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RESEARCH ARTICLE

MORPHOMETRIC ANALYSIS OF RAIKHEDA WATERSHED, PARBHANI DISTRICT, MAHARASHTRA USING GEOSPATIAL TECHNIQUES

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ABSTRACT

The morphometric analysis of any watershed provides an account about the topography of the area, geological conditions and runoff potential of the watershed. Morphometric analysis is the measurement of a three-dimensional geometry of the landforms and has traditionally been applied to watershed, drainages, hill slopes and other group of terrain features. The morphometric characteristics of a watershed represent its attributes and can be helpful in synthesizing its hydrological behaviour. Remote Sensing and GIS technique is a powerful tool for morphometric analysis. It provides efficient tool in drainage delineation and updating. It is effective in overcoming most of the problems of land and water resources planning and management on the account of usage of conventional methods of data process. Morphometric analysis of a watershed is an essential first step, towards basic understanding of watershed dynamics. Any hydrological investigation, such as determining the potential and management of groundwater, must consider the drainage basin analysis. The physiographic properties of drainage basins, such as stream length and size, drainage density, area and slope of the drainage area, and the shape and size of the drainage area, can be connected with a number important hydrologic phenomenon. Considering this, the present study, 'Morphometric Analysis of Raikheda Watershed, Parbhani District, Maharashtra using Geospatial Techniques' was conducted during the year 2024-25. The morphometric characteristics of the Raikheda watershed were determined using ArcGIS software and SRTM DEM downloaded from USGS. Raikheda watershed covers an area about 6 km^2, with basin length 4.12m and perimeter 12m. The total length of stream in the watershed was 7110 m. The length of first, second and third order streams were 2813m, 4165m, and 132m respectively. The overall, mean stream length for the watershed was 824m. The value of the mean of the all bifurcation ratio(Rb) was 5.57. The value of drainage density (Dd) 1.185km/km^2 indicate coarse pattern of drainage network. The drainage texture value was 3.08. The value of the stream frequency (Fs) was determined as 6.17 which is indicate permeable sub-surface material and moderate to low relief. The value of the form factor (Ff) was determined as 0.35 which indicated elongated shape of watershed. The value of elongation ratio (Re) was 0.67 which also, indicated the elongated shape of watershed. elongated in shape. The value of circulatory ratio for the watershed was found as 0.52. Average constant of channel maintenance(C) was 0.843 for the watershed. The value of basin relief (R) 71m indicated moderate relief, higher infiltration and low runoff potential of the watershed. The value of relief ratio was 0.0172. In the Raikheda watershed the value of ruggedness numbe r(Rn) was 0.0841, indicating slightly rugged area with moderate relief and medium degree of soil erosion. The Raikheda watershed has low degree of slope with higher infiltration rate.The study helped to understand the basin hydrology, ground water potential, identification of sites for soil and water conservation works, and for overall natural resource management.

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INTRODUCTION

Watershed management has been defined in India as a rational utilization of land and water resources for sustained production with minimum hazard to natural resources. One of the major objectives in the watershed development programme is to manage the land surface as to retain as much rainfall as possible and conserve both soil and water. In planning of watershed development programme various type of soil and water conservation works such as bunding, terracing, nala bunding, underground dam, diversion ditches, vegetative waterways are taken up according to the availability of site, location and land capability classification. A drainage basin is a

part of land where water from rainfall is contributing to a common point. It is useful element of the catchment, and all flow of water is governed by its properties (Christopher et al. 2010). Remote Sensing and GIS techniques are efficient tools used to analyze the hydrological process of the drainage basin (Waikar and Nilawar 2014). Drainage basin analysis is an essential used to assess and manage both ground and surface water resource. Important characteristics of the drainage basin such as shape, length of tributaries, size, and slope are highly correlated with drainage basin hydrological process (Rastogi and Sharma 1976). Drainage basin networks exhibit temporal and spatial variations. Such runoff patterns change hydrological systems and significantly change both catchment inputs and output such as stream discharge, suspended sediment, solutes and litters, and watershed characters. Hydrological behavior of the drainage basin is used to design appropriate type of soil and water management system, prior work, erosion prone area, food analysis, and selection of appropriate site for different water infrastructures (Dutta and Sharma, 2002; Waikar and Nilawar, 2014).

Geographic Information System (GIS) technology can be a useful tool in the analysis of watershed morphometry. A thorough evaluation of the features of watersheds is made possible by the integration of Remote Sensing and GIS in morphometric analysis. With the use of these technologies, which offer numerous types of spatial data, scientists may analyze and understand the complex relationships that exist between hydrological processes, environmental variables, and landforms. Researchers can obtain important insights into the morphology and behavior of watersheds by utilizing the capabilities of RS and GIS. This can help with informed decision-making in a variety of fields connected to water resources, land management, and environmental planning (Rajshekhar and Mathew, 2024).

Remote sensing has the ability of obtaining synoptic view of large area and very useful in analyzing the drainage morphometric parameter. Many works have been carried out on morphometric analysis of watershed using RS and GIS. Sarita et al. (2013) presented their work prioritizing erosion-prone area through morphometric analysis, Sayeed et al. 2017 proven effective methods for drainage basin delineation, and morphometric analysis using Remote Sensing and GIS techniques.

The physiographic properties of drainage basins, such as stream length and size, drainage density, area and slope of the drainage area, and the shape and size of the drainage area, can be connected with a number important hydrologic phenomenon. For example, ridgeline delineation, characterization, priority evaluation, problem identification, evaluation of potentials and management needs, identification of erosion-prone areas, evolving water conservation strategies, and reservoir and check dam site selection can all benefit from the use of remote sensing data in conjunction with conventional data (Waikar and Nilawar, 2017). The morphometric analysis of any watershed provides an account about the topography of the area, geological conditions and runoff potential of the watershed. Morphometric analysis is the measurement of a three-dimensional geometry of the landforms and has traditionally been applied to watershed, drainages, hill slopes and other group of terrain features. The morphometric characteristics of a watershed represent its attributes and can be helpful in synthesizing its hydrological behaviour. Remote sensing and GIS technique is a powerful tool for morphometric analysis. It provides efficient tool in drainage delineation and updation. It is effective in overcoming most of the problems of land and water resources planning and management on the account of usage of conventional methods of data process. Hence, morphometric analysis of a watershed is an essential first step, towards basic understanding of watershed dynamics.
Horton (1945) explained the concept of formation of streams and basins quantitively using the mathematical description to the modern quantitative geomorphology. He described the morphometric properties such as linear, areal and relief characteristics of watershed. Each of the properties provide the useful information for understanding the nature and behaviour of stream orders. Strahler (1964) stated that the morphometric analysis of a watershed provides the quantitative aspects of the characterization of watersheds. Various scholars have carried out morphometric analysis of river basins using Remote Sensing and GIS techniques. This study was conducted with objectives to delineate and determine marphometric characteristics of Raikheda watershed, Jintur Tahsil, Parbhani district, Maharashtra State using Remote Sensing and GIS Techniques.

METHODOLOGY

Raikheda watershed (647.62 ha) is situated in Parbhani district of Marathwada region, which is 57 Km away from the Parbhani city and about 13 Km away from JinturTahasil. It is located at $19^0$60'N latitude and $76^0$61'E longitude. Raikheda watershed is situated at an altitude of 407 m above mean sea level (MSL).Raikheda watershed is a part of Purna sub-basin, which drains in Godavari river (GP-54/03/01). Soil and Water Conservation works were undertaken during the year 2009-10 in, under the project of IWMP-8.The watershed development programme was implemented by Department of Agriculture, Government of Maharashtra under Integrated Watershed Management Programme funded by NHM/EGS.

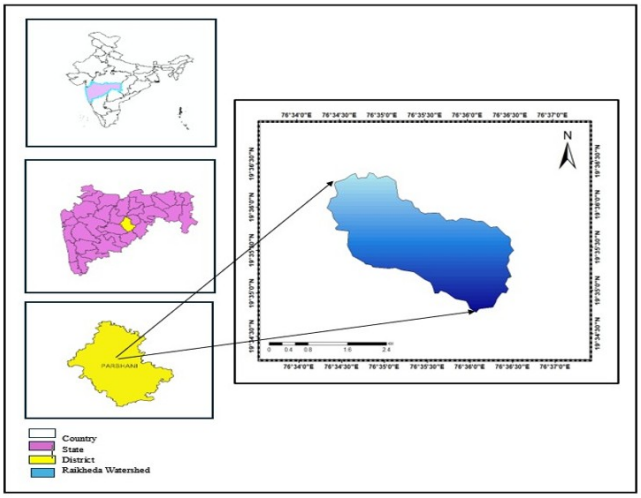


Fig. 1 Location Map of Raikheda watershed

Delineation of Watershed: SRTM -DEM of the watershed was downloaded from the USGS. The data was analysed, and produced using the Arc GIS software. Watershed delineation is a process for creating a boundary that represents the contributing for a specific control point or water outlet, with the intent of characterization and analysis of portions of a study area. The study watershed and stream networks are automatically generated from DEM using Arc GIS.

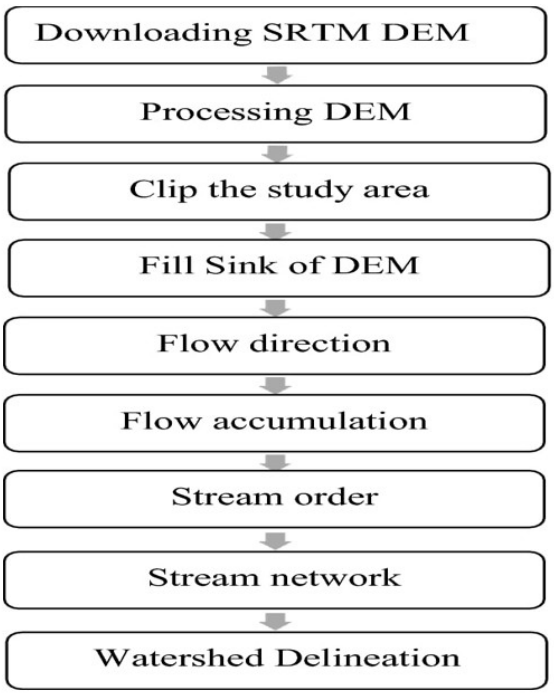


Fig. 2. Steps in Watershed Delineation

The overall methodology used to delineate and generate stream networks is shown in Fig 2.

RESULTS AND DISCUSSION

The morphometric parameters of the Raikheda watershed were analyzed in detail. The analysis revealed that the Raikheda watershed covers a total area of 6.00 km², as presented in Table 4**.** Stream length is an important morphometric parameter that reflects the morphological characteristics of a watershed. It is one of the most significant hydrological characteristics of a drainage basin, as it influences surface runoff, infiltration, and erosion processes. A greater total stream length generally indicates a well-developed drainage network, whereas shorter stream lengths are commonly associated with steeper slopes and higher relief. In general, stream length decreases with increasing stream order due to the reduction in the number of higher-order streams. In the present study, the total stream length of the watershed is 7110 m**.** The lengths of the first, second and third order streams are 2813 m , 4165 m, and 132 m respectively (Table 4). The stream length is good indicator of the morphological characteristics of the watershed. Higher stream length indicates well drained area. It is the most important hydrological characteristics of the basin as it affects the surface runoff. Smaller stream length indicates steep slope. The stream length decreases as the stream order increases. The total length of stream in the study watershed is 7110 m. The length of first, second and third order streams is 2813m, 4165m, and 132m respectively.

The mean stream length is the characteristics of a drainage network and its associated surface (Strahler 1964). It is calculated by dividing the total length of all streams under a stream order by the number of the same order. Generally, it is calculated for each order of streams separately. The mean stream length for 1st order is 97m, for 2nd order it is 595m, and for 3rd order it is 132m. It is quite obvious that the mean length of the stream keeps on increasing with increasing of the stream order. The overall, mean stream length for the watershed is 824m. The stream length ratio is defined as the ratio of the mean stream length of a given order to the mean stream length of next lower order and has an important relationship with surface flow and discharge (Horton, 1945). Bifurcation ratio is the ratio of a number of the stream segments of specified order and a number of streams in the next higher order. The Rb is dimensionless property. Basically, there are two classes of Rb value; low and high. Low class means the drainage pattern is not affected by the geologic structures, whereas the high class means the drainage pattern is controlled by the geologic structures. In the present study the value of the mean of the all Rb is 5.57. Drainage density is the ratio of total length of streams to the total area of watershed. The lower density is associated with the region where the length of the stream is less while the area coverage is large. It is important parameter which indicates dissection of landscape and peak run off potential of watershed.

The drainage density pattern is: coarse if Dd is less than 5 km per sq. km, medium if Dd is between 5-10 km per square kilometre and fine if Dd is more than 10 km per square km. In the present study the value of the Dd is 1.185km/km^2 which indicates coarse pattern of drainage network. The variation in the value of drainage texture depends upon in the number of natural factors such as climate, rainfall, vegetation, rock, soil type and their infiltration capacity and relief of the basin. High drainage density is a resultant of weak impermeable sub surface material. The drainage density less than 2 indicate very coarse, 2-4 is related to coarse, between 4-6 is moderate, and 6-8 is fine and greater than 8 is very fine drainage texture. It is observed if the drainage texture is 3.08 it indicates the permeable material with low relief. Stream frequency (Fs) is the total number of channel segments of all stream orders per unit area (km2). A total number of channel segments are dimension-less. Commonly, there are the low and the high classes of stream frequency which are relative among the investigated watersheds in a research area. In the present study the value of the Fs is 6.17 which is indicate that stream frequency indicates permeable sub-surface material and moderate to low relief. Form factor is a ratio of watershed area to the square of the length of the watershed. Flood hydrograph always affects the basin form. There are some different value ranges of form factor. The range values for form factor are 0.78 (circular). There are also other range values for Rf classification, i.e., elongated (0 or low value) and circular. In the present study the value of the form factor is 0.353 which is indicate that the watershed is elongated in nature. Elongation ratio is the ratio of the diameter of a circle of the same area as the basin to the maximum basin length. Therefore, Re is a dimension-less property. Generally, elongation ratio value is classified into two classes, i.e., the low value which means elongated watershed, and high value which means circular watershed. There are many classifications used in some papers. Four classes of Re are elongated (0.9). Three classes of Re are less elongated (< 0.7), oval (0.8 – 0.9), and circular (>0.9). Last but not least, two classes of Re are the low class and the high class.In the present study the value of Re is 0.67 which indicate that the Basin has the more elongated in shape. Circularity ratio is the ratio between the areas of a watershed to the area of the circle having the same circumference as the perimeter of the watershed. Rc is also a dimension-less property. In the present study the value of circulatory ratio is 0.52 which indicate that Circulatory ratio is low, basin is elongated in nature. The Constant of channel Maintenance is the inverse of the drainage density (Schumm, 1956).

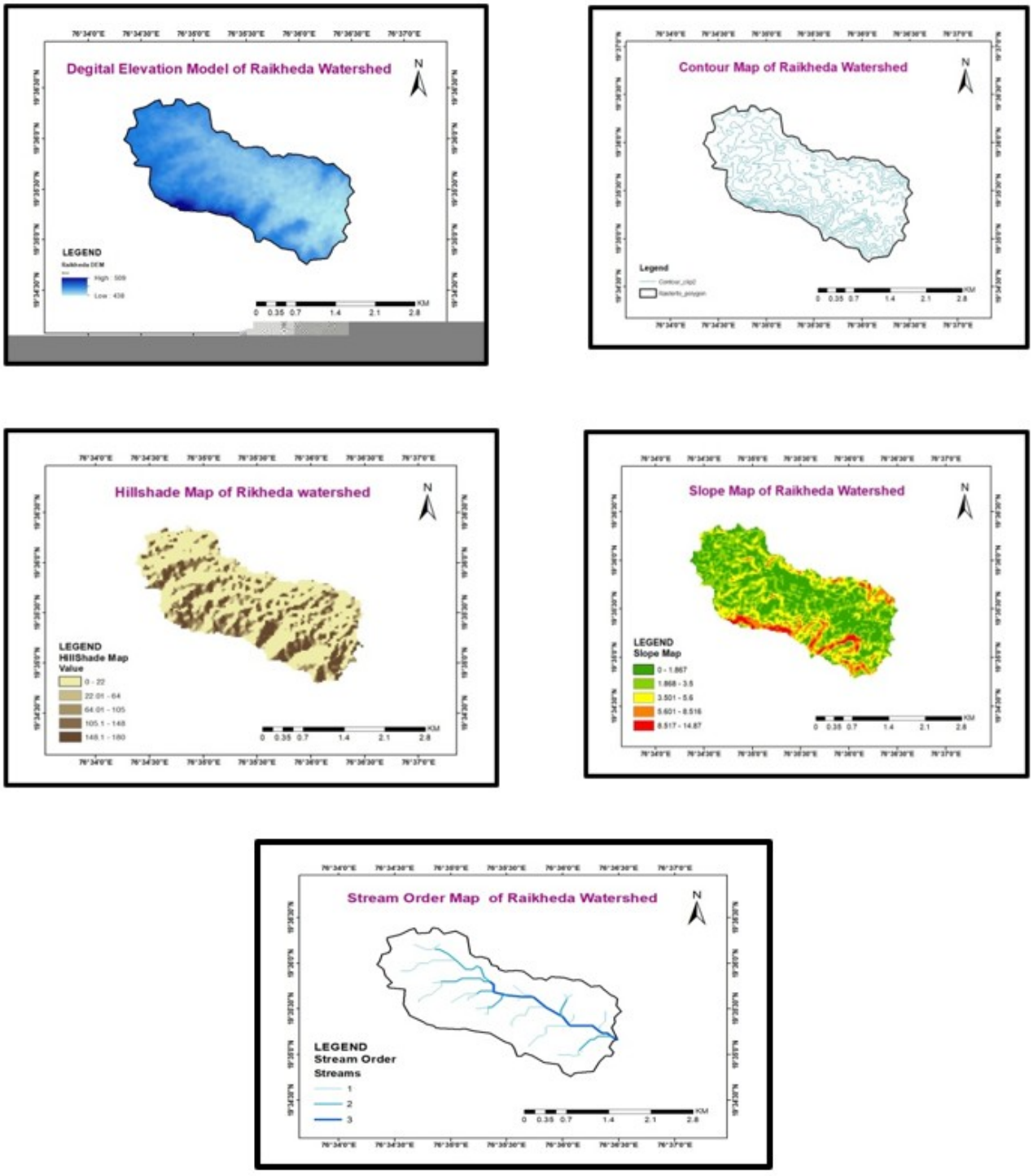


Fig. 3. Various maps of Raikheda watershed

Table 1. Formulae for Determination of Linear Parameters

Sr. No.	Morphometric Parameters	Formula	References
1.	Stream Order (Nu)	Hierarchical rank	Strahler, 1964
2.	Stream Length (Lu)	Length of the Stream in km	Horton, 1945
3.	Mean Stream Length (Lsm)	Lsm = Lu/Nu Where, Lu = Total stream length of order 'u'; Nu = Total no. of stream segments of order 'u'	Horton, 1945
4.	Stream Length Ratio (RL)	RL= Lu / Lu-1 Where, Lu= stream length of a given order; Lu-1= stream length of next lower order	Horton, 1945
5.	Bifurcation Ratio (Rb)	Rb = Nu / Nu +1 Where, Rb = Bifurcation Ratio; Nu = No. of stream segments of a given order; Nu +1= No. of stream segments of next higher order	Schumn, 1956
6.	Mean bifurcation ratio (Rbm)	Rbm = Average of bifurcation ratios of all orders.	Strahler, 1957

Table 2. Formulae for Determination of Areal Parameters

Sr. No.	Morphometric Parameters	Formula	References
1.	Drainage Density (Dd)	Dd = Lu/A Where, Dd = Drainage Density (1/km); Lu = Total stream length of all orders; A = Basin Area (km2)	Horton, 1945
2.	Stream Frequency (Fs)	Fs = Nu/A Where, Fs = Stream Frequency; Nu = Total no. of streams of all orders and; A = Area of the basin (km2)	Horton, 1945
3.	Drainage Texture Ratio (Dt)	Dt = Nu /P Where, Nu = No. of streams in a given order; P = Perimeter of basin (km)	Horton, 1945
4.	Form Factor (Ff)	Ff = A/Lb2 Where, A = Basin Area; Lb = Basin length	Horton, 1945
5.	Constant Channel Maintenance (C)	C = 1/ Dd Where, Dd = Drainage Density	Horton, 1945
6.	Circulatory Ratio (Rc)	Rc = 4πA/ P^2 Where, A = Basin area (km2); P= Perimeter of the basin (km)	Miller, 1953
7.	Elongation Ratio (Re)	Re = √A /π / Lb Where, A= Basin area (km2); Lb= Basin length (km)	Schumn, 1956
8.	Length of Overland Flow (Lg)	Lg = 1/ 2 * Dd Where, Dd = Drainage Density	Horton, 1945

Table 3. Formulae for Determination of Relief Parameters

Sr. No.	Morphometric Parameters	Formula	References
1.	Basin Relief (R)	R = H-h Vertical distance between the lowest and highest points of watershed	Schumn, 1956
2.	Relief Ratio (Rr)	Rr = H / Lb Where, H = Basin Relief (km); Lb = Basin length (km)	Schumn, 1956
3.	Ruggedness Number (Rn)	Rn = H x Dd Where, H = Basin Relief (km); Dd = Drainage Density	Schumn, 1956

Table 4 Basin parameters of Raikheda watershed

Basin Area (A)	Basin Perimeter(P)	Basin length (L)
6 km^2	12 km	4.12km

Therefore, higher the drainage density lowers the constant of channel maintenance and vice versa. Higher value indicates least erodible and vice versa.Regarding the Raikheda watershed the average constant of channel maintenance(C) is 0.843. This high value indicates low structural disturbances, high permeability, low to moderate slopes and low surface run off. (Table 7)

Table 5. Number of stream Order and It's Count

Sr.no	Number of stream Order	Total no. of streams
1	1st Order stream	29
2	2nd Order stream	7
3	3rd Order stream	1

Basin relief is the difference in elevation between the highest and the lowest point of the basin.The maximum elevation of the Raikheda watershed is 509 m and minimum elevation is 438m .The value of basin relief (R) 71m indicates moderate relief, higher infiltration and low runoff conditions of watershed.Relief Ratio (Rh) is the difference in the elevation of the highest and lowest points in a watershed. To classify it, researchers did it based on the values of relief ratio in their study area relatively. Generally, the low value of relief ratio means low relief and the high value means steep slope and high relief. In the present study the value of relief ratio is 0.0172 which is the characteristics features of average resistant rocks of the area.Ruggedness number is the product relief of basin (R) and drainage density (Dd).Ruggedness number (Rn) gives an idea of overall roughness of watershed. It can describe the slope steepness and length of the basin. The watershed's low ruggedness value suggests that the area is less prone to soil erosion. In the Raikheda watershed the value of Rn is 0.0841, which indicates that the area is slightly rugged with moderate relief and medium degree of soil erosion (Table 8).

Table 6. Linear Parameters of Raikheda watershed

Stream order (u)	Stream count (Nu)	Stream Length (Lu)	Mean Stream Length (Lsm)	Stream length ratio (Rl)	Bifurcation ratio (Rb)
1	29	2813	97	1.48	4.14
2	7	4165	595	0.0317	7.00
3	1	132	132	-	-
Total	**37**	**7110**	**824**		**Mean RB=5.57**

Table 7. Areal Parameters of Raikheda watershed

Sr. no Parameter Value Sr. No.	Parameter	Value
1.	Drainage density	1.185
2.	Drainage texture (Dt)	3.08
3.	Texture ratio(T) (Km) Stream frequency (Fs)	6.17
4.	Form factor (Ff)	0.353
5.	Elongation ratio (Re)	0.67
6.	Circularity ratio (Rc)	0.52
7.	Constant of channel maintenance (C)	0.843
8.	Length of overland flow (Lg)	0.422

Table 8. Relief Parameters of Raikheda watershed

Sr. no Parameter Value Sr. no.	Parameter	Value
1.	Basin relief (R)	71m
2.	Relief ratio (Rr)	0.0172 (dimensionless)
3.	Texture ratio(T) (Km) Ruggedness Number (Rn)	0.0841

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