PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol x(x): xx–xx
https://doi.org/10.14719/pst.7725

HORIZON
e-Publishing Group
HePG

RESEARCH ARTICLE

Prioritization of subwatersheds in the Jajmau basin, Kanpur, via drainage morphometry

Nisha Sahu[1*], J K Saha[1], Rahul Mishra[1], Nishant Kumar Sinha[1], Mrunalini Kancheti[2] & H Biswas[3]

[1]ICAR-Indian Institute of Soil Science, Bhopal 462 038, Madhya Pradesh, India

[2]ICAR-Indian Institute of Pulse Research, Kanpur 208 024, Uttar Pradesh, India

[3]ICAR-National Bureau of Soil Survey and Land Use Planning, Nagpur 440 033, Maharashtra, India

*Email: nishasahu5@gmail.com

OPEN ACCESS

ARTICLE HISTORY
Received: 13 February 2025
Accepted: 26 March 2025
Available online
Version 1.0 : 16 July 2025

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

CITE THIS ARTICLE
Nisha S, Saha JK, Rahul M, Nishant KS, Mrunalini K, Biswas H. Prioritization of subwatersheds in the Jajmau Basin, Kanpur, via drainage morphometry. Plant Science Today (Early Access). https://doi.org/10.14719/pst.7725

Abstract

Advanced, reliable and cost-effective tools such as GIS and remote sensing play very important roles in prioritizing and extracting drainage in basins. In the present study, thirty-two morphometric aspects, including linear, aerial and relief parameters with standard formulae, are considered and computed to prioritize the sub watersheds. The toposheet (1:50000 scale) downloaded from the SOI and SRTM DEM (30 m resolution) from the Earth Explorer were used to extract drainage and delineate the watershed and sub watershed of the basin via ArcGIS 10.8 software (Spatial Analysis tools). The drainage of any region depends on topography, slope, hillshade, aspect, vegetation cover and many more. The results revealed that drainage is dentritic to sub-dentritic, which shows that the study area has homogenous *i.e* very gentle slope and uniform soil *i.e* alluvial soil throughout. The Jajmau Basin is divided into four sub watersheds and prioritized via the compound value and ranking methods. Sub watershed SW-1 needs high priority and immediate attention in terms of management aspects, whereas SW-4 needs the least attention. Hence, the prioritize watershed would be beneficial and attract decision makers, policy formers and management planners for the effective planning of resources at the parcel level in a more precise manner.

Keywords

DEM; GIS; morphometric analysis; remote sensing; watershed

Introduction

With alarming growth in population, natural resources such as water and soil are being overused and utilized in an indiscriminate manner which reduces their quality for future use. In India, the maximum percentage of topsoil is lost in soil erosion or other land degradation activities. In our country, more than 2500 tanneries are in the Uttar Pradesh state. And more than 80 % of them are involved in chrome tanning process. Jajmau (Kanpur) is one of the major leather processing centers in the state and more than 18 % tanning industries are located at Jajmau. Therefore, planning and managing natural resources in a sustainable manner for increasing population is a major challenge. The streams and drains of the area and flow of water depend on several factors like slope, topography, aspect, hillshade, geology, parent material and vegetation cover. But most of the factors are controlled by the nature of the soil of the area. The physiographic characteristics like scale, texture and gradient of the basin bear an interrelationship with various hydrological phenomena. Morphometry means the measurement of shapes and is used to express quantitative landforms.

The watershed is an optimal unit for the sustainable development and management of natural resources (1). The traditional method of analyzing morphometric parameters is very laborious and consumes considerable time. However, with the advancements in geospatial and computational technologies, such as Geographic Information System (GIS) and Remote Sensing (RS) techniques, more precise and accurate assessments can be performed easily. Many researchers use Digital Elevation Models (DEMs) to derive topographic properties (2-5).

Morphological parameters play a very crucial role in the proper understanding of any watershed and its management. It is largely affected by parent material, lithology and geology. Thus, information on the above properties is very helpful for understanding the drainage pattern of a basin (6). Many researchers have used advanced techniques to study the drainage morphometry of basins (7-9). DEMs are freely available and can be explored to obtain a more detailed topography of the study area. Most researchers have used the 30 m resolution Shuttle Radar Topographic Mission (SRTM) DEM and the CARTOSAT DEM to extract morphometric parameters (10-11). With the advancement of computer technology and high-resolution imagery, these data provide more reliable results for any basin in less time. The prioritization of watersheds was based on the linear, aerial and relief criteria which represent the one, two and three-dimensional properties of watersheds, respectively. These aspects of morphometry help to identify severely eroded zones, which is an important step in the process of management planning. The compound value scoring method is the simplest way to prioritize sub watersheds. Detailed knowledge about basin drainage is extremely helpful in hydrological modeling, delineation of management zones and conservation and restoration of natural resources (12, 13). The present study highlights the usefulness of advanced tools such as GIS and remote sensing in prioritizing sub watersheds in the Jajmau basin. The main objectives of the study were analysis of morphometry of the basin, compound scoring for identification of sub watershed of high priority for management planning.

Materials and Methods

Study Area

The study area, Jajmau (26.38 N latitude and 80.44 E longitude), is in one of the industrial areas of Kanpur, Uttar Pradesh, India (Fig. 1). It is situated on the left bank of the Ganga River and the right bank of its tributary Panku River. About 400 tanneries are located at Jajmau, which is one of the higly polluted zones. In long term, treated and untreated wastewater is used for irrigation in agricultural lands, which comprises nearly 10 villages. The slope of this area is nearly level and slope percentage vary from 1 to 3. The average annual temperature varies from 22-25 °C and two types of monsoons, i.e., southwest (June-September) and northeast (October-December), prevail in this region. Jajmau experiences the extremes of temperature, ranging from 3 °C in the winter months between December to February, to 48 °C in summer between May to June. It has subtropical humid climate, with an average annual rainfall of 800 mm. Monsoon rainfall is the main source for storage sectors and occurs at a maximum during south-western monsoon periods. The cropping pattern has changed from cereal to vegetables including cauliflower in many areas. Flower cultivation is also carried out in a few places in the region.

Data collection

In this paper, the drainage morphometrics of the area was discussed by dividing the watershed into number of sub-watersheds and identification of management zone by priority. The main data used are Shuttle Radar Topographic Mission (STRM) digital elevation model DEM (30 m resolution) downloaded from earth explorer (https://earthexplorer.usgs.gov/) and 1:50000 scale toposheets (63B/7, 63B/8) collected from Survey of India (SOI).

Extraction of the drainage network

The downloaded toposheets were converted to Tiff format, georeferenced and rectified via ArcGIS 10.8 software. The georeferenced toposheets are mosaiced and then clipped to the study area via the Arc Toolbox. Using these tools, the fill sinks, flow direction, flow accumulation, stream order and drainage network of the basin are derived. The extracted

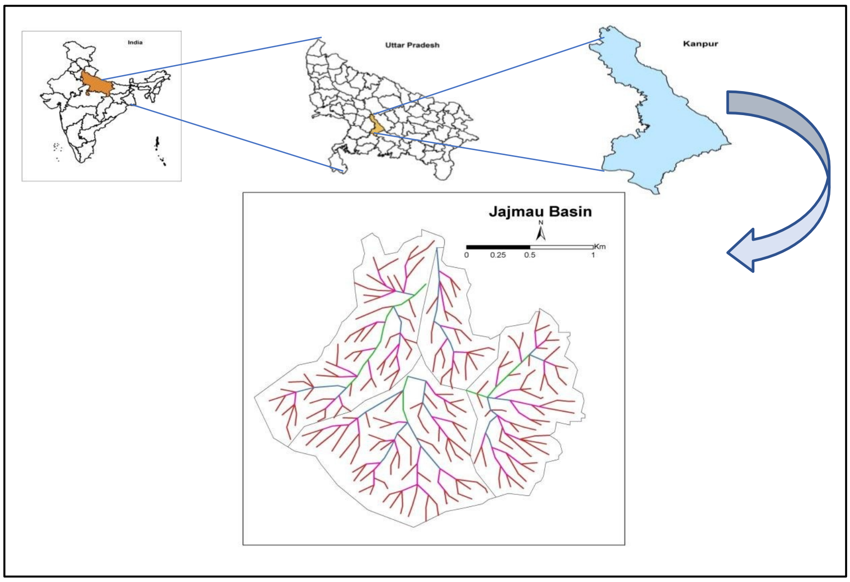

Fig. 1. Location map of the study area.

drainage was cross-checked with a mosaiced toposheet. Strahler's (14) stream ordering method was followed and the area was divided into four sub-watersheds on the basis of pour points of the basin. The results obtained with the DEM data were clipped to the boundary of the Jajmau basin and projected into the WGS84 UTM system. Slope and aspect maps were generated both from the SRTM DEM (30 m). The different thematic layers (basin and subbasin boundaries, drainage, relief, slope and aspect) were projected on the same spatial reference system (WGS-84/UTM) for overlay analysis in ArcGIS. The flowchart of the database and methodology is shown in Fig. 2.

Computation of morphometric properties

The morphometric analysis provides physiological and methodical information about the drainage basin. The parameters of the basin area, perimeter, length and width, as well as the number and length of streams in various stream orders, are automatically extracted through ArcGIS tools. Standard formulae adopted from (14-17) (Table 1) are used to compute linear, areal and relief aspects for prioritization of sub-watersheds.

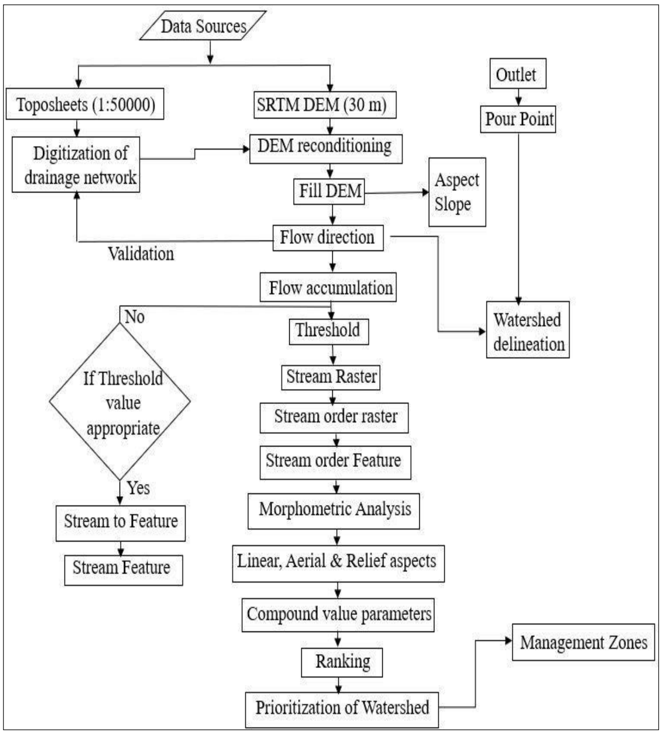

Fig. 2. Flowchart of the data sources and methodology for morphometric analysis.

Table 1. Formulae for computing morphometric parameters

S.No.	Morphometric parameters	Formula/relationship	References
		Basic parameters	
1.	Area (A)	GIS analysis/DEM	
2.	Perimeter (P)	GIS analysis/DEM	
3.	Basin length (Lb)	$Lb=1.312A^{0.568}$	(17)
4.	Mean basic width (Wb)	Wb=A/Lb	(17)
5.	Stream order (U)	Hierachical rank	(14)
6.	Stream number (Nu)	Nu=N1+ N2+ + Nn	(15)
		Linear parameters	
7.	Stream length (Lu)	Length of stream	(15)
8.	Mean stream length (Lsm)	Lsm=Lu/Nu, where Lu=total stream length of order "u", Nu= total no. of stream segments of order "u"	(14)
9.	Stream length ratio (Lur)	Lur =Lu/Lu-1, where Lu=total stream length of order "u", Lu-1= the total stream length of its next lower order	(15)
10.	Mean stream length ratio (Rslm)	Rslm=∑ Lur/n	(17)
11.	Bifurcation ratio (Rb)	Rb=Nu/Nu+1, where Nu=total no. of stream segments of order "u", Nu+1= No. of stream segments of the next higher order	(17)
12.	Mean bifurcation ratio (Rbm)	Rbm=average of the bifurcation ratio of all order	(18)
13.	Rho coefficient (ρ)	ρ = Rslm/Rbm	
		Aerial parameters	
14.	Drainage texture (Dt)	Dt=Nu/P, where Nu is the total no. of streams of all order, P is the perimeter of the basin	(15)
15.	Texture ratio (Rt)	Rt=N1/P, where N1is the total no. of first order streams	(19)
16.	Drainage density (Dd)	Dd=Lu/A, where Lu is the total stream length of all orders, A is the total area of the basin in km^2	(19)
17.	Stream frequency (Fs)	Fs=Nu/A, where Nu is the total number of streams of all order, A is basin area	(19)
18.	Drainage intensity (Di)	Di=Fs/Dd where Fs is the stream frequency, Dd is the drainage density	(19)
19.	Infiltration number (If)	If= Fs* Dd where Fs is the stream frequency, Dd is the drainage density	(19)
20.	Length of overland flow (Lof)	Lof =1/(Dd*2), where Dd is the drainage density	(15)
21.	Form factor (Ff)	Ff=A/Lb where A is basin area, Lb is the square of the basin length	(19)
22.	Circulatory ratio (Rc)	$Rc=4\pi A/P^2$ where A is basin area, P is the perimeter of the basin	(16)
23.	Elongation ratio (Re)	Re=2 sqrt(A/π)/Lb, A is basin area, Lb is basin length	(17)
24.	Constant channel maintenance (C)	Inverse of drainage density	(17)
25.	Shape factor (Sf)	Reciprocal of form factor	(19)
26.	Compactness constant (Cc)	$Cc= 0.282\ P/A^{0.5}$ where P is the perimeter of the basin, A is basin area	(19)
		Relief aspects	
27.	Elevation of the basin outlet (z)	GIS analysis/DEM	
28.	Maximum elevation of the basin (Z)	GIS analysis/DEM	
29.	Total basin Relief (H)	H=Z-z	(17)
30.	Relief ratio (Rh)	Rh=H/Lb where H is relief, Lb is basin length	(17)
31.	Relative Relief (Rr)	Rr=H/P where H is relief, P is perimeter	(20)
32.	Ruggedness number (Rn)	Rn=H*D, where H is relief, D is drainage density	(14)

Prioritization of subwatersheds

In this study, the prioritization of subwatersheds is based on allotting the ranks to each morphometric parameter. The compound values of all the parameters are derived by calculating the means of the assigned ranks. Soil degradation is directly related to linear and relief aspects but inversely related to aerial parameters. Thus, the prioritization of subwatersheds is based on higher values of linear and relief parameters and lower values of aerial parameters and vice versa. The high priority indicates an urgent action plan for the protection, conservation and management of soil.

Results and Discussion

Using SRTM DEM data, the whole study area is divided based on pour points into four sub-watersheds (SW), SW-1 to SW-4, as shown in Fig. 3 (a). The drainage pattern ranges from dentritic to sub-dentritic type of the basin (Fig. 3 (b)), which indicates that the study area has homogenous and uniform soil and rocks. The morphometric analysis of the Jajmau Basin is explained in three different aspects (linear, aerial and relief) obtained via the methods and formulae mentioned in Table 1. The slope, hillshade and aspect of the basin are also evaluated, which can help in understanding watershed management (Fig. 4).

Basic parameters

The area (A) of the watershed, ranges from 1.306 to 0.445 km^2, affects the volume of runoff, with SW-4 being the largest and SW-1 being the smallest. The outside edge of the watershed that encloses its area is called the perimeter (P). The smallest and largest sub-watershed perimeters values are 3.269 km (SW-1) and 5.732 km (SW-2) in size, respectively. Many researchers have given varying descriptions of basin length. It is derived using the mathematical formula in Table 1 in this instance, with SW-4 having the longest value (3907.45 m) and SW-1 having the shortest value (2119.81 m).

The basin width explains the distance of the line that is drawn perpendicular to the basin length. In this study, the basin width is longest for SW-4 (334.37 m) and shortest for SW -1 (210 m).

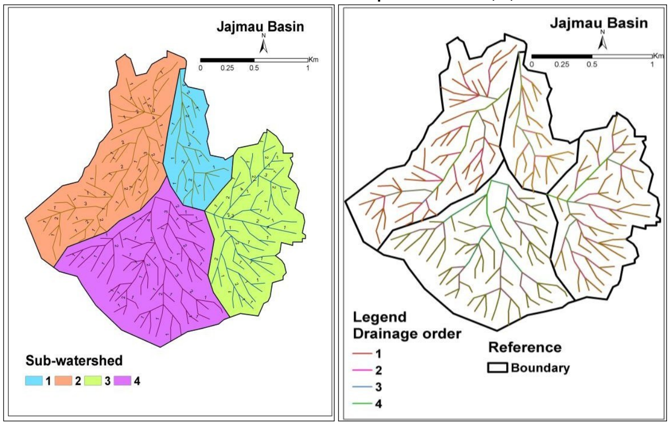

Fig. 3. (a) Subwatershed and (b) drainage order of the Jajmau basin.

Linear Parameters

Stream order is defined by the arrangement of the channels. In current research, the Jajmau Basin adheres to Strahler's classification of streams, which defines the simplest unbranched tributaries as first-order streams and the merging of two first-order streams results into a second order stream (Table 2). The stream order of the watershed is assigned to the stream of highest order (fourth order). Stream number (Nu) classifies the surface runoff characteristics, meaning a greater number of first-order streams represents increased erodibility and more permeable topography (21). It is obtained via the method (15) followed the "law of stream numbers" which postulates a negative correlation between the order of stream and stream number, meaning as the stream order increases the quantity of streams decreases. In this study SW-4 (50) contains the highest stream count and SW-1 (18) contains the lowest stream count. The stream length is defined as the total length of all subsequent stream segments within the basin (22).

The aggregate length of the streams is maximized in the first order and then diminishes with the progression of stream order as per the Second Law of Stream Length (15). Results show that SW-2 had the longest stream length at 12458 m while SW-1 had the shortest at 4974 m. Highly uneven terrain greatly influences the mean stream length ratio, with the slope being between 0.40 and 0.7.

This suggests there were strong resistant rocks that almost flattened the basin's outline and the configuration of surface flow. The bifurcation ratios from 3 to 5 are indicative of a natural-drainage system existing within uniform rock (23). More bifurcation denotes better dissection of drainage basins (15), which reduces the probability of flood and erosion (24). In this case, the values were between 1.79-3.25.

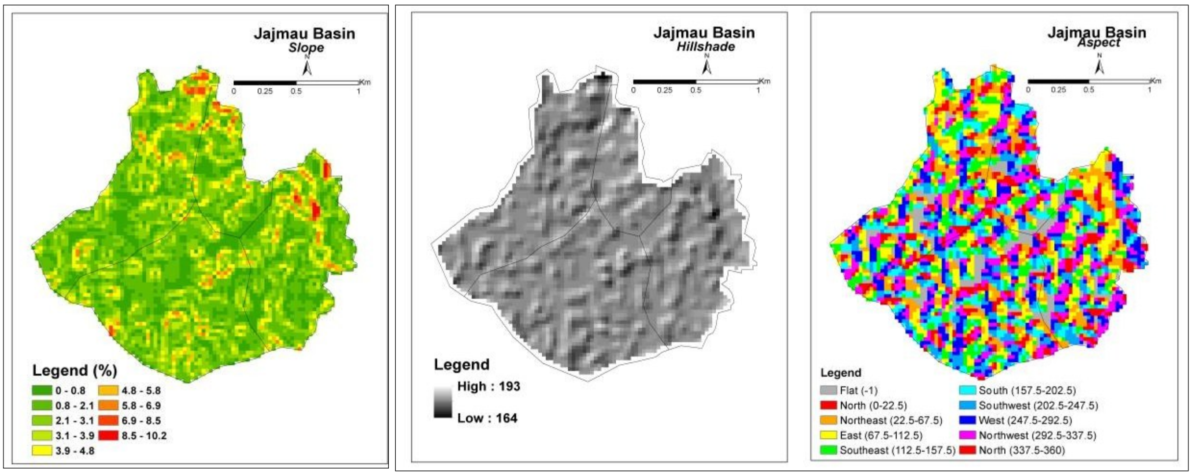

Fig. 4. Slope, hillshade and aspect of the Jajmau basin.

Table 2. Stream orders and stream numbers of subwatersheds in the Jajmau basin

Stream order	SW-1	SW-2	SW-3	SW-4
Stream number (Nu)				
1st Order (Nu1)	18	48	43	50
2nd Order (Nu2)	7	19	17	24
3rd Order (Nu3)	7	8	8	11
4th Order (Nu4)		9	6	2
Total	32	84	74	87
Stream length (Lu)				
1st Order (Lu1)	3165	8029	6988	9206
2nd Order (Lu2)	847	2289	2582	2700
3rd Order (Lu3)	962	994	894	1814
4th Order (Lu4)		1146	682	414
Total	4974	12458	11146	14134
Bifurcation ratio (Rb)				
Nu1/Nu2 (Rb1)	2.57	2.53	2.53	2.08
Nu2/Nu3 (Rb2)	1	2.38	2.12	2.18
Nu3/Nu4(Rb3)	-	0.88	1.33	5.5
Total	3.57	5.79	5.98	9.76
Stream length ratio (Rl)				
Lu2/ Lu1 (Rl**1**)	0.27	0.29	0.37	0.29
Lu3/ Lu2 (Rl**2**)	1.13	0.43	0.35	0.67
Lu4/ Lu3 (Rl**3**)	-	1.15	0.76	0.23
Total	1.4	1.87	1.48	1.19

The Rho coefficient (ρ) reflects the storage capacity of the basin (25). In this case, SW-1 exhibited the greatest value while SW-4 showed the least value in Table 3.

Aerial parameters

The measurement of drainage density (Dd) indicates the length of streams in relation to the total area of land. In the case of Jajmau basin, the drainage density is measured between 10.8 - 11.3 km^{-1} with the highest value reported at SW-3 and the lowest value at SW-4. These low values of drainage density are due to the region having gentle slopes, soil cover and runoff. (Fs), the frequency of the stream, is defined as the ratio of the total number of stream segments associated with a selected area to the area of the watershed. The values of Fs ranges from 66.58 km^{-2} (SW-4) to 75.3 km^{-2} (SW-3), drainage pattern is highly dependent on these values. The spacing of the streams describes the drainage texture. It can be classified into five different textures, along with very coarse (<2), coarse (2-4), moderate (4-6), fine (6-8) and very fine (>8). The drainage texture is computed as the ratio of total length of streams to area and indicates the density of streams, which is very fine > 8, ranging from 9.78 - 17.87km^{-1}. Another important parameter of the basin is the infiltration number which is an indicator of infiltration and surface runoff numbers. A higher number indicates greater surface runoff and little infiltration rate in all subwatersheds of Jajmau basin. The length of overland flow is one of the important parameters affecting both the geographical and hydrological evolution of a watershed (26). The length of overland flow is between 0.044-0.046. The drainage intensity is indicative of the effectiveness of both the drainage density and the stream frequency on surface denudation of any watershed. It ranges from 6.16-6.77, where it is highest at SW-2 and lowest at SW-4. The texture ratio of different sub-watersheds ranges from 5.51 to 10.27. The FF ratio is defined as the ratio of the basin area to the square of the basin length (19). However, in most of the studies the form factor ranges from zero (extremely long shape) to unity (round shape). In our study, the form factor ranges from 0.08 to 0.10, which states that all the sub-watersheds are elongated. The value of the elongation ratio may be classified into three types: (a) circular greater than0.9, (b) oval between 0.9 to 0.8 and (c) elongated less than0.7. In our research, the elongation ratio ranges between 0.33 and 0.36, which indicates that it is elongated in shape with moderate relief. The circularity ratio is the proportion of watershed area to the area of a circle that has the same circumference as the basin perimeter (27). The ratio values are useful for determining the level of watershed development. For instance, lower values indicate younger stages while middle values indicate more mature ones and higher values indicate older stages of a watershed (28). The values indicate that the basin is less circular and more elongated, ranging between 0.439 and 0.693. Lemniscate's ratio is used to calculate the catchment's slope (29). The values vary from 2.52 to 2.92, with the highest values occurring in SW-4 and the lowest in SW-1. Only the slope (1.20-1.50) affects the compactness coefficient, which is unaffected by the watershed's size. One important characteristic that affects flow and sediment amount is the form factor. Less erosion susceptibility is indicated by lower values and vice versa. The values of SW-1 and SW-4 are 10.08 and 11.68, respectively.

Table 3. Computed morphometric parameters of subwatersheds

Parameters	SW-1	SW-2	SW-3	SW-4
Area (km^2)	0.445171	1.148320	0.982121	1.306550
Perimeter (km)	3.269	5.732	4.682	4.867
Basin length (m)	2119.81	3631.19	3322.64	3907.45
Mean basin width (m)	210	316.23	295.58	334.37
Stream order	3	4	4	4
Stream number (Nu)	32	84	74	87
Stream length (m)	4974	12458	11146	14134
Mean stream length (m)	155.44	148.31	150.62	162.45
Mean stream length ratio (Rslm)	0.7	0.62	0.49	0.40
Mean bifurcation ratio (Rb)	1.79	1.93	2.00	3.25
Rho coefficient (ρ)	0.39	0.32	0.25	0.12
Drainage density (km^{-1})	11.2	10.8	11.3	10.8
Stream frequency (km^{-2})	71.89	73.15	75.3	66.58
Drainage texture (km^{-1})	9.78	14.65	15.80	17.87
Infiltration number	805.17	790.02	850.89	719.06
Length of overland flow	0.044	0.046	0.044	0.046
Drainage intensity	6.42	6.77	6.66	6.16
Texture ratio	5.51	8.37	9.18	10.27
Form factor ratio (Ff)	0.10	0.08	0.09	0.09
Elongation ratio (Re)	0.36	0.33	0.34	0.33
Circulatory ratio (Rc)	0.523	0.439	0.563	0.693
Lemniscate's ratio (K)	2.52	2.87	2.81	2.92
Compactness constant (Cc)	1.38	1.50	1.33	1.20
Shape factor (Sf)	10.08	11.48	11.24	11.68
Constant channel maintenance (C)	0.089	0.092	0.088	0.092
Elevation of basin outlet	114	119	123	127
Maximum elevation of the basin	128	129	131	130
Total basin relief	14	10	8	3
Relief ratio	6.60	2.75	2.41	0.77
Relative relief	4.28	1.74	1.70	0.62
Ruggedness number	156.8	108	37.45	14.60

Relief parameters

The drainage basin's three-dimensional characteristics are known as the relief parameters. Using the ArcGIS platform, the elevation of the basin's highest elevation and its outlet elevation are taken from the SRTM DEM. Because of its low overall relief, the basin is less vulnerable to soil erodibility. Compared to total relief, the relief ratio offers a more accurate representation of the relief features. The relief ratio in this investigation varied between 6.60 (SW-1) to 0.77 (SW-4). SW-1 is more vulnerable to erosion since watersheds are more likely to experience erosion when the relief ratio is higher. Likewise, a watershed's vulnerability to erosion increases with its relative relief. The ruggedness number reflects the roughness of the watershed. The values are found high, indicating a high risk of erosion.

Prioritization of sub-watersheds

Based on the different morphometric parameters listed on the Table 4, the sub-watershed of the study area is prioritized for management planning. Soil loss or erosivity is directly related to linear and relief parameters and inversely to aerial aspects. Hence, higher values of linear and relief features indicate greater chance of soil erosion. Therefore, the subwatersheds with high values of these parameters are ranked first, followed by those with high values. In case of aerial parameters, the smallest value stands first rank and so on. The aerial parameters with the largest values are ranked last (30, 31). For each aspect, the compound value is calculated by averaging the ranks allotted. Finally, the lowest compound value is rated as the highest priority and so on. Compared with other sub-watersheds, SW-1 needs more attention and observed to be more prone to soil erosion. The SW-4 is the best among all the zones and this zone requires minimum care and attention for management, planning and conservation.

Table 4. Subwatershed prioritization based on the ranking of the Jajmau basin

Parameters	SW-1	SW-2	SW-3	SW-4
Mean stream length ratio (Rslm)	1	2	3	4
Mean bifurcation ratio (Rb)	4	3	2	1
Rho coefficient (ρ)	1	2	3	4
Drainage density (km^{-1})	2	4	1	3
Stream frequency (km^{-2})	3	2	1	4
Drainage texture (km^{-1})	4	3	2	1
Infiltration number	2	3	1	4
Length of overland flow	3	2	4	1
Drainage intensity	3	1	2	4
Form factor ratio (Ff)	4	1	3	2
Elongation ratio (Re)	4	1	3	2
Circulatory ratio (Rc)	2	1	3	4
Lemniscate's ratio (K)	1	3	2	4
Compactness constant (Cc)	3	4	2	1
Shape factor (Sf)	1	3	2	4
Constant channel maintenance (C)	2	3	1	4
Total basin relief	1	2	3	4
Relief ratio	1	2	3	4
Relative relief	1	2	3	4
Ruggedness number	1	2	3	4
Compound value	2.2	2.3	2.35	3.15
Final rank	I	II	III	IV

Conclusion

In contrast to traditional methods, modern technologies like GIS and remote sensing are essential, dependable and affordable for assessing the drainage morphometry of the Jajmau Basin. It is particularly helpful to define the features of a basin using the calculated values of the linear, aerial and relief parameters from DEMs, aspects, hillshades and slopes. To setting management priorities for watersheds, the current study offers accurate data for 32 morphometric characteristics. Numerous topographical and geological features can be better understood because of the drainage system's dendritic to subdentritic features. The prioritization of subwatersheds is based on compound value calculations and rankings. The SW-1 needs high priority for management aspects, whereas SW-4 needs the lowest priority. Conservation, planning and management practices should focus on high-priority zones. This study will be highly valuable for planners and decision-makers in sustainable watershed development programs for managing natural resources at the micro level.

Acknowledgements

The authors express their sincere gratitude to the ICAR-Indian Institute of Soil Science, Bhopal, for providing the laboratory facility for analysis.

Authors' contributions

NS, JKS and NKS planned the experiments. RM and MK analyzed the samples and performed the statistical analysis. NS wrote the manuscript. HB contributed to the final correction of the manuscript.

Compliance with ethical standards

Conflicts of interest: The authors declare that they do not have any conflicts of interest.

Ethical issues: None

References

1. Patel DP, Dholakia MB, Naresh N, Srivastava PK. Water harvesting structure positioning by using geo-visualization concept and prioritization of mini-watersheds through morphometric analysis in the Lower Tapi Basin. Journal of the Indian Society of Remote Sensing. 2012;40:299-312. https://doi.org/10.1007/s12524-011-0147-6
2. Senthamizhan M, Balamurugan P, Shunmugapriya K. Morphometric analysis of Thadayampatti Watershed, Madurai District, Tamil nadu, India. Int J Eng Develop Res. 2016;4(3):103-07.
3. Magesh NS, Jitheshlal KV, Chandrasekar N, Jini KV. Geographical information system based morphometric analysis of Bharathapuzha river basin, Kerala, India. Appl Water Sci. 2013;3:467 -77. https://doi.org/10.1007/s13201-013-0095-0
4. Altaf F, Meraj G, Romshoo SA. Morphometric analysis to infer hydrological behavior of Lidder watershed Western Himalaya. India Geograph J. 2013. https://doi.org/10.1155/2013/178021
5. Pareta K, Pareta U. Quantitative morphometric analysis of a watershed of Yamuna Basin, India using ASTER (DEM) data and GIS. Int J Geomat Geosci. 2011;2(1):248-69.

6. Bhattacharya RK, Das Chatterjee N, Das K. Subbasin prioritization for assessment of soil erosion susceptibility in Kangsabati, a plateau basin: a comparison between MCDM and SWAT models. Sci Total Environ. 2020;734:139474. https://doi.org/10.1016/j.scitotenv.2020.139474
7. Pathare JA, Pathare AR. Prioritization of microwatershed based on morphometric analysis and runoff studies in upper Darna basin, Maharashtra, India. Model Earth Syst Environ. 2020;6:1123-30. https://doi.org/10.1007/s40808-020-00745-6
8. Islam MR, Khan MNI, Khan MZ, Roy B. A three decade assessment of forest cover changes in Nijhumdwip national park using remote sensing and GIS. Environ Challenges. 2021;4:100162. https://doi.org/10.1016/j.envc.2021.100162
9. Kudnar NS, Rajasekhar M. A study of the morphometric analysis and cycle of erosion in Wainganga Basin, India. Model Earth Syst Environ. 2020;6:311-27. https://doi.org/10.1007/s40808-019-00680-1
10. Nag S, Roy MB, Roy PK. Optimum prioritization of subwatersheds based on erosion susceptible zones through modeling and GIS techniques. Model Earth Syst Environ. 2020;6:1529-44. https://doi.org/10.1007/s40808-020-00768-z
11. Abdeta GC, Tesemma AB, Tura AL, Atlabachew GH. (2020) Morphometric analysis for prioritizing subwatersheds and management planning and practices in Gidabo Basin, Southern Rift Valley of Ethiopia. Appl Water Sci. 2020:10. https://doi.org/10.1007/s13201-020-01239-7
12. Pune D, Umrikar BN. Morphometric analysis of Andhale watershed, Taluka Mulshi. Appl Water Sci. 2017;7:2231-2243. https://doi.org/10.1007/s13201-016-0390-7
13. Waiyasusri K, Chotpantarat S. Watershed prioritization of kaeng lawa subwatershed, khon kaen province using the morphometric and land-use analysis: a case study of heavy flooding caused by tropical storm podul. Water (Switzerland). 2020:12. https://doi.org/10.3390/W12061570
14. Strahler AN. Quantitative geomorphology of drainage basins and channel networks. Handb Appl Hydrol. 1964. https://ci.nii.ac.jp/naid/10017204166
15. Horton RE. Erosion development in stream and their drainage basins. Geol Soc Am Bull. 1945;56:275-70. https://doi.org/10.1130/0016-7606(1945)56
16. Miller VC (1953) A quantitative geomorphologic study of drainage basin characteristics in the Clinch Mountain Area, Virginia and Tennessee. Project NR 389042, Technical Report, Columbia University, Department of Geology, ONR Geography Branch, New York. 1953.
17. Schumm SA. Geological Society of America Bulletin evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. Geol Soc Am Bull. 1956;67:597-646. https://doi.org/10.1130/0016-7606(1956)67
18. Strahler AN. Quantitative analysis of watershed geomorphology. Eos Trans Am Geophys Union. 1957;38:913-20. https://doi.org/10.1029/TR038i006p00913
19. Horton RE. Drainage-basin characteristics, Eos, Trans. Am. Geophys. Union. 1932;13:350-61. https://doi.org/10.1029/TR013i001p00350
20. Melton MA. An analysis of the relations among elements of climate, surface properties and geomorphology. Columbia Univ, New York. 1957. https://doi.org/10.21236/AD0148373
21. ElKashouty M. Watershed delineation and morphometric analysis using remote sensing and GIS mapping techniques in Qena-Safaga-Bir Queh, Central Eastern Desert. International Journal of Water Resources and Environmental Engineering. 2020;12(2):22-46. https://doi.org/10.5897/IJWREE2019.0896
22. Shrivastava L, Shashikant N, Rani R. GIS-based morphometric analysis of Pench River Basin. International Journal of Recent Scientific Research. 2017;8(5):16953-16959. https://doi.org/10.24327/IJRSR
23. Kale VS, Gupta A. Introduction to geomorphology. Calcutta: Orient Long- man Ltd. 2001.
24. Eze EB, Efiong J. Morphometric parameters of the Calabar river basin: Implication for hydrologic processes. J Geograph Geol. 2010;2(1):18-26. https://doi.org/10.5539/jgg.v2n1p18
25. Arefin R, Mohir M M I, Alam J. Watershed prioritization for soil and water conservation aspect using GIS and remote sensing: PCA-based approach at northern elevated tract Bangladesh. Applied Water Science. 2020;10:91. https://doi.org/10.1007/s13201-020-1176-5
26. Javed A, Khanday MY, Rais S. Watershed prioritization using morphometric and land use analysis parameters: a remote sensing and GIS based approach. J Geol Soc India. 2011;78:63-75. https://doi.org/10.1007/s12594-011-0068-6
27. MR R, C B, Achyuthan H. Quantitative analysis of the drainage and morphometric characteristics of the Palar river basin, Southern Peninsular India; using bAd calculator (bearing azimuth and drainage) and GIS. Geol Ecol Landscapes. 2019;3:295-307. https://doi.org/10.1080/24749508.2018.1563750
28. Adnan M S G, Dewan A, Zannat K, Abdallah A Y M. The use of watershed geomorphic data in flash flood susceptibility zoning: A case study of the Karnaphuli and Sanguriver basins of Bangladesh. Natural Hazards. 2019;99:425-48. https://doi.org/10.1007/s11069-019-03749-3
29. Thomas J, Joseph S, Thrivikramji K, Abe G, Kannan N. Morphometrical analysis of two tropical mountain river basins of contrasting environmental settings, the Southern Western Ghats, India. Environ Earth Sci. 2012;66:2353-66. https://doi.org/10.1007/s12665-011-1457-2
30. Bharath A, Manjunatha M, Tangadagi RB, Preethi S. Journal of Green Engineering (JGE) Environmental Assessment for Rainwater Harvesting at GITAM. Campus. 2020;10:1776-85.
31. Singh AP, Arya AK, Singh D Sen. Morphometric analysis of Ghaghara River basin, India, using SRTM data and GIS. J Geol Soc India. 2020;95:169-178. https://doi.org/10.1007/s12594-020-1406-3