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Manuscript ID:
IJWGAFES-2026-031003

DOI: 10.5281/zenodo.24578084

DOI Link:
https://doi.org/10.5281/zenodo.24578084

Volume: 3
Issue: 10
October
Year: 2026
E-ISSN: 3066-1552

Submitted: *08 Sept 2026*
Revised: *15 Sept 2026*
Accepted: *16 Oct 2026*
Published: *31 Oct. 2026*

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How to cite this article:
Dhote, A. R. (2026). An Integrated Remote Sensing and GIS-Based Approach for Quantitative Morphometric Analysis of the Purna River Basin in the Western Vidarbha Region of Maharashtra. International Journal of World Geology, Geography, Agriculture, Forestry and Environment Sciences, 3(10), 24–26. https://doi.org/10.5281/zenodo.24578084

An Integrated Remote Sensing and GIS-Based Approach for Quantitative Morphometric Analysis of the Purna River Basin in the Western Vidarbha Region of Maharashtra

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Abstract

Watershed planning plays a crucial role in sustainable management of land and water resources, especially in semi-arid regions facing water scarcity and land degradation. The present study demonstrates the application of Geographic Information System (GIS) and Remote Sensing techniques for watershed analysis and planning of the Purna River Basin located in the Western Vidarbha region of Maharashtra, India. Satellite imagery, Survey of India toposheets, and digital elevation models (DEM) were used to delineate the watershed and analyze its drainage characteristics. Various thematic layers such as drainage network, slope, elevation, and land use/land cover were generated using GIS tools. Morphometric parameters including linear, areal, and relief aspects were computed to understand the hydrological behavior and terrain characteristics of the basin. The results indicate that the Purna River Basin exhibits dendritic drainage patterns, moderate relief, and varying slope conditions influencing surface runoff and soil erosion. The integration of GIS and Remote Sensing proved to be effective for spatial analysis, data integration, and decision-making in watershed planning. The study highlights the usefulness of geospatial techniques in identifying priority areas for soil and water conservation measures and provides valuable inputs for sustainable watershed management in the Western Vidarbha region.

Keywords: *GIS; Remote Sensing; Watershed Planning; Morphometric Analysis; Drainage Characteristics; Purna River Basin; Western Vidarbha; Maharashtra*

Introduction

A watershed is a natural hydrological unit that drains surface runoff to a common outlet and forms the basic unit for land and water resource management. Effective watershed planning is essential for the sustainable utilization of water resources, soil conservation, and the reduction of land degradation. In recent years, Geographic Information Systems (GIS) and Remote Sensing (RS) techniques have become important tools for watershed analysis due to their ability to integrate spatial and non-spatial data and provide accurate information on drainage, terrain, and land-use characteristics.

The Western Vidarbha region of Maharashtra has a semi-arid climatic condition and experiences irregular rainfall and frequent water stress during the winter and summer seasons. Therefore, it is essential to efficiently utilize the surface runoff of the basin, for which scientific watershed studies are required. The Purna River, a tributary of the Tapi River, is characterized by varied topography and drainage conditions that influence surface runoff and groundwater recharge. Hence, the present study applies GIS and Remote Sensing techniques to analyze the watershed characteristics of the Purna River Basin for effective watershed planning and sustainable water resource management.

Study Area

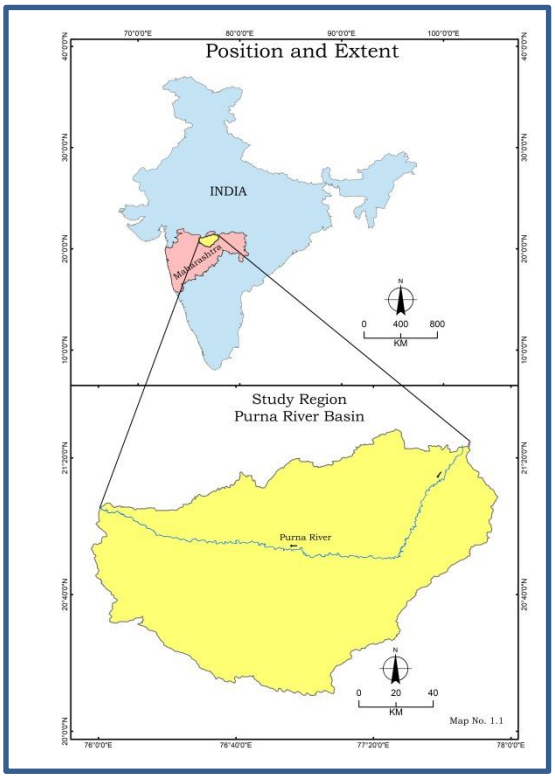
The Purna basin lies between 20° 8' 31" to 21°28'30" North latitude to 75° 58' 25" to 77° 56' 20"' East longitude. The Purna is the right bank tributary of the Tapi River. It drains the western part of Vidharbha region of Maharashtra stste. The Purna basin has an area of about 1786.44 km. The basin covers 32 talukas of five district of Maharashtra. The Twelve main rivers discharge their water in the Purna River. The shape of the Purna river basin is like a dish and on his northern side Melghat hills and southern side Ajanta hills. This basin is formed by the deposition of alluvial soil by the sub tributaries of Purna River. The tributaries of the Purna River have a very large catchment area. They create a dendritic drainage pattern. The east-west elongated basin exhibiting slight convexity towards the south and broad, easterly edge tapering towards the west constitutes a part of the Narmada-Tapi rift zone. It is bounded by Satpura Hill Range (Melghat Hill Range) in the north and Ajanta Hill Range in the south. The central part is a gently sloping alluvial plain, deposited by the Purna River and its tributaries.

The aggraded basin of Purna has twelve major tributaries, which develop a sub-parallel drainage pattern before their confluence with the main river. The Purna River basin has a monsoon climate is characterized by a hot summer and general dryness throughout the year except during the south-west monsoon season. In the Purna River basin, two types of soil traces created these are Shallow Coarse red and Alluvium soil. In the Northern part of this basin is shallow coarse soil and in the southern and central part of the basin is black soil is dominant.

Data Sources and Methodology

In Present paper for Topographical maps of 1:50,000 scale (SOI) No. 46P/13-14; 55C/4,8,11-12,15-16;55D/1 to 3,5, to 7,9, to 16; 55G / 3-4, 6 to 8,10 to 12, 14 to 16; 55H/ 1 to 7, 9-10,13 (1:50,000) and -LISS-III satellite imagery of April 2017 and November 2017.The Purna river basin is covered by Forty-eight LISS-III images. Digital Elevation Model (DEM) is an elevation data that is collected by transforming the contour maps to raster format by digitizing and surface analyzing. DEM, spatial resolution 30 meters data have been used for the geomorphological study.

Location Map:



Morphometric Parameters

Sr. No.	Parameter	Formula	Reference
Linear Aspects			
1	Stream Order (u)	Hierarchical Rank	Strahler(1994)
2	Stream Number (Nu)	Stream number with Stream order	Horton (1945)
3	Stream Length (Lu)	Length of the Stream	Horton (1945)
Areal Aspects			
1	Drainage Density (Dd)	D = A /Lu	Horton (1945)
2	Stream Frequency (Fs)	Fs = A/ Nu	Horton (1945)
3	Elongation ratio (Re)	Re=2√(A/Pi)/Lb	Schumm(1956)
4	Circularity ratio (Rc)	Rc=4*Pi*A/P2,	Strahler (1964)
5	Form factor (Ff)	Rf=A/Lb2	Horton (1945)
Relief Aspects			
1	Absolute Relief		Smith's (1935)
2	Relative Relief (Rr)		
3	Dissrction Index(DI)		Singh and Dubey (1994)

Results and Discussion (Morphometric Characteristics)

Stream order analysis of the Purna River Basin reveals a well-developed drainage network classified up to the **eighth order**, following **Strahler's stream ordering method.** The **Mun sub-watershed** records the highest number of first-order streams (6,258), indicating intense dissection and active erosion processes. Sub-watersheds such as **Utavli, Vishwamitri, and Nirguna** also exhibit comparatively longer stream lengths. Several sub-watersheds, including **Pedhi, Chandrabhaga, Shahanur, Wan, Purna, Nalganga, Biswa, and Morna,** fall within the **1,000–2,000 first-order stream segment** category.In hilly and undulating terrain, a higher number of short first-order streams are developed, whereas in plain areas with gentle slopes, higher-order stream segments become more prominent. Overall, the number and cumulative length of stream segments decrease with increasing stream order, indicating dominant surface runoff in the upper reaches of the basin.

The basin exhibits a **drainage density of 1.88 km/km²**, suggesting permeable subsurface material, intermediate drainage conditions, and low to moderate relief. Low stream frequency further supports favorable infiltration conditions. The **elongation ratio** of sub-watersheds ranges from **0.25 to 0.42**, and low **form factor values** indicate predominantly elongated basin shapes, which favor longer runoff duration and enhanced groundwater recharge.

Relief analysis shows that absolute relief varies from **203 m to 1,162 m**, with the maximum elevation of **1,188 m above mean sea level** observed in the **Satpura Hills**. Areas of **very low relative relief** cover **38.70% (6,882.53 km²)** of the basin, mainly in the central region, while moderately low relief zones are more prominent in the southern part of the basin.

Watershed Planning and Management Implications

The morphometric analysis indicates that the Purna River Basin is an **8th-order drainage basin** with a well-developed drainage network dominated by first-order streams, particularly in sub-watersheds such as the Mun basin. These areas, characterized by undulating and hilly terrain, are more prone to soil erosion and should be treated as **high-priority zones** for watershed intervention. Sub-watersheds with high cumulative stream length, including Man, Pedhi, Purna, Ghan, and Morna, require immediate soil and water conservation measures.

The **moderate drainage density (1.88 km/km²)** and low stream frequency suggest permeable subsurface conditions and favorable groundwater recharge potential. Hence, measures such as **check dams, contour bunding, gully plugging, and farm ponds** are recommended to reduce runoff and enhance recharge. Elongated basin shape, as indicated by low elongation ratio and form factor values, supports longer runoff duration, which can be effectively utilized through water harvesting structures.

Relief analysis shows that large areas of the basin have **very low to moderate relief,** making them suitable for agricultural development with moisture conservation practices, while moderately low relief areas require afforestation and vegetative measures. Overall, **GIS and Remote Sensing** provide an effective framework for prioritization and sustainable watershed management in the Purna River Basin.

Conclusion

This study shows that the Purna River Basin is an **8th-order drainage system** with a well-developed network, moderate drainage density, elongated basin form, and low to moderate relief, reflecting varied runoff and recharge conditions. The application of **GIS and Remote Sensing** proved effective for watershed delineation, morphometric analysis, and spatial assessment of basin characteristics. The results provide a scientific basis for identifying priority areas and implementing suitable soil and water conservation measures, supporting regional watershed planning in Western Vidarbha. The study highlights the importance of geospatial techniques for sustainable water resource management and offers scope for future research through integrated hydrological modeling and long-term watershed monitoring.

Acknowledgement

The author expresses sincere gratitude to the institution and academic mentors for their valuable guidance, encouragement, and support throughout this research. Special appreciation is extended to the organizations and agencies providing satellite imagery, Digital Elevation Model (DEM) data, topographical maps, and other geospatial resources essential for conducting the morphometric analysis of the Purna River Basin.

The author also acknowledges the contributions of researchers and scholars whose pioneering work in Remote Sensing, Geographic Information Systems (GIS), hydrological modelling, and watershed management provided a strong theoretical and methodological foundation for this study.

Financial support and sponsorship

Nil.

Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of thesis paper.

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