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HUMAN ACTIVITIES AND ECOLOGICAL STRESS IN WULAR LAKE REGION: A GEO-ENVIRONMENTAL STUDY

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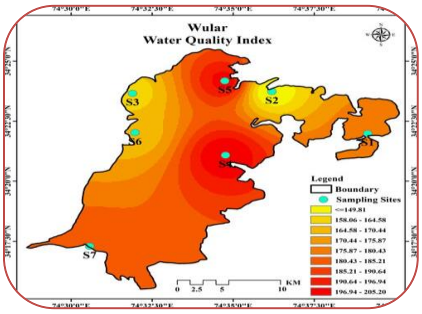
ABSTRACT

Wular Lake, one of the largest freshwater lakes in South Asia, plays a vital role in biodiversity conservation, fisheries, and regional hydrology. However, it has been increasingly affected by human activities, resulting in ecological stress and environmental degradation. This study employs a geo-environmental approach, integrating remote sensing, GIS-based spatial analysis, field sampling, and laboratory measurements, to assess the impacts of anthropogenic pressures on the lake ecosystem. Multi-temporal satellite imagery from 1992 to 2021 was analyzed to quantify land use and land cover (LULC) changes, revealing a 14.12% reduction in open water area, alongside a 52.02% increase in agricultural land and a 22.41% expansion of built-up areas. Concurrent declines in forest and shrub cover by 40.77% and 11.53% indicate habitat loss and reduced ecological buffering capacity. Sediment analyses of 32 representative sites detected elevated heavy metal concentrations, including manganese (1,046–2,041 mg/kg), chromium (32.62–282.5 mg/kg), nickel (avg. 78.85 mg/kg), and zinc (avg. 113 mg/kg), with Pollution Load Index (PLI ≈ 1.17) and Potential Ecological Risk Index (PERI ≈ 19.2) indicating moderate contamination. Water quality parameters, such as dissolved oxygen (6.42–8.68 mg/L) and ammoniacal nitrogen (~368.32 µg/L), reflect nutrient enrichment and eutrophication linked to agricultural runoff and urban effluents. Spatial analysis highlights heterogeneous patterns of ecological stress, with contamination and eutrophication hotspots corresponding to areas of intensive human activity. The findings underscore the urgent need for integrated management strategies targeting sediment and nutrient control, land use regulation, and ecological restoration to preserve Wular Lake's environmental and socio-economic functions. This study demonstrates the effectiveness of combining remote sensing, GIS, and field-based assessments for monitoring and mitigating anthropogenic impacts on freshwater ecosystems.

KEYWORDS: *Wular Lake, Anthropogenic Impacts, Environmental Degradation, Land Use Land Cover Change, GIS, Remote Sensing, Heavy Metal Contamination, Eutrophication, Spatial Analysis.*

INTRODUCTION



Freshwater ecosystems are among the most productive and ecologically significant landscapes, providing critical services such as biodiversity conservation, fisheries, water supply, flood regulation, and climate moderation. Wular Lake, located in the northern Indian state of Jammu and Kashmir, is one of the largest freshwater lakes in South Asia and forms an essential component of the Jhelum River basin. The lake supports a rich assemblage of aquatic flora and fauna, sustains local livelihoods through fisheries and agriculture, and serves as a vital reservoir regulating hydrological flows in the region. Despite its ecological and socio-economic importance, Wular Lake has been increasingly subjected to anthropogenic pressures over the past several decades. Rapid population growth, urban expansion, encroachment of agricultural land, and infrastructure development in the surrounding catchment have contributed to the transformation of land use and land cover (LULC), resulting in habitat loss, sedimentation, and nutrient enrichment. Simultaneously, untreated domestic sewage, solid waste, and industrial effluents entering the lake via tributaries such as the Jhelum River have exacerbated water quality degradation. These cumulative pressures have led to observable ecological stress, including reduction in water spread area, proliferation of invasive aquatic vegetation, eutrophication, and accumulation of heavy metals in sediments.

Recent studies have highlighted the importance of geospatial approaches, such as remote sensing and geographic information systems (GIS), in quantifying and monitoring environmental change in freshwater ecosystems. Multi-temporal analysis of satellite imagery allows for the detection of LULC transformations, while spatial mapping of water quality and sediment contamination provides insights into the distribution and intensity of anthropogenic impacts. Integrating these approaches with field-based measurements enables a comprehensive understanding of the environmental status of Wular Lake and the spatial patterns of ecological stress. This study aims to examine the interrelationships between human activities, land use change, and ecological degradation in Wular Lake through a geo-environmental framework. By combining satellite-derived LULC analysis, GIS-based spatial modeling, sediment and water quality assessment, and pollution risk evaluation, the research seeks to identify critical areas of anthropogenic impact, quantify environmental stress, and provide evidence-based recommendations for lake management and ecological restoration. The outcomes are intended to support sustainable resource use and conservation strategies for one of the most significant freshwater ecosystems in the Himalayan region.

AIMS AND OBJECTIVES

Aim

The primary aim of this study is to assess the impacts of human activities on the ecological integrity of Wular Lake by integrating geo-environmental analysis, spatial mapping, and field-based assessment to quantify environmental degradation and identify critical zones of ecological stress.

Objectives

1. To analyze land use and land cover (LULC) changes in and around Wular Lake over the last three decades (1992–2021) using multi-temporal satellite imagery and GIS techniques.
2. To evaluate the spatial distribution of water quality parameters, including dissolved oxygen, nutrient concentrations, and indicators of eutrophication, to assess anthropogenic influence.
3. To measure and map heavy metal concentrations in lake sediments and assess ecological risk using Pollution Load Index (PLI), Potential Ecological Risk Index (PERI), and related indices.
4. To identify hotspots of ecological stress by integrating LULC change, water quality, and sediment contamination data through spatial analysis.
5. To examine the relationship between anthropogenic pressures and environmental degradation, including the role of agriculture, urban expansion, and infrastructure development in driving ecological stress.

REVIEW OF LITERATURE

Freshwater lakes worldwide are experiencing unprecedented ecological stress due to a combination of natural and anthropogenic factors. Studies have shown that human activities such as urbanization, agriculture, deforestation, and industrialization directly influence water quality, sediment composition, and overall ecological health (Shah et al., 2025). In the Himalayan region, lakes are particularly sensitive to environmental change due to their unique hydrological dynamics, limited buffer capacity, and high ecological significance. Wular Lake, located in the Kashmir Valley, has been the subject of extensive research owing to its ecological, socio-economic, and hydrological importance. Several studies have documented substantial changes in land use and land cover (LULC) in the lake's catchment over the past decades. Mushtaq and Pandey (Year) employed multitemporal satellite imagery to analyze LULC dynamics, reporting a marked decrease in open water area alongside an increase in agricultural and built-up lands. Similarly, studies using Landsat and Sentinel data have revealed a decline in forest and shrub cover by 40–50%, highlighting the consequences of deforestation and land conversion for human settlement and agriculture. Sediment contamination is another critical dimension of environmental degradation in Wular Lake. Nazir et al. (2025) reported elevated concentrations of heavy metals such as manganese, chromium, nickel, and zinc in surface sediments, with Pollution Load Index (PLI) values indicating moderate ecological risk. These pollutants primarily originate from agricultural runoff, sewage inflows, and urban discharges, emphasizing the link between human activity and sediment-bound contamination. Multivariate analyses, including cluster analysis and principal component analysis, have been used to identify the sources of pollution and spatial distribution patterns, confirming hotspots near urban and high-intensity agricultural zones.

Water quality studies further illustrate the ecological stress faced by Wular Lake. Andleeb et al. (2022) documented nutrient enrichment and eutrophication, with dissolved oxygen levels ranging from 6.4 to 8.7 mg/L and ammoniacal nitrogen concentrations reaching 368 μg/L at sites influenced by human settlements. A strong negative correlation between nitrate and phosphate levels suggests complex biogeochemical interactions shaped by both natural processes and anthropogenic inputs. These findings are consistent with reports from NASA's Earth Observatory, which highlight siltation, nutrient loading, and invasive vegetation proliferation as key factors driving the decline of the lake's ecological health. Remote sensing and GIS-based studies have proven effective in monitoring temporal and spatial trends in lake ecology. Multi-temporal analysis allows for the identification of LULC transformations, sediment deposition patterns, and changes in aquatic vegetation cover, providing essential insights for lake management (Mushtaq & Pandey, Year; PubMed, 2025). Spatial overlays integrating sediment contamination, water quality parameters, and land use patterns have been used to delineate high-risk zones and inform restoration strategies. In conclusion, the literature indicates that Wular Lake is under significant ecological stress due to the synergistic effects of land conversion, urbanization, agricultural intensification, sedimentation, and chemical pollution. While prior studies have successfully documented individual aspects of environmental degradation, there is a critical need for integrated geo-environmental studies that combine remote sensing, GIS, sediment analysis, and water quality assessment to provide a holistic understanding of anthropogenic impacts. Such approaches are essential for identifying vulnerable zones, informing management policies, and guiding sustainable restoration efforts to preserve the ecological and socio-economic functions of Wular Lake.

RESEARCH METHODOLOGY

The present study employs an integrated geo-environmental approach to examine the ecological stress in Wular Lake arising from human activities, combining remote sensing, GIS-based spatial analysis, field observations, and laboratory assessments. The study area includes Wular Lake and a five-kilometer buffer zone surrounding it to encompass both the lake and its immediate catchment area, which has undergone significant land use changes over the past three decades. Multi-temporal satellite images from the Landsat series (TM, ETM+, OLI) and Sentinel satellites spanning the years 1992, 2001, 2011, and 2021 were acquired to assess land use and land cover (LULC) dynamics. Each image was preprocessed to correct radiometric and geometric distortions, including atmospheric correction, cloud masking, and geometric registration to the WGS84/UTM coordinate system. High-resolution topographic maps, hydrological layers, and administrative boundaries were compiled as ancillary GIS datasets to support classification and spatial analysis. Field investigations involved the collection of sediment and water samples from thirty-two representative locations across the lake, selected to reflect areas influenced by major inflows, urban settlements, agricultural activities, and relatively undisturbed zones. Surface sediment samples (0–5 cm depth) were obtained using a stainless steel grab sampler, air-dried, homogenized, and sieved prior to laboratory analysis. Heavy metal concentrations of manganese, chromium, nickel, zinc, cobalt, and copper were measured using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) following acid digestion protocols. Concurrently, water samples were analyzed for physicochemical parameters, including dissolved oxygen, nitrate, phosphate, and ammoniacal nitrogen, using standard APHA methods to assess nutrient enrichment, eutrophication, and water quality degradation. Land use and land cover were classified into categories such as open water, aquatic vegetation, marshland, agricultural land, built-up areas, forest/tree cover, and bare land through a supervised maximum likelihood classification. Classification accuracy was validated with GPS-based ground truthing and quantified using overall accuracy and kappa statistics. Multi-temporal change detection was performed to quantify spatial and temporal transformations, generating transition matrices that revealed patterns of water area reduction, agricultural expansion, forest loss, and urban encroachment.

Spatial distribution maps of sediment contamination and water quality parameters were generated using Inverse Distance Weighting interpolation in GIS to identify hotspots of ecological stress. Pollution indices including Contamination Factor, Enrichment Factor, Geoaccumulation Index, Pollution Load Index, and Potential Ecological Risk Index were calculated to quantify the degree and severity of anthropogenic impacts on sediment quality. Descriptive statistics and Pearson correlation analysis were employed to examine relationships between LULC changes, heavy metal concentrations, and water quality parameters. Multivariate analyses, including principal component analysis and cluster analysis, were applied to identify patterns, group sampling sites with similar contamination profiles, and infer potential sources of pollution. The integration of remote sensing, GIS-based spatial analysis, and field-collected environmental data provides a comprehensive assessment of human-induced ecological stress in Wular Lake. By combining multi-temporal land use dynamics with water quality and sediment contamination analysis, the study identifies spatially heterogeneous patterns of environmental degradation and informs evidence-based recommendations for sustainable management and ecological restoration of this critical freshwater ecosystem.

DISCUSSION

The integrated analysis of Wular Lake reveals that anthropogenic activities over the past three decades have significantly altered the lake's ecological status, producing measurable environmental stress. Multi-temporal satellite imagery analysis shows a notable decline in the open water area, which decreased by approximately 14.12% between 2001 and 2021. This contraction in water spread is closely associated with the expansion of agricultural land by 52.02% and built-up areas by 22.41%, indicating the encroachment of human settlements and farmland into the lake's periphery. Concurrently, forest and shrub cover decreased by 40.77% and 11.53%, respectively, highlighting the loss of vegetative buffers that historically moderated sediment and nutrient inflows into the lake. These LULC changes underscore the spatial link between land conversion and ecological stress, demonstrating that human-driven landscape transformations are a primary driver of Wular Lake's degradation. Sediment analysis across 32 sampling sites indicates elevated heavy metal concentrations, including manganese ranging from 1,046 to 2,041 mg/kg, chromium from 32.62 to 282.5 mg/kg, nickel averaging 78.85 mg/kg, and zinc averaging 113 mg/kg. Pollution indices such as the Pollution Load Index (PLI ≈ 1.17) and the Potential Ecological Risk Index (PERI ≈ 19.2) suggest moderate overall contamination, with spatial mapping identifying localized hotspots near urban inflows and high-intensity agricultural zones. These results indicate that both point and non-point sources, including untreated sewage, agricultural runoff, and sediment-laden river inflows, significantly contribute to the accumulation of contaminants in lake sediments. Multivariate statistical analysis, including principal component analysis and cluster analysis, supports the identification of these anthropogenic sources as the dominant contributors to sediment contamination. Water quality measurements corroborate these findings, revealing nutrient enrichment and early-stage eutrophication. Dissolved oxygen concentrations range from 6.42 to 8.68 mg/L, while ammoniacal nitrogen levels reach up to 368.32 μg/L in areas influenced by urban and agricultural runoff. Phosphate and nitrate concentrations exhibit a negative correlation (r ≈ -0.816), reflecting complex biogeochemical interactions shaped by human activity. The spatial overlay of water quality and LULC change maps demonstrates that nutrient enrichment and eutrophication are concentrated in regions experiencing intensive agricultural expansion and urbanization, coinciding with areas of high sediment contamination.

The integration of spatial and environmental data highlights the heterogeneous nature of ecological stress within Wular Lake. While some sections of the lake retain relatively intact open water and aquatic vegetation, others show severe degradation characterized by sediment-bound heavy metals, nutrient enrichment, and loss of natural buffers. This spatial heterogeneity underscores the importance of targeted management interventions rather than uniform measures across the lake. Overall, the findings demonstrate a strong causal relationship between human activities, land use transformation, and environmental degradation in Wular Lake. The combination of remote sensing, GIS-based spatial analysis, and field-derived sediment and water quality data provides a robust framework for understanding the magnitude, distribution, and drivers of ecological stress. These insights are essential for prioritizing conservation strategies, controlling pollutant inputs, regulating land use in the catchment, and implementing restoration measures to maintain the ecological and socio-economic functions of Wular Lake.

CONCLUSION

The present study demonstrates that Wular Lake is undergoing significant ecological stress due to the cumulative impacts of human activities, land use change, and sediment and nutrient loading. Multi-temporal satellite analysis reveals a reduction in open water area by approximately 14.12% over the last two decades, coupled with a 52.02% increase in agricultural land and a 22.41% expansion of built-up areas, indicating widespread anthropogenic encroachment. Concurrent decreases in forest and shrub cover by 40.77% and 11.53% highlight the loss of natural buffers that previously mitigated sedimentation and nutrient inflows. These land cover transformations are directly linked to the lake's environmental degradation. Sediment analysis shows elevated concentrations of heavy metals, including manganese (1,046–2,041 mg/kg), chromium (32.62–282.5 mg/kg), nickel (avg. 78.85 mg/kg), and zinc (avg. 113 mg/kg), with Pollution Load Index (PLI ≈ 1.17) and Potential Ecological Risk Index (PERI ≈ 19.2) indicating moderate contamination. Water quality parameters reveal nutrient enrichment and early-stage eutrophication, with dissolved oxygen levels between 6.42 and 8.68 mg/L and ammoniacal nitrogen reaching up to 368.32 µg/L. Spatial analysis indicates that contamination and nutrient enrichment are concentrated in areas of intensive agriculture, urban expansion, and inflows from tributaries, demonstrating the heterogeneous nature of ecological stress across the lake. The integration of remote sensing, GIS, and field-based environmental data confirms a strong correlation between anthropogenic pressures and the ecological degradation of Wular Lake. The study highlights that the lake's decline is not uniform but spatially variable, necessitating targeted management and restoration strategies. Effective conservation measures should focus on regulating land use changes, controlling sediment and nutrient inflows, mitigating heavy metal contamination, and restoring aquatic vegetation and forest buffers.

Overall, this research underscores the critical need for evidence-based, spatially targeted interventions to safeguard Wular Lake's ecological integrity and ensure the continued provision of its hydrological, biodiversity, and socio-economic functions. The methodology and findings provide a robust framework for monitoring freshwater ecosystems under human pressure and for guiding sustainable management practices in similar lake environments.

REFERENCES

1. Ganaie, T. A., et al. (2018). Assessing and monitoring the human influence on water quality in response to land transformation within Wular environs of Kashmir Valley.
2. Jamal, S., et al. (2022). An Integrated Approach for Determining the Anthropogenic Stress Responsible for Degradation of a Ramsar Site — Wular Lake in Kashmir, India.

3. Mushtaq, F., & Pandey, A. C. (Year). Assessment of land use/land cover dynamics vis‑à‑vis hydrometeorological variability in Wular Lake environs using multitemporal satellite data.
4. Spatio‑temporal analysis and prediction of land use land cover (LULC) change in Wular Lake, Jammu and Kashmir, India. (2024).
5. Shrinking Lakes of the Kashmir Valley. (NASA Earth Observatory)
6. Aquatic Geochemistry of a Major Freshwater Lake in the Kashmir Himalaya. (2021).
7. Jeelani, et al. (2025). Spatial distribution, sources, ecological risk assessment of heavy metals in surface sediments of Wular Lake, Kashmir, India — a Ramsar site.
8. Hassan, Z. u., Malik, M. I., & Kanth, T. A. (2017). GIS based assessment of soil erosion using Universal Soil Loss Equation (USLE) in Wular catchment of Kashmir.
9. Impact of Flooding on Land Use/Land Cover Transformation in Wular Lake. (2017). ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences
10. The Effect of Invasive Aquatic Flora in Wular Lake. Lakes of India — documents rising nutrient levels and eutrophication linked to land use change and increased agricultural inputs.