Biannual Open Access Journal
Peer-Reviewed/Refereed International Journal
JOURNAL OF GLOBAL RESOURCES
ISDESR, Jaipur, India

www.isdesr.org

ISSN: 2395-3160 (Print)
ISSN: 2455-2445 (Online)
January 2025, Volume 11 (01)
DOI Prefix: 10.46587/JGR

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SPATIO-TEMPORAL DYNAMICS OF GAP-SAGAR LAKE IN DUNGARPUR CITY OF RAJASTHAN: A GEOSPATIAL ANALYSIS OF HUMAN INTRUSION

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How to cite this paper:
Patidar Savitri (2025 Spatio-Temporal Dynamics of Gap-Sagar Lake in Dungarpur City of Rajasthan: A Geospatial Analysis of Human Intrusion, Journal of Global Resources, Vol. 11 (01)

DOI:
10.46587/JGR.2025.v11i01.015

Received: 27 October 2024
Reviewed: 26 November 2024
Final Accepted: 14 Dec. 2024

OPEN ACCESS
Freely available Online
www.isdesr.org

Abstract: *This study investigates the spatio-temporal dynamics of Gap-Sagar Lake, Dungarpur City, Rajasthan, from 2002 to 2022 using GIS techniques to analyse the change detection and evaluate the impact of human activities on water quality. Gap-Sagar Lake, a vital freshwater resource, has faced significant anthropogenic pressure, leading to reduced surface area and deteriorating water quality. Geospatial technology, specifically Landsat-7 ETM (2002) and Landsat-8 OLI/TIRS (2022), were employed to assess land use and land cover changes (LULC) in the lake's surroundings. The results highlight a 16.5-hectare decrease and transformed in built-up areas and a sharp decline in water quality, marked by rising levels of total dissolved solids (TDS), nitrates, and phosphates, indicative of ongoing eutrophication. This study underscores the urgent need for sustainable management practices to mitigate further ecological degradation and to protect this crucial water body for future generations*.

Key words: Spatio-Temporal Analysis, Geospatial, Eutrophication, Anthropogenic Activities

Introduction

Wetlands are among the most productive ecosystems on the planet, comprising diverse aquatic environments such as lakes, ponds, and rivers. These ecosystems are widely regarded for their rich biodiversity and high productivity, yet they remain highly sensitive to both natural processes and anthropogenic activities (Ghermandi et al., 2010; Talukdar and Pal, 2019; Wanjala et al., 2020). Wetlands deliver a multitude of socio-economic and ecological benefits, including the conservation of biodiversity, flood mitigation, water purification, and ecological restoration (Xu et al., 2019, 2020). They are also vital for providing essential ecosystem services such as water for irrigation, fisheries, recreational opportunities, and the harvesting of non-timber forest products (Islam and Kitazawa, 2013; Bassi et al., 2014). Lacustrine wetlands, specifically lakes, represent a critical subset of wetland ecosystems, playing a fundamental role in maintaining the health of habitats, supporting natural resources, and contributing to both regional and global hydrological cycles. Lakes are indispensable for regulating climate, preserving biodiversity, and enhancing human well-being (Asgher et al., 2021). In addition to providing indirect ecological services, they offer significant direct economic benefits to human populations (Barbier, 1993; Bassi et al., 2014).

Economically, wetlands are vital to society, as they directly and indirectly support numerous individuals through the provision of diverse services and benefits, such as agriculture and tourism (Verhoeven and Setter, 2010; Guareschi et al., 2020; Sun et al., 2020). Despite these advantages, wetlands are under greater threat compared to other natural resources due to human activities (Grzybowski and Glińska, 2019). According to NASA data, many lakes worldwide are experiencing a gradual decline or even complete disappearance. This phenomenon can be attributed to a variety of factors, including climate change, anthropogenic activities, and natural events. In addition to natural causes, human activities such as dam construction, irrigation systems, and changes in land use practices significantly impact water levels and the overall health of lakes. The reduction in wetland areas is primarily driven by both natural processes and human interventions (Sivakumar and Ghosh, 2016; Mandal et al., 2021). Freshwater lakes are especially susceptible to pollution from both point and non-point sources, including industrial waste, domestic sewage, municipal runoff, and agricultural activities, all of which degrade water quality and threaten the ecological integrity of these systems.

The disappearance of lakes has far-reaching negative consequences for both the environment and human communities. Ecologically, the loss of lakes can result in diminished biodiversity and alterations in water quality and hydrology. For human populations, the absence of lakes can lead to a decline in fish and other aquatic resources, as well as reduced opportunities for recreation and tourism. The loss of a lake can also has substantial economic and social repercussions, including decreased access to clean drinking water and a decline in tourism revenue. The threats to wetlands and surface water bodies across the Earth's surface are of significant concern. Assessing and monitoring human encroachment and activities near water bodies is crucial for effective environmental resource management and promoting sustainable development. Monitoring land use and land cover changes (LUCCs) over time and predicting future temporal and spatial trends are essential (Amini and Salehi, 2016). Geospatial technologies, such as remote sensing, GIS, and GPS, are highly effective for analyzing change detection on a global scale. Numerous studies have utilized remote sensing and GIS technologies to map and analyze land use and land cover changes due to human activities near lakes, rivers, and other water bodies (Ghazal et al., 2012; Urooj and Ahmad., 2019). At national and regional levels, many studies have focused on land use and land cover changes around lakes (Navatha et al., 2011; Bhardwaj et al., 2017; Panwar, 2017; Singh et al., 2020; Asgher et al.,

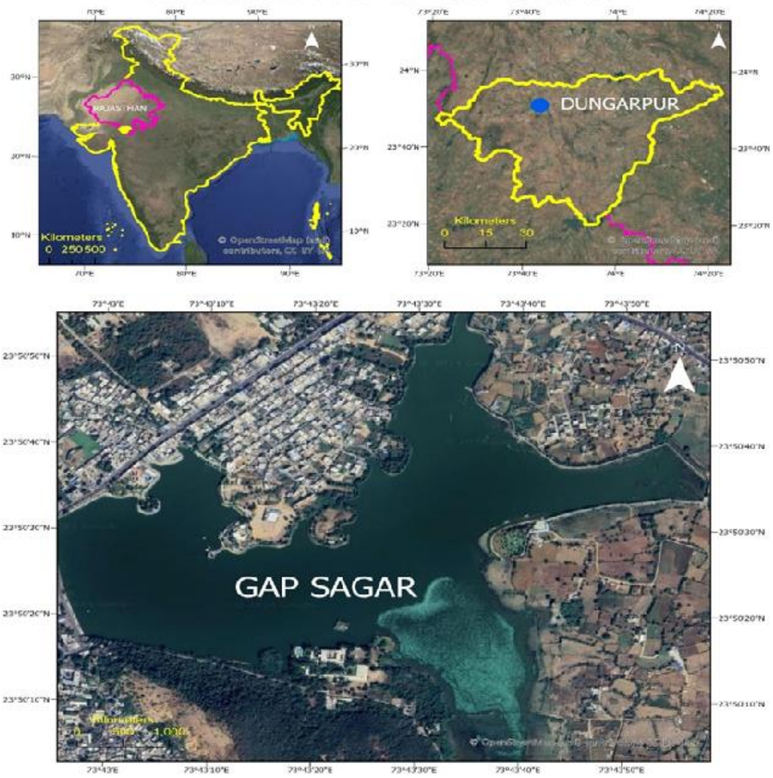
2021) as well as on the degradation of storage capacity (Sivakumar and Ghosh, 2016; Kundapura et al., 2019). Overall, these studies highlight the importance of water bodies in maintaining ecological stability and address the challenges of water body encroachment due to human settlement and agricultural activities. The primary impacts of human-induced actions on wetlands include reductions in surface area, alterations in hydrological patterns, changes in water quality, and the introduction of non-native species.

Similarly, various wetlands play a crucial role in maintaining the local ecosystems of their respective study areas, including Gap-Sagar Lake (Also Called Gaib Sagar Lake). Located at the heart of Dungarpur town in Rajasthan, India, Gap-Sagar Lake is an artificial lake known for its significant biodiversity and attractiveness to tourists. The lake features numerous shallow off-shores where migratory birds can be observed, adding to its ecological and aesthetic value. Historically, the lake has also been vital for managing the city's drainage system during the rainy season and sustaining water availability for surrounding agricultural fields, thereby supporting the local community's livelihoods. However, the lake is facing increasing pressures from a growing population and climate variability, which have adversely affected its ability to support biodiversity and maintain ecological balance (Ficken et al., 2019). The primary threats to Gap-Sagar Lake stem from human encroachment in its peripheral and off-shore areas, leading to reductions in the lake's area, biodiversity loss, and water quality degradation. Therefore, this study aims to analyze and utilize GIS tools to detect changes in Gap-Sagar Lake from 2002 to 2022. The study will assess the impacts of human activities on water quality and eutrophication, with the goal of promoting sustainable resource management practices.

The Study Area

Gap-Sagar Lake is located at Dungarpur city of Rajasthan state in India (Figure 1). Lake often referred to as Gaib Sagar, is an artificial lake. It lies between Coordinates 23°50′20″N 73°43′08″E to 23º08'39"N 73º07'19"E. It was constructed in the 18th century (1428 AD.) by Maharawal Gopinath (Gaipa Rawal) of who later on built Badal Mahal in the center of this ' Gaib Sagar Gang ' as sang in praise by Gavri Bai aka *Meera of Vagad*. In addition to giving his thirsty '*praja',* or people, plenty of water, he also put Dungarpur on the flight path of migratory birds. He brought 124 species of birds to his '*praja*', which attracts tourists to Dungarpur annually (S. Dilip, 2014). The total perimeter of the lake is approx 7.16 km. (InidaWRIS-2022) and it covers an area of 89.90 hectares including its peripheral area. The lake's elevation changes from 1027 feet in the west to 1038 feet in the east. Aesthetically lake has tourist beauty it has so many temples (*Shreinathjii's* 52 temples Shiv temple with 108 *Shivlingha*), ghats, and picturesque landscapes. Lake views featuring migrating birds, particularly in the southern portion of the lake, are its most appealing feature . 'Badal Mahal' and 'Udai Villas' are two significant historical palaces in the middle of the Lake. Apart from its aesthetical significance, the rich biodiversity of plants and animals in the lake is excessive to sustain the ecosystem. For this reason, over a hundred migratory bird species visited for breeding and feeding. Despite its historical, tourism, and ecological significance, the lake is essential for providing drinking water and irrigation to the local people. It supports people's livelihoods through farming and fishing. However, in recent years anthropogenic activities have disturbed the ecology of the lake, and the storage area of the lake has been reduced gradually. Overall, the lake is at its threatening point. It has been noted that the number of migratory birds has declined in recent years. Due to the water quality of lake and human disturbance, they avoid visiting this place and go near by the village ponds. Consequently, the study aims to figure out the extent of Gap-Sagar Lake's temporal dynamic change around its peripheral area in the last twenty years (2002–2022). What type of land use land cover (LULC) has changed the most? Additionally, it accesses the water quality of lake to endorse ecological resource managing activities in future.

Figure 01: Location of Study Area



Database and Methodology

Data Collection

For the purpose of this study, the following key satellite data were extracted from USGS website (https://earthexplorer.usgs.gov/) LANDSAT -7 ETM (Oct 22nd 2002) and LANDSAT-8 OLI/TIRS (Oct 24th 2022) tile data's of Path-148 and Row -14 to analyses the change detection dynamics around the lake in last twenty years. Both LANDSAT images having 30-meter spatial resolution with BAND sets 4, 3 and 2. (NIR-RED-GREEN) BAND-8 (PAN Image) of 15-meter resolution was taken for image pan sharpening or fusion pre-process of both time-period. To access the lake area's eutrophication state and water quality parameters data collection by sampling and site visiting from lake for year 2022 and pre-period water quality data collected from CPCB/SPCB's/PCCs under national water quality monitoring (NWMP). Apart from its secondary data take into consideration for in-depth knowledge about the area of interest.

GIS Database Generations

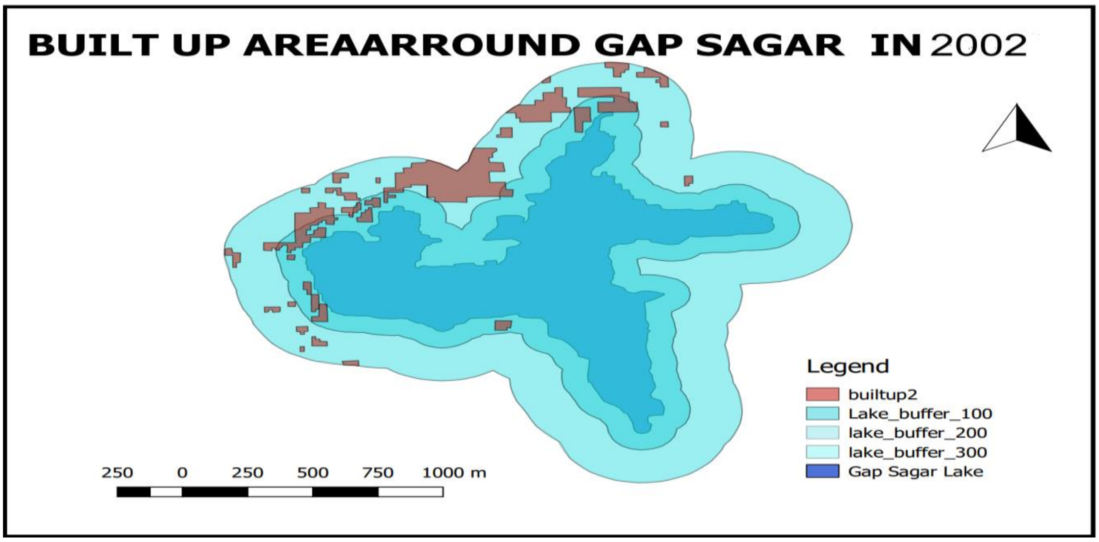
Using Quantum GIS and SAGA software with pre-processing (atmospheric correction, radiometric correction and image pan-sharpening by Colour Normalised Brovey Sharpening) tool for visual interpretation and post processing (area calculation and accuracy assessment) take considered to image enhancement and increase sharpness. The methodology of visual interpretation and manual digitization was employed to extract both qualitative and quantitative data from the image for the analysis of the structural variations in the lake area boundary. Utilizing the simple digitization technique, specifically vectorization, the lake perimeter was delineated for various years, taking into account the ground control points provided by spatial data and on-site observations. Historical information regarding the condition of the lake in 1964 was obtained from a published topographic map. The spatial detection of change in the build-up area of the lake periphery was established using data from the MSS Landsat satellite 2002 and 2022 image respectively. The method of GIS-based overlay involves superimposing individual vector layers to analyze changes and generate comprehensive suitability maps for various land uses (Malczewski, 2004). American landscape architects in the late 19th and early

20th centuries employed GIS-based hand-drawn overlay techniques (Steinitz et al., 1976). In this research project, GIS-based spatial data analysis, specifically digital overlay methods, were utilized to examine change detection in lake area from 2002 to 2022. By overlaying spatial layers of lake boundaries of different time period a map illustrating the reduction in lake area was produced. To access the water quality and eutrophication status water sampling was taken and measures the PH, TDS and dissolved material (oxygen, nitrogen and phosphorus) status of different time period.

Results and Discussions

The analysis of spatial data derived from multiple satellite images reveals substantial alterations in the Gap-Sagar Lake and its surrounding environment between 2002 and 2022. By employing GIS-based manual (hands on practice) digitization and spatial overlay techniques, the study identified significant changes in the lake area, supported by statistical datasets. These changes are predominantly driven by anthropogenic activities within and around the lake's vicinity, which have contributed to the accumulation of various contaminants in the water, subsequently triggering the process of eutrophication. Figure 2 illustrates the manual digitization of the built-up area around the lake, highlighting different buffer zones. The digitized image from 2002 shows that approximately 6.88 hectares of land were affected by human intrusion. Within the 300-meter buffer zone, 3.45 hectares were encroached upon, while the 200-meter buffer zone accounted for 2.73 hectares of encroached land (Changes depicted in Table1). Notably, the heritage palace located near the 200-meter periphery in the southern-middle portion of the lake is not considered an encroached built-up area. In 2002, the total percentage of encroached land was 38.50 percent of the total influenced area, with 21.49 percent within the 300-meter buffer zone and 16.96 percent within the 200-meter zone.

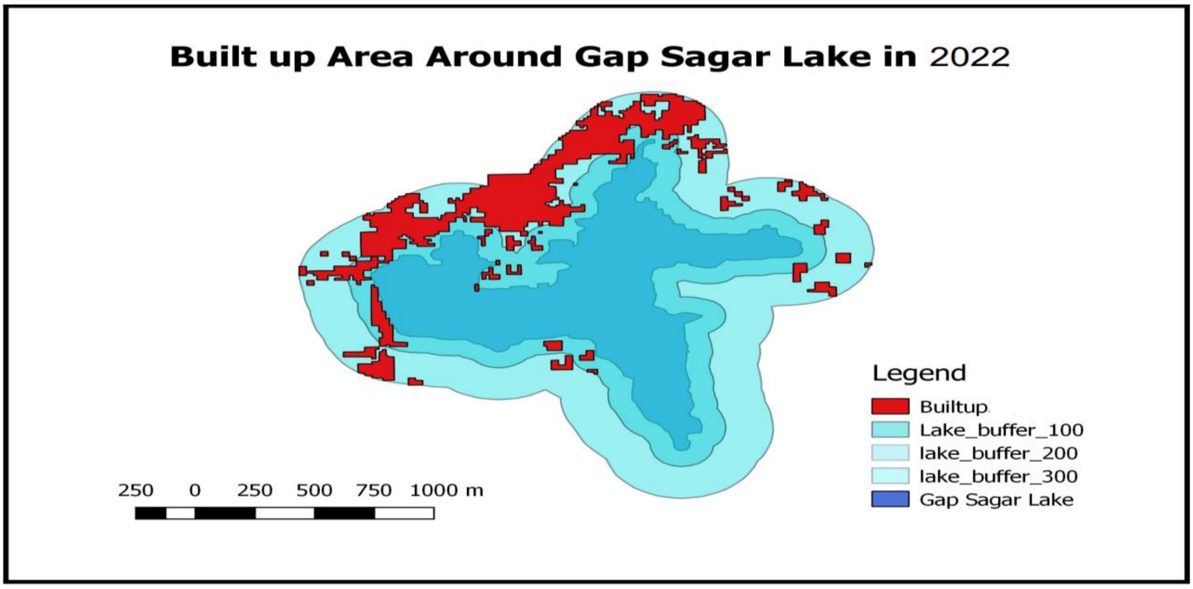
Figure 02: Encroachment Status around Lake in 2002



Source: Landsat-7, 2002

Figure 2 further demonstrates that anthropogenic encroachment was more significant within the 300-meter buffer zone than in the 200-meter zone. Encroachment predominantly occurred in peripheral areas of the lake, where regulatory authorities and local governance bodies often permitted unauthorized land acquisition and construction activities. In 2002, urban demographic growth was relatively low, and urbanization and migration activities were less pronounced, resulting in fewer instances of plot subdivision around the lake. Figure 3 illustrates the encroachment status in the surrounding area of the lake in the 2022 image. It reveals that from 2002 to 2022, the built-up area around the lake gradually increased. In 2022, a total of 9.75 hectares were encroached upon near the lake, predominantly in the northern and western regions, with some intrusion toward the eastern side as well. In 300-meter radius it was 6.30 hectare and in 200 meter-periphery it was 4.02 hectare of overall encroachment in 2022 shown in table.1.The results indicate that the northwestern part of the lake has been progressively encroached upon, primarily due to human activity, including land brokers. Over the past two decades, approximately 58.41 percent of the total built-up area has been subjected to human interference.

Figure 03: Encroachment Status around Lake in 2022



Source: Landsat-8, 2022

Table 01: Temporal Change of Past Twenty Years Surrounding the Lake

Year	Encroached built-up area in 200 Meter Buffer (hect.)	Encroached built-up area in 300 Meter Buffer (hect.)	Total Encroached built-up area (Area in hect.)
2002	2.73	3.45	6.88
2022	4.02	6.30	9.75
Overall Change in last twenty years	6.75	9.75	16.5

Source: Area Calculated of Different Time Periods in QGIS 3.22.5 with Raster Calculator

According to Nagar Parishad documents, in 1993–94, the Urban Improvement Trust (UIT) of the city authorized the development of plots around the lake's periphery. Since then, human encroachment has steadily increased, transforming the surrounding area into residential or built-up zones. Consequently, the aesthetic value of the lake has significantly diminished. Figure 4 depicted the overall change detection of last twenty years in the periphery area of Gap-Sagar Lake. It overviewed that about 16.5-hectare land converted into built-up area in past twenty years (Table.1). It recognized that in 300-meter buffer, the change was about 9.75 hectare and in 200 meter it is 6.75 hectare respectively. Inclusively A significant amount of land was converted into residential areas on the eastern portion of the lake between 2002 - 2022. On the other hand, property around the western portion of the lake has been developed into resorts and hotels. The figure also illustrated that in last 20 years, there has been more encroachment seen in the 300-meter buffer zone compare to 200- and 100-meter buffer zones.

Previous studies (Steinitz et al., 1976; Sivakumar and Ghosh, 2016; Bashir and Ahmad, 2017; Panwar, 2017; Asgher et al., 2021; Ganaie et al., 2021) have similarly reported the shrinking of peripheral areas around lakes. Key contributing factors include anthropogenic activities, rapid population growth, illegal construction, encroachment, eutrophication, and climate change, all of which influence land use and land cover (LULC) patterns surrounding lake areas. Anitha, 2022 also highlighted the application of satellite image processing and heads-up digitization techniques for assessing waterbody encroachment using geospatial technology, noting an increase in human settlements and a reduction in water bodies and vegetation cover in Manapparai Taluk, Tamil Nadu, and India. The results of these studies affirm that geospatial technology is an effective tool for analyzing land-use changes and assessing the impact of LULC on the environment.

Figure 04: Land Transformation around Lake

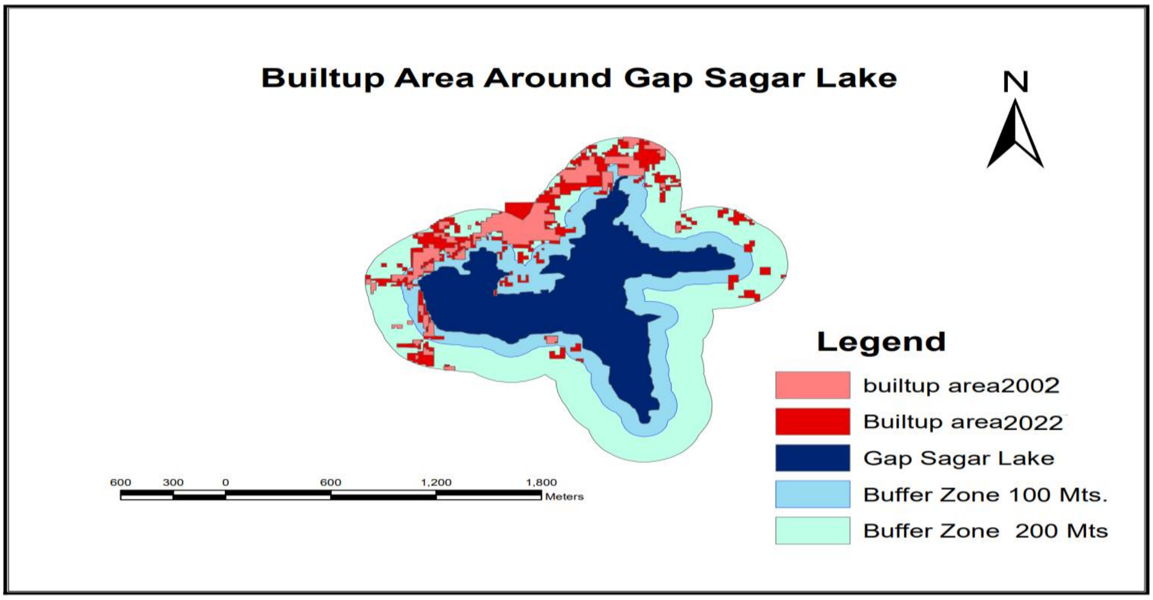


Table 2 highlights the impact of human intrusion on the water quality and eutrophication of Gap-Sagar Lake in Dungarpur city. Over the analysis period from 2002 to 2022, the pH value decreased by 2.2 percent, indicating that the lake's water may become increasingly acidic in the future. Total Dissolved Solids (TDS) showed a significant increase of 148.3 ppm, surpassing acceptable thresholds outlined by standards such as the British Standard (BS), signaling heightened pollution levels in the lake. Over the past two decades, the average temperature of the lake rose by 8℃, driven by various environmental factors.

Table 02: Impact of Human Induced Activities on Water Quality and Eutrophication Status on Gap Sagar Lake

Parameters		Unit of Measurements	2002	2022	Status
Water Quality	P^H	–	6.5	4.3	Decrease in P^H
	TDS	ppm	302.2	450.5	Increase in TDS
	Temperature	℃	26º	34º	Average temperature seems to increase by various influencer
	Dissolved Oxygen	mg/L	7.5	5.6	Decrease in DO but less that acceptable limit
	Chloride	mg/L	249	255	Increase in chloride limit to acceptable
Eutrophication	Nitrate	mg/L	25.2	32.02	Increase in Nitrate give indication of near future eutrophication
	Phosphorus	µg/L	55.0	73.00	Increases in phosphorus it indicates increase of eutrophication

Source: Field Survey, 2022 & NWMP-2002

The average concentration of Dissolved Oxygen (DO) dropped by 1.9 mg/L, raising serious concerns about the health of the aquatic ecosystem. Chloride levels, which are linked to salinity and the presence of dissolved minerals, increased by approximately 6 mg/L. Nitrate concentrations also rose by 7.1 mg/L, although still within permissible limits; however, this upward trend suggests potential eutrophication risks in the future. Additionally, phosphorus contamination increased, remaining within acceptable limits but reflecting the lake's vulnerability to eutrophication in the near future. Overall, the decline in water quality of Gap-Sagar lake primarily stems from the discharge of sewage through non-point pollution sources such as the market area, habitation, and solid waste generated by residential and commercial activities. Additionally, runoff from the catchment area introduces further contaminants into the lake. Construction residues, agricultural runoff, animal waste, and improper disposal of garbage contribute to the pollution load in the lake. Moreover, the entry of agricultural runoff and chemical detergents into Gap-Sagar Lake results in an elevation of inorganic substances, triggering Eutrophication that poses a threat to the aquatic fauna inhabiting the water body and its surroundings. The overall trends indicate possible long-term problems, such as increasing risks of eutrophication, decreased oxygen levels, and enhanced acidity, even though the decrease in phosphate contamination is a favorable development. These alterations indicate that management and intervention are required to stop the ecosystem of Gap-Sagar Lake from further deteriorating.

Previous studies have also emphasized that changes in land use significantly impact lake water quality, with water quality metrics correlating to the presence of dissolved solids resulting from anthropogenic activities (Ganaie et al., 2018; Asgher et al., 2021). For instance, pollution from solid waste and sewage discharges was observed in the water quality assessments of Ding and Roop Sagar lakes in Bharatpur, Rajasthan (Kaur et al., 2022). Anthropogenic factors, combined with natural processes, consistently emerge as the principal drivers of terrestrial landscape transformation, affecting both land development and degradation. Without systematically evaluating these factors within a specific geographic region, land transformation remains unaddressed. Among the various factors driving transformation, human intervention stands out as the most significant, producing noticeable effects in relatively short periods. Evidence of such land transformation is prevalent globally (Dadhwal, 2010). The analysis suggests that Gap-Sagar Lake is experiencing considerable environmental stress. The decline in water quality, as reflected by increasing pollutant levels, rising temperatures, and elevated chemical concentrations, poses a potential threat to the lake's aquatic ecology.

Conclusion

The analysis of change detection around Gap-Sagar Lake from 2002 to 2022 reveals a concerning trend, marked by a significant decline in both the lake's surface area and water quality. As a result, the lake's area has decreased from 89.90 hectares to 73.85 hectares over the 20-year period. Over the past two decades, approximately 16.5 hectares of land surrounding the lake have been encroached upon due to human activities. The land has been predominantly converted into built-up areas, including residential developments, hotels, restaurants, and resorts. Alongside this physical transformation, the lake's water quality has deteriorated, as evidenced by changes in key physical and biological parameters such as pH, total dissolved solids (TDS), temperature, dissolved oxygen, chloride, nitrate, and phosphorus levels. These shifts suggest a future decline in water quality and an increased risk of eutrophication. The encroachment around the lake's periphery is closely linked to population growth and the escalating demand on local resources. Illegal human activities have emerged as the primary driver of both land encroachment and the degradation of the lake's freshwater ecosystem.

Remote sensing and GIS technologies have proven invaluable in accurately and precisely analyzing the spatio-temporal dynamics of these changes. Predicted land use/land cover

(LULC) maps act as early warning systems for environmental and ecosystem changes, providing crucial guidance for local land-use planning and pollution control efforts. Geospatial technology-based research offers a forward-looking approach to sustainable management practices, particularly for the conservation and land-use planning around water bodies like lakes. However, there are notable challenges associated with geospatial change detection, including the high cost of satellite data acquisition and the dependence of LULC change detection accuracy on spatial resolution. In developing countries like India, the expense of generating national-level products remains a significant barrier. Additionally, tracking changes in water quality over time is complicated by seasonal variations, and the lack of reliable catchment area data due to poor record-keeping by local authorities further hampers accurate assessments.

In conclusion, the significant changes in the peripheral areas of Gap-Sagar Lake pose a serious threat to both the lake's ecological health and its aesthetic value. To address these issues, there is an urgent need to implement sustainable management practices. Local governance, in collaboration with community-based programs, must work together to tackle the challenges related to water quality degradation and illegal land encroachment around the lake's periphery. A coordinated approach will be essential to preserving the lake's natural beauty and ensuring the long-term sustainability of its ecosystem.

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