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Remote Sensing and GIS-Based evolution of drainage network in the VidArbha Region of Maharashtra (INDIA)

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ABSTRACT

Waterways provide valuable information for regional drainage, water movement on the surface, irrigation support and environmental planning. The present study introduces a GIS based spatial evaluation of the mapped water ways in Vidarbha region of Maharashtra. The analysis was based on the extraction, classification and quantification of linear hydrographic elements of rivers, streams, canals and drains. The spatial processing was done using GIS based spatial processing and the area class-wise composition, total mapped length and the hydrographic pattern of the area was examined. The waterway features mapped were primarily streams (2,316 features, total length ~15,343.61 km) with several smaller tributary and local drainage channels. Rivers had the greatest total mapped length, suggesting that they represent the most continuous drainage corridors. Only secondary managed-water features were canals and drains were a small percentage of the mapped network. Major rivers such as Penganga, Wardha, Purna, Wainganga and Pranhita were identified as the surface-water connectivity in the region. The mapped waterway density is estimated at 0.173 km per km² which represents a moderately developed waterway network. This study is helpful to illustrate the application of the GIS technique in analysing the distribution of water ways, dominance of water ways by the classes and the regional hydrographic structure. The results serve as a spatial basis for watershed planning, irrigation management, drainage assessment, understanding flood risks and environmental monitoring in Vidarbha region of Maharashtra.

Keywords: GIS; Waterway Network; Vidarbha Maharashtra; Hydrographic assessment; Drainage Mapping.

INTRODUCTION

Waterways are an integral component of regional hydrological and environmental systems. Surface-water movement, drainage connectivity, agricultural water availability, flood response and ecological processes are controlled by rivers, streams, canals, and other associated channels. The spatial distribution is used for land use, the growth of settlements, irrigation potential, the behaviour of the watershed and the planning of regions in terms of environment. The GIS-based evaluation of waterway networks has significance in the context of waterway network structure and distribution in the Vidarbha region of Maharashtra where natural drainage systems are juxtaposed with agricultural plains, forestry, settlements and managed water channels.

There have been recent developments in datasets that describe the characteristics of waterways at global levels, and the use of geospatial technologies has enhanced the mapping and analysis of waterway systems. drainage networks can be depicted with more spatial detail and consistency from high resolution hydrographic data. The importance of data products of river hydrographics, drainage structure and hydrological connectivity was highlighted by Amatulli et al. (2022). Likewise, Lin et al. (2021) demonstrated that the vector-based river-network data is helpful for marking the variable drainage density in various landscapes. These studies suggest that not only should waterways be assessed but smaller streams and connected drainage elements that affect the overall hydrographic pattern.

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In India, water-resource management is intricately linked with governance, public engagement, agriculture, ecological sustainability and regional development. Both government and public participation in water-resource management is an important factor, as noted by Vyas and Nath (2021). Philip (2024) further discussed the need for social and ecological approaches in the allocation of water resources, especially in relation to water security. These views illustrate that waterway mapping is more than a technical activity, it is a planning tool that may inform decision-making for water distribution, conservation and sustainable water resource use.

Water-resource assessment has been a key application of remote sensing and GIS over the past few decades, given that it can map, measure, classify and interpret spatial features across large areas. According to Jagadeesha and Manavalan (2025), Water management is assisted with geoinformatics-based water monitoring, modelling, planning and decision making. Tarate et al. (2024) also highlighted the significance of geospatial technology for water management in sustainable agriculture in India. The presence of surface water, drainage characteristics and irrigation networks are important factors in agriculture, and GIS-based waterway analysis can help to clarify the spatial association between natural channels and managed water systems.

There is a growing availability of open and global hydrographic datasets for regional studies of water ways. The authors Monteiro and Patrício (2024) showed that the available waterway information from OpenStreetMap can be used to assist in the analysis of hydrography and emphasized that this information may be incomplete in certain areas. This is significant in GIS based studies as the mapped waterway features are reliant on both quality and availability of source data. Hydro SHEDS and related datasets have also been used for hydrological and environmental studies. Zixi et al. (2025) raised the discussion of using Hydro SHEDS data for climate change and biodiversity studies, indicating that hydrographic can be used for much more than simply mapping rivers.

New research has also aimed at enhancing the quality of datasets of river networks by integrating multiple sources. Liu et al. (2025) shared a new River vector dataset for the entire globe, which was created by fusing multiple river data sources. This is significant because one dataset is unlikely to capture all the minor streams and seasonal channels or those locally altered. Despite these constraints, mapped hydrographic data are still useful to define the general spatial patterns, distribution of waterways by classes and length-related features of drainage systems.

Applications of GIS and remote sensing also include sustainable development and resource planning. From the perspectives of the government, industry and academia, Teja et al. (2026) explored the role of remote sensing and GIS in achieving Sustainable Development Goals in India. According to their study, geospatial information can be used to aid planning in water resources, agriculture, environmental monitoring and disaster management. Thus, spatial analysis of waterways could help to understand the drainage organization, surface-water connectivity and regional environmental management.

There exists a significant network of rivers, streams, canals and drains in Vidarbha region of Maharashtra that shape its hydrographic and land use structure. The use of GIS can assist in identifying the spatial distribution, class-wise composition, overall mapped length and the overall drainage pattern of these features. The primary goal of the present study is to evaluate the spatial distribution and structure of waterway network in Vidarbha region of Maharashtra with the help of GIS based approach. In particular the study is designed to undertake the following: to allocate waterways mapped to major categories, to compute the contribution of each waterway in terms of number of features and length, to identify important waterways by name and to interpret the overall waterway pattern of the area. This assessment can be helpful for watershed planning, water-resource management, irrigation support, understanding the flood risk, and environmental monitoring on a spatial basis.

METHODOLOGY

Geospatial Research Framework

In the present study, GIS based spatial assessment framework was used to explore distribution, structure and classification of water way networks in Vidarbha region of Maharashtra. The research used secondary vector geospatial information of linear hydrographic features including river, stream, canal and drain. GIS techniques

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were employed because they offer a systematic method for mapping, extracting, measuring and interpreting spatial features of a specified geographic area. For the analysis, the hydrographic data was accessed from the Western Zone India Geo Package dataset provided by Geofabrik GmbH (2026) which was built based on OpenStreetMap data. The prime methodology was to study spatial distribution of mapped waterways and to learn about the distribution pattern of waterways over the selected area.

Study Area Delineation

Vidarbha region of Maharashtra was chosen as the study area as it hosts an important system of natural and modified waterways that impact the regional connectivity, drainage, agriculture, water movement and settlement. The study area was restricted to the Vidarbha region of Maharashtra by using Administrative boundary data. Processed and interpreted only those waterways having a waterway feature within the defined study boundary. This has helped to exclude features beyond the defined geographical limits and ensured the final output were specific to the waterway network of Vidarbha region of Maharashtra.

Spatial Data Preparation and Standardization

The collected geospatial data were moved to a GIS environment for inspection, cleaning and processing. The coordinate reference system was checked before carrying out any measurement-based analysis. The spatial layers were reprojected when needed to a suitable projection for distance-based analysis as a projected coordinate system was required for the calculations of length and density. The waterway features were then clipped to the study-area boundary spatially. Invalid, duplicate, incomplete and irrelevant features were considered and discarded if necessary. This pre-processing step removed invalid linear waterway features from the final dataset that were not valid for classification, measurement and spatial interpretation.

Waterway Classification and Spatial Analysis

The waterway features were classified as major features (feature-class attributes) as rivers, streams, canals and drains. This classification was significant because it allows separating the larger waterways from the smaller drainage channels and natural or modified water-conveyance systems. The number of waterway features mapped in each category were summed to determine the distribution of waterway types relative to each other in the region. A length-based analysis was also performed by calculating the total waterway length (after projection) for each waterway class. These values were then compared class-wise to assess the predominant waterway types and what proportion of the waterway network they make up.

The spatial distribution analysis was performed to study the distribution and concentration of waterways in Vidarbha region of Maharashtra. To estimate waterway density the total length of waterways was compared to the area of the study region. This aided in the delineation of the relatively dense or sparse flow patterns. Named rivers and streams were also reviewed to aid in the interpretation of major hydrographic features. The analysis was conducted both quantitatively and visually, which involved the regional waterway system.

Map Preparation and Result Interpretation

The last step was the production of a classified GIS map, summary tables and spatial interpretations of the waterway network. A main map had been drawn to illustrate the distribution of rivers, streams, canals and drains within Vidarbha region of Maharashtra as separate cartographic representations to each class. The number of features and class wise distribution of water ways were presented with the help of supporting tables. The outcomes were related to drainage structure, surface-water connectivity and to a larger extent to the regional landscape characteristics. The results of this study are based on geospatial data mapped and recorded, and therefore are a GIS assessment of the mapped waterway features. The existing method offers a spatial framework for the study of the waterways of Vidarbha region of Maharashtra, which needs some ground verification at the seasonal level, but also on the local channels that have not been mapped and the hydrological variations that occur at the field level.

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RESULTS

Spatial Distribution of Waterway Networks

A total of 2,316 linear waterway features were mapped in Vidarbha region of Maharashtra and analyzing them in space revealed a total of 2,316 waterway features. The features were grouped under the following broad categories: Rivers, streams, canals and drains. This is represented in the spatial distribution of these waterways (see Figure 1) which indicate that the waterway network is extensive and the main waterways are mostly natural drainage entities.

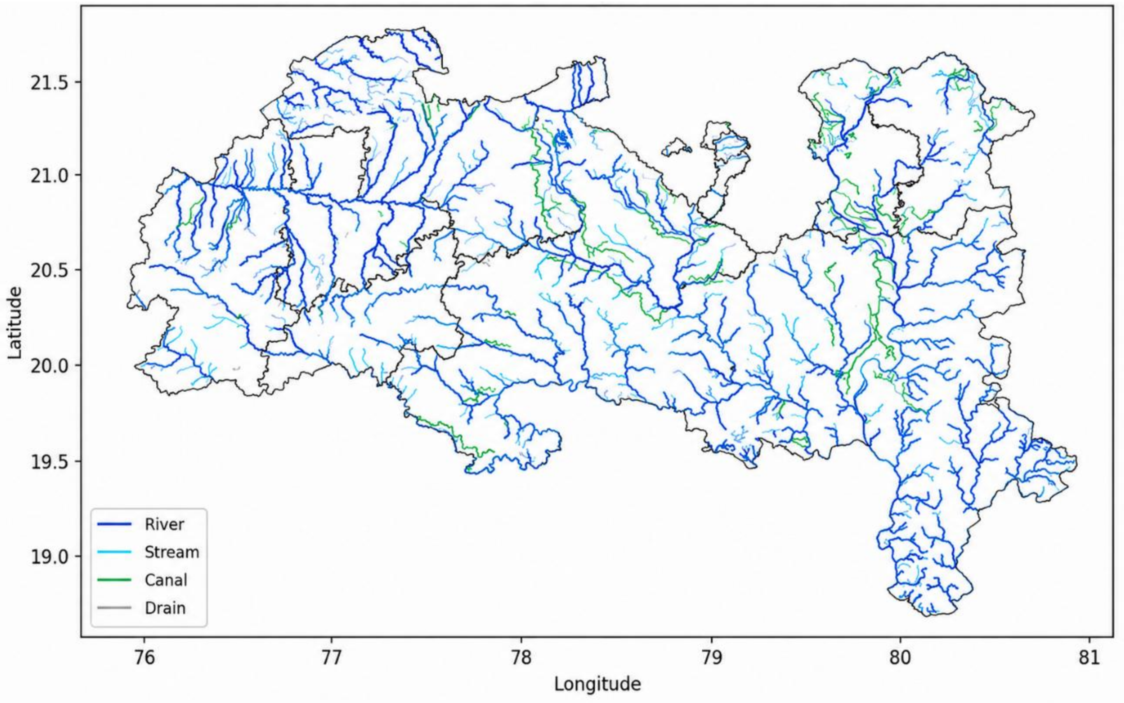

Figure 1. Spatial Distribution of Waterway Networks in Vidarbha Region of Maharashtra

Class-wise Composition of Waterway Features

The waterway network was divided into four main classes: river, stream, canal and drain. Streams were the most numerous of these features with a total of 942 features, representing 40.67% of all waterway features. The second largest group were rivers with 804 features (34.72%). The majority of features, 466, were canals, with the fewest, 104, being drains. As presented in Table 1, streams were the major waterway class followed by rivers, canals and drains.

Table 1. Class-wise Distribution of Mapped Waterway Features

Waterway class	Number of features	Feature share (%)
Stream	942	40.67
River	804	34.72
Canal	466	20.12
Drain	104	4.49

Length-based Distribution of Waterways

The length distribution of mapped waterways is shown in Table 2. Waterway length mapped in Vidarbha region of Maharashtra was around 15,343.61 km, out of which rivers accounted for the highest length of 10,291.20 km that is 67.07% of the total water way length mapped. Streams contributed 3,170.49 km, accounting for 20.66%.

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The area covered by canals was 1,840.46 km and drains was 41.46 km with the percentages of 11.99% and 0.27% respectively of the total length.

Table 2. Class-wise Length of Waterway Networks

Waterway class	Total length (km)	Mean length per feature (km)	Length share (%)
River	10,291.20	12.80	67.07
Stream	3,170.49	3.37	20.66
Canal	1,840.46	3.95	11.99
Drain	41.46	0.40	0.27

The length-wise comparison is further shown in Figure 2, where rivers clearly have the highest contribution to the total mapped waterway length.

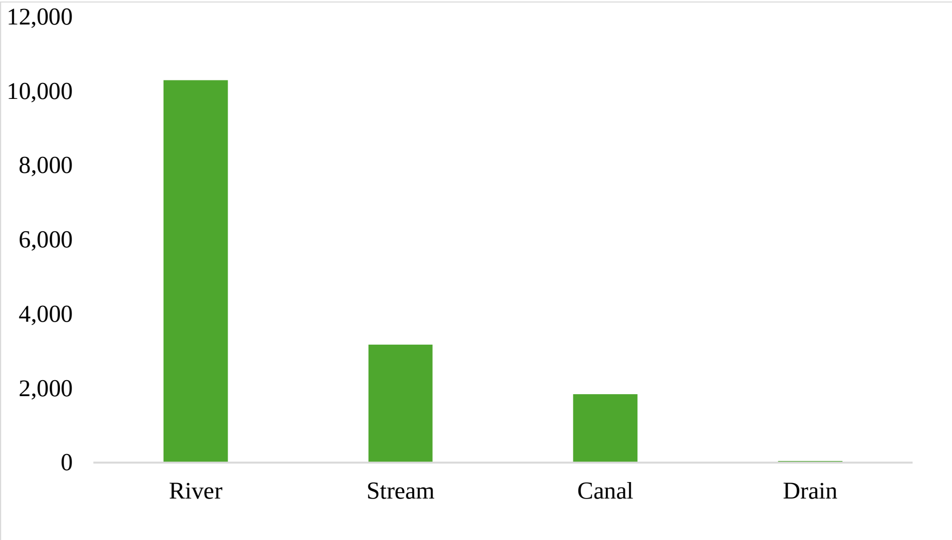

Figure 2. Class-wise Total Length of Mapped Waterways

Major Named Waterways

The waterways identified in the study area are given in Table 3. Of these, the Penganga River had the longest mapped length of 580.93 km in 32 mapped segments. Wardha River was the second largest named waterway with 432.78 km, on 12 segments. It was followed by Purna river (341.44 km) and Wainganga river (314.41 km).

Table 3. Major Named Waterways Identified in the Study Region

Rank	Named waterway	Class	Mapped segments	Total mapped length (km)
1	Penganga	River	32	580.93
2	Wardha	River	12	432.78
3	Purna	River	5	341.44
4	Wainganga	River	11	314.41
5	Adan	River	2	205.87
6	Bandia	River	1	139.47
7	Murna	River	1	124.34

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8	Katepurna	River	4	124.16
9	Pus	River	2	115.25
10	Pranhita	River	13	115.07

DISCUSSION

The natural drainage pattern of Vidarbha region of Maharashtra is quite strong and is mostly controlled by the major rivers and their associated stream networks. The waterway system that has been mapped does not represent all waterway classes equally, but rather indicates a distinction between the dominant natural channels and secondary local and managed drainage features. The pattern is important to understand the movement of surface water, watershed response, availability of water for agriculture and drainage connectivity across the region. The use of GIS-based interpretation is appropriate because drainage network is an entity that can be best understood from the spatial arrangement, channel length, channel density and classification of the features. This is corroborated by the study of Pande et al. (2021) which demonstrated the importance of remote sensing and GIS applications in the study of watershed characteristics in Maharashtra.

Streams are the largest number of features mapped in the study area indicating that there were many small drainage channels scattered throughout Vidarbha region of Maharashtra. These stream networks enable the transfer of water from lower order catchments to higher order streams and act as the conduit for local runoff movement. Their mean length however, is also low, suggesting they are primarily tributary or local drainage features and not the main hydrographic network. This difference needs to be recognized because watershed interpretation should not be based solely on drainage feature density. The drainage characteristics should also be interpreted considering length, density, spatial arrangement, connectivity and data quality (Shekar and Mathew, 2024).

The main spatial structure of the waterway network is given by rivers as they make up the highest percentage of the total mapped waterway length. Large rivers like Penganga, Wardha, Purna, Wainganga and Pranhita are important drainage channels and have a strong influence on surface-water connectivity in the region. They suggest that drainage system in Vidarbha region of Maharashtra is a long and continuous river system. These rivers not only do create the hydrographic network but also affect agricultural support, settlement patterns, regionally available water, and watershed behaviour.

A secondary but significant element of the mapped waterway network are canals. The presence of these shows the importance of water channels which are managed or modified in irrigation, agricultural water transport and local water distribution. While canals are not the predominant feature of the hydrographic system, their presence suggests some interaction between natural drainage features and human-controlled infrastructure for water-resource management. This is important because many agricultural landscapes rely on both natural systems of surface-water and managed water-distribution systems. Singh et al. (2023) also noted that the use of remote sensing and GIS-based watershed assessment is beneficial for land and water conservation planning.

The percentage of drains in the mapped network is the lowest of the mapped network. This could reflect a lack of spatial extent of formal drainage channels available from the available data, but could also imply underrepresentation of small local channels. It is challenging to capture all features of seasonal streams, minor drains, roadside channels and informal channels for run-off in secondary geospatial data. So, low drain values do not mean that there is no drainage feature. As mentioned by Pierson and Mehrabi (2024), water features can be identified better with more advanced methods like deep learning, especially for smaller features which are not always mapped.

The estimated waterway density indicates a moderately developed mapped drainage network. This indicates a hydrographic system that can be seen and measured in Vidarbha region of Maharashtra, but with local variations. Waterway density and distribution across the region could be affected by differences in topography, land use and vegetation cover, basin shape, geological setting, and completeness of mapping. Drainage density can be used to interpret run-off potential, surface-water connectivity, infiltration behaviour and watershed response. The purpose of the density value should be viewed as an indicator for the region, however, and not as a uniform value for the whole study area.

The results are relevant for watershed planning, irrigation management, understanding flood risk, and environmental monitoring. Because the main waterway structure is rivers and streams, planning should focus on natural drainage corridors and stream connectivity, riparian areas, and river-basin management. These characteristics are necessary for the continuity of surface-water flow, for minimizing drainage blockages, and for maintaining the ecological continuity. The canals need to be viewed in the context of managed water supply and agricultural water distribution. Thorleifson (2024) highlighted the general significance of spatial mapping in comprehending land and resource systems.

Water-related environmental mapping can be further enhanced by remote sensing and GIS. Yuan et al. (2025) highlighted the usefulness of remote sensing in mapping water-related environments and associated hydrological landscapes. This is significant as it can help future waterway studies of Vidarbha region of Maharashtra where vector data of waterways and satellite imagery can be used together to identify minor waterways, seasonal streams and in some places modified waterways.

The waterway system of Vidarbha region of Maharashtra is largely natural with long river stretches as the backbone and shorter river stretches for local drainage. Canals introduce an element of managed water and drains are still small in the mapped dataset. In future the assessment could be enhanced with the use of high resolution satellite imagery, field verification, seasonal flow information, as well as advanced mapping techniques. Such improvements would also improve the accuracy of identification of minor, seasonal and locally modified waterways and would make the waterway analysis more useful for watershed planning, irrigation support, flood assessment, and environmental management using the GIS.

CONCLUSION

The spatial assessment by GIS has been done and the results show that the waterways in Vidarbha region of Maharashtra are well defined and are mostly natural. The primary hydrographic system in the area is made up of rivers and streams; secondary hydrographic systems include canals and drains. It was found that streams were the most common waterway class mapped, indicating that there were many more of the smaller tributary and local drainage channels. But the total length mapped was the greatest for rivers, showing that these were the most important and continuous drainage courses. This difference in the number of features and feature lengths illustrate the importance of considering both distribution and spatial extent when evaluating waterway networks. The occurrence of important rivers like Penganga, Wardha, Purna, Wainganga and Pranhita also indicates that the drainage system of the region is based on big rivers. Canals help to have localised movement of water and also to control water distribution – especially for agricultural and irrigation purposes. Drains were a relatively small component of the mapped drainage network and this may be due to the lack of development of drainage network or small local drains being poorly mapped. The results show that the hydrographic structure of Vidarbha region of Maharashtra is river led and stream supported with medium waterway density mapped. The study is valuable from a spatial perspective for watershed planning, irrigation management, drainage assessment, understanding flood risk and environmental monitoring. A later study could be complemented by high-resolution satellite imagery as well as seasonal flow data and field verification, to get a more accurate representation of the minor, seasonal and locally modified waterways.

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