
**MONITORING THE CHARACTERISTICS OF REACH OF RIVER
YAMUNA USING REMOTE SENSING AND GIS**

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ABSTRACT:

Remote sensing and Geographic Information Systems (GIS) offer powerful tools for both quantitative and qualitative analyses of river morphology. This research focuses on the channel migration of the Yamuna River in North India, monitored from 1989 to 2022 using cloud-free Landsat images from the USGS. The analysis, conducted with Arc GIS 9.3, involved visualizing the satellite imagery and classifying it into water and non-water categories. The Digital Shoreline Analysis System (DSAS) was utilized to quantify river migration over a 50.2 km stretch through 1004 transects at 50-meter intervals. Findings indicate that the net shoreline movement (NSM) for the left shoreline is a maximum of 1535.53 m eastward and 1013.51 m westward, while the right shoreline shows a maximum NSM of 1631.74 m east and 992.48 m west. The endpoint rate (EPR) for the left shoreline is highest at 46.62 m/year east and 30.77 m/year west, with the right shoreline showing a maximum EPR of 69.89 m/year east and 42.81 m/year west. Finally, the linear regression rate (LRR) indicates a maximum of 46.18 m/year eastward and 28.14 m/year westward for the left shoreline, while the right shoreline records a maximum LRR of 72.33 m/year east and 44.08 m/year west.

KEYWORDS: Channel migration, Arc GIS, Satellite images, DSAS tool.

INTRODUCTION

River networks are often perceived as permanent features, yet they continually shift due to geomorphologic processes like bank erosion and point bar deposition. The Yamuna, India's second-largest tributary of the Ganges, illustrates these dynamics as it flows through several states, originating in the Himalayas. Bank erosion occurs when water's centrifugal force creates spiral flows that erode banks, while point bar deposition occurs when sediment accumulates outside the channel. Remote sensing and GIS technologies facilitate monitoring these changes, enabling analysis of large areas and inaccessible regions. However, remote sensing also comes with challenges, such as requiring specific skills for image interpretation. This study aims to assess the morph metric characteristics and migration patterns of the Yamuna in Delhi and nearby regions, focusing on flood risks exacerbated by climate change. Key objectives include using remote sensing data to evaluate river characteristics, calculate migration, and visually represent these changes.

LITERATURE REVIEW

Remote sensing and Geographic Information System (GIS) techniques have become essential tools for environmental monitoring, river analysis, land degradation assessment, and water quality management. Several researchers have demonstrated the effectiveness of geospatial technologies in studying dynamic environmental processes.

[1] Remote Sensing and Geographic Information System were effectively applied by Xiaojun Yang et al. (1999) to analyze channel migration changes in the Yellow River Delta. Their study highlighted the usefulness of satellite imagery in identifying river channel shifts and understanding deltaic geomorphological changes over time. The integration of GIS with remotely sensed data improved the accuracy of spatial analysis and supported river management planning.

[2] Reddy et al. (2002) conducted a geomorphological analysis of degraded lands in a basaltic river basin using remote sensing and GIS techniques. The study demonstrated that geospatial tools are highly efficient for mapping degraded lands, soil erosion zones, and watershed characteristics. Their findings emphasized the importance of satellite data in sustainable land resource management and environmental planning.

[3] Ritchie et al. (2003) reviewed various remote sensing techniques for assessing water quality parameters such as turbidity, chlorophyll concentration, and suspended sediments.

The authors concluded that remote sensing offers a cost-effective and rapid method for large-scale water quality monitoring compared to conventional field-based sampling methods.

[4] Singh et al. (2010) investigated the impact of land-use and land-cover changes on groundwater quality in the Lower Shiwalik Hills using GIS and remote sensing approaches. Their research established a strong relationship between changing land-use patterns and groundwater contamination, highlighting the importance of spatial analysis in environmental protection and groundwater management.

[5] Islam (2010) applied remote sensing and GIS techniques to study river channel migration processes. The study demonstrated that temporal satellite imagery can effectively detect riverbank erosion, channel shifting, and sediment deposition. The research also emphasized the importance of geospatial technologies for river hazard assessment and floodplain management.

[6] Lam-Dao et al. (2011) analyzed land-use and riverbank changes in the Mekong Delta using time-series remotely sensed data. Their findings revealed significant riverbank erosion and land-use transformation due to urbanization and natural hydrological processes. The study highlighted the usefulness of multi-temporal satellite data in monitoring environmental changes.

[7] Chebud et al. (2012) combined remote sensing techniques with artificial neural networks for water quality monitoring. Their research demonstrated that integrating advanced computational models with satellite observations can improve the prediction accuracy of water quality parameters. The study contributed significantly to the development of intelligent environmental monitoring systems.

[8] Somvanshi et al. (2012) used an integrated remote sensing and GIS approach to analyze the water quality of the Gomti River. The study identified pollution-prone areas and demonstrated the effectiveness of geospatial techniques for river water quality assessment and management.

MATERIALS AND METHODOLOGY

STUDY AREA

The Yamuna River, also known as the Jumna, originates from the Yamunotri Glacier in the Himalayas and is the major tributary of the Ganges River. The river flows through several

Indian states including Uttarakhand, Himachal Pradesh, Haryana, Delhi, Uttar Pradesh, Rajasthan, and Madhya Pradesh before joining the Ganges at Prayag in Allahabad. The upper part of the river has a steep gradient and strong erosive force, which forms deep valleys in the Lesser Himalayas. Several tributaries such as Tons, Chambal, Hindon, and Sind join the main river system. According to Bawa et al. (2014), the Yamuna Basin can be divided into high-energy natural upper reaches, human-modified middle reaches, and rejuvenated lower reaches. The basin covers an area of about 366,000 km² and receives annual rainfall ranging from 400 mm to 2000 mm, mainly during the monsoon season. Most parts of the river are alluvial in nature and continuously deposit sediments along the floodplains. Geomorphic features identified through satellite imagery include paleo-channels, floodplains, ridges, depressions, and salt-affected zones. Sinha et al. (2005) reported that tectonic uplift and erosion in the Himalayan region caused heavy sediment production and frequent flooding in the lower Yamuna basin. Due to variations in stream power and sediment load, the river forms bars, bends, and migrating channels. The present study area covers a 50.2 km stretch of the Yamuna River from Bhagpat on the Uttar Pradesh–Haryana border to the Okhla Barrage in Delhi.



Figure 1. Shows study area.

The study utilizes freely available satellite data from the USGS website, specifically using Landsat imagery from different years: Landsat 5 Thematic Mapper from 1989, Landsat 7 from 2001, Landsat 8 from 2013, and Landsat 9 from 2022, all with a resolution of 30 meters. Table 3.4 illustrates the data utilized in the present research. The process involves applying atmospheric and geometric corrections prior to extracting water bodies from the satellite images.

Landsat 5 and Landsat 7 include seven spectral bands (B1 to B7), while Landsat 8 and Landsat 9 comprise eleven bands (B1 to B11). Each band captures different colors and wavelengths, necessitating specific combinations of bands for effective data extraction. For water body extraction, composite images using Band 3, Band 4, and Band 5 are constructed, leveraging their respective resolutions, as the 30m resolution is deemed sufficient for the study's requirements.

The Thematic Mapper (TM) sensor onboard Landsat 5 was designed to collect multispectral images of the Earth’s surface for environmental monitoring, land-use mapping, agriculture, geology, forestry, and water resource studies. Landsat 5 was launched in 1984 and operated for nearly 29 years, making it one of the longest-running Earth observation satellites.

The TM sensor captures data in seven spectral bands ranging from visible light to thermal infrared. Most bands have a spatial resolution of 30 meters, while the thermal band has a resolution of 120 meters that is commonly resampled to 30 meters for analysis.

Table .1. Bands, wavelength and resolution of Landsat 5.

Landsat5ThematicMapper(TM)		
Landsat 5	Wave length (micrometers)	Resolution (meters)
Band1 – Blue	0.45-0.52	30
Band2 – Green	0.52-0.60	30
Band3– Red	0.63-0.69	30
Band4-NearInfrared(NIR)	0.76-0.90	30
Band5-ShortwaveInfrared(SWIR)1	1.55-1.75	30
Band6– Thermal	10.40-12.50	120(30)
Band7-ShortwaveInfrared(SWIR)2	2.08-2.35	30

DSAS ANALYSIS FOR RIVER MIGRATION

This study calculated changes in water migration using the Digital Shoreline Analysis System (DSAS) tool, a free application developed in ArcGIS that predicts and measures statistical differences in coastline change, useful for migration studies. Required inputs for DSAS include long-year river polyline and user guide points, with a focus on the migration of the Yamuna River in the study area. The left and right shorelines and a baseline were established from the water segment of 1989, allowing for perpendicular projections of slices based on user-defined guides. Sections of lengths between 2500 m were sampled at 50 m intervals, determined by accuracy needs and required detail, resulting in 1004 sections for analysis. DSAS employs methods such as Net Shoreline Movement (NSM), Linear Regression Rate (LRR), and End Point Rate (EPR) for measurement. NSM calculates the distance between the oldest and youngest shoreline locations, while LRR uses least squares regression to account

for all data over the years to measure long-term river changes. EPR is the distance from the streamline divided by the time elapsed between the oldest and most recent measurements.

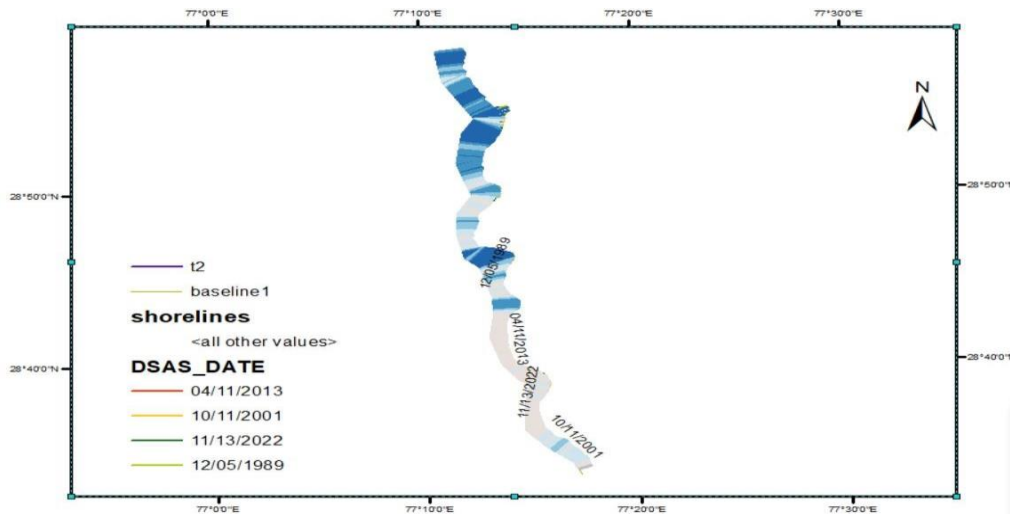


Figure 2. Transectsat 50m interval on left shoreline.

RESULT AND DISCUSSION

➤ NET SHORE LINE MOVEMENT (NSM)

The study focused on the Net Shoreline Movement (NSM) from 1989 to 2022 and used the DSAS tool to quantify the distance between the earliest and latest river profile places. With positive NSM values denoting eastward movement and negative values denoting westward movement, the study reveals considerable migration in the river meanders. The findings highlight the dynamic character of the river's border as seen by the DSAS approach and demonstrate that there has been significant movement of the river meanders during the studied time.

➤ LEFT SHORELINE MOVEMENT

For 1004 transects of the research region, the average net shoreline movement for the left coastline is 10.9013 meters. The standard deviation is 410.63 meters, and the negative value denotes westward progress. At 474 transects, or 23.7 kilometers downstream from Bhagpat, Haryana, the highest eastward migration is 1535.53 meters. 10.3 km downstream from Bhagpat, Haryana, the greatest westward migration is 1013.51 mat 206 transects. Up to transects 510, large-scale movement is visible. The graph between the NSM of the left coast and transects that are cast at 50-meter intervals is displayed in Figure3.

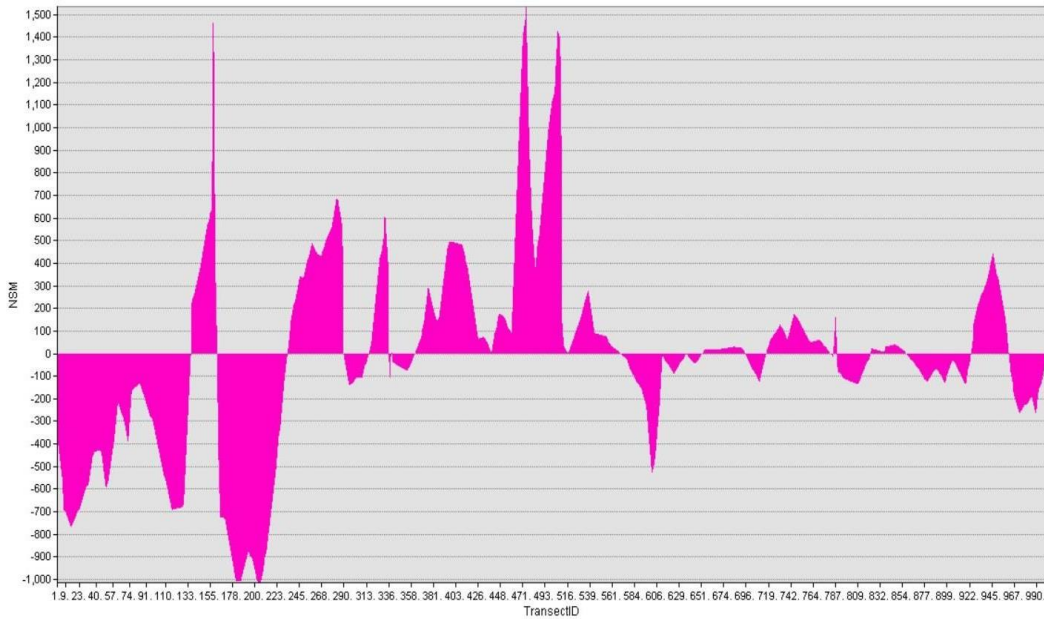


Figure 3. Graph between Left Net shoreline movement and transects.

➤ **RIGHT SHORELINE MOVEMENT**

For 1003 transects of the research region, the average net shoreline movement for the left coastline is 59.96 meters, with a standard deviation of 390.4059 meters. At 474 transects, or 23.7 kilometers downstream from Bhagpat, Haryana, the highest eastward migration is 1631.74 meters. At 204 transects, or 10.2 kilometers downstream from Bhagpat, Haryana, the highest westward migration is 992.48 meters. Up to transects 507, large-scale movement is seen. The right shore NSM and transects, which are cast at 50-meter intervals, are displayed in Figure 4.

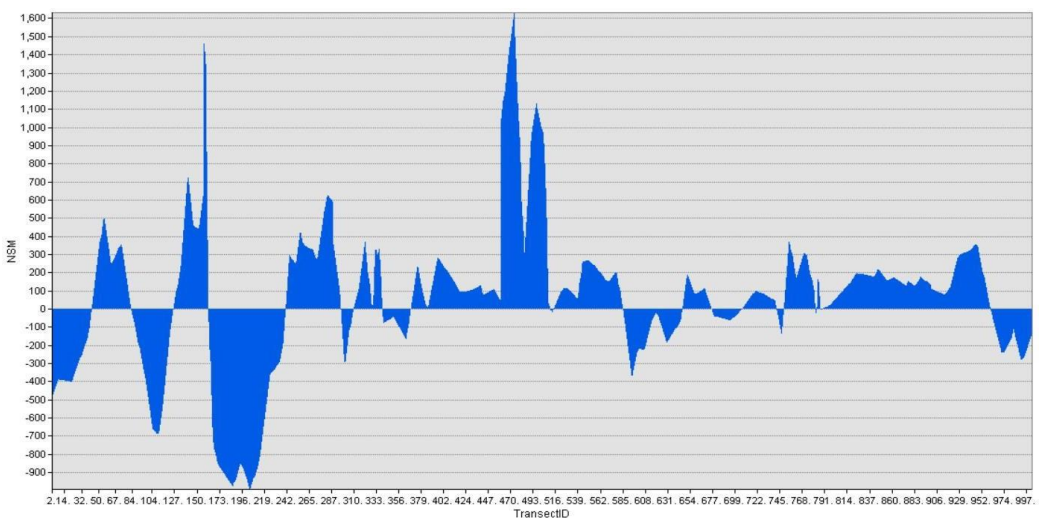


Figure4... Graph between Right Net shoreline movement and transects.

CONCLUSION

The study area extends from Baghpat to Okhla Barrage, where the migration characteristics of the river reach were analyzed. The Net Shoreline Movement (NSM) analysis of the left shoreline revealed a maximum eastward migration of 1535.53 m at transect 474, while the maximum westward migration was 1013.51 m at transect 206. Similarly, the right shoreline recorded a maximum eastward migration of 1631.74 m at transect 474 and a maximum westward migration of 992.48 m at transect 204.

The End Point Rate (EPR) analysis indicated that the left shoreline experienced a highest eastward migration rate of 46.62 m/year at transect 474, whereas the maximum westward migration rate was 30.77 m/year at transect 206. For the right shoreline, the highest eastward EPR was observed at transect 474 with 69.89 m/year, while the maximum westward rate reached 42.811 m/year at transect 204.

The Linear Regression Rate (LRR) results also demonstrated significant channel migration. The left shoreline showed a maximum eastward LRR of 46.18 m/year at transect 474 and a maximum westward LRR of 28.14 m/year at transect 206. In the case of the right shoreline, the highest eastward LRR was 72.33 m/year at transect 474, while the greatest westward migration rate was 44.08 m/year at transect 204. Detailed information regarding left and right shoreline movements for each transect is provided in Appendix 1.

The analysis suggests that intense river migration occurred up to transect 510, corresponding to nearly 25.5 km downstream from Baghpat. The river channel in the region between Haryana and Uttar Pradesh is highly unstable and exhibits substantial lateral migration. In contrast, the river profile within Delhi remains comparatively stable.

FUTURE SCOPE OF THE STUDY

The study on monitoring the characteristics of the Yamuna River using Remote Sensing and GIS can be further extended in several directions to improve river management, flood control, and environmental sustainability. Some important future scopes are as follows

- **Use of High-Resolution Satellite Data**

Future studies can utilize high-resolution satellite imagery from advanced sensors for more accurate mapping of riverbank erosion, channel migration, and floodplain changes. This will improve the precision of shoreline and geomorphologic analysis.

- **Integration of UAV and Drone Survey**

Drone-based surveys may be integrated with GIS and remote sensing techniques to generate detailed topographic and river morphology data for small-scale and real-time

monitoring.

- **Application of Machine Learning and Artificial Intelligence**

Artificial Intelligence (AI) and Machine Learning (ML) techniques can be applied for automatic detection of river migration patterns, erosion-prone zones, and flood risk prediction.

- **Long-Term River Dynamics Analysis**

Future research can include longer temporal datasets to understand long-term geomorphic changes, sediment transport, and climate change impacts on the river system.

- **Flood Hazard and Risk Mapping**

GIS-based flood inundation models may be developed to identify vulnerable settlements, agricultural land, and infrastructure along the Yamuna River corridor.

- **Sediment Transport and Water Quality Assessment**

Further studies can combine hydrological data with remote sensing techniques to analyze sediment load, pollution levels, and water quality variations in different stretches of the river.

- **Development of Decision Support Systems**

A GIS-based decision support system can be developed for planners and government agencies to support river training works, embankment planning, and disaster management.

- **Impact of Urbanization and Land Use Change**

Future investigations may focus on the influence of rapid urbanization, industrial development, and land use/land cover changes on river morphology and ecological conditions.

- **Climate Change Impact Assessment**

Climate variability and changing rainfall patterns can be studied to evaluate their effects on river discharge, flooding frequency, and channel instability.

- **Real-Time Monitoring System**

Integration of remote sensing, GIS, IoT sensors, and GPS technologies can help establish a real-time river monitoring and early warning system for sustainable river basin management.

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