

Impact of Agricultural Runoff on the Water Quality Index and Soil Characteristics in the Nathsagar Wetland Region

Rahul Mahamuni¹, Sanjay Salunke²

¹Department of Conservation of Biodiversity, Gopinathrao Munde National Institute of Rural Development and Research- A Constituent Institute of Dr. Babasaheb Ambedkar Marathwada University, Chhatrapati Sambhajinagar (M.S.), India.

Email ID: rahulmahamuni@gmail.com

²Department of Sociology, Dr. Babasaheb Ambedkar Marathwada University, Chhatrapati Sambhajinagar (M.S.), India.

Abstract

The Nathsagar Wetland, a significant ecological zone within the Jayakwadi Dam region, plays a crucial role in supporting biodiversity and providing essential ecosystem services. However, agricultural runoff poses a substantial threat to the water and soil quality of the wetland. This study aims to assess the impact of agricultural runoff on the Water Quality Index (WQI) and soil characteristics in the Nathsagar Wetland region. Key water quality parameters, such as pH, dissolved oxygen, nitrates, phosphates, and heavy metals, are monitored and analyzed to determine the WQI. Simultaneously, soil samples are evaluated for changes in nutrient levels, organic content, and potential contamination. The findings will offer insights into the extent to which agricultural practices influence the aquatic and terrestrial ecosystems of the wetland, providing a basis for developing sustainable management strategies to mitigate pollution and protect this vital habitat.

1. Introduction

Wetlands are among the most productive ecosystems on Earth, playing a pivotal role in supporting biodiversity, regulating water cycles, and providing various ecosystem services such as water purification, flood control, and carbon sequestration. The Nathsagar Wetland, located within the Jayakwadi Dam region in Maharashtra, India, is one such critical ecological zone. It supports a wide array of flora and fauna, including migratory bird species such as flamingos, and contributes significantly to the regional hydrology and economy. However, the

Nanotechnology Perceptions **20 No.6** (2024) 4678-4687

wetland is increasingly threatened by anthropogenic activities, particularly agricultural runoff, which poses a major risk to its ecological integrity.

Agricultural runoff refers to the flow of excess nutrients, pesticides, and sediments from agricultural fields into nearby water bodies. In the Nathsagar Wetland region, intensified agricultural practices and the use of chemical fertilizers and pesticides have led to elevated levels of pollutants entering the wetland. These pollutants can drastically alter the Water Quality Index (WQI), a composite measure that reflects the overall health of the water based on parameters such as pH, dissolved oxygen, nitrate and phosphate levels, and heavy metal concentrations. Poor water quality can have cascading effects on the wetland's aquatic life, bird populations, and surrounding terrestrial ecosystems.

The impact of agricultural runoff is not confined to water bodies alone; it also affects soil health, which is a critical component of the wetland's ecosystem. Runoff can lead to nutrient imbalances, reduced organic content, and contamination with harmful substances like heavy metals in the soil. These changes in soil characteristics can disrupt the growth of native plant species, alter habitat conditions, and exacerbate the loss of biodiversity. Hence, there is an urgent need to understand the extent to which agricultural runoff influences both water and soil quality in the Nathsagar Wetland region.

This study aims to assess the impact of agricultural runoff on the water quality and soil characteristics of the Nathsagar Wetland, with the objective of determining the current status of the WQI and identifying key changes in soil properties. By analyzing water and soil samples for various physical, chemical, and biological parameters, the research seeks to elucidate the pathways through which agricultural activities are affecting the wetland ecosystem. The findings are expected to provide insights into developing sustainable management strategies to mitigate the adverse effects of agricultural runoff and protect this ecologically important wetland.

Understanding the link between agricultural practices and the health of the Nathsagar Wetland is crucial for ensuring the sustainability of the region's natural resources. This research will contribute to the growing body of knowledge on wetland conservation and offer practical solutions for balancing agricultural productivity with ecological preservation.

2. Review of Literature

The relationship between agricultural runoff and wetland ecosystem health has been a subject of extensive research, given the increasing pressure on freshwater resources due to intensive

farming practices. Wetlands are highly sensitive to external inputs, particularly pollutants from agricultural runoff, which can disrupt their ecological balance and degrade water quality. The Nathsagar Wetland, situated within the Jayakwadi Dam region, is one such vulnerable wetland that faces substantial challenges from agricultural activities in its surrounding areas. This review of literature explores the impacts of agricultural runoff on wetland ecosystems, focusing on water quality indices (WQI), soil characteristics, and strategies for sustainable management.

Impact of Agricultural Runoff on Wetland Water Quality

Agricultural runoff typically contains elevated levels of nutrients, especially nitrates and phosphates, due to the widespread use of chemical fertilizers. These nutrients can lead to eutrophication in wetlands, causing algal blooms, oxygen depletion, and significant changes in aquatic life. Carpenter et al. (1998) highlighted the dangers of nutrient enrichment in freshwater ecosystems, which can lead to the loss of biodiversity and habitat quality. Similarly, Smith et al. (1999) showed that excessive nutrient inputs could disrupt aquatic food webs by favoring fast-growing algal species over more sensitive aquatic plants and animals.

In the context of the Nathsagar Wetland, the influx of agricultural pollutants such as pesticides and herbicides has the potential to reduce the water quality significantly, as noted in studies by Pandey et al. (2014) on other Indian wetlands. Parameters such as pH, dissolved oxygen, and heavy metal concentrations are critical components of the Water Quality Index (WQI), which is widely used to assess the health of water bodies. Mishra and Tripathi (2008) demonstrated that these parameters often show significant deviations in agricultural catchment areas compared to less-disturbed regions, indicating the profound impact of runoff on water quality.

Soil Characteristics Affected by Agricultural Runoff

Agricultural runoff does not only affect water quality but also influences soil health in wetland ecosystems. The addition of excess nutrients, particularly nitrogen and phosphorus, can alter soil nutrient balances and reduce organic matter content. According to Sharpley et al. (2003), nutrient imbalances in soil due to runoff can lead to the degradation of soil structure and fertility, thereby affecting plant growth and habitat conditions. In wetlands, this issue is compounded by the deposition of sediments carried by runoff, which can smother native vegetation and change soil composition.

The accumulation of heavy metals such as cadmium, lead, and mercury in soil due to agricultural activities poses an additional threat. Studies by Singh et al. (2005) have shown that heavy metals can persist in soils for extended periods, potentially entering food chains and causing toxic effects on wildlife. The contamination of wetland soils can disrupt nutrient cycling and diminish the wetland's ability to support diverse plant and animal communities. For instance, the work of Reddy and DeLaune (2008) highlights the importance of maintaining healthy soil characteristics in wetlands for the sustainability of their ecosystem functions.

Water Quality Index (WQI) as an Indicator of Wetland Health

The Water Quality Index (WQI) is a composite metric that integrates various water quality parameters to provide a comprehensive assessment of the overall health of a water body. It has been widely used to evaluate the impact of anthropogenic activities, including agricultural

runoff, on freshwater ecosystems (Said et al., 2004). The components of WQI, such as pH, dissolved oxygen, biochemical oxygen demand, and concentrations of nitrates, phosphates, and heavy metals, are influenced by both natural processes and human activities. Studies by Abbasi and Abbasi (2012) have shown that WQI values are often lower in regions affected by agricultural runoff compared to less impacted areas, underscoring the need for regular monitoring and assessment.

Sustainable Management Strategies for Mitigating Agricultural Runoff

Efforts to mitigate the impacts of agricultural runoff on wetlands have focused on implementing sustainable agricultural practices and restoration strategies. Buffer zones, constructed wetlands, and riparian vegetation have been recommended to reduce nutrient and sediment loads entering wetland ecosystems (Dosskey, 2001). Practices such as controlled fertilizer application, organic farming, and integrated pest management can also help minimize the amount of pollutants reaching wetlands (Tilman et al., 2002).

In the Indian context, wetland conservation policies have emphasized the need for communitybased management and sustainable agricultural practices to protect wetland biodiversity (Gopal, 2013). Specific interventions aimed at restoring the hydrological and ecological functions of wetlands have shown promise in reducing the adverse effects of agricultural runoff.

Relevance to the Nathsagar Wetland

Previous studies on Indian wetlands have highlighted the widespread impact of agricultural activities on wetland health, yet the specific context of the Nathsagar Wetland has not been thoroughly examined. Understanding the local agricultural practices, runoff patterns, and pollutant levels is crucial for assessing the wetland's current status and implementing effective conservation measures. This research aims to fill the gap by analyzing the water quality index and soil characteristics of the Nathsagar Wetland in the face of agricultural runoff. The findings will contribute to the development of region-specific strategies to mitigate pollution and enhance wetland sustainability.

In summary, the literature underscores the significant influence of agricultural runoff on water quality and soil health in wetland ecosystems. There is a pressing need for comprehensive studies that assess the cumulative effects of runoff on both aquatic and terrestrial components of wetlands. This research will build upon the existing knowledge base to offer insights into the sustainable management of the Nathsagar Wetland and similar ecosystems.

3. Methodology

The methodology of this research is designed to assess the impact of agricultural runoff on the Water Quality Index (WQI) and soil characteristics of the Nathsagar Wetland in the Jayakwadi Dam region. This involves a systematic approach for the collection and analysis of water and soil samples, followed by the evaluation of key parameters to determine the extent of pollution and its effects on the wetland ecosystem.

1. Study Area

The study is conducted in the Nathsagar Wetland, a significant ecological zone located within the Jayakwadi Dam region in Maharashtra, India. The wetland is surrounded by agricultural land, where intensive farming practices contribute to potential runoff. Sampling sites are selected to cover areas with varying levels of exposure to agricultural runoff, including locations upstream and downstream of major inflow points from surrounding agricultural fields.

2. Sampling Design

a. Water Sampling

Water samples are collected from 10 different sites within the Nathsagar Wetland. The sites are chosen based on their proximity to agricultural runoff sources, inflow points, and relatively unaffected areas for comparison. Sampling is carried out during both the pre-monsoon (dry season) and post-monsoon (wet season) periods to account for seasonal variations in water quality. At each site, surface water samples are collected in sterile containers at a depth of approximately 0.5 meters.

b. Soil Sampling

Soil samples are collected from the same 10 locations where water sampling is conducted to maintain consistency in assessing the impact of runoff. Samples are taken from the top 15 cm of the soil profile using a soil auger. Both pre-monsoon and post-monsoon samples are collected to examine seasonal variations in soil characteristics.

3. Analysis of Water Quality Parameters

The collected water samples are analyzed for the following key parameters to determine the Water Quality Index (WQI):

- pH: Measured using a calibrated pH meter to assess the acidity or alkalinity of the water.
- Dissolved Oxygen (DO): Determined using the Winkler titration method, as it indicates the water's ability to support aquatic life.
- Nitrates and Phosphates: Analyzed using a UV-visible spectrophotometer to quantify the levels of these nutrients, which can contribute to eutrophication.
- Biochemical Oxygen Demand (BOD): Measured using the standard BOD test to evaluate the amount of organic matter in the water.
- Heavy Metals (e.g., cadmium, lead, mercury): Assessed using atomic absorption spectroscopy (AAS) to determine the concentration of toxic metals that may enter the wetland through agricultural runoff.

The Water Quality Index (WQI) is calculated using a weighted arithmetic mean method, incorporating the above parameters to provide an overall assessment of the water quality at each sampling site.

4. Analysis of Soil Characteristics

The collected soil samples undergo laboratory analysis to determine changes in the following soil characteristics:

- Nutrient Levels (Nitrogen, Phosphorus, Potassium): Measured using standard soil testing methods, including Kjeldahl digestion for nitrogen, Olsen's method for phosphorus, and flame photometry for potassium.
- Organic Content: Evaluated using the loss-on-ignition method, which involves heating the soil sample to a specified temperature and measuring the weight loss, indicative of organic matter content.
- Heavy Metal Concentration: Analyzed using atomic absorption spectroscopy (AAS) to detect the presence and levels of toxic metals such as cadmium, lead, and mercury.
- Soil pH and Electrical Conductivity (EC): Measured to assess the soil's chemical properties and its ability to support plant growth.

5. Data Analysis

a. Statistical Analysis

The data obtained from water and soil analyses are subjected to statistical analysis using software such as SPSS or R. Descriptive statistics are used to summarize the data, while inferential statistics (e.g., ANOVA, t-tests) are applied to detect significant differences between sampling sites and seasonal variations. Correlation analysis is performed to explore relationships between water and soil quality parameters.

b. Water Quality Index (WQI) Calculation

The WQI is calculated for each sampling site using the weighted arithmetic mean method, which involves assigning weights to each parameter based on its importance to overall water quality. The WQI values are classified into categories ranging from "excellent" to "unsuitable for drinking" to assess the impact of agricultural runoff on the wetland.

6. Mitigation Recommendations

Based on the analysis of water quality and soil characteristics, recommendations for sustainable management strategies are developed to mitigate the impact of agricultural runoff on the Nathsagar Wetland. This may include suggestions for buffer zones, controlled fertilizer application, and community-based conservation initiatives.

7. Limitations of the Study

The study acknowledges potential limitations, such as the variability in sampling conditions, the temporal nature of agricultural runoff events, and the limitations of available laboratory techniques. These factors are considered when interpreting the results to ensure a comprehensive understanding of the findings.

8. Ethical Considerations

All research activities are conducted in accordance with environmental guidelines and ethical standards, ensuring minimal disturbance to the wetland ecosystem. Appropriate permissions are obtained for sample collection, and all waste generated during the analysis is disposed of responsibly.

4. Results

1. Water Quality Index (WQI) Analysis: The WQI for the Nathsagar Wetland varied significantly across the sampling sites, particularly between pre-monsoon and post-monsoon periods. The WQI values indicated that water quality was generally poorer during the postmonsoon season, likely due to increased agricultural runoff caused by rainwater carrying contaminants from surrounding farmland. Key findings include:

- o pH Levels: The pH ranged from slightly acidic to neutral across all sampling sites. There was a notable decrease in pH (more acidic conditions) at sites closer to agricultural inflows during the post-monsoon period, likely due to the introduction of chemical fertilizers.
- o Dissolved Oxygen (DO): Lower DO levels were observed at sites with heavy agricultural runoff, especially post-monsoon, indicating higher organic loads and increased microbial activity consuming oxygen.
- o Nitrates and Phosphates: These nutrient levels showed a significant increase in the post-monsoon season, particularly at sites downstream of major agricultural inflow points. The increased concentration is indicative of nutrient pollution from fertilizers.
- o Biochemical Oxygen Demand (BOD): Elevated BOD levels were detected post-monsoon, reflecting a higher organic load likely originating from decomposing agricultural residues.
- o Heavy Metal Concentrations: The presence of heavy metals (cadmium, lead, and mercury) was detected in both seasons, with concentrations slightly higher during the postmonsoon period, suggesting that agricultural activities contribute to the contamination of the wetland.

2. Soil Characteristics Analysis: The impact of agricultural runoff on soil characteristics was evident through changes in nutrient levels, organic content, and metal contamination. Key observations include:

- o Nutrient Levels (Nitrogen, Phosphorus, Potassium): Elevated nitrogen and phosphorus levels were observed in soils collected during the post-monsoon period, suggesting leaching from fertilizers. Potassium levels did not show significant seasonal variation.
- o Organic Content: There was a noticeable decline in organic content in soils closer to runoff sources, likely due to nutrient imbalances and the displacement of organic matter by sediments from the runoff.
- o Heavy Metal Contamination: The soil analysis revealed detectable concentrations of heavy metals such as cadmium, lead, and mercury. These contaminants were more prevalent in soils sampled near agricultural areas, indicating that runoff is a source of soil contamination.

5. Discussion

1. Influence of Agricultural Runoff on Water Quality: The findings confirm that agricultural runoff significantly affects the water quality of the Nathsagar Wetland. Elevated levels of nitrates and phosphates during the post-monsoon season are indicative of nutrient pollution, which can lead to eutrophication. The observed decrease in dissolved oxygen and

the increase in BOD further indicate the adverse effects of organic pollution, which can harm aquatic life by creating hypoxic conditions. The presence of heavy metals, though within permissible limits in some cases, still poses a long-term risk to the ecosystem's health.

2. **Seasonal Variations in Water and Soil Quality:** The comparison between pre-monsoon and post-monsoon data reveals that seasonal agricultural activities, combined with rainfall, exacerbate the transport of pollutants into the wetland. The increase in heavy metal concentrations and nutrient levels post-monsoon highlights the need for better management practices, such as controlled fertilizer use and the establishment of buffer zones to reduce runoff during rainy seasons.

3. **Soil Health Impacts and Ecological Implications:** Changes in soil characteristics, particularly the nutrient imbalances and heavy metal accumulation, can alter the wetland's vegetation structure, making it less hospitable for native plant species. This, in turn, may disrupt habitat conditions for wildlife, including migratory bird species that depend on the wetland. The loss of organic matter in the soil could further degrade soil fertility, impacting plant growth and nutrient cycling.

4. **Comparison with Previous Studies:** The results align with findings from other studies on the impact of agricultural runoff on wetlands, where nutrient enrichment, heavy metal contamination, and organic pollution are common outcomes. The findings are consistent with the work of Carpenter et al. (1998) on nutrient pollution and Sharpley et al. (2003) regarding soil nutrient imbalances caused by agricultural practices.

5. **Recommendations for Sustainable Management o Buffer Zones and Riparian Vegetation:** Establishing buffer zones and planting riparian vegetation along the periphery of the wetland can help filter out sediments, nutrients, and contaminants before they reach the water.

- o **Controlled Use of Fertilizers:** Implementing best management practices for fertilizer application, such as precision agriculture, can reduce the amount of nutrients entering the wetland.

- o **Monitoring Programs:** Regular monitoring of water and soil quality is essential for tracking changes and identifying pollution sources. A comprehensive monitoring program that includes WQI assessment and soil testing can help guide conservation efforts.

- o **Community Involvement:** Engaging local communities in wetland management and promoting sustainable farming practices can help mitigate the adverse effects of agricultural runoff.

6. Conclusion

The study reveals that agricultural runoff significantly impacts the Nathsagar Wetland's water and soil quality, posing a threat to its ecological balance. Analysis of the Water Quality Index (WQI) indicates that nutrient enrichment from fertilizers and pesticides has led to deteriorating water quality, particularly with elevated levels of nitrates, phosphates, and heavy metals. These pollutants contribute to issues such as eutrophication, algal blooms, and reduced dissolved oxygen, which adversely affect aquatic life. The study also finds that soil health is

compromised due to nutrient imbalances, decreased organic content, and the presence of heavy metals, leading to poor soil structure and reduced plant growth potential.

The results highlight the need for immediate attention to the environmental management of the Nathsagar Wetland. By understanding the extent to which agricultural runoff affects both aquatic and terrestrial components, this research provides valuable insights into the pathways through which agricultural activities impact wetland ecosystems. The findings underscore the urgency of implementing conservation strategies to protect the Nathsagar Wetland from further degradation and promote sustainable agricultural practices.

7. Suggestions

1. **Implementation of Buffer Zones and Riparian Vegetation:** Establishing buffer zones with riparian vegetation around agricultural fields can help reduce the influx of pollutants entering the wetland. These vegetative buffers act as natural filters, trapping sediments and absorbing excess nutrients, thereby improving water quality.
2. **Adoption of Sustainable Agricultural Practices:** Encourage the use of organic fertilizers, controlled fertilizer application, and integrated pest management to reduce the concentration of chemical pollutants in runoff. Practices such as crop rotation, no-till farming, and cover cropping can further help in maintaining soil fertility and reducing erosion.
3. **Construction of Wetland Treatment Areas:** Creating constructed wetlands or artificial ponds can help treat agricultural runoff before it reaches the Nathsagar Wetland. These treatment areas can be designed to capture and filter pollutants through natural processes, thus minimizing their impact on the main wetland ecosystem.
4. **Regular Monitoring and Assessment of Water Quality:** Establish a regular monitoring program for key water quality parameters and soil characteristics to detect early signs of pollution. This will help in taking timely corrective actions and assessing the effectiveness of implemented management strategies.
5. **Public Awareness and Community Involvement:** Conduct educational programs and workshops to raise awareness among local farmers and communities about the harmful effects of agricultural runoff on wetland ecosystems. Encourage community involvement in conservation efforts and promote best practices in sustainable agriculture.
6. **Policy Interventions and Regulatory Measures:** Advocate for stricter regulations on the use of chemical fertilizers and pesticides in the areas surrounding the wetland. Policies should incentivize sustainable farming practices and provide support for farmers transitioning to eco-friendly agricultural techniques.
7. **Restoration of Degraded Wetland Areas:** Undertake restoration activities to rehabilitate areas of the Nathsagar Wetland that have been severely affected by pollution. This may involve replanting native vegetation, removing invasive species, and enhancing hydrological connectivity to restore natural water flow patterns.
8. **Promoting Agroforestry and Silviculture:** Integrating trees and shrubs within agricultural landscapes (agroforestry) can help improve soil quality, reduce runoff, and enhance biodiversity. Silviculture practices should be encouraged to provide a multifunctional

landscape that supports both agricultural productivity and ecological conservation. By implementing these suggestions, the long-term sustainability of the Nathsagar Wetland can be safeguarded, ensuring that it continues to provide essential ecosystem services and support biodiversity while allowing for agricultural development.

References

1. Mitsch, W. J., & Gosselink, J. G. (2007). *Wetlands* (4th ed.). John Wiley & Sons.
2. Brown, R. M., McClelland, N. I., Deininger, R. A., & Tozer, R. G. (1970). A water quality index – do we dare? *Water and Sewage Works*, 117(10), 339-343.
3. Sharpley, A. N., & Menzel, R. G. (1987). Impact of nitrogen and phosphorus on water quality. *Advances in Agronomy*, 41, 297-324. [https://doi.org/10.1016/S0065-2113\(08\)60887-1](https://doi.org/10.1016/S0065-2113(08)60887-1)
4. Smith, V. H. (2003). Eutrophication of freshwater and coastal marine ecosystems: A global problem. *Environmental Science and Pollution Research*, 10(2), 126-139. <https://doi.org/10.1065/espr2002.12.142>
5. Vymazal, J. (2011). Constructed wetlands for wastewater treatment: Five decades of experience. *Environmental Science & Technology*, 45(1), 61-69. <https://doi.org/10.1021/es101403q>
6. Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R., & Polasky, S. (2002). Agricultural sustainability and intensive production practices. *Nature*, 418, 671-677. <https://doi.org/10.1038/nature01014>
7. Kabata-Pendias, A. (2010). *Trace elements in soils and plants* (4th ed.). CRC Press.
8. Zedler, J. B. (2000). Progress in wetland restoration ecology. *Trends in Ecology & Evolution*, 15(10), 402-407. [https://doi.org/10.1016/S0169-5347\(00\)01957-7](https://doi.org/10.1016/S0169-5347(00)01957-7)
9. Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge University Press.
10. Nair, P. K. R. (1993). *An introduction to agroforestry*. Kluwer Academic Publishers.