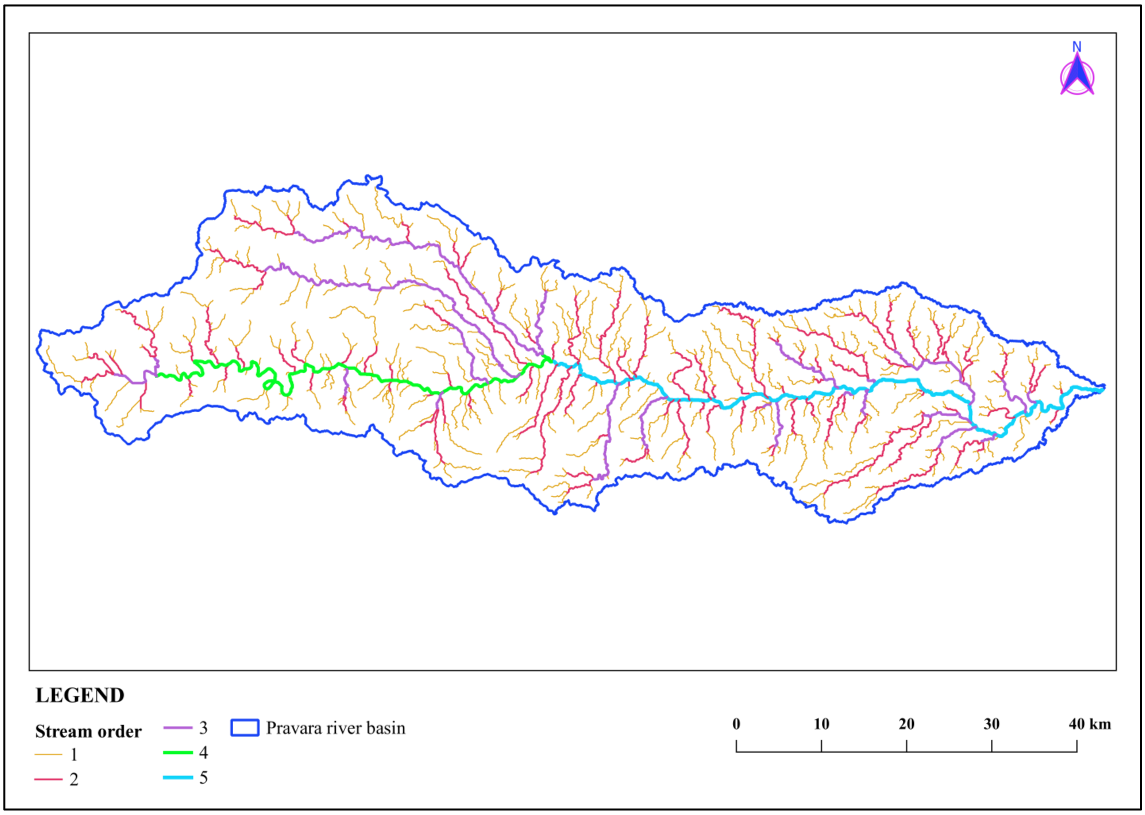

Fig 2: Map of Stream Orders

Streams Number (N_u): Number of streams also described as total counts of stream segments of different order separately and is inversely proportional to the stream order Stream number is denoted by N_u.

Total stream length (L_u): Total stream length is calculated as measuring the length of all ordered perennial streams within the catchment area of the watershed and is denoted by L_u.

Mean stream length ($L^{\bar{u}}$): Mean stream length is the ratio of total stream length of particular order to the total number of same ordered stream and is denoted by $L^{\bar{u}}$.

Watershed perimeter (P_r): Watershed perimeter is the total length of outer boundary of the watershed .

Maximum length of the watershed (L_b): It is the distance between the remotest point of the watershed to the outlet.

Stream Length Ratio (R_l): The stream length ratio *(R_l)* is the ratio of the mean length of the stream of a given order ($L^{\bar{u}}$) to the mean length of the streams of the next smaller order *($L^{\bar{u}}$ $_{-1}$*).

$$R_l = \frac{L^{\bar{u}}}{L^{\bar{u}} - 1} \qquad \dots (3.1)$$

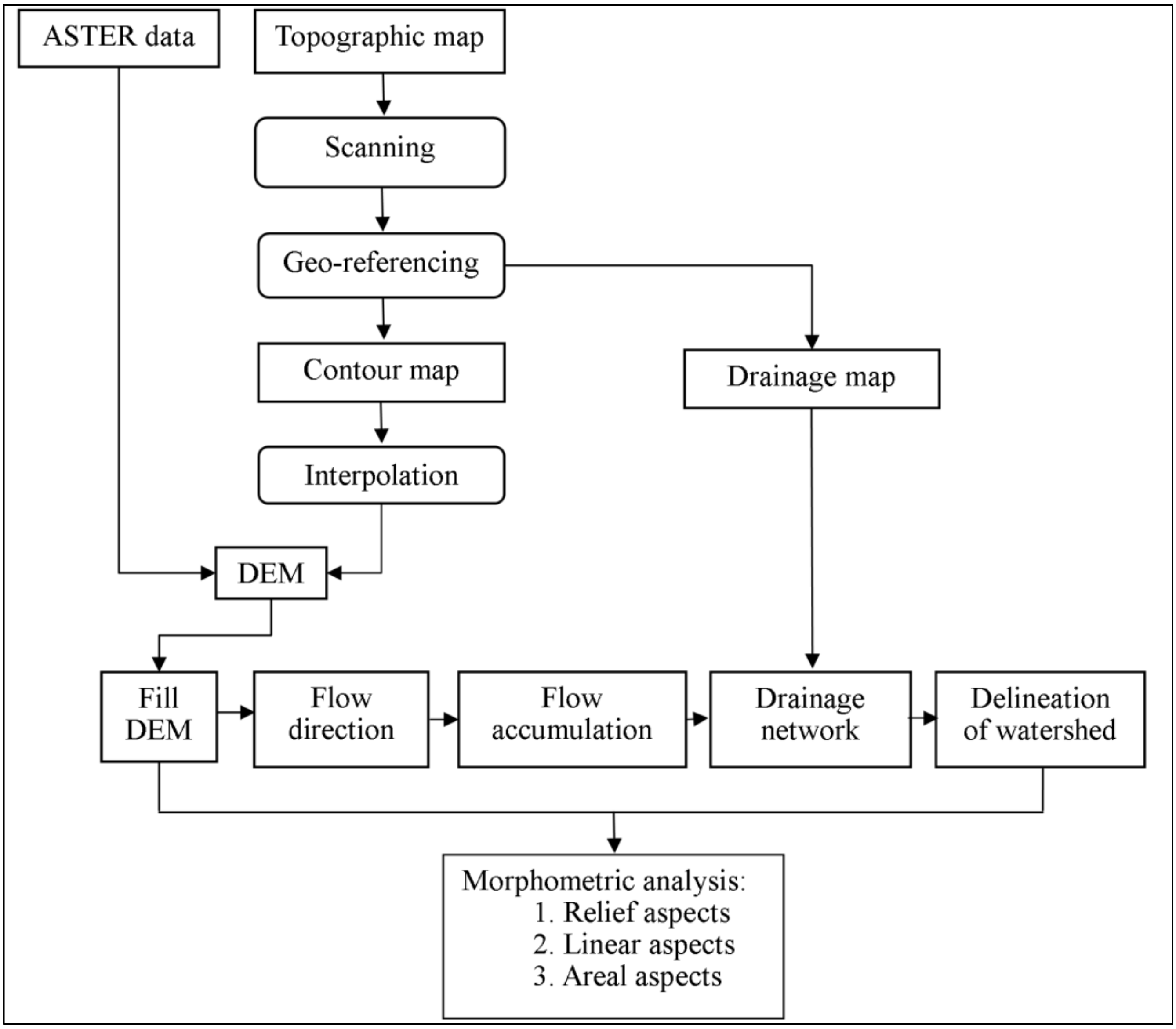

Fig 3: Methodology used in this study

Bifurcation Ratio (R_b): The bifurcation ratio is the ratio of the number of streams in lower order *(N_u)* to the next order *(N_{u+1})*. It is seen that the bifurcation ratio is lower in alluvial region as compare to the Himalayan zone.

$$R_b = \frac{N_u}{N_{u+1}} \qquad \dots (3.2)$$

Form factor (F_f): Form factor is defined as the ratio of basin area (A) to square of the maximum length of the basin (L_b). The smaller value of form factor, more elongated will be the watershed The watershed with high form factors have high peak flows of shorter duration (Horton, 1932) [6].

$$R_f = \frac{A}{L_b 2} \qquad \dots (3.3)$$

Elongation Ratio (R_e): It is calculated as the ratio of equal diameter of the circle which have same area as that of the watershed to the maximum length of the basin Elongation ratio is denoted by *(R_e)*.

$$R_e = \frac{2}{Lb}\sqrt{\frac{A}{\pi}} \qquad \dots (3.4)$$

Circulatory Ratio (R_c): The circulatory ratio is influenced by the length and frequency of stream. The circularity ratio is a similar measure as elongation ratio, originally defined by (Miller, 1953) [10], as the ratio of the area of the basin to the area of the circle having equivalent circumference as the basin perimeter and it is denoted by the (R_c).

$$R_c = \frac{12.57A}{{P_r}^2} \quad \ldots (3.5)$$

Drainage Density (D_d): Drainage density is the linear parameter of the morphometric analysis and is sensitive indicator for erosion calculation by the stream and effect of topographic characteristics to the outlet. It is defined as the ratio of the total length of the streams in all ordered to the area of watershed or basin .It is provides the link between the form attributes of the basin and the processes operating along stream course. The unit of the drainage density is km/km^2, which is indicate the proximity of channel spacing, thus provide an idea about quantity measures of the watershed (Strahler 1964) [4] Drainage density is denoted by *(D_d)*.

$$D_d = \frac{L_u}{A} \quad \ldots (3.6)$$

Stream Frequency (F_s): Drainage frequency calculated as the number of streams per unit area of the watershed. It mainly depends upon the lithology of the catchment and indicate the texture of the drainage network.

$$F_s = \frac{N_u}{A} \quad \ldots (3.7)$$

Length of overland flow (L_o): The overland flow and surface are quite different; the overland flow refers to that flow of precipitated water, which moves over the land surface leading to the stream channels, while the channel flow reaching to the outlet of watershed is referred as surface runoff. The overland flow is significant in the smaller watershed, whereas runoff is in bigger watersheds. The length and depth of overland flow are small and found in laminar condition.

Horton defines the length of overland flow as the length of flow path, projected on the horizontal plan of non-channel flow, from a point on drainage divide to the adjacent stream channel. It is one of the most important independent variable, affects both the hydrologic and physiographic development of watershed.

The length of overland flow is calculated as one-half of the reciprocal of the drainage density i.e.

$$L_o = \frac{1}{2} D_d \quad \ldots (3.8)$$

Texture Ratio (T): It is the ratio of the total number of first order stream segment to the perimeter of the watershed.

$$T = \frac{N_1}{P_r} \quad \ldots (3.9)$$

Maximum watershed Relief (H): Basin relief is the maximum elevation difference between highest and lowest point of the watershed.

Compactness Coefficient (C_c): Compactness coefficient is the shape parameter of a watershed and is the ratio of perimeter of watershed to circumference of equivalent circular area of the watershed. The *(C_c)* is independent of size of watershed and dependent only on the slope (Horton, 1945) [7] .

$$C_c = 0.2821 \frac{P^{0.5}}{A} \quad \ldots (3.10)$$

Result and Discussion

In the present study, morphometric analysis of the parameters, such as stream order, stream length, bifurcation ratio, drainage density, stream frequency, circulatory ratio, form factor, elongation ratio, texture ratio, compactness coefficient, length of over land flow and area, perimeter, elevation difference, basin length, total relief, number of stream and total stream length of the watershed has been carried out using the mathematical equation and their results are summarized in Table 2.

Table 2: Results of morphometric analysis for Pravara River Basin watershed.

Parameters		Pravara river basin
Area (km^2)		2639.927
Perimeter (km)		513.556
Number of Streams	I	475
	II	117
	III	30
	IV	2
	V	1
Stream Length in km	I	986
	II	507
	III	217
	IV	74
	V	89
Basin Length (Km)		161.113
Total Relief (m)		1123
Number of Stream		625
Total Stream Length (km)		1873
Mean Bifurcation Ratio		6.24
Drainage Density		0.71
Stream Frequency		0.24
Circulatory Ratio		0.13
Form Factor		0.10
Elongation Ratio		0.36

Texture Ratio	1.22
Compactness Coefficient	2.84
Relief Ratio	6.97
Length of overland flow	0.35

Stream Order
The term "stream orders" is the primary step of morphometric analysis. Which is based on the delineated streams and their branching proposed by (Strahler, 1964) [4]. Bifurcation ratio is depending on stream order as well as number of streams. Total number of streams and stream length of all order is 625 and 1873 km respectively.

Stream Length
The values of length (Lu) and total stream length are shown in Table 2. According to Horton's second law (1945) the stream length characteristics of the sub-basins validates the "laws of stream length". Which states that the average length of streams of each of the different orders in a drainage basin tends closely to approximate a direct geometric ratio (Horton, 1945) [7].

Bifurcation Ratio
The bifurcation ratio is of the catchment is reflect the geological as well as tectonic characteristics of the watershed (Gajbhiye *et al.*, 2013) [5]. Lower value of Rb indicates the partially disturbed watershed without any distortion in drainage pattern. High value of Rb indicates the severe over land flow and low recharge for the sub-watershed. In this study the value of mean bifurcation ratio is 6.24.

Drainage Density
Drainage density depends upon both climate as well as physical characteristics of the drainage basins. It is a basic length scale in the landscape, is recognized to be the transition point between scales where unstable channel-forming processes yield to stable diffusive processes (Tarboton *et al.*, 1992) [15]. Drainage density is effected by various factors, among which resistance to erosion of rocks, infiltration capacity of the land and climatic conditions rank high. According to (Langbein, 1947) [9], the significance of drainage density as a factor which determine the time of travel by water within the basin and suggested that it varies between 0.55 to 2.89km/km^2 for humid region. In this study drainage density is 0.71.

Stream Frequency
Drainage frequency or channel frequency is directly related to stream population per unit area of the watershed (Horton, 1932) [6]. It is indicate the close correlation with drainage density value of the sub watershed. Higher value of drainage frequency shows the high runoff. In this study watershed producing more runoff.

Circulatory Ratio
Circulatory ratio (Rc) influenced by the length and frequency of the stream, geological structures, land use land cover (LULC), climatic variability, relief and slope of the watershed. In this present study circulatory ratio is 0.13.

Form Factor
Most of the researcher are suggested that the value of form factor is less than 0.7854 for perfectly circular basin (Gajbhiye *et al.*, 2013) [5]. In watershed, the smaller value of the form factor show maximum elongation of the basin. The high value of farm factor shows high peak in short duration and vice versa. In this study found that the value of form factor is 0.10.

Elongation Ratio
Generally the range of elongation ratio lies between 0.6 to 1.0 which has follow high to low relief respectively. However value categorized into three segments greater than 0.9, lie between 0.9 to 0.8 and less than 0.8 following circular, oval and elongated respectively. In this watershed elongation ratio is 0.36, where as the feature of watershed lies elongated in nature. In order to archive, sub-watersheds to be elongated and steep slope with high relief (Chopra *et al*., 2005; Gajbhiye *et al*., 2013) [4, 5].

Texture Ratio
Texture ratio is depends upon properties of lithology of the basin, infiltration of the soil and relief aspect of the terrain (Vijith and Satheesh, 2006) [16]. In the present study the texture ratio of the watershed is 1.22 and categorized as fine gravel soil. The lower values of texture ratio indicate that the basin is plain with lower degree of slopes.

Compactness Coefficient
A circular basin is the most hazardous from a drainage stand point because it will yield the shortest time of concentration before peak flow occurs in the basin (Javed *et al*., 2009) [8]. The value of compactness coefficient was found 2.84 in watershed.

Relief Ratio
The values of relief ratio is 0.01 It is noticed that the low values of R_h indicate less steepness of the basin (Vittala *et al.*, 2004) [17] and is an indicator of intensity of erosion process operating on the slopes of the watershed.

Length of overland flow
The length of overland flow (Lg) approximately equals half the reciprocal of the drainage density (Horton, 1945) [7]. This factor relates inversely to the average slope of the channel and is quite synonymous with the length of sheet flow. The value of length of overland flow in watershed is 0.35.
The morphometric analysis was carried out for Pravara River Basin watershed using the QGIS 3.16 technique Landscape morphology is a function of drainage, climate, and structure of a particular basin region.
The conventional methods of morphometric analysis are time-consuming and error prone, while use of QGIS 3.16 technique allows for more reliable and accurate estimation of similar parameters of watershed.
The morphometric analysis of watershed shows their relative characteristics with respect to hydrologic response. The morphometric analysis of watershed exhibits the dendritic drainage pattern and the variation in stream ratio might be due to changes in slope as well as topographic features of the study region.

Following conclusion were drawn from the study
1. The low R_c value also indicates that as the basin is almost elongated in shape, it has a high discharge rate of runoff

and poorly permeable soil condition.
2. The low R_e and low R_f values confirmed that the basin is elongated and thus the basin has a flatter peak with a longer duration.
3. As the both low D_d and R_c values indicating low permeable sub soil conditions, accompanied with the low R_b values and all the low values of Re, R_f, and F_s indicating a flater peak of flow for a longer duration, the basin is not well capable of absorbing water into the soil and less groundwater recharging while the more risk of flooding.
4. If such floods will be emerged, those could be managed easily from this type of elongated basins than from circular basins by adopting suitable precautionary measures and surplus water can be conserved by creating obstruction in watershed and can be utilized for irrigation.

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