

Assessment of the Impact of Human Activities on the Degradation of Lake Ecosystems Using Remote Sensing and GIS

ABSTRACT

Loktak Lake, situated in Manipur, India, is a globally recognized Ramsar wetland site due to its ecological and socio-economic significance. The lake provides a habitat for diverse species and sustains the livelihoods of local residents. However, it is currently facing sustainability challenges due to increasing human activities. This research examines the environmental health of Loktak Lake by assessing the impacts of these activities through multiple methods. Remote sensing and GIS analysis reveal a rise in agricultural and urban development, as well as deforestation, which have collectively led to a reduction in the lake's area and a decline in water quality. Socio-economic surveys conducted among 20 households indicate that approximately 70% of respondents depend solely on fishing for their livelihood, underscoring the lake's importance. However, this heavy reliance has led to overexploitation and resource degradation. Unsustainable agricultural practices, excessive fishing, and improper waste disposal are identified as major human-induced threats. Among waste disposers, 15% admitted to discarding garbage in uncontrolled areas or near the lake, contributing to the rising water pollution reported by 57.1% of respondents. Additionally, 14.3% observed a loss of native species. These findings reveal a harmful cycle where ecological degradation adversely impacts both the broader environment and the local communities dependent on the lake. Therefore, urgent conservation strategies are needed, with particular focus on effective solid waste management and sustainable resource use.

Keywords: Socio-economic, livelihood, water pollution, Remote sensing and GIS.

1. INTRODUCTION

India is one of the twelve mega-biodiversity countries in the world, with the Western Ghats and the North East recognized as global biodiversity hotspots. Manipur, a mountainous state in the North East, is endowed with rich wetlands and biodiversity, supporting a large population that depends on these resources for their livelihood. Often described as the 'Jewel of India,' the state's lifeline is Loktak Lake.

Manipur has two major river basins—the Manipur River Basin and the Barak River Basin. The Manipur River Basin sustains a wide variety of wetlands, locally known as *pats*. Altogether, the state has 155 wetlands covering an area of 47,020 hectares, which constitutes about 2.1% of its geographical area. While most wetlands are concentrated in the valley districts, two man-made reservoirs are located in the hill districts of Senapati and Tamenglong. Among them, Loktak Lake stands out as the largest wetland in Northeast India. Loktak Lake holds immense socio-economic and cultural significance for Manipur. As the largest natural freshwater lake in Northeast India, it sustains both the ecological balance and the livelihoods of surrounding communities. Rich in biodiversity, it was designated as a Wetland of International Importance under the Ramsar Convention in 1990. On its southern fringes lies Keibul Lamjao National Park—the world's only floating wildlife sanctuary and the last natural habitat of the critically endangered Sangai deer (brow-antlered deer). The lake

also functions as a vital breeding ground for riverine fish, supports a thriving fishery industry, and provides habitat for a diverse array of migratory and resident waterfowl

Loktak Lake is increasingly threatened by various human-induced activities. Deforestation and shifting cultivation in the catchment areas have accelerated soil erosion, resulting in excessive siltation. The problem is further aggravated by the uncontrolled proliferation of floating vegetation, locally known as *phumdis*. In addition, nutrient runoff from agricultural fields, discharge of untreated domestic sewage from Imphal through the Nambul River, and pesticide contamination have severely impacted the lake's ecological health. Encroachments for fishponds, road construction, and human settlements have further disrupted its natural ecosystem. The situation has been compounded by artificial hydrological interventions, particularly the construction of the Ithai Barrage at the lake's southern end. These alterations, coupled with vegetation loss in the catchment, have intensified siltation, nutrient loading, and the overall ecological degradation of the lake.

The purpose of this study is to develop a methodology for assessing the degradation state of lake ecosystems in Loktak Lake using Geographic Information System (GIS) techniques. This methodology can also be applied more broadly, regardless of lake type or location. Specifically, the study aimed to 1) To identify major human activities contributing to the environmental degradation of loktak lake. 2)To evaluate the socio-economic dependence of local communities on Loktak Lake and its role in ecosystem degradation.

622. MATERIALS AND METHODS

63 2.1 STUDY AREA

Loktak Lake is a floodplain wetland of Manipur River located between 93° 46' and 93° 55' E, and from 24° 25' to 24° 42' N. The location floods because of the lateral flows, and it receives water through back flow from Sugunu hump as well. Likewise, the confluence of several rivers, the oval-shaped lake has an extreme length and width of 32 km and 13 km, respectively. The depth of the lake varies from 0.5 m - 4.6 m with an average depth of 2.7 m. The lake has a surface area of 287 sq km which is mainly controlled by maintaining an operational water level at Ithai at 768.5 m above MSL.

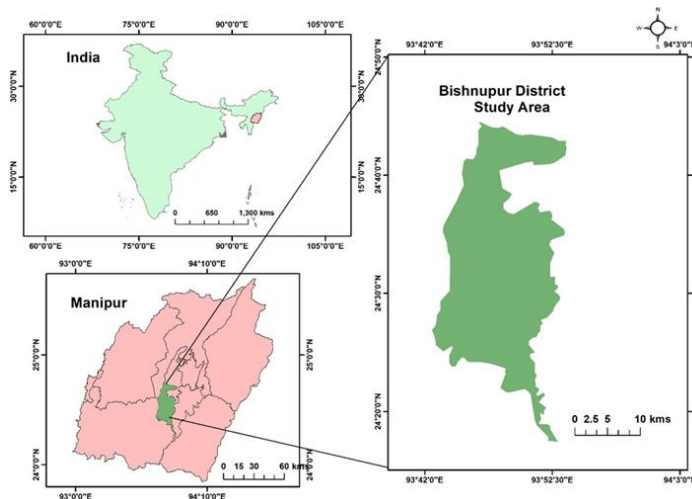


Figure 1: Study area Map. Source: computed by the authors in ArcMap 10.

2.2 DATA USED

To assess the suitability of sites for ecotourism, data were collected from both primary and secondary sources, leading to the development of fourteen criteria layers. The material for this study was compiled from multiple sources. Primary data were obtained through field surveys, interviews, and questionnaires completed by structured interviews with 6 villages around Loktak Lake. These were supplemented with statistical records, GPS-based field survey data, and other GIS datasets. Topographical maps at a 1:50,000 scale from the Survey of India (SOI) and tourist guide maps from the district tourism office were used to define extent, location, and spatial characteristics. Relief, slope, and visibility maps were derived from the Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) with 30 m spatial resolution, accessed via the US Geological Survey (USGS) Earth Explorer. Land Use/Land Cover (LULC) data were prepared using Sentinel-2 imagery with 10 m resolution. Raster data were standardized through spatial interpolation to ensure consistency, while vector data were converted to raster using standard spatial resolutions.

2.3 DATA PROCESSING

2.3.1 Data Analysis

Land use Landcover analysis of Loktak Lake (2021)

The LULC map of 2021 shows a patchwork of land cover around Loktak Lake that contains considerable *Phumdis* (both thick and thin vegetation). The open water bodies (blue) cover a large central and west region of the lake; however, the water bodies are fragmented surrounding the open water sides are *Phumdis* with thin vegetation (light green) mainly located in the southern and eastern portion. The areas of *Phumdis* with thick vegetation (dark green) are located south-central to the lake, while the area of fishing (brown), is the most represented on the 2021 LULC map, especially in the northern and eastern regions of the lake. The settlement area (red) can be observed spreading along the lake periphery with clustering occurring at the southern and southwestern edges, signaling encroachment due to habitation.

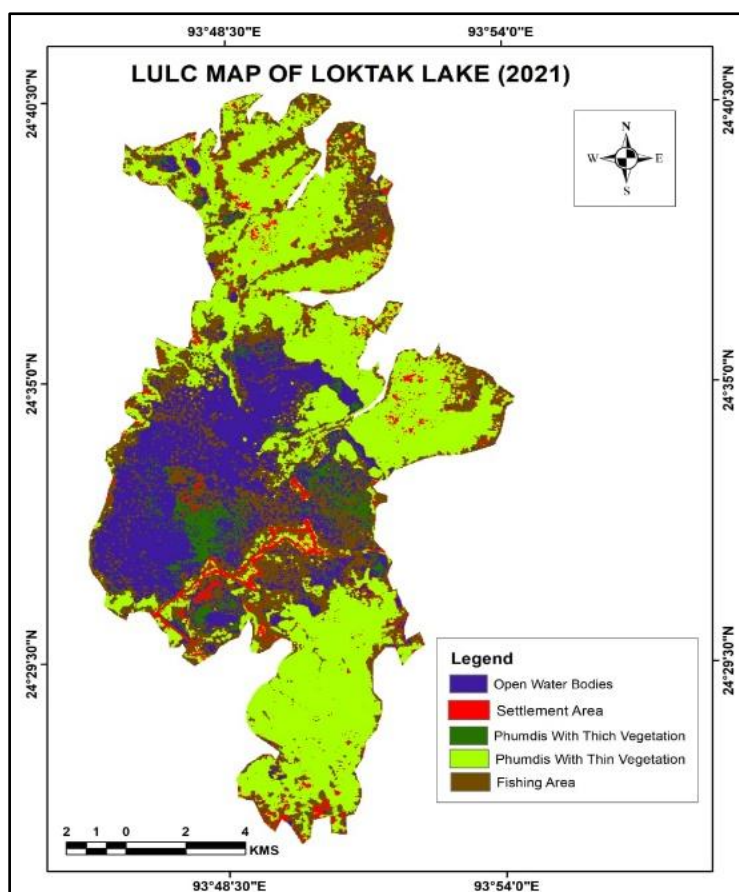


Figure 2.3.1: Map showing LULC of Loktak Lake (2021). (Source: computed by the authors in ArcMap 10.8)

Land use land cover analysis of Loktak Lake (2022)

In 2022, the open water bodies depict an observable increase in spatial footprint especially in the central and western areas of the lake compared to 2021, implying a decline in the *Phumdi* cover or water spread of seasonal nature. *Phumdis* with thick vegetation appear to have slightly declined, particularly in the southern areas. *Phumdis* with thin vegetation continue to occupy the eastern and northern areas, but appear to be more fragmented than they were in 2021. The settlement areas exhibit small increases, particularly around the southern and southeastern edges. Fishing areas still exist that were also quite large, but appear to have decreased slightly around the margins of the lake, possibly due to the changing nature of water levels or land cover.

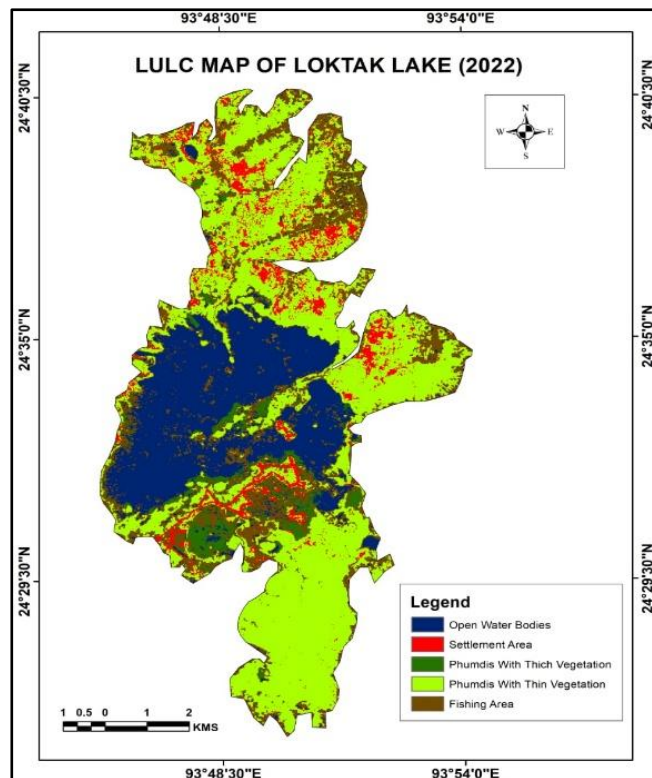


Figure 2.3.2: Map showing LU/LC of Loktak Lake (2022). (Source: computed by authors in ArcMap 10.8)

Land use Land cover analysis of Loktak lake (2023)

By 2023, the extent of open water has again increased, having a greater contiguous area in the central-western aspect that might indicate either seasonal flooding, vegetation removal or management intervention. Turf covered *Phumdis* have continued to decrease in area covered, quickly becoming very small and highly fragmented. Much covered purpose *Phumdis* occupy most of the eastern and southern regions but have also seen a slight decrease since prior years. More settlement areas have appeared in subsequent years, particularly southern and northeastern have become even more abundant which might indicate more anthropogenic pressures which increases vulnerability. Fishing areas have limited spatial re-distribution in the northern and eastern edges of the lake.

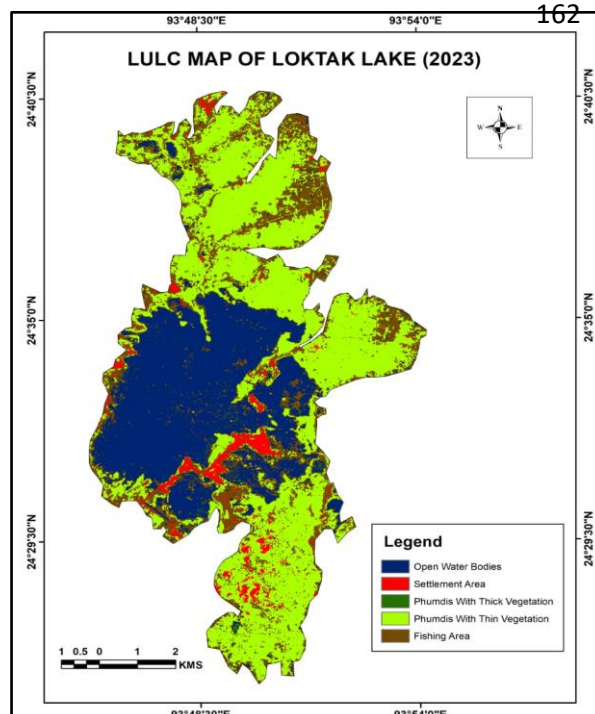


Figure 2.3.3: Map showing LU/LC of Loktak lake (2023). Source: Computed by authors in ArcMap 10.8)

2.4 RESULTS

The LULC of Loktak Lake for the years 2021, 2022 and 2023 is shown in Figure 2.4.1. the area coverage for the five LULC classes and the trends in changes are given in table 2.4.1 and Table 2.4.2. The LULC of 2021 showed that *Phumdi* and fishing area accounted most of the area, amounting to approximately 70.14%. It was followed by water body covering about 25.92%, while settlement areas covered the least which is 3.92%. the year 2022 shows that *Phumdi* and water body covered majority of the area, accounting for 73.89%. It was followed by fishing area covering about 19.57%, whereas the settlement area occupies the least amounting to 6.50%.

The trend of *Phumdi* and water body covering a majority of the area was followed in 2023, accounting for 30.22% and 45.48% of the total area, respectively. However, the fishing area shared increase in 2023 accounting for 21.08% while the settlement area occupies least amount accounting 3.19%.

LULC Change Detection (2021-2023)

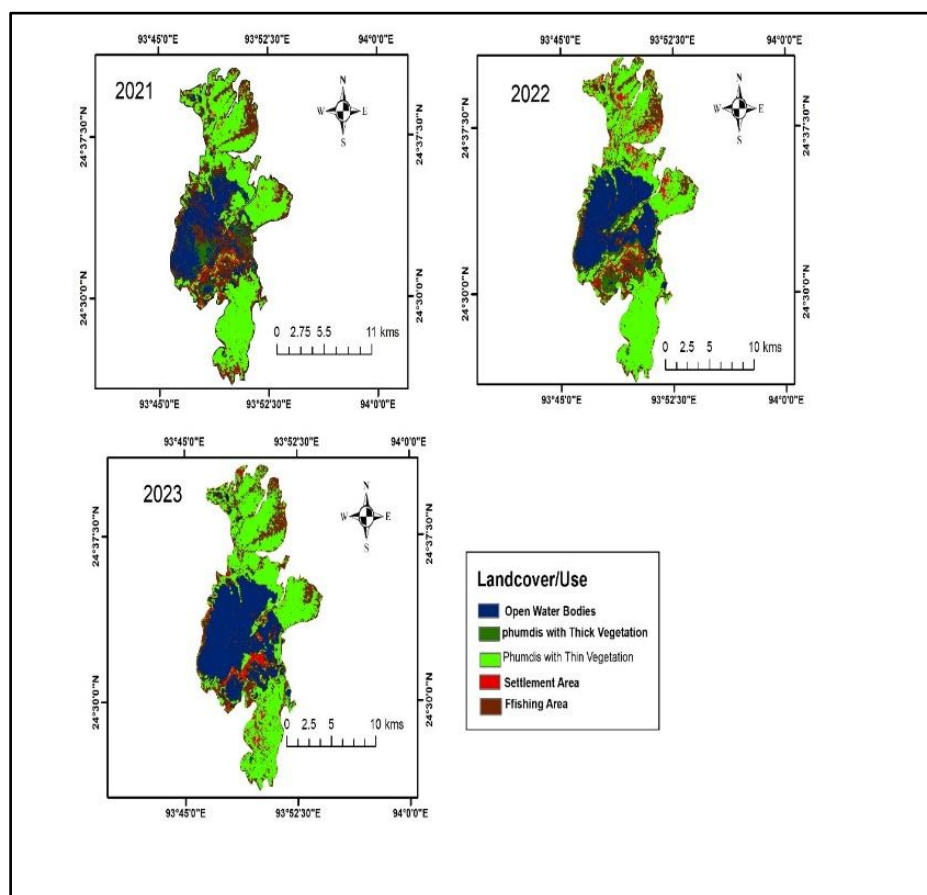


Figure 2.4.1: LULC Map of Loktak Lake for the year 2021,2022 & 2023

Table 2.4.1: Results of LULC classification for 2021, 2022 and 2023 images showing the area of each category and each percentage

Year	2021		2022		2023	
LULC (Area)	Area(km2)	%	Area (km2)	%	Area(km2)	%
Open water bodies	3971.48	21.20	4597.60	24.52	5662.59	30.22
Phumdis with thick	695.01	3.71	603.10	3.21	44.72	0.23
Vegetation						
Phumdis with thin	8472.40	45.23	8654.03	46.16	8477.18	45.25
Vegetation						
Settlement areas	736	3.92	1220	6.50	597.85	3.19
Fishing area	4855.74	25.92	3669.58	19.57	3949.16	21.08
Total	18731	100	18745	100	18732	100

Table 2.4.2: Results of the LULC classification for 2021,2022 and 2023 images showing the area changed and percentage at Loktak lake area

Year	2021-2022		2022-2023	
LULC (Area)	Area(km2)	%	Area (km2)	%
Open water bodies	+626.12	+3.34	+1064.99	+5.68
Phumdis with thick	-91.91	-0.49	-558.38	-2.98
Vegetation				
Phumdis with thin	+181.63	+0.96	-176.85	- 0.94
Vegetation				
Settlement areas	+484	+2.58	-622.15	-3.321
Fishing area	-1186.16	-6.32	+279.58	+1.49

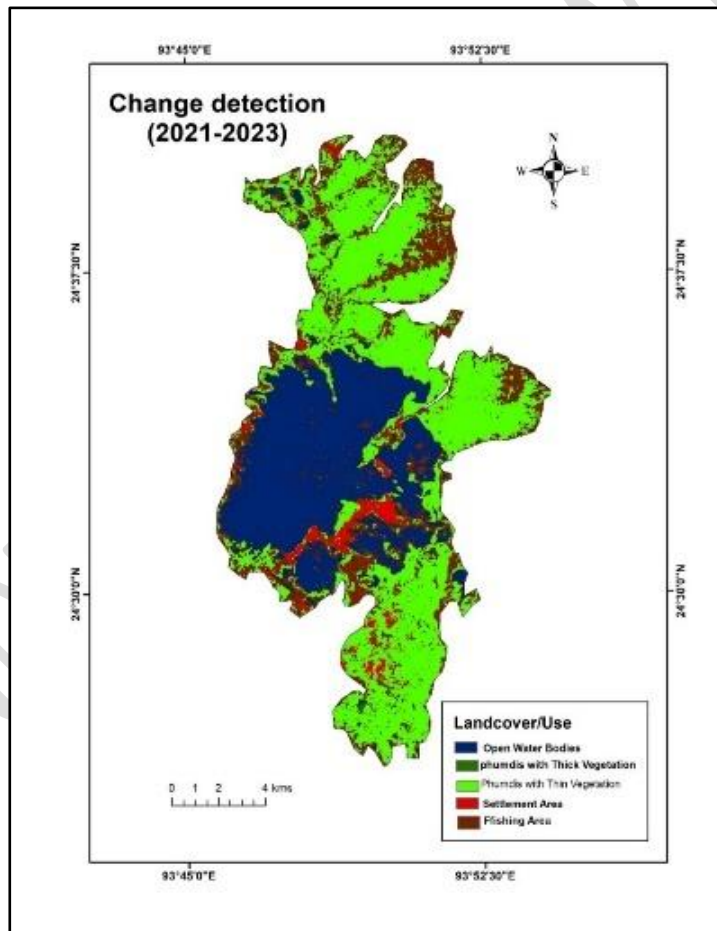


Figure 2.4.2: LULC change detection (2021-2023). Source: Computed in ArcMap 10.8

2.5 CONCLUSION

The analysis of Land Use and Land Cover (LULC) for Loktak Lake during 2021–2023 reveals clear patterns of ecological change. Across all three years, *Phumdi* and open water bodies consistently occupied the largest share of the lake area, highlighting their central role in maintaining the lake's ecological balance. However, the coverage of fishing areas showed a gradual increase, indicating growing human dependence on the lake for livelihood. By contrast, settlement areas, although the smallest category, demonstrated minor fluctuations, suggesting ongoing but limited encroachment.

These findings suggest that while the natural components of the ecosystem (*Phumdi* and water bodies) remain dominant, human activities particularly fishing is exerting increasing spatial influence. Such trends may have implications for biodiversity conservation, water quality, and sustainable resource management. The gradual expansion of fishing areas, coupled with settlement growth, signals the need for stricter management policies and community-based conservation efforts to prevent further degradation of the lake ecosystem.

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