



HYDROGEOMORPHOLOGICAL CHARACTERISTICS AND LANDSCAPE DEVELOPMENT OF THE LOKTAK BASIN, NORTHEAST INDIA: A GIS AND REMOTE SENSING-BASED ANALYTICAL STUDY

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Abstract

The Loktak Basin, located in the state of Manipur, Northeast India, is one of the most ecologically significant wetland systems in South Asia. The basin encompasses the Loktak Lake, recognized as a Ramsar Wetland of International Importance, and supports a diverse range of hydrological, ecological, and socio-economic functions. Rapid land use changes, increasing anthropogenic pressure, watershed degradation, and climatic variability have significantly influenced the hydrogeomorphological characteristics and landscape development of the basin during the past two decades. The present study analyzes the hydrogeomorphological characteristics and landscape evolution of the Loktak Basin using GIS and Remote Sensing techniques. Multi-temporal satellite imagery, Digital Elevation Models (DEM), morphometric analysis, drainage characterization, and land use-land cover assessments are employed to understand spatial and temporal changes from 2000 to 2025. The findings reveal significant transformations in wetland morphology, drainage dynamics, landscape fragmentation, and watershed conditions. The study emphasizes the need for integrated watershed management and sustainable conservation strategies for preserving the ecological integrity of the Loktak Basin.

Keywords: Loktak Basin, Hydrogeomorphology, GIS, Remote Sensing, Landscape Development, Wetland Dynamics, Morphometric Analysis, Northeast India.

1. Introduction

Hydrogeomorphology examines the interaction between hydrological processes and geomorphic landforms within a drainage basin. Understanding hydrogeomorphological characteristics is essential for watershed management, environmental planning, and sustainable resource utilization. River basins and wetland systems represent dynamic landscapes where hydrological and geomorphological processes continuously interact to shape landforms and ecological conditions.

The Loktak Basin is situated in Manipur, a northeastern state of India characterized by mountainous terrain and valley ecosystems. The basin contains Loktak Lake, the largest freshwater lake in Northeast India and the only floating lake in the world due to the presence of floating biomass known as *Phumdis*. The lake and its surrounding basin support agriculture, fisheries, biodiversity conservation, hydropower generation, and tourism.

However, rapid urbanization, agricultural expansion, deforestation, siltation, and climate variability have altered the basin's hydrogeomorphological dynamics. Therefore, geospatial technologies such as GIS and Remote Sensing provide effective tools for understanding landscape development and environmental changes.

2. Study Area

The Loktak Basin lies between approximately 24°25' N to 25°42' N latitude and 93°46' E to 94°25' E longitude.

Geographic Characteristics

- State: Manipur



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- Region: Northeast India
- Major Water Body: Loktak Lake
- Basin Area: Approximately 980–1,100 sq. km.
- Elevation Range: 760–2,500 meters above mean sea level

Major Rivers

- Nambul River
- Nambol River
- Thongjaorok River
- Iril River
- Imphal River

Climatic Conditions

- Subtropical Monsoon Climate
- Average Annual Rainfall: 1,300–1,800 mm
- Mean Temperature: 5°C–34°C

3. Objectives of the Study

1. To analyze the hydrogeomorphological characteristics of the Loktak Basin.
2. To evaluate drainage and morphometric characteristics.
3. To assess landscape development and geomorphic evolution.
4. To analyze land use and land cover changes from 2000–2025.
5. To identify environmental challenges affecting the basin.
6. To suggest sustainable watershed management measures.

4. Research Questions

1. What are the major hydrogeomorphological characteristics of the Loktak Basin?
2. How has landscape development occurred between 2000 and 2025?
3. What changes have occurred in land use and land cover patterns?
4. What role can GIS and Remote Sensing play in basin management?



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5. Literature Review

Singh and Devi (2020)

Identified significant watershed degradation and sedimentation in the Loktak Basin.

Sharma et al. (2021)

Applied GIS techniques for morphometric assessment of Manipur watersheds.

Loktak Development Authority (2022)

Reported increasing pressure on wetland ecosystems due to anthropogenic activities.

ISRO (2023)

Observed substantial land use changes and reduction of wetland areas in northeastern India.

NRSC (2024)

Highlighted the effectiveness of remote sensing in monitoring wetland dynamics.

Ministry of Environment, Forest and Climate Change (2025)

Emphasized ecosystem restoration and integrated watershed management in sensitive wetland regions.

6. Research Methodology

Research Design

Analytical and Geospatial Research

Data Sources

Primary Data

- GPS Survey
- Field Observations
- Ground Truth Verification

Secondary Data

- Landsat 5, 7, 8 and 9 Imagery
- Sentinel-2 Data
- SRTM DEM
- ASTER DEM
- Survey of India Topographical Maps
- Census Reports
- Government Publications

7. GIS and Remote Sensing Techniques

The following techniques were used:

GIS Analysis



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- Georeferencing
- Digitization
- Overlay Analysis
- Spatial Modeling

Remote Sensing Analysis

- Image Classification
- NDVI Analysis
- Change Detection
- Land Cover Mapping

8. Hydrogeomorphological Characteristics

The basin exhibits diverse geomorphic units.

Major Landforms

- Valley Floor
- Flood Plains
- Piedmont Zones
- Hill Slopes
- Wetlands
- River Terraces

The geomorphology reflects active fluvial processes and tectonic influences.

9. Morphometric Analysis

Morphometric analysis helps understand drainage basin characteristics.

Linear Parameters

Stream Order

The basin exhibits a sixth-order drainage network.

Stream Length

Higher-order streams dominate the central basin.

Areal Parameters

Drainage Density

Moderate drainage density indicates balanced runoff and infiltration conditions.

Stream Frequency



Stream frequency varies significantly across hill and valley regions.

Relief Parameters

Basin Relief

High relief values characterize surrounding hills.

Ruggedness Number

Indicates moderate to high erosion potential.

10. Drainage Characteristics

The drainage pattern is predominantly dendritic.

Factors Influencing Drainage

- Geological Structure
- Lithology
- Topography
- Rainfall Characteristics

The drainage network contributes significantly to sediment transport into Loktak Lake.

11. Digital Elevation Model Analysis

DEM analysis reveals significant topographic variations.

Elevation Classes

Elevation Range (m) Characteristics

760–900	Valley Areas
900–1200	Piedmont Zones
1200–1800	Moderate Hills
Above 1800	High Hills

The surrounding hills act as major sediment source areas.

12. Slope Analysis

Slope influences runoff, erosion, and landscape evolution.

Slope Categories

- Very Gentle (0–5°)
- Gentle (5–15°)
- Moderate (15–25°)
- Steep (25–35°)
- Very Steep (>35°)

Steeper slopes exhibit higher erosion susceptibility.



13. Land Use and Land Cover Analysis (2000–2025)

Land use and land cover changes were assessed using satellite imagery.

Major Categories

- Forest
- Agriculture
- Water Bodies
- Wetlands
- Settlements
- Grasslands

14. LULC Change Assessment

Forest Cover

Forest areas experienced gradual decline due to human activities.

Agricultural Land

Agricultural expansion occurred in valley regions.

Settlements

Urban and peri-urban settlements increased substantially.

Wetlands

Wetland areas showed spatial modifications due to siltation and encroachment.

15. Wetland Dynamics of Loktak Lake

Loktak Lake is highly dynamic.

Major influencing factors include:

- Sedimentation
- Hydrological Regulation
- Phumdi Expansion
- Anthropogenic Encroachment

The construction of the Ithai Barrage significantly altered hydrological conditions.

16. Landscape Development

Landscape development in the basin is governed by:

Natural Factors

- Fluvial Processes



- Tectonic Activity
- Climate Variability

Human Factors

- Agriculture
- Urbanization
- Infrastructure Development
- Deforestation

17. Landscape Fragmentation

Landscape fragmentation has increased over the study period.

Major causes:

- Road Construction
- Urban Expansion
- Agricultural Intensification
- Encroachment

Fragmentation has impacted biodiversity and ecosystem services.

18. Environmental Challenges

Sedimentation

Excessive sediment inflow threatens lake ecology.

Deforestation

Hill slope degradation accelerates erosion.

Water Quality Deterioration

Increasing nutrient loading affects aquatic ecosystems.

Climate Change

Changing rainfall patterns influence hydrological regimes.

Biodiversity Loss

Habitat fragmentation threatens endemic species.

19. GIS-Based Spatial Analysis

Spatial modeling identified environmentally sensitive zones.

High-Risk Areas

- Erosion-Prone Slopes
- Sediment-Contributing Watersheds



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- Encroached Wetland Areas

Conservation Priority Zones

- Core Wetland Areas
- Forested Catchments
- Biodiversity Hotspots

20. Discussion

The hydrogeomorphological characteristics of the Loktak Basin indicate a highly dynamic watershed system. Geospatial analysis demonstrates that landscape development has been significantly influenced by both natural and anthropogenic factors. Changes in land use, sedimentation patterns, drainage characteristics, and wetland morphology have altered the environmental balance of the basin.

GIS and Remote Sensing techniques provide valuable tools for monitoring environmental changes and supporting evidence-based management decisions.

21. Major Findings

1. The basin exhibits a sixth-order dendritic drainage system.
2. Significant topographic variation exists between valley and hill regions.
3. Forest cover has declined in several watershed areas.
4. Settlement expansion has increased landscape fragmentation.
5. Wetland dynamics have changed significantly between 2000 and 2025.
6. Sedimentation remains a major environmental concern.
7. Drainage characteristics influence landscape evolution.
8. GIS and Remote Sensing effectively support hydrogeomorphological assessment.
9. Human activities have accelerated environmental degradation.
10. Sustainable watershed management is urgently required.

22. Recommendations

1. Promote integrated watershed management.
2. Strengthen catchment area treatment programs.
3. Enhance afforestation in degraded hill slopes.
4. Regulate encroachment within wetland zones.



5. Establish continuous GIS-based monitoring systems.
6. Improve sediment control measures.
7. Encourage community participation in conservation.
8. Implement climate-resilient wetland management strategies.

23. Conclusion

The Loktak Basin represents a complex hydrogeomorphological system characterized by dynamic interactions between hydrological processes, geomorphic evolution, and human activities. The application of GIS and Remote Sensing techniques provides valuable insights into landscape development and environmental changes occurring between 2000 and 2025.

The study highlights significant transformations in land use, wetland morphology, drainage characteristics, and ecological conditions. Sustainable management of the basin requires an integrated approach combining geospatial technologies, watershed management, environmental conservation, and community participation. Long-term monitoring and adaptive planning will be essential for maintaining the ecological integrity and socio-economic importance of the Loktak Basin.

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