Pen & Prosperity
Website: https://penandprosperity.vgcet.com
Volume 2 :: Issue 3 :: September 2025 :: e-ISSN- 3048-9555 :: DOI Link : https://doi.org/10.70798/PP/020300039

Environmental Drivers in Kanwar Lake Wetland: An Ecological Assessment

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Abstract:

Wetland ecosystems were recognized as dynamic environments in which multiple environmental drivers interacted to influence ecological processes and biodiversity. Kanwar Lake (Kabartal Wetland), located in Begusarai District of Bihar, India, had been identified as a significant freshwater wetland and was designated a Ramsar site due to its ecological importance. However, increasing anthropogenic activities and climatic variability had affected the ecological stability of the wetland. The present study was conducted during 2023–2024 to assess major environmental drivers influencing the ecological condition of Kanwar Lake. Field observations and environmental parameter assessments were undertaken to examine hydrological patterns, water quality characteristics, and nutrient dynamics within the wetland ecosystem. The results indicated that nutrient enrichment, seasonal hydrological fluctuations, sediment deposition, and anthropogenic disturbances had acted as primary environmental drivers affecting ecological processes in the lake. Variations in pH, dissolved oxygen, turbidity, and nutrient concentration were observed across sampling locations and seasons. These environmental drivers were inferred to influence ecosystem productivity, microbial activity, and overall wetland health. The study highlighted the importance of environmental monitoring and sustainable management strategies for the conservation of Kanwar Lake.

A R T I C L E I N F O

Article history:
Received: 10 August 2025
Received in revised form
20 August 2025
Accepted 29 August 2025

Citation: Kumar. K, (2025) "Environmental Drivers in Kanwar Lake Wetland: An Ecological Assessment", *Pen and Prosperity*, Vol. 2, Issue. 3, September 2025.

Keywords: *Wetland Ecology, Environmental Drivers, Kanwar Lake, Ramsar Wetland, Ecosystem Dynamics, Water Quality.*

1. Introduction:

Wetlands were considered among the most productive ecosystems on Earth due to their ability to support high biological diversity and maintain ecological processes such as nutrient cycling, water purification, and carbon sequestration (Mitsch & Gosselink, 2015). Environmental drivers including hydrological variability, nutrient availability, climate, and anthropogenic activities were known to regulate wetland ecosystem functioning (Zedler & Kercher, 2005).

Kanwar Lake, also known as Kabartal Wetland, had been recognized as one of the largest freshwater oxbow lakes in the Indo-Gangetic plains. The wetland had historically supported diverse flora and fauna and served as an important habitat for migratory birds. However, recent ecological assessments had indicated

environmental degradation due to agricultural expansion, sediment accumulation, and water diversion (Rai & Kumar, 2022).

Environmental drivers in wetland ecosystems had been broadly categorized into natural drivers and anthropogenic drivers. Natural drivers included rainfall patterns, hydrological connectivity, sediment transport, and seasonal temperature variation. Anthropogenic drivers included land-use change, agricultural runoff, and resource exploitation. These drivers collectively influenced ecological processes such as nutrient cycling, primary productivity, and microbial activity.

Understanding the environmental drivers influencing Kanwar Lake was considered essential for wetland conservation planning. Therefore, the present study was undertaken to analyze major environmental drivers affecting the ecological condition of Kanwar Lake during 2023–2024.

2. Study Area:

Kanwar Lake is located in Begusarai district of Bihar at approximately 25°35′–25°40′ N latitude and 86°05′–86°10′ E longitude. The wetland was formed as an oxbow lake due to the meandering of the BurhiGandak River, a tributary of the Ganga River. It lies about 22 km northwest of Begusarai town and covers several thousand hectares during the monsoon season, making it one of the largest freshwater oxbow lakes in Asia.

The lake is situated in the Indo-Gangetic floodplain, where seasonal hydrological fluctuations influence its ecological characteristics.Kanwar Lake was located in Begusarai district of Bihar and had originated as an oxbow lake formed by the meandering of ancient river channels in the Indo-Gangetic floodplain. The wetland covered a large area during the monsoon season and experienced substantial reduction in water spread during the dry period.

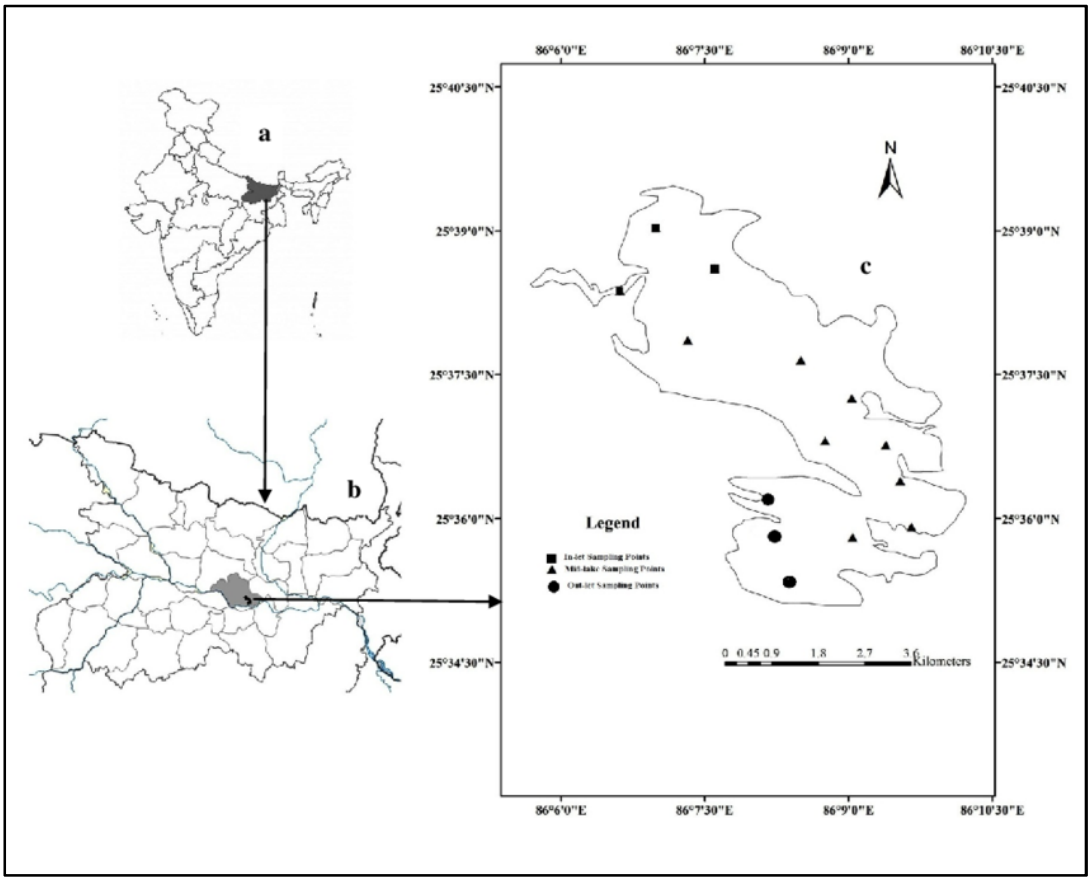

Fig. 1. Kanwar lake, Bihar, India

The surrounding landscape had been dominated by agricultural activities, particularly rice and wheat cultivation. Runoff from agricultural fields had contributed nutrients and sediments into the lake ecosystem. Seasonal flooding and sediment deposition had further influenced the hydrological and ecological characteristics of the wetland.The climate of the region had been characterized as subtropical with three major seasons: summer, monsoon, and winter. Rainfall during the monsoon season had been identified as a major hydrological driver affecting lake water levels and nutrient input.

3. Materials and Methods:

3.1 Research Design:

The study had been conducted between January 2023 and December 2024. Environmental data had been collected from multiple locations within the wetland to analyze spatial variation in ecological drivers.

Sampling sites had been selected based on hydrological connectivity, land-use influence, and accessibility.

3.2 Environmental Parameters:

Several environmental parameters had been measured to identify ecological drivers influencing the wetland.

Table 1. Environmental parameters measured during the study

Parameter	Ecological significance
Temperature	Influenced biological and microbial activity
pH	Indicated chemical balance of water
Dissolved Oxygen	Determined aerobic ecosystem processes
Turbidity	Reflected sediment load and water clarity
Conductivity	Indicated dissolved ionic concentration
Nitrate	Represented nutrient enrichment
Phosphate	Controlled primary productivity

3.3 Data Collection:

Water samples had been collected seasonally from selected locations. Physicochemical parameters had been analyzed using standard limnological techniques described by Wetzel (2001).

Hydrological observations had been recorded to examine seasonal variations in water level and sediment deposition.

4. Results:

4.1 Hydrological Drivers:

Hydrological variability had been identified as a major environmental driver influencing Kanwar Lake. Seasonal rainfall during the monsoon period had caused substantial increases in water level and spatial expansion of the wetland. During the dry season, water levels had decreased significantly, leading to exposure of large portions of lakebed sediments.

Table 2. Seasonal variation in hydrological conditions (2023–2024)

Season	**Water level**	**Hydrological condition**
Summer	Low	Reduced inflow
Monsoon	High	Flooding and sediment inflow
Winter	Moderate	Stable water conditions

These variations had influenced nutrient transport, sediment deposition, and ecological productivity.

4.2 Water Quality Characteristics

Water quality parameters had shown spatial and seasonal variability across the lake ecosystem.

Table 3. Observed range of physicochemical parameters

Parameter	Observed range
Temperature	18–32 °C
pH	7.1–8.3
Dissolved Oxygen	4.5–8.0 mg/L
Turbidity	Moderate to high
Nitrate	0.4–1.5 mg/L
Phosphate	0.05–0.45 mg/L

The results indicated that nutrient concentrations had increased during the monsoon season due to agricultural runoff.

4.3 Nutrient Dynamics:

Nutrient enrichment had been identified as an important environmental driver affecting ecological processes within the wetland.

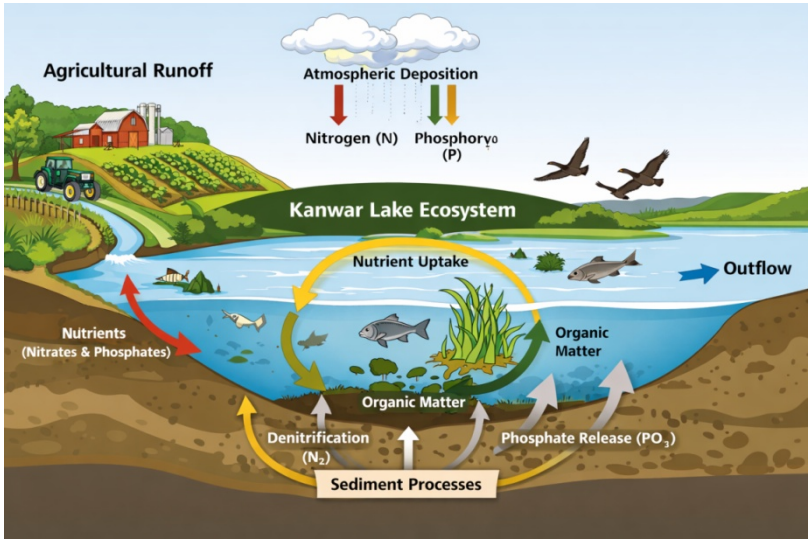

Figure 2.Conceptual diagram of nutrient flow in Kanwar Lake ecosystem

Agricultural runoff had transported nitrogen and phosphorus compounds into the wetland ecosystem. These nutrients had contributed to increased biological productivity and microbial activity.

4.4 Sedimentation and Habitat Modification:

Sediment deposition had been observed in shallow zones of the lake. Seasonal flooding had transported suspended sediments into the wetland basin, gradually reducing water depth.

Table 4. Major environmental drivers identified in Kanwar Lake

Driver	Ecological impact
Hydrological variability	Influenced habitat distribution
Nutrient enrichment	Increased productivity
Sedimentation	Reduced water depth
Anthropogenic pressure	Altered ecosystem structure

5. Discussion:

The results obtained during the present investigation (2023–2024) indicated that multiple environmental drivers had interacted to influence the ecological functioning of Kanwar Lake wetland. Wetland ecosystems were widely recognized as highly dynamic environments in which hydrological variability, nutrient inputs, sedimentation processes, and anthropogenic pressures collectively regulated ecosystem stability and productivity. The observed environmental patterns in Kanwar Lake were therefore interpreted within the broader framework of wetland ecological theory.

Hydrological variability had been identified as one of the most influential environmental drivers in the lake ecosystem. Seasonal fluctuations in water level, particularly during monsoon months, had significantly affected nutrient transport, sediment deposition, and ecological productivity. Similar observations had been reported in floodplain wetlands where seasonal inundation had played a critical role in maintaining ecosystem connectivity and nutrient exchange (Junk, Bayley, & Sparks, 1989; Mitsch & Gosselink, 2015). During the monsoon period, increased surface runoff and riverine inflow had contributed to the expansion of wetland area and facilitated the transport of suspended sediments and dissolved nutrients into the lake basin. These processes had enhanced nutrient availability and biological productivity, thereby supporting ecosystem functioning.

Conversely, reduced water levels during the dry season had exposed large portions of the lakebed, resulting in sediment oxidation and altered nutrient cycling dynamics. Such hydrological contractions had been reported to influence microbial processes and organic matter decomposition in wetland sediments (Wetzel, 2001). The seasonal alternation between inundation and exposure had therefore created dynamic ecological conditions that regulated nutrient transformation and biogeochemical cycling.

Nutrient enrichment had emerged as another critical environmental driver influencing the wetland ecosystem. The increased concentrations of nitrate and phosphate observed during the study period were likely associated with agricultural runoff from surrounding farmland. Agricultural landscapes had been widely recognized as major sources of nutrient input into freshwater ecosystems (Carpenter et al., 1998). Nutrient enrichment could enhance biological productivity and microbial activity within aquatic systems; however, excessive nutrient accumulation could also lead to eutrophication and ecological imbalance.

Previous studies had demonstrated that nutrient loading could stimulate microbial respiration, organic matter decomposition, and internal nutrient recycling processes (Bianchi, 2011). In the context of Kanwar Lake, increased nutrient availability had likely promoted microbial-mediated nutrient transformations such as nitrification, denitrification, and organic carbon mineralization. These microbial processes were essential for maintaining nutrient balance within wetland ecosystems.

Sedimentation had also been recognized as a significant environmental driver affecting the ecological structure of Kanwar Lake. Field observations during the study period indicated that suspended sediments transported during seasonal flooding had gradually accumulated in shallow zones of the lake. Sediment deposition had the potential to reduce water depth and alter habitat conditions within the wetland. Similar patterns had been observed in other floodplain lakes where sedimentation had contributed to long-term morphological changes and ecological transformation (Zedler & Kercher, 2005).

Sediment accumulation could influence wetland ecology in several ways. Firstly, increased sedimentation could reduce water transparency, thereby affecting photosynthetic productivity and aquatic habitat conditions. Secondly, sediments often acted as reservoirs for nutrients and organic matter, which could be released back into the water column under changing redox conditions (Wetzel, 2001). These sediment-water interactions had important implications for nutrient cycling and ecosystem productivity.

Anthropogenic activities had also been identified as key drivers affecting the ecological condition of Kanwar Lake. Land-use change, agricultural expansion, and resource exploitation had exerted considerable pressure on the wetland ecosystem. Human-induced environmental stress had been widely recognized as a major factor contributing to wetland degradation across many regions of the world (Davidson, 2014). In the case of Kanwar Lake, the expansion of agricultural land surrounding the wetland had increased the likelihood of nutrient runoff and sediment inflow.

Furthermore, hydrological alterations caused by irrigation infrastructure and water diversion had potentially modified the natural hydrological regime of the lake. Alterations in hydrological connectivity could disrupt ecological processes such as nutrient transport and sediment dynamics. According to Mitsch and Gosselink (2015), the maintenance of natural hydrological processes was essential for sustaining wetland ecosystem health and biodiversity.

The interaction between natural and anthropogenic drivers had therefore shaped the ecological functioning of Kanwar Lake. Environmental drivers rarely acted independently; rather, they interacted in complex ways to influence ecosystem processes. For example, hydrological variability could regulate nutrient transport, while sedimentation could modify habitat structure and influence nutrient retention within the wetland.Climate variability could also play an important role in shaping wetland environmental conditions. Changes in rainfall patterns and temperature regimes had been reported to influence wetland hydrology, water quality, and biological productivity (Erwin, 2009). Although climate data were not the primary focus of the present investigation, seasonal rainfall patterns had clearly influenced hydrological conditions in Kanwar Lake during the study period.

From an ecological perspective, the combined effects of hydrological variability, nutrient enrichment, sedimentation, and anthropogenic pressure had created a complex environmental system in which multiple drivers interacted simultaneously. Such interactions were typical of floodplain wetlands, where ecosystem functioning was closely linked to natural hydrological cycles and landscape connectivity (Junk et al., 1989).The findings of the present study therefore suggested that environmental monitoring should be considered an essential component of wetland management strategies. Continuous assessment of water quality, hydrological patterns, and nutrient dynamics would help identify ecological changes at an early stage and facilitate effective conservation planning. Sustainable management strategies aimed at reducing

nutrient input, controlling sediment inflow, and maintaining hydrological connectivity could significantly improve the ecological condition of Kanwar Lake.

In summary, the discussion highlighted that the ecological dynamics of Kanwar Lake were strongly influenced by a combination of natural and anthropogenic environmental drivers. Hydrological variability had regulated nutrient transport and habitat conditions, nutrient enrichment had influenced ecosystem productivity, sedimentation had altered physical habitat structure, and anthropogenic pressures had intensified ecological stress. The integration of these environmental drivers provided a comprehensive understanding of the factors shaping the wetland ecosystem.

6. Conclusion:

The study conducted during 2023–2024 had identified several key environmental drivers influencing the ecological condition of Kanwar Lake wetland. Hydrological variability, nutrient enrichment, sedimentation, and anthropogenic activities had emerged as dominant factors affecting ecosystem processes. These drivers had influenced water quality, nutrient cycling, and biological productivity within the wetland. Continuous environmental monitoring and sustainable management strategies were therefore considered necessary for the long-term conservation of Kanwar Lake.

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