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Morphometric analysis using remote Sensing and GIS techniques of Pingalgarh watershed VNMKV, Parbhani, India

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Abstract
The study of morphometric parameters plays a vital role in understanding and managing watersheds, making it a an essential component of hydrological surveys. It is most significant for soil and water conservation recharge structure development, planning and management. A morphometric analysis of Pingalgarh watershed of VNMKV has been carried out using geoprocessing techniques. This technique is found suitable for the extraction of Pingalgarh watershed and its drainage networks. The analysis of Morphometric parameters *viz*; form factor, elongation ratio, circulatory ratio, Relief ratio, drainage density, stream frequency, bifurcation ratio, ruggedness number, stream order, stream length, etc., are calculated with the help of Arc GIS 10.8 software and Digital elevation model. The watershed area is 30.43 Sq. Km covered and drainage shows dendritic and sub-dendritic drainage pattern with stream orders of sub-basins were found ranging from I to V orders. There are one 5th order, three 4th order, twelve 3rd order, forty sixth 2nd order and one hundred ninety-nine 1st order streams are found in study area. The total stream length of study area is 119.983 km. The drainage density value being as 3.943 km/km^2. Mean bifurcation ratio value is 3.790 which shows that mean of bifurcation ratio for entire basin is under range of 3.0 to 5.0. The values of basin fall under the range of bifurcation ratio in which the geologic structures do not distort the drainage pattern. The study is advantageous in water and land resource progress plan with the help of remote sensing and GIS techniques.

Keywords: Watershed management, morphometric analysis, bifurcation ratio, water and land resource, drainage density

Introduction
The dimensions of study area lies amongst 19.25080 N latitude and 76.79520E longitude in Parbhani district of Marathwada region of Maharashtra state. The area of Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani is approximately about 3043 Ha. The catchment area falls under semi-arid tropics. The slope of the land area varies from 0.5 percent to 1.5 percent, major area is under agriculture. The average annual rainfall of the study area is estimated as 938.7 mm. About 94% of the total rainfall is received during the months from June to September. Pingalgarh watershed flows across VNMKV, Parbhani main campus and it is a part of Godavari- Purna basin.

The prominent stream namely Pingalgarh watershed flows about 8 km as a main drain line across university area. The catchment area falls under assured rainfall zone of Marathwada region. The soils in the region are deep black, medium black, coarse and shallow. The predominant soil in the region is Vertisol (Black cotton soil). Under rainfed agriculture, major kharif crops of the region are sorghum, cotton, pigeon pea, green gram, black gram, pearl millet and soybean, whereas major rabi crops are rabi sorghum, safflower, chickpea and sunflower.

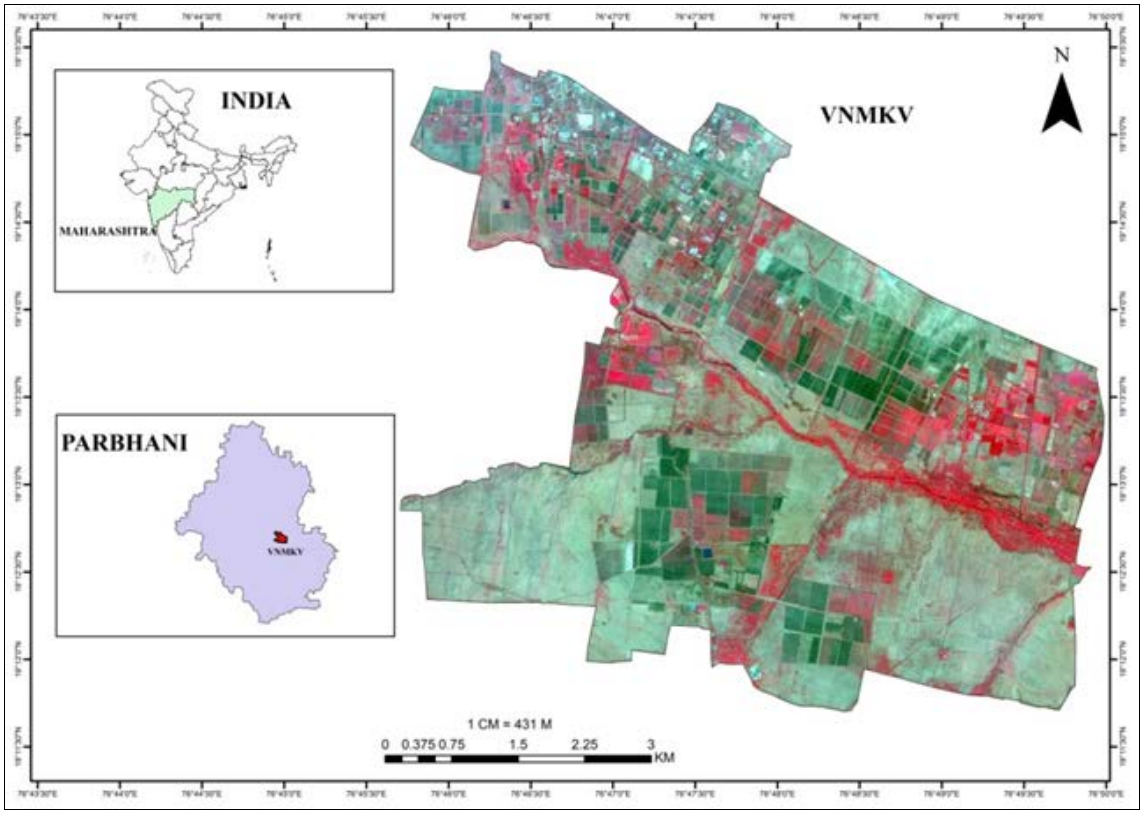

Fig 1: Location map of Pingalgarh watershed VNMKV, Parbhani

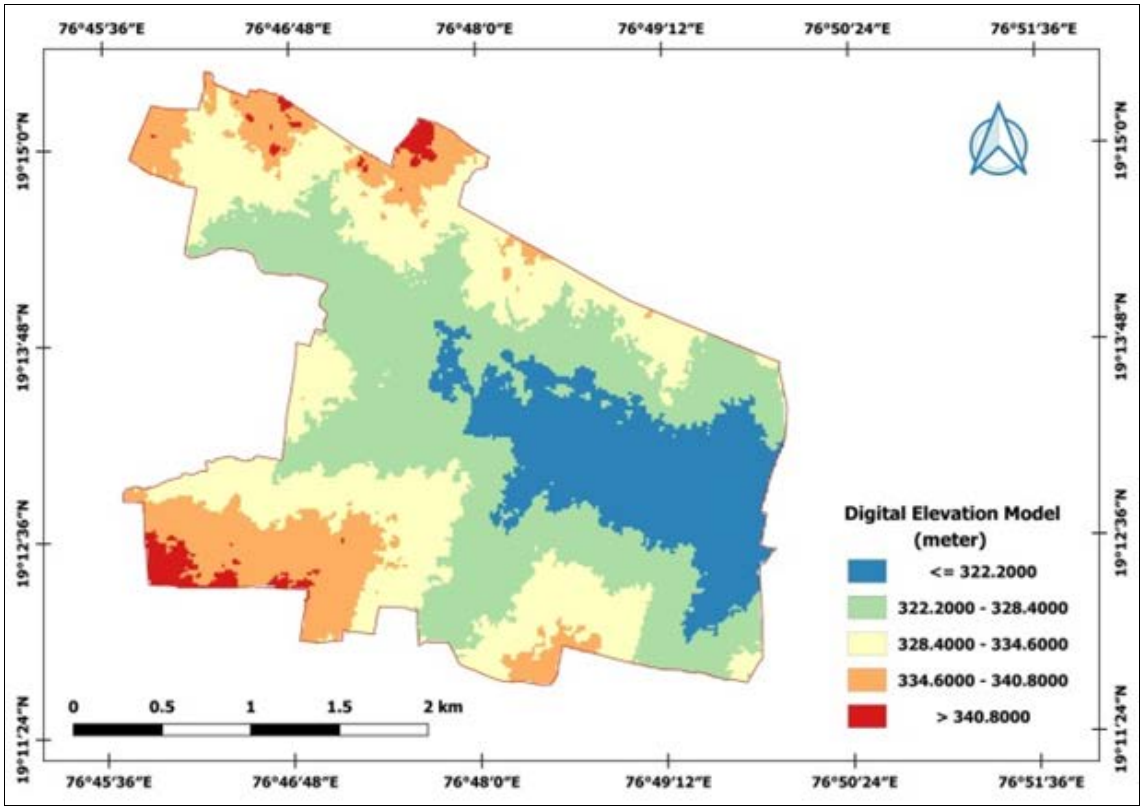

Fig 2: Digital Elevation Model of Pingalgarh Watershed.

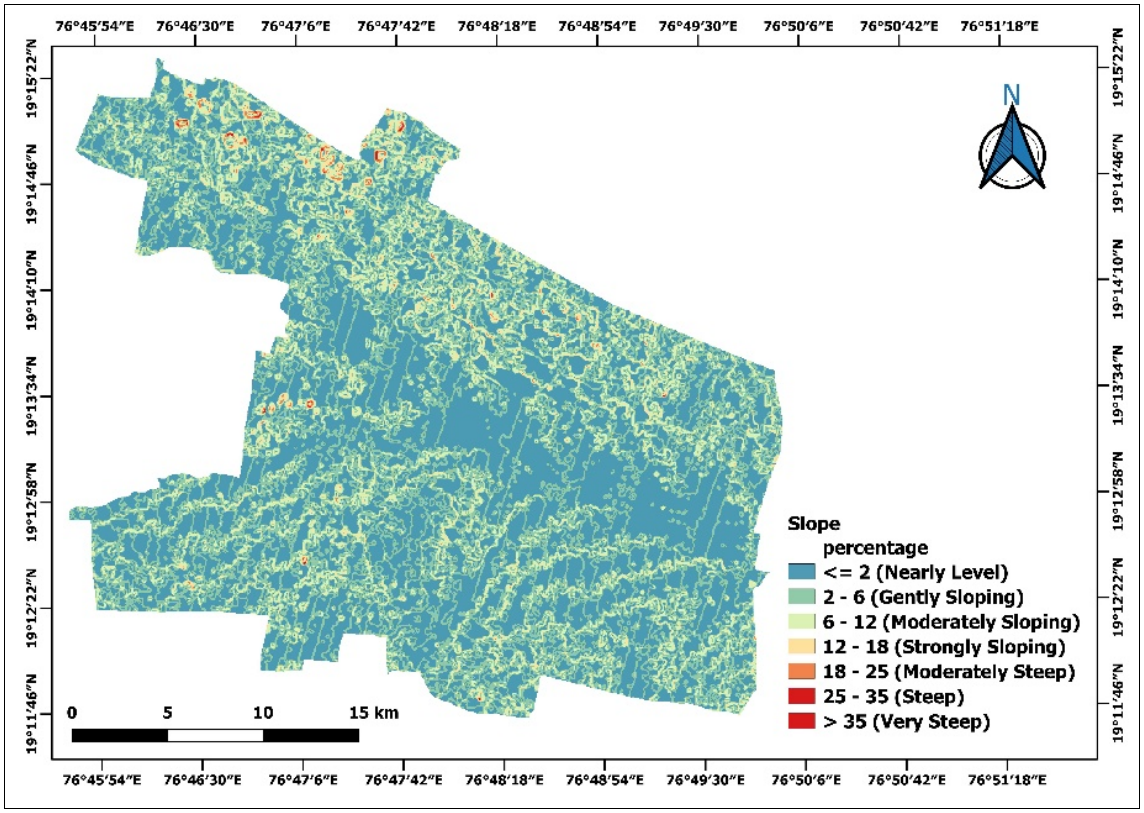

Fig 3: Slope pattern of Pingalgarh Watershed (Study area)

Materials and Methods

Extraction of data and analysis of morphometric variables of the watershed are structured by the combined use of the Cartosat-1 DEM with spatial resolution 10 m and Resourcesat-2A (IRS-R2) image with spatial resolution 5.8 m. acquired on 2022. The boundary of the Pingalgarh watershed has been delineated using remote sensing and GIS. The DEM and Resourcesat-2A with a resolution of 5.8 m, purchased from the NRSC, Hyderabad. The geo-reference of the imageries were done in QGIS environment. In this study, DEM are used for the analysis of relief features in the QGIS hydrology tool. After filling the DEM, the flow direction was computed for every cell. Then flow accumulation was considered to generate the drainage network of the watershed. The watershed has been divided into the cells and coordinates of the central points of the cells were rectified in QGIS environment. Cell-wise average slope and dissection index were also calculated. For evaluating the watershed hydro-geomorphic characteristics, the selected parameters of the linear, areal and relief aspects have been extracted in QGIS considering the formulae propounded by the geomorphologists and hydrologists (Table 2).

Data Collection and Software Used

The distinct information and data required for the present study were procured from different sources, which were then imported to GIS environment.

A brief review of data collection and GIS software is given in ensuing section.

Table 1: Data collection for the study

Data	Description	Source
Meteorological Data	Rainfall	Meteorological observatory, VNMKV, Parbhani
Remote sensing data	DEM / Satellite Images	NRSC, Hyderabad
Soil data	Soil texture	Soil sample collection, VNMKV, Parbhani

Table 2: Linear, Areal and Relief aspects calculated for morphometric analysis

Sr. No.	Morphometric Parameters	Formula	Reference
Linear Aspect			
1.	Perimeter (P)	Length of the drainage basin boundary	----
2.	Basin length (Lb.)	Maximum length of the basin measured parallel to the main drainage line	Strahler (1964) [12]
3.	Stream length (Lu)	Length of the Major stream	Horton (1945) [5]
4.	Mean stream length (Lsm)	Lsm = Lu / Nu, Lu = Total stream length of order ‘u’ Nu = Total no. of stream segments of order ‘u’	Strahler (1964) [12]
5.	Bifurcation ratio (Rb)	Rb = Nu / Nu + 1, Nu = Total no. of stream segments of order ‘u’ Nu + 1 = Number of segments of the next higher order	Schumm (1956) [8]
6.	Mean bifurcation ratio (Rbm)	Rbm = Average of bifurcation ratios of all orders	Strahler (1957) [11]
7.	Stream length ratio (Rl)	Rl = Lu / Lu – 1, Lu = The total stream length of the order ‘u’	Horton (1945) [5]

		Lu – 1 = The total stream length of its next lower order	
Arial Aspects			
8.	Total Area (A)	Total area of river basin	---
9.	Drainage density (Dd)	Dd = ∑Lu / A	Horton (1932) [6]
10.	Stream frequency (Fs)	Fs = ∑Nu / A	Horton (1932) [6]
11.	Form factor (Rf)	Rf = A / Lb²	Horton (1932) [6]
12.	Circularity ratio (Rc)	Rc = 4 A / P²	Miller (1953) [7]
13.	Drainage texture (T)	T= Dd × Fs	Horton (1945) [5]
14.	Elongation ratio (Re)	Re = 1.128√A / Lb	Schumm (1956) [8]
15.	Length of overland flow (Lg)	Lg = 1/2Dd	Hoerton 1945 [5]
Relief Aspects			
16.	Basin Relief (R)	R = H− h, H is maximum elevation and h is minimum elevation within the basin.	Schumm (1956) [8]
17.	Dissection Index (DI)	DI = R/Ra	Singh S (1994) [9]
18.	Relief Ratio (Rr)	Rr = R/Lb	Scumm (1956)
19.	Ruggedness number (Rn)	Rn = R × Dd R is the basin relief and Dd is the drainage density	Strahler (1958) [13]

3. Results and Discussion

The results of morpgometric analysis of pingalgarh watershed VNMKV, Parbhani.

Linear Aspects of Pingalgarh watershed

In this present study, the linear aspects of Pingalgarh watershed consists of parameters like perimeter, stream order, stream number, stream length, stream length ratio and bifurcation ratio.

Perimeter (P): The Perimeter of Pingalgarh watershed is 32.63 km.

Basin Length (Lb.): Lb measures geometrical size and shape of a drainage basin. Pingalgarh watershed has a Lb of 8.29 km Length of the Main Stream

Length of the Main Stream: This in general denoted by length of the main stream. In the digitization procedure, the main channel length was digitized using ArcGIS-10.8 software. The analysis showed that the length of the main stream is 8.29 km.

Stream Order (Nu): The first step towards drainage basin analysis is the designation of stream order which shows the relative and hierarchical relationship between stream segments, their connectivity and the discharge having contributions of the watershed (Figure 3). In the overall drainage of the basin area pattern of drainage comprises dendritic, parallel and trellis patterns since are constituted of network of various tributaries and its master stream which flows along the general slope direction which in turn are well adhered to the respective geological structures.

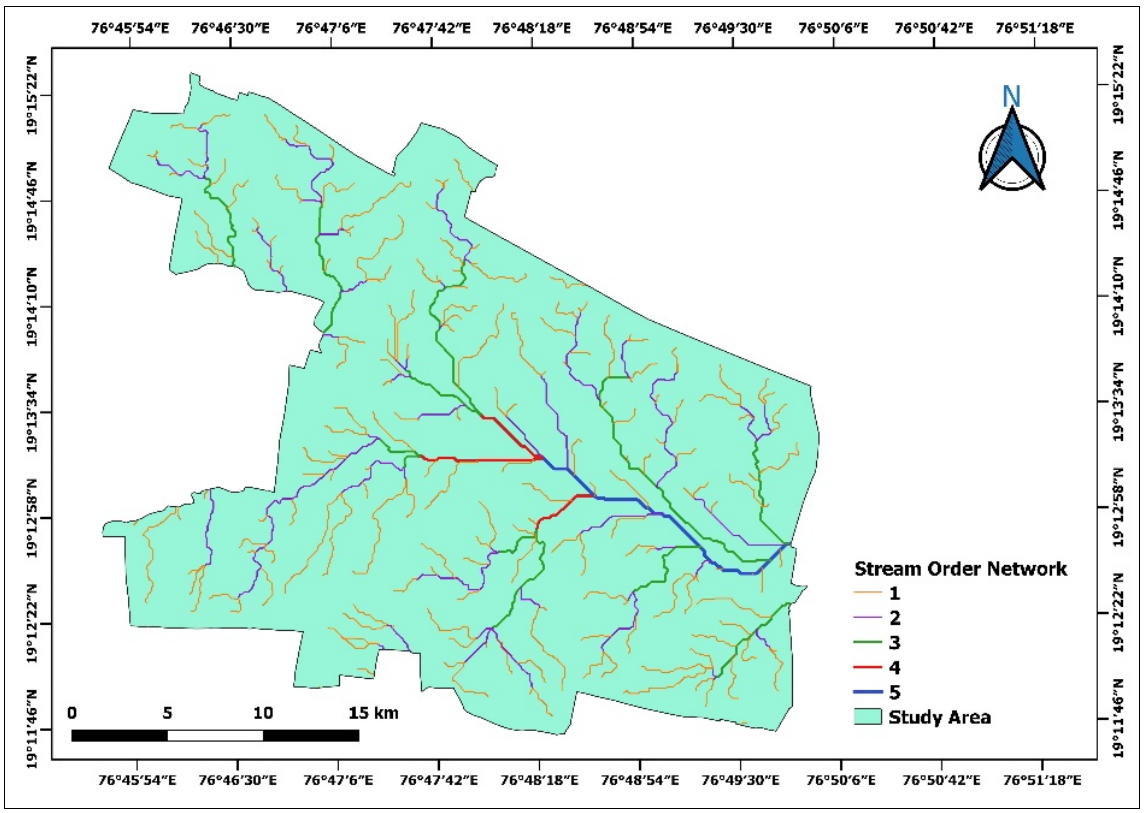

Fig 4: Stream Order of Pingalgarh watershed.

Stream Number (u)

Horton stated that the numbers of stream segments of each order eventually form an inverse geometric sequence with the order number. The total number of streams in the study area is 658 as

mentioned above.

Stream Length (Lu)
The stream network of Pingalgarh watershed was previously categorized into several orders, which were then computed using "Measure" tool of Arc GIS software using DEM as primary data. The stream length according to the law proposed by Horton2 has been computed. The total length of streams (Lt) in Pingalgarh watershed is 181.52 km.

Bifurcation Ratio (Rb)
The bifurcation ratio can be defined as a ratio of the number of stream segments of given order to the number of segments of next higher order. Bifurcation ratio is a good index of relief and dissection. Values of Rb typically range from the theoretical minimum of 2.0 to 5.0. For the study area mean bifurcation ratio is 3.79 indicates that the geologic structures did not distorted or disturbed the drainage patteren.

Areal Aspects of Pingalgarh watershed

The areal aspects generally include various parameters like area, drainage density, drainage texture, stream frequency, form factor, circularity ratio, etc. It is found that size of the basin is inversely related to maximum flood discharge per unit area.

Area (A): The Area of Pingalgarh watershed is 30.43 km^2 i.e 3043 Ha.

Drainage Density (Dd)
The drainage density has been found to be an important indicator of the linear scale of landform element in stream which is topographically eroded and is defined as a ratio of the total length of streams of all orders to its drainage area. The value of drainage density (Dd) is 3.94. The low drainage density is often found to be favored by highly permeable subsoil region bearing dense vegetation cover whose relief is low, whereas high drainage density always favored in regions having weak or impermeable sub-surface materials, sparse vegetation and high mountain relief (Figure 4).

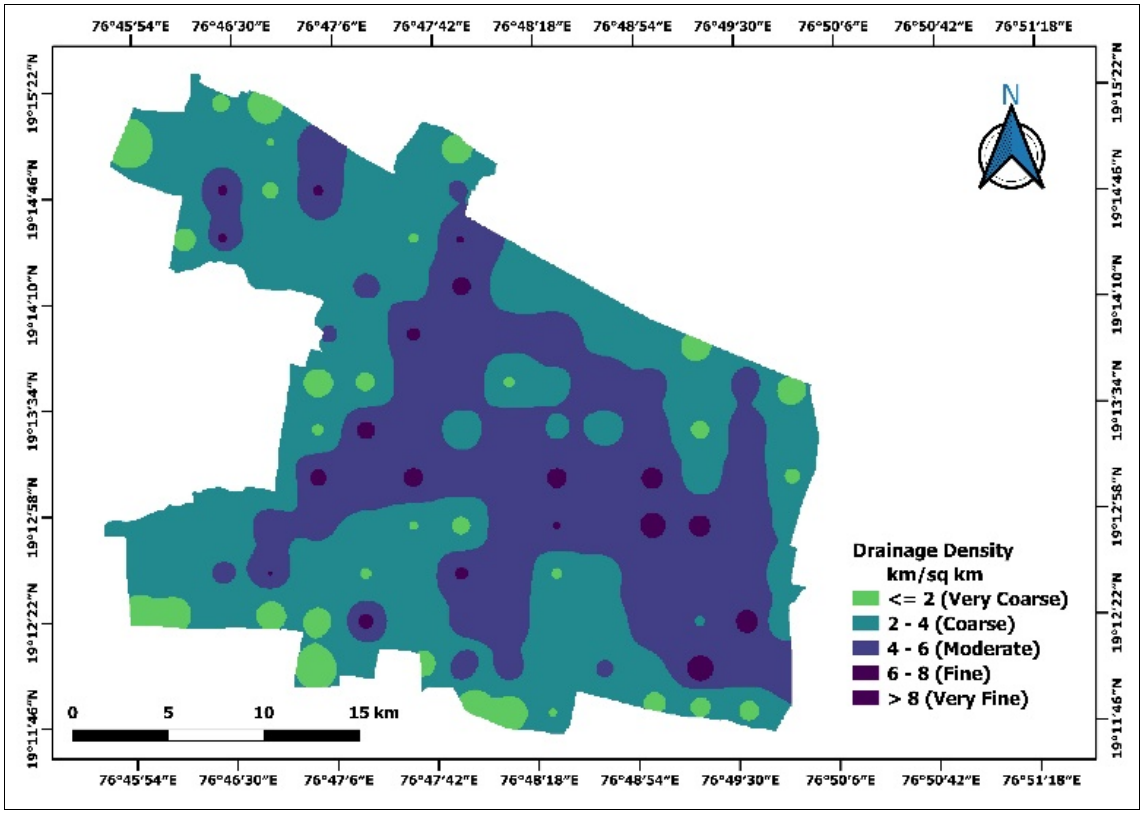

Fig 5: Drainage density of Pingalgarh watershed

Drainage Texture (T): Drainage texture has been categorized as:

1. Less than 2 shows very coarse,
2. Value between 2 and 4 shows coarse,
3. Value between 4 and 6 shows moderate,
4. Value between 6 and 8 shows fine and
5. Rest greater than 8 shows very fine drainage texture.

In the present study the drainage texture value of Pingalgarh watershed stands at 7.998, it indicates that the pattern of texture of Pingalgarh watershed is fine drainage texture.

Stream Frequency (Fs)
The value of stream frequency of Pingalgarh watershed found to be 8.57. Thus, the stream frequency falls under moderate frequency class in the study area (Fig. 5). The stream frequency found in the study area shows a positive correlation with its calculated drainage density, indicating an increase in the stream population with the increase in drainage density.

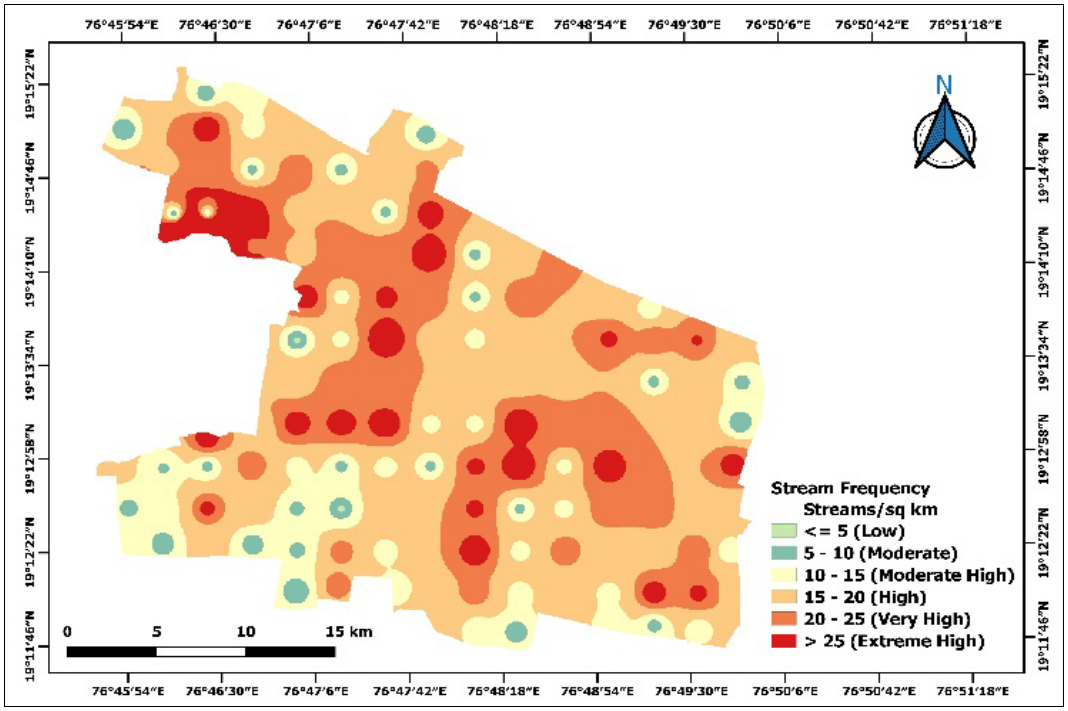

Fig 6: Stream frequency of Pingalgarh watershed

Form Factor (Rf)

The value of form factor of Pingalgarh watershed is 0.44 indicating the moderate form factors have moderate peak flows of moderate duration.

Length of Overland Flow (Lg)

In this study, the computed value of length of overland flow is 0.127 which shows low surface runoff of the study area. It approximate equals to half of reciprocal of drainage density.

Relief Aspects of Pingalgarh watershed

Basin relief (R): The Basin relief (R) of Pingalgarh watershed basin is 34. This indicates that low runoff and high infiltration conditions are dictated by a smaller basin relief

Dissection Index (DI)

Dissection Index implies degree of dissection or vertical erosion. It explains the development of landscape in any physiographic region. The value of 'DI' varies between '0' (shows the complete absence of vertical erosion and prevalence of flat surface) and '1' (vertical cliffs/escarp- ment on land or at seashore). Higher 'DI' value implies larger terrain's undulation and hence instability. Higher 'DI' value results in enhanced erosion leading to large amounts of sediment debris. 'DI' value of the study area is 0.62, which indicates the basin is a moderately dissected (Fig. 7).

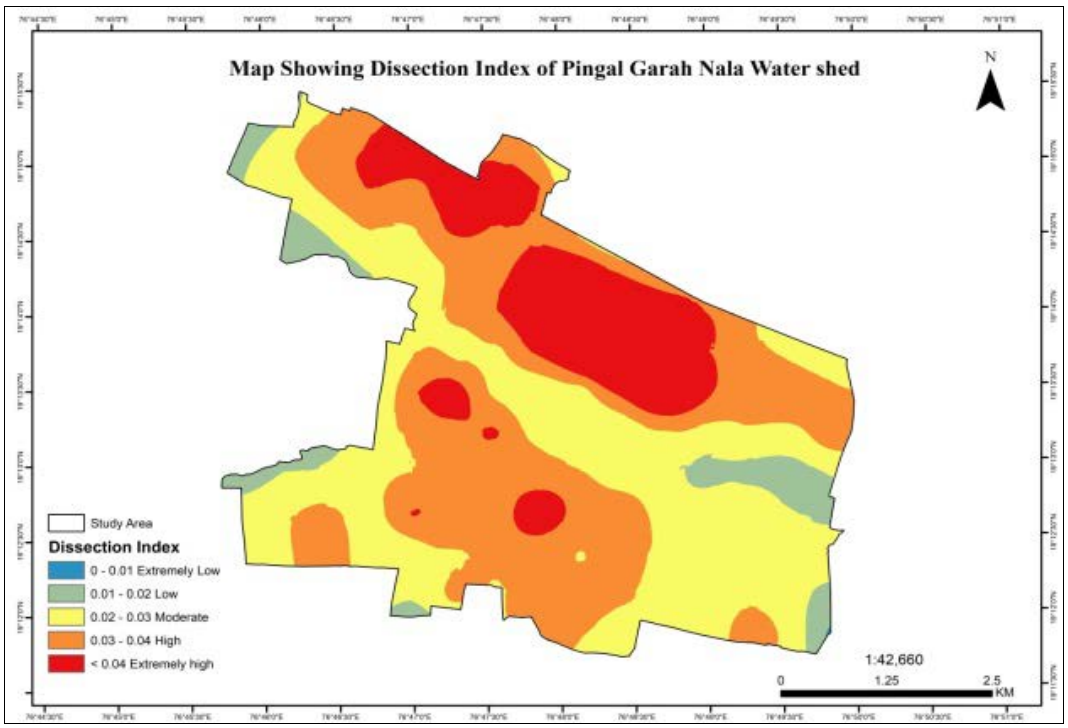

Fig 7: Dissection Index of Pingalgarh watershed

Relief Ratio (Rr)

The Relief Ratio (Rr) of Pingalgarh watershed is 0.004 as shown in Table 4. Pingalgarh watershed has the lowest Rr value is 0.004 indicating with gentle slope and low relief.

Ruggedness Number (Rn)

The Ruggedness Number (Rn) of Pingalgarh watershed is 0.134. This indicates that the area is rugged with low relief and low stream density, as slopes are short and small.

Table 3: Mean stream length (Lsm) of Pingalgarh watershed

Name	Stream order	Stream length of order (Lu)	Total number of stream segments (Nu)	Mean stream Length (Lsm)	Bifurcation ratio (Rb)	Stream length ratio (Rl)
Pingalgarh watershed	1	67.901	199	0.341	4.326	-
	2	29.995	46	0.652	3.833	1.911
	3	15.843	12	1.320	4.000	2.025
	4	3.02	3	1.007	3.000	0.762
	5	3.224	1	3.224	-	3.203

Table 4: Result of morphometric analysis of Pingalgarh watershed, VNMKV, Parbhani

Morphometric parameters	Result
Perimeter (P)	32.635 (Km)
Basin length (Lb)	8.292 (Km)
Mean bifurcation ratio (Rbm)	3.790
Total Area (A)	30.43(Km^2)
Drainage density (Dd)	3.943
Stream frequency (Fs)	8.577
Form factor (Rf)	0.443
Circularity ratio (Rc)	0.359
Drainage texture (T)	7.998
Elongation ratio (Re)	0.751
Length of overland flow (Lg)	0.127
Basin Relief (R)	34
Dissection Index (DI)	0.03036
Relief Ratio (Rr)	0.004
Ruggedness number (Rn)	0.134

Conclusion

This study shows that remote sensing techniques and the GIS play a crucial role in the timely and cost-effective preparation of drainage maps and morphometric analysis and the assessment of morphometric drainage parameters is more suitable than traditional ones. Mean bifurcation ratio value is estimated to be 3.790 shows that mean bifurcation ratio for entire basin is in the range of 3.0 to 5.0. The values of basin fall in the range of bifurcation ratio in which the geologic structures do not distort the drainage pattern. This study is useful in water and land resource development plan with the help of remote sensing and GIS techniques.

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