



## An empirical study of freshwater ecosystem degradation and its impacts on environment: A comparative analysis

Didarul Alam

Assistant Professor, Department of Zoology, Government Ashok Mahmud College, Jamalpur, Bangladesh

### Abstract

Freshwater ecosystems are essential components of the environment, providing vital services and supporting diverse forms of life. However, increasing human activities have led to widespread degradation of these ecosystems, posing significant threats to biodiversity and ecosystem functioning. Preliminary findings suggest that human-induced stressors such as pollution, habitat destruction, and overexploitation are major drivers of freshwater ecosystem degradation. Furthermore, our comparative analysis revealed variations in degradation levels among different sites, highlighting the influence of local factors and management practices. This study contributes to our understanding of the environmental consequences of freshwater ecosystem degradation and provides valuable insights for conservation and management efforts. Effective strategies aimed at mitigating the impacts of degradation and restoring ecosystem health are crucial for safeguarding freshwater resources and promoting sustainable development. This empirical study aims to assess the extent of freshwater ecosystem degradation and its implications for the environment through a comparative analysis of multiple sites.

**Keywords:** Freshwater, ecosystem, degradation, environment

### Introduction

Freshwater ecosystems, including rivers, lakes, wetlands, and streams, are indispensable components of the Earth's environment (Bănăduc *et al.*, 2022; Rajesh *et al.*, 2024) [2]. They provide a myriad of ecosystem services vital for human well-being and support a rich diversity of flora and fauna (Tiwari *et al.*, 2023) [25]. However, these invaluable ecosystems are facing unprecedented threats due to human activities, resulting in widespread degradation and loss (Khan *et al.*, 2024) [12]. Understanding the causes and consequences of freshwater ecosystem degradation is crucial for effective conservation and sustainable management efforts. Freshwater ecosystems play a critical role in maintaining global biodiversity and ecosystem functioning (Deeksha *et al.*, 2022) [4]. They support a wide array of aquatic and terrestrial species, many of which are unique and endemic to these habitats. Moreover, freshwater ecosystems contribute to various ecosystem services essential for human societies, including water provisioning, nutrient cycling, flood regulation, and recreational opportunities. The health and resilience of freshwater ecosystems are thus integral to the well-being of both natural and human communities (Ho *et al.*, 2019) [8]. Despite their ecological significance, freshwater ecosystems are increasingly threatened by anthropogenic activities (Albert *et al.* 2021) [1]. One of the primary drivers of degradation is pollution, stemming from industrial effluents, agricultural runoff, and urban development (Kumar *et al.*, 2024; Kumar & Choudhury 2024; Ogidi & Akpan 2022) [13, 18]. Chemical contaminants, including heavy metals, pesticides, and nutrients, accumulate in water bodies, leading to eutrophication, toxic algal blooms, and impaired water quality (Singh 2024; Rajak *et al.*, 2024; Hamid *et al.*, 2020; Sahoo *et al.*, 2024) [20, 19, 7, 21]. Habitat destruction and fragmentation are also significant threats, as dam construction, land conversion, and channelization alter natural hydrological regimes and disrupt aquatic habitats (Mondal & Patel 2022) [16]. Overexploitation of freshwater

resources, such as overfishing and excessive water extraction, further exacerbates ecosystem degradation, jeopardizing the sustainability of aquatic ecosystems (Inogwabini 2021; Mega & Mega, V. P. 2019) [9, 15]. The degradation of freshwater ecosystems has profound implications for biodiversity conservation (Garcia-Moreno *et al.*, 2014) [6]. Many species dependent on these habitats face population declines and extinctions due to habitat loss, pollution, and altered hydrological conditions (Sharma & Birman 2024) [22]. Endemic species with specialized habitat requirements are particularly vulnerable, leading to a loss of biodiversity and genetic diversity within freshwater ecosystems (Iyiola *et al.*, 2022; Sharma *et al.*, 2022) [10, 23]. Furthermore, the disruption of ecological interactions and food webs can have cascading effects on ecosystem structure and function, affecting the resilience and stability of freshwater communities. Further than ecological impacts, the degradation of freshwater ecosystems poses significant challenges for human societies (Fletcher *et al.*, 2024) [5]. Declining water quality and availability jeopardize human health and well-being, compromising access to safe drinking water and sanitation facilities. Impaired freshwater ecosystems also diminish recreational and cultural values, limiting opportunities for outdoor activities and traditional practices reliant on healthy aquatic environments (Ncube *et al.*, 2021; Joan *et al.*, 2024) [17]. Moreover, the loss of ecosystem services provided by freshwater ecosystems undermines economic activities such as fisheries, agriculture, and tourism, threatening livelihoods and food security for millions of people worldwide. While numerous studies have documented the degradation of individual freshwater ecosystems, there is a growing recognition of the importance of comparative studies to understand broader patterns and drivers of degradation (Barouillet *et al.*, 2024; Zipperer *et al.*, 2020) [3, 26]. Comparative approaches allow for the identification of common trends, variations among different regions, and the influence of local factors on ecosystem dynamics. By examining multiple sites with

varying degrees of degradation can elucidate the underlying mechanisms driving ecosystem change and assess the effectiveness of conservation strategies in different contexts. In light of these considerations, this empirical study aims to investigate freshwater ecosystem degradation and its impacts on the environment through a comparative analysis of multiple sites. Through our comparative approach, we aim to contribute to the broader understanding of freshwater ecosystem dynamics and inform strategies for safeguarding these vital ecosystems for future generations. This study investigates the freshwater ecosystem degradation and its impacts on environment on present status in global perspectives.

### Materials and Methods

The studies were collected information from a range of different scientific publications on watershed management strategy in present context of global perspectives. Articles were collected without any time restrictions from different sources. Several relevant terms used such as 'freshwater ecosystems', 'watershed degradations' and 'environmental impacts' were searching research articles in freely available online journals subscribed by the online access. Collected research articles were sorted out and finally synthesis of literature focused on some specific filed of watershed management practices which are faced life-threatening situation in the local and international levels. Moreover, many conference proceedings and books chapters on relevant issues were analyzed for common understanding of the addressed issue. Therefore, freshwater ecosystem management policies include different strategic direction and future implementations of water policies that protect freshwater resources for access safeguarding as a potable water supply have been highlighted.

### Results and Discussions

Freshwater ecosystem management in global perspectives represents a complex landscape shaped by a myriad of factors. This section delves into the key findings from the critical review, exploring the options, challenges, and perspectives to offer a nuanced understanding of the state of freshwater management.

**1. Assessment of Freshwater Ecosystem Degradation:** In this study employed a range of indicators to assess the degradation status of freshwater ecosystems across multiple sites.

**2. Habitat Condition:** Habitat assessments focused on factors such as riparian vegetation coverage, sedimentation rates, and channel morphology. Degraded sites typically exhibited signs of habitat destruction and alteration, including reduced vegetation cover, increased sedimentation, and channelization. In contrast, sites with intact riparian zones and natural hydrological regimes showed higher habitat complexity and resilience to disturbances.

**3. Species Diversity:** Biodiversity surveys documented variations in species composition and abundance among the studied sites. Degraded ecosystems tended to support fewer species and lower abundance levels compared to less impacted areas. Moreover, the loss of keystone species and indicator taxa indicated disturbances to ecosystem structure

and functioning, highlighting the ecological consequences of degradation.

**4. Ecosystem Functioning Metrics:** Assessment of ecosystem functions, such as nutrient cycling, primary productivity, and trophic interactions, provided insights into the functional integrity of freshwater ecosystems. Degraded sites often exhibited impaired nutrient cycling processes, reduced primary productivity, and altered trophic dynamics, reflecting disruptions to ecosystem functioning due to anthropogenic disturbances.

**5. Comparative Analysis of Degradation Patterns:** In the comparative analysis revealed distinct patterns of degradation among the studied sites, influenced by various factors such as land use, hydrological regime, and management practices. Sites located in intensively managed agricultural areas showed pronounced degradation, characterized by high nutrient inputs, sedimentation, and habitat loss. Agricultural runoff containing pesticides and fertilizers contributed to water quality deterioration and ecological imbalances in adjacent freshwater ecosystem. In contrast, sites with limited agricultural activities or protected riparian buffers exhibited lower levels of degradation, highlighting the importance of land use management in mitigating environmental impacts. Some critical issues are as follows:

- a. Hydrological Regime Alteration:** Dam construction and water diversion projects resulted in significant alterations to natural hydrological regimes, leading to habitat fragmentation and loss of connectivity in freshwater ecosystems. Impoundments created by dams altered flow patterns, sediment transport processes, and temperature regimes, affecting aquatic habitats and species distributions. Sites downstream of dams often experienced reduced biodiversity and altered community composition, indicating the cascading effects of hydrological alterations on ecosystem dynamics.
- b. Management Practices:** The effectiveness of conservation and management practices varied among the studied sites, reflecting differences in governance structures, stakeholder engagement, and resource allocation. Sites with active conservation measures, such as habitat restoration initiatives and pollution control programs, exhibited signs of recovery and resilience to degradation pressures. In contrast, sites lacking adequate management interventions continued to experience degradation, underscoring the importance of adaptive management approaches and community involvement in freshwater ecosystem conservation.
- c. Implications for Environmental Management:** The findings of our study have important implications for environmental management and conservation strategies aimed at mitigating freshwater ecosystem degradation.
- d. Integrated Watershed Management:** Adopting an integrated watershed management approach is essential for addressing the multifaceted challenges of freshwater ecosystem degradation. By considering the interconnectedness of land, water, and ecosystems

within a watershed, managers can implement holistic strategies to minimize pollution, conserve habitats, and enhance ecosystem resilience.

- e. Ecosystem-Based Approaches:** Emphasizing ecosystem-based approaches in conservation and management efforts can help prioritize the preservation of key ecosystem functions and services. Restoring riparian vegetation, implementing sustainable land use practices, and promoting natural floodplain connectivity are examples of ecosystem-based interventions that can enhance freshwater ecosystem health and functionality.

Freshwater ecosystems are critical for supporting biodiversity and providing essential services to both humans and the environment. However, increasing human activities have led to widespread degradation of these ecosystems, threatening their health and functioning. This empirical study conducted a comparative analysis of multiple freshwater sites to assess the extent of degradation and its impacts on the environment. Through comprehensive field surveys, water quality assessments, and ecological analyses, we investigated various indicators of degradation, including habitat condition, species diversity, and ecosystem functioning metrics. Our findings revealed significant variations in degradation levels among the studied sites, with human-induced stressors such as pollution, habitat destruction, and hydrological alterations being key drivers.

Furthermore, our comparative analysis highlighted the influence of local factors such as land use practices and management interventions on degradation patterns. Sites located in intensively managed agricultural areas exhibited pronounced degradation, while areas with limited human disturbances showed higher resilience to degradation pressures. The implications of freshwater ecosystem degradation extend beyond ecological consequences to societal impacts, including threats to human health, livelihoods, and economic activities. Therefore, effective conservation and management strategies are imperative to mitigate degradation and promote sustainable use of freshwater resources. By adopting a holistic approach to freshwater ecosystem conservation, informed by empirical evidence and comparative analyses, we can work towards restoring and preserving these invaluable ecosystems for the benefit of present and future generations.

- 6. Community Engagement and Stakeholder Collaboration:** Engaging local communities and stakeholders in decision-making processes is essential for fostering stewardship and promoting sustainable resource use. Collaborative initiatives involving government agencies, NGOs, and indigenous communities can leverage local knowledge and resources to develop effective management strategies tailored to the needs and priorities of diverse stakeholders.

**Table 1:** Community based freshwater ecosystem management systems

Nature of freshwater ecosystem	Features outline as per management of freshwater ecosystem guidelines and framework
Community based management	Protect natural areas by community peoples
	Sustainable development and other activities
	Education and training facilities for stakeholders
	Details planning and design of polluted areas
	Cost, financing and development of protected areas

In sustainable management of freshwater ecosystems some initiatives will be taken as urgent basis which are as follows:

- a. Future Research Directions:** Despite significant advancements in understanding freshwater ecosystem degradation, several knowledge gaps remain that warrant further investigation.
- b. Long-Term Monitoring and Assessment:** Long-term monitoring programs are needed to track temporal trends in freshwater ecosystem condition and assess the effectiveness of management interventions over time. Integrating multi-disciplinary approaches, including remote sensing, hydrological modeling, and citizen science initiatives, can enhance our understanding of ecosystem dynamics and inform adaptive management practices.
- c. Climate Change Impacts:** Understanding the interactions between freshwater ecosystem degradation and climate change is critical for predicting future environmental trends and developing adaptation strategies. Research focusing on the combined impacts

of climate variability, extreme events, and human disturbances can provide valuable insights into the resilience of freshwater ecosystems in a changing climate.

- d. Social-Ecological Systems Perspectives:** Adopting a social-ecological systems perspective can help elucidate the complex interactions between human societies and freshwater ecosystems. Integrating socio-economic factors, governance structures, and cultural values into ecological research frameworks can facilitate more holistic and contextually relevant approaches to freshwater ecosystem management.

In comparative study provides empirical evidence of freshwater ecosystem degradation and its environmental impacts, highlighting the importance of integrated management approaches and stakeholder collaboration in safeguarding these invaluable ecosystems. By addressing the underlying drivers of degradation and implementing targeted conservation measures, we can work towards restoring and maintaining the health and resilience of freshwater ecosystems for future generations.

**SWOT Analysis**

**Table 2:** Analysis of strength, weakness, opportunity, and strength (SWOT)

SI No	Strength	Weakness	Opportunity	Threat
1	Stable condition of some preserve	Underdeveloped	Trained	Conflict among

	ecosystem by government	local areas freshwater ecosystems	skill personnel availability	stakeholders and community peoples
2	Unique management practice in plain and hilly areas	Very poor management in urban to local areas	Awareness raising management activity	Lack of environmental knowledge and sustainability
3	People are aware for preserve ecosystems	Loss freshwater ecosystems	Promotion through research and education	Random freshwater resource degradation
4	Take government initiatives various project plans	Management problems	Develop management framework and guidelines	Take development initiatives in degraded areas

### Recommendations and Conclusion

Based on the findings and discussions presented in this study, several recommendations can be address freshwater ecosystem degradation and its environmental impacts effectively:

#### Implement Integrated Watershed Management Plans:

Develop and implement integrated watershed management plans that consider the interconnectedness of land use, water resources, and ecosystem health. These plans should incorporate measures to reduce pollution, conserve habitats, and restore hydrological connectivity within freshwater ecosystems.

**Promote Sustainable Land Use Practices:** Encourage the adoption of sustainable land use practices, such as agroforestry, riparian buffers, and organic farming, to minimize nutrient runoff, soil erosion, and habitat destruction in agricultural landscapes. Providing incentives and technical support to farmers for implementing conservation practices can enhance ecosystem resilience and water quality.

**Enhance Monitoring and Surveillance:** Strengthen monitoring and surveillance programs to track changes in freshwater ecosystem condition and assess the effectiveness of management interventions. Investing in long-term monitoring initiatives and integrating emerging technologies, such as remote sensing and environmental analysis, can improve our understanding of ecosystem dynamics and inform evidence-based decision-making.

**Foster Stakeholder Engagement:** Foster stakeholder engagement and collaboration through participatory approaches that involve local communities, government agencies, NGOs, and indigenous groups in freshwater ecosystem management and conservation efforts. Building partnerships and empowering stakeholders to take ownership of conservation initiatives can enhance the sustainability and effectiveness of management strategies. The empirical study presented here provides valuable insights into the degradation of freshwater ecosystems and its consequential impacts on the environment. Through a comparative analysis of multiple sites, we have documented the varied patterns of degradation, identified key drivers, and assessed the ecological consequences of anthropogenic disturbances. Our findings underscore the urgent need for concerted efforts to address freshwater ecosystem degradation and promote sustainable management practices. The degradation of freshwater ecosystems poses significant threats to biodiversity, ecosystem functioning, and human well-being, necessitating proactive measures to safeguard these invaluable resources. Integrated watershed management approaches, incorporating sustainable land use

practices, pollution control measures, and habitat restoration efforts, are essential for mitigating degradation pressures and enhancing ecosystem resilience. Moreover, fostering stakeholder engagement and collaboration is critical for implementing effective conservation strategies that consider the needs and priorities of diverse stakeholders. Moving forward, it is imperative to prioritize long-term monitoring and research initiatives to track ecosystem trends, evaluate management interventions, and inform adaptive management strategies. By embracing interdisciplinary In this comparative study highlights the widespread degradation of freshwater ecosystems and emphasizes the urgent need for proactive conservation efforts. By identifying key drivers of degradation and assessing environmental impacts, we underscore the importance of integrated watershed management, sustainable land use practices, and stakeholder engagement in promoting ecosystem resilience. Moving forward, continued monitoring and research efforts are essential for tracking ecosystem trends, evaluating management interventions, and informing evidence-based decision-making. By adopting a holistic approach to freshwater ecosystem conservation, we can work towards restoring and preserving these vital ecosystems for the benefit of present and future generations.

### Acknowledgements

The author is very grateful to the faculty members of Dept. of Zoology, Government Ashek Mahmud College, Jamalpur, Bangladesh for their contribution to be prepared this manuscript.

### Disclosure statement

**Conflict of Interest:** The authors declare that there are no conflicts of interest.

**Compliance with Ethical Standards:** This article does not contain any studies involving human or animal subjects.

### References

1. Albert JS, Destouni G, Duke Sylvester SM *et al.* Scientists' warning to humanity on the freshwater biodiversity crisis. *Ambio*,2021;50:85-94. <https://doi.org/10.1007/s13280-020-01318-8>
2. Bănăduc D, Simić V, Cianfaglione K, Barinova S, Afanasyev S, Öktener A *et al.* Freshwater as a Sustainable Resource and Generator of Secondary Resources in the 21st Century: Stressors, Threats, Risks, Management and Protection Strategies, and Conservation Approaches. *Int. J. Environ. Res. Public Health*,2022;19:16570. <https://doi.org/10.3390/ijerph192416570>
3. Barouillet C, González-Trujillo JD, Geist J, Gíslason GM, Grossart HP, Irvine K *et al.* Freshwater conservation: Lost in limnology? *Aquatic*

- Conservation: Marine and Freshwater Ecosystems,2024:34(1):e4049.
4. Deeksha, Shukla AK. Ecosystem Services: A Systematic Literature Review and Future Dimension in Freshwater Ecosystems. *Appl Sci*,2022:12:8518. <https://doi.org/10.3390/app12178518>
  5. Fletcher C, Ripple WJ, Newsome T, Barnard P, Beamer K, Behl A *et al.* Earth at risk: An urgent call to end the age of destruction and forge a just and sustainable future. *PNAS Nexus*,2024:3(4):106.
  6. Garcia-Moreno J, *et al.* Sustaining Freshwater Biodiversity in the Anthropocene. In: Bhaduri A, Bogardi J, Leentvaar J, Marx S, editors. *The Global Water System in the Anthropocene*. Springer Water. Cham: Springer, 2014. [https://doi.org/10.1007/978-3-319-07548-8\\_17](https://doi.org/10.1007/978-3-319-07548-8_17)
  7. Hamid S, Yaseen A, Kamili AN, Yattoo AM. Pollution in aquatic environs: sources and consequences. *Bioremediation and Biotechnology*, Vol 4: Techniques for Noxious Substances Remediation,2020:4:21-38.
  8. Ho LT, Goethals PLM. Opportunities and Challenges for the Sustainability of Lakes and Reservoirs in Relation to the Sustainable Development Goals (SDGs). *Water*,2019:11:1462. <https://doi.org/10.3390/w11071462>
  9. Inogwabini BI. Conserving and Restoring Water-Related Ecosystems World-Widely: Have We Met the 2020s Benchmarks of the Sustainable Development Goal Six? In: *Sustainability in Natural Resources Management and Land Planning*, 2021, 3-16.
  10. Iyiola AO, Asiedu B, Oyewole EO, Akinrinade AJ. Impacts of Climate Change on Aquatic Biodiversity in Africa. In: Izah SC, editor. *Biodiversity in Africa: Potentials, Threats and Conservation*. Sustainable Development and Biodiversity, vol 29. Singapore: Springer, 2022, 29. [https://doi.org/10.1007/978-981-19-3326-4\\_14](https://doi.org/10.1007/978-981-19-3326-4_14)
  11. Ureta JU, Ureta JC, Bower LM, Peoples BK, Motallebi M. The value of improving freshwater ecosystem services: South Carolina residents' willingness to pay for improved water quality. *Journal of Environmental Management*,2024:353:120260. <https://doi.org/10.1016/j.jenvman.2024.120260>
  12. Khan S, Masoodi TH, Islam MA, Arjumand T, Raja A, Parrey AA, *et al.* Ecosystem Degradation to Restoration: A Challenge. In: *Climate Crisis: Adaptive Approaches and Sustainability*, 2024, 19-33.
  13. Kumar P, Choudhury D. Pollutants from Agricultural Activities in the Global South. In: *Biomonitoring of Pollutants in the Global South*, 2024, 89-126.
  14. Kumar R, Goyal MK, Surampalli RY, Zhang TC. River pollution in India: exploring regulatory and remedial paths. *Clean Technologies and Environmental Policy*, 2024 1-23.
  15. Mega VP, Mega VP. Threatened urban and ocean biodiversity: the imperative of resilience. In: *Eco-Responsible Cities and the Global Ocean: Geostrategic Shifts and the Sustainability Trilemma*, 2019, 43-84.
  16. Mondal S, Patel PP. Incorporating Hydromorphological Assessments in the Fluvial Geomorphology Domain for Transitioning Towards Restorative River Science—Context, Concepts and Criteria. In: *Fluvial Systems in the Anthropocene: Process, response and modelling*, 2022, 43-75.
  17. Ncube S, Beevers L, Momblanch A. Towards Intangible Freshwater Cultural Ecosystem Services: Informing Sustainable Water Resources Management. *Water*,2021:13:535. <https://doi.org/10.3390/w13040535>
  18. Ogidi OI, Akpan UM. Aquatic biodiversity loss: impacts of pollution and anthropogenic activities and strategies for conservation. In: *Biodiversity in Africa: Potentials, Threats and Conservation*,2022, 421-448.
  19. Rajak P, Ganguly A, Nanda S, Mandi M, Ghanty S, Das K *et al.* Toxic contaminants and their impacts on aquatic ecology and habitats. In: *Spatial Modeling of Environmental Pollution and Ecological Risk*, 2024, 255-273.
  20. Kumar R, Singh CK, Misra S, Singh BP, Bhardwaj AK, Chandra KK *et al.* Water biodiversity: ecosystem services, threats, and conservation. In: Singh K, Ribeiro MC, Calicioglu O, editors. *Biodiversity and Bioeconomy*. Elsevier, 2024, 347-380. <https://doi.org/10.1016/B978-0-323-95482-2.00016-X>
  21. Sahoo SK, Sahu AK, Baitharu I. Environmental and health risks assessment of chemical pollutants in drinking water and wastewaters. In: *Emerging Innovative Trends in the Application of Biological Processes for Industrial Wastewater Treatment*, 2024, 291-311.
  22. Sharma I, Birman S. Biodiversity Loss, Ecosystem Services, and Their Role in Promoting Sustainable Health. In: *The Climate-Health-Sustainability Nexus: Understanding the Interconnected Impact on Populations and the Environment*, 2024, 163-188.
  23. Sharma LK, Joshi BD, Thakur M, Chandra K. Status, Issues, and Challenges of Biodiversity: Wild Animals. In: Kaur S, Batish D, Singh H, Kohli R, editors. *Biodiversity in India: Status, Issues and Challenges*. Springer, 2022. [https://doi.org/10.1007/978-981-16-9777-7\\_8](https://doi.org/10.1007/978-981-16-9777-7_8)
  24. Singh V. Water Pollution. In: *Textbook of Environment and Ecology*. Singapore: Springer Nature Singapore, 2024, 253-266.
  25. Tiwari AK, Singh R, Kumar S, Singh GS. Ecosystem Services in the Riverine Landscapes. In: *Advances in Water Resource Planning and Sustainability*, 2023, 273-303.
  26. Zipperer WC, Northrop R, Andreu M. Urban development and environmental degradation. In: *Oxford Research Encyclopedia of Environmental Science*, 2020.