The Himalayan Geographers
A Peer-Reviewed Journal
Print ISSN 2362-1532
Email: geography@pncampus.edu.np
Journal Site: http://ejournals.pncampus.edu.np/thg
DOI: https://doi.org/10.3126/thg.v14i1.80632

Published by
Department of Geography
Prithvi Narayan Campus
Tribhuvan University
Pokhara, Nepal

Degradation Dynamics and Conservation Imperatives of Phewa Wetland, Nepal

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Received 23 October, 2024, accepted 23 November, 2024, Published 25 December 2024

Abstract

Phewa Wetland, a vital ecological area within Nepal's Phewa Lacustrine Plain, is experiencing rapid degradation due to escalating natural and anthropogenic pressures. This study employs a mixed-method approach combining field observation, GIS-based spatial analysis, and secondary data review to assess the wetland's ecological status, sedimentation trends, biodiversity, and human impacts. Between 1978 and 2024, the wetland area is unstable in size. Urban expansion, agricultural encroachment, invasive plants and sediment inflow is major contributors. Additional threats include nutrient overloading, unregulated waste disposal, and weak policy enforcement. The findings underscore the urgent need for integrated conservation strategies such as legal boundary demarcation, agrochemical regulation, sediment control infrastructure, invasive species management and active community involvement. Without immediate intervention, Phewa Wetland faces the risk of ecological collapse, endangering both biodiversity and the livelihoods that depends on it. Preserving this wetland is essential not only for local sustainability but also for Nepal's broader environmental resilience.

Keywords: *Anthropogenic pressure, biodiversity conservation, ecological succession, Phewa wetland, sedimentation, sustainable management, wetland*

Introduction

Wetlands occupy a unique ecological niche, existing at the intersection of terrestrial and aquatic systems, yet fully belonging to neither. As a result they have historically resisted full integration into conventional ecological paradigms (NRS, 1995). Wetlands are ecosystems characterized by hydric soils and water-tolerant vegetation that occur where the water table is at or near the surface long enough each year to support aquatic plant communities (U.S. ACE, 1987). Though they vary

greatly from marshes and swamps to bogs and fens all wetlands share the defining trait of being shaped by water presence and its influence on soil and biota (RCB, 2002). Basnet (2023) indicate that wetland degradation in the Phewa area is driven by ineffective governance, fragmented management policies, and weak institutional coordination. Their ecological, economic, cultural, and recreational values are profound. Wetlands not only serve as biodiversity hotspots, hosting species uniquely adapted to water-saturated conditions, but they also play a pivotal role in maintaining the global water cycle (Keddy, 2010).

The functional overlap wetlands share with both terrestrial and aquatic systems makes them crucial testing grounds for ecological theories such as succession, energy flow, and nutrient cycling (Percenthat et al., 1993) as global recognition of ecosystem services grow, so too does the imperative to understand and protect wetlands not only peripheral ecosystems, but as vital infrastructure for environmental resilience and sustainability (RCS**,** 2019). Sarkar and Maji (2022) highlights the rapid urbanization and shifting land use patterns are major drivers of wetland degradation and ecological imbalance. *The* agriculture practices, urbanization, aquaculture and industry as the primary drivers of global wetland area and carbon sequestration loss over the past 14 years (Wood & Habibullah, 2022).

Wetlands are areas where water soaks the soil for extended periods, supporting specially adapted plant and animal species. Wetlands play vital roles in hydrology, ecology and biodiversity conservation but are increasingly threatened by human development (Patel**,** 2021).

Nepal became a contracting party to the Ramsar Convention, committing to the global framework for conserving wetlands of international importance and promoting their wise use to safeguard biodiversity, water regulation, and human well-being (RCS, 1987).

The wetlands and lakes of the Pokhara Valley, particularly Phewa Lake and its surrounding lacustrine plain, are undergoing rapid degradation and transformation. Once vibrant and ecologically productive sites, these areas are being increasingly encroached upon by urban expansion, unsustainable agricultural practices, and sedimentation caused by unchecked erosion from small tributaries or streams originating within this watershed. Other wetlands around the Pokhara area including Phewa, Nureny, Khaste, Dipang, Maide, and Kamal Pokhari are either already disappearing or are severely threatened with drying up and turning into dry land.

Wetlands are the most productive ecosystems, providing essential services such as water purification, biodiversity support, flood control, and habitat for a wide variety of species. However, their capacity to absorb pollutants without functional degradation is limited.

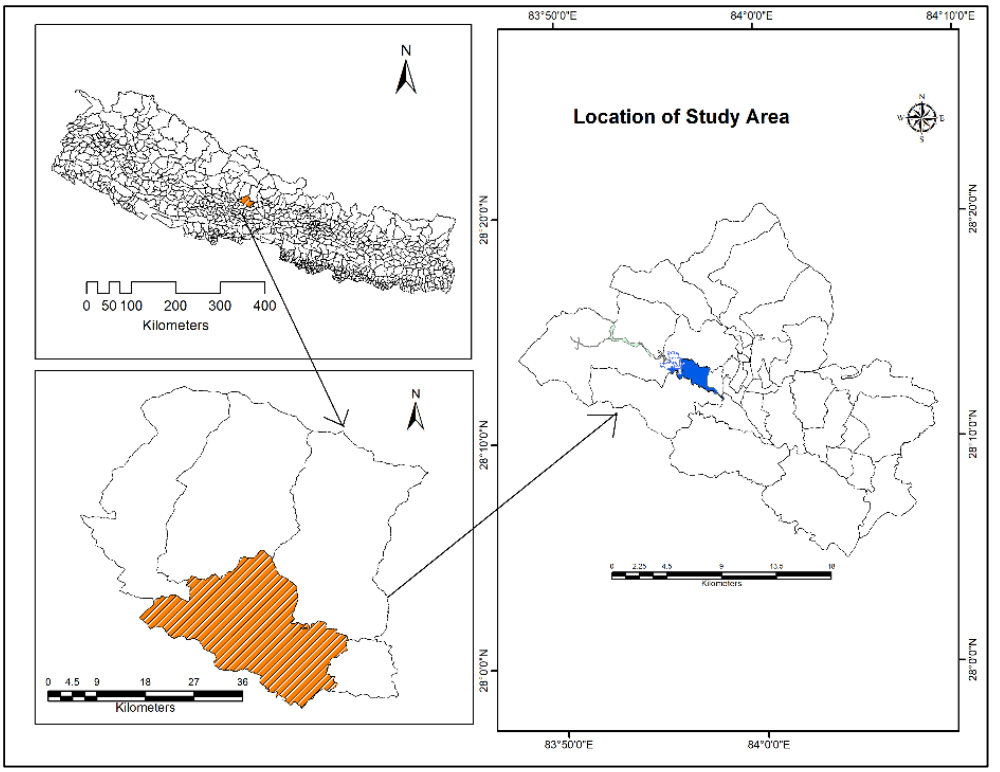
Phewa Wetland has been significantly altered by sediment carried by Harpan Khola and its smaller tributaries and rivulets originating from the upper sloping watershed. This process, along with human encroachment, has contributed to biodiversity loss. This study aims to investigate the degradation issues of the Phewa Wetland, with the goal of identifying dynamic conservation strategies based on local knowledge and available information resources.

Study area

Phewa Lake, the second-largest lake in Nepal, is located in the rapidly growing Pokhara Metropolitan City (PMC) (Fig. 1). It is a popular tourist destination because of its scenic beauty and close proximity to the Annapurna and Machhapuchhre mountain ranges. The lake's watershed covers parts of wards 5, 18, 22, 23, and 24 of PMC. The lake is surrounded by a wetland area that plays an important role in its ecosystem. Due to the region's humid subtropical climate, Phewa Lake receives heavy rainfall during the monsoon season, causing seasonal changes in water levels. The surrounding landscape is rugged, with steep slopes to the north and gentler ones to the south.

Figure 1

Location map of the study area



The highest point in the watershed is Panchase, which rises to 2,470 meters above sea level. Over time, Phewa Lake has changed from an *oligotrophic* state (low in nutrients and clear water) to a *eutrophic* state (high in nutrients, often leading to algae growth), mainly due to pollution and nutrient inflows. Wetlands are found at more than five locations around the lake, but the largest and most significant is located on the northwestern side. Among them Phewa Wetland covers 125.26 hectares and supports diverse biodiversity, including a wide variety of aquatic plants.

Methods and materials

This study on the status of wetlands in the Phewa Lacustrine Plain employs a combination of primary and secondary data sources to ensure a comprehensive and accurate assessment. Primary data were obtained through direct field observations. Observations were made at multiple sites around Phewa Lake to monitor ongoing changes such as lake encroachment, sedimentation in the Harpan stream, pollution from tourism activities and urban runoff, aquatic vegetation growth (particularly water hyacinth), and the effects of surrounding landslides. Fieldwork focused on usage patterns and conservation challenges in the wetland areas. Anthropogenic pressure is visibly transforming wetland area into agricultural land. There are different sites of wetland in Phewa area such as Ghaira Chautara, Sedi Bagar, Khapauti Bagar, Bhakunde, and Chankhapur.

In addition to primary data, a broad range of secondary sources were consulted, including Aerial photo (1979), topographical maps (1:25,000 scale, 1998) and different time phases google earth pro (date 2008, 2018 and 2024) are used for analysis temporal Changes in Phewa wetland and land cover from 1979 to 2024 time period.

The required information was described using mixed methods. Satellite images and topographical maps were geo-referenced and digitized using ArcGIS version 10.8. These spatial data were used to identify historical and current changes in wetland boundaries, land use and sedimentation patterns. The study concludes with suggestions for wetland degradation analysis, land-use practices and potential conservation strategies, based on data from the Phewa Lacustrine Plain.

Result and discussion

Stages of lake ecological series and environmental value

Lakes are large inland water bodies formed by various geological processes such as glaciation, faulting, and the formation of depressions or lowlands. These depressions allow water to accumulate and create extensive waterbodies. Over time, some of these lakes especially those in large valleys become filled with sediment or may partially dry out if a natural dam breaks, leaving behind shallow water. Such evolving landforms often feature a mix of water, swamps, mud, and vegetation,

forming a unique ecosystem that supports diverse biota, including numerous species of flora and fauna. Wetlands typically form along shorelines, near water sources or can sometimes cover an entire basin. The Phewa Wetland is one such example, with its origin linked to surrounding water sources and geological history.

Over time, they evolve through distinct ecological stages, eventually transitioning into wetlands or terrestrial ecosystems. Lakes undergo a natural aging process known as ecological succession, progressing through four distinct stages. In

Figure 2

Phewa Wetland

Sources: https://nepalitimes.com/here-now/pokhara-s-shrinking-phewa-lake.

oligotrophic (Having the deficiency of plants) stage, lakes are deep, clear, and nutrient-poor, supporting limited but stable aquatic life. Over time, as nutrients and sediments accumulate the lake enters the mesotrophic stage, where biological activity increases and aquatic ecosystems become more diverse (Lamichhane, 2005). This leads to the eutrophic stage, marked by excessive nutrient enrichment and rapid plant growth, which can crowd out other life forms and result in shallower, murkier waters (Figure 2).

Eventually, lake reaches the dystrophic stage, where heavy sedimentation and organic decay dominate, causing a decline in aquatic species as the lake gradually fills in and transitions into a swamp, marsh or even dry land (Lamichhane, 2005). Wetlands

act as vital ecosystems, supporting a variety of species and performing essential functions like water purification, flood control and biodiversity support. Globally diverse in climate and form wetlands include marshes and swamps. It is considered wetland have more valued for their ecosystem services and conservation importance.

Phewa Wetland hosts a wide variety of species including fish (18 species), birds (e.g., Ruddy Shelduck, Common Teal), reptiles, amphibians, and aquatic invertebrates. Zooplankton such as *Daphnia*, *Keratella*, and *Neodiaptomus* are common, while invasive species like water hyacinth indicate nutrient overloading. This biodiversity is both ecologically and economically significant.

Tributaries discharge significant nutrient and sediment loads from Harpan Khola and its tributaries contributes 6.15 m^3/s of water, depositing 4.45 g/s of TN and 0.97 g/s of TP. Total sediment inflow is estimated at 159,553 metric tons annually, displacing 180,614 cubic meters of water. At this rate, the lake could fully silt up within 287 years (Lamichhane, 1998). Human encroachment in areas like Pame and Khapaudi further accelerates degradation while lake area reduces the wetland might be expand but previous wetland is convert to dry land, The dry area is used for paddy field. Therefore, during the winter season the wetland seem dry. However, during the summer season rise the water level Phewa Lake damming the monsoon rainfall so wetland cover extensive up to Bhakunde area.

Current threats to Phewa wetland

The Phewa Wetland is currently facing several significant threats driven by human activities. Key issues include nutrient loading from agricultural runoff and wastewater which causes eutrophication; sedimentation that alters the wetland's structure and the spread of invasive plant species, which displace native biodiversity. Rapid and unregulated urban development including illegal encroachment and conversion of wetland areas into agricultural land then it is shrinking. These pressures are compounded by weak regulatory enforcement and lack of coordinated conservation policies. As a result, biodiversity is declining, and the area is becoming increasingly unsuitable for migratory birds especially during the summer and winter seasons. Recent studies indicate that among the wetland in PMC Phewa Wetland is undergoing significant environmental degradation due to a range of anthropogenic pressures. Overall, the ecological health of Phewa Wetland is under serious threat, demanding urgent coordinated conservation and policy responses.

Causes of wetland degradation

A temporal study from 1979 to 2024, including field surveys, revealed several key factors contributing to the ongoing degradation of the Phewa wetlands (Figure 3). The most significant threat responsible for 60% of the damages sedimentation caused by landslides and sedimentation borne by Hrpan Khola (stream) and its tributaries,

which are rapidly filling wetland basins and disrupting their natural ecological balance.

Figure 3

Phewa Wetland status in, 1988, 2008, 2018 and 2024

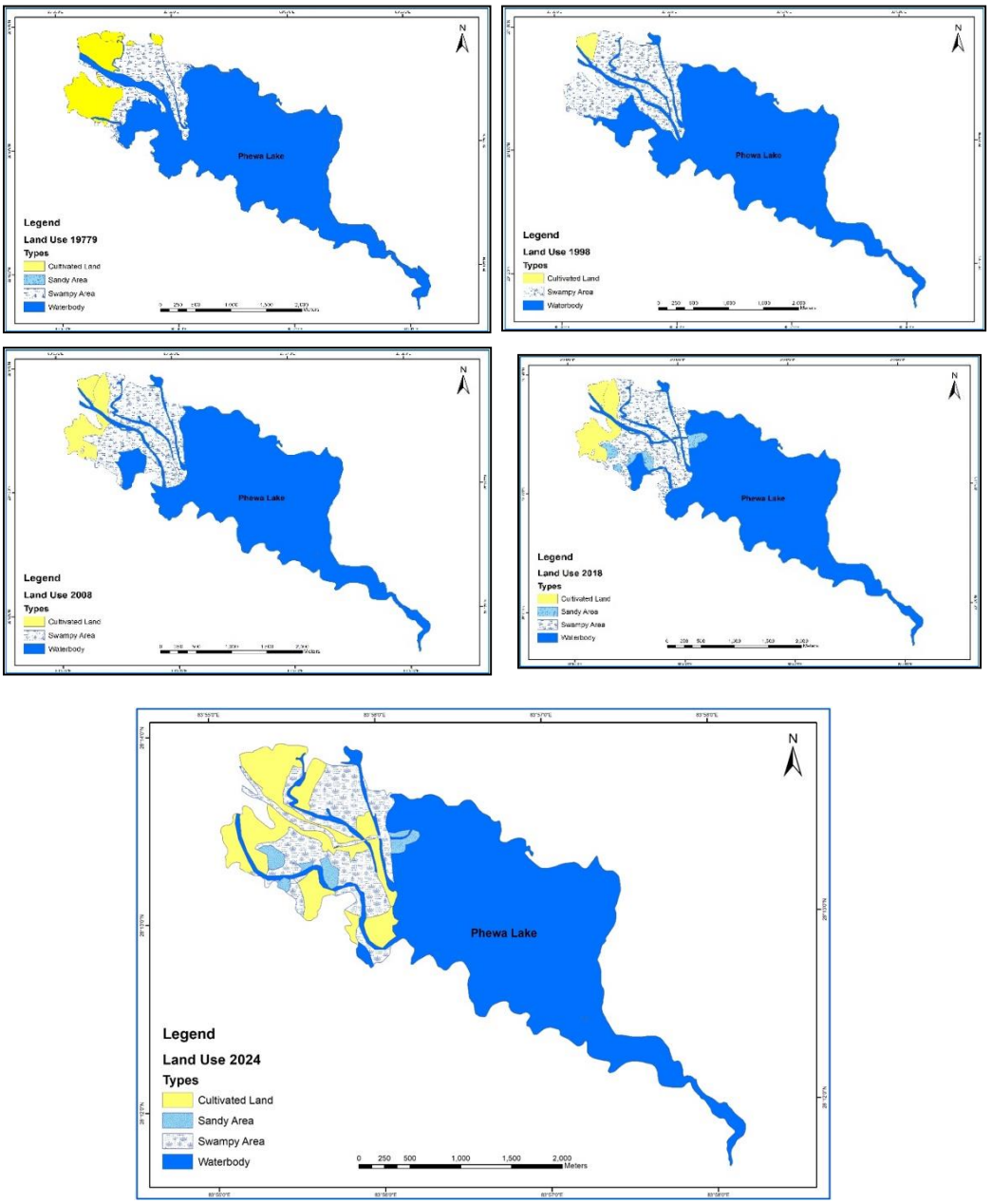


Table 1

Temporal Changes in Phewa Wetland Land Cover (1979–2024)

Aerial Photograph 1979		
Types	Area (Sq km)	Percent
Cultivated Area	0.659	11.07
Sandy Area	0.003	0.05
Swampy Area	0.805	13.53
Water body	4.483	75.33
Total	**5.951**	**100.00**
1998 Top sheet map		
Cultivated Area	0.081	1.31
Swampy Area	1.382	22.43
Water body	4.699	76.26
Total	**6.162**	**100.00**
2008 Google earth map		
Cultivated Area	0.413773	6.71
Swampy Area	1.252621	20.33
Water body	4.495946	72.96
Total	**6.16234**	**100.00**
2018 Google earth map		
Cultivated Area	0.4428	7.19
Sandy Area	0.1485	2.41
Swampy Area	1.1986	19.45
Water body	4.3724	70.95
Total	**6.1623**	**100.00**
2024 Google earth map		
Cultivated Area	0.915	14.88
Sandy Area	0.138	2.24
Swampy Area	0.959	15.59
Water body	4.139	67.29
Total	**6.151**	**100.00**

Table 1 and figure 3 show that the analysis of land cover changes in the Phewa Wetland area from 1979 to 2024 reveals a clear pattern of ecological degradation driven by both natural and anthropogenic factors. In 1979, the wetland was largely dominated by open water, covering approximately 4.483 square kilometers or 75.33 percent of the total area. However, by 2024, this had declined to 4.139 square

kilometers (67.29%), indicating a steady shrinkage of the lake surface due to sediment deposition, urban encroachment, and altered hydrological dynamics. While swampy areas initially expanded reaching 1.382 square kilometers (22.43%) by 1998, likely due to sediment buildup and eutrophication they later declined to 0.959 square kilometers (15.59%) in 2024. This reduction suggests that once-transitional wetland zones are now drying up or being converted to farmland.

The most dramatic transformation is observed in cultivated land. Initially occupying 0.659 square kilometers (11.07%) in 1979, it fell to 0.081 square kilometers (1.31%) in 1998, possibly due to policy intervention or temporary wetland expansion. However, by 2024, cultivated land surged to 0.915 square kilometers (14.88%), overtaking swampy zones in areal coverage. This resurgence reflects aggressive agricultural encroachment, facilitated by weak enforcement of wetland boundaries and growing local demand for arable land. Additionally, sandy areas absent in earlier datasets, first appear in 2018 and remain present in 2024, signaling increased sediment inflow from tributaries like Harpan Khola. These sandy areas now occupy around 2.24 percent of the total wetland area and mark critical area of ecological transition.

The analysis of land cover changes in the Phewa Wetland area from 1979 to 2024 reveals a clear pattern of ecological degradation driven by both natural and anthropogenic factors. In 1979, the wetland was largely dominated by open water, covering approximately 4.483 square kilometers or 75.33 percent of the total area. However, by 2024, this had declined to 4.139 square kilometers (67.29%), indicating a steady shrinkage of the lake surface due to sediment deposition, urban encroachment, and altered hydrological dynamics. While swampy areas initially expanded—reaching 1.382 square kilometers (22.43%) by 1998, likely due to sediment buildup and eutrophication they later declined to 0.959 square kilometers (15.59%) in 2024. This reduction suggests that once-transitional wetland zones are now drying up or being converted to farmland. The most dramatic transformation is observed in cultivated land.

Anthropogenic pressures

Human activities are a major driving force behind the degradation of the Phewa Wetland, with urbanization, agriculture, grazing and waste disposal exerting significant pressure on the ecosystem. The land use data from 1979 to 2024 clearly illustrates the growing anthropogenic pressures that have steadily degraded the Phewa Wetland. In 1979, the area was dominated by water bodies (75.33%) with relatively low human disturbance, and cultivated land occupied 11.07 percent. By 1998, cultivation had drastically dropped to just 1.31 percent, while swampy areas and water bodies expanded, likely due to increased runoff and sedimentation from upstream sources. However, by 2008 and into 2024, cultivated areas began to rise again, reaching around 6.71 percent, suggesting renewed agricultural encroachment

especially near the lake's shoreline. This aligns with reports of paddy farming intensifying nutrient loading and siltation. Simultaneously, rapid urban growth in regions like Hallanchowk, Pame and Khapaudi introduced more impervious surfaces, increasing polluted runoff filled with sediments, chemicals and waste. Overgrazing in riparian zones like Pame and Bhakunde further destabilized stream banks, contributing to erosion and sediment inflow. Waste from tourism and households added significantly to pollution with solid and liquid waste jointly accounting for nearly half of the pollution load.

Challenges and way forward for the conservation of Phewa wetland

The Phewa Wetland is undergoing serious ecological degradation, largely driven by intensifying human activities such as urbanization, agriculture, waste disposal and overgrazing. A clear picture of this transformation emerges when comparing land use data from 1979 to 2024 with ground-level threats. In 1979, water bodies dominated the area, covering 75.33 percent, with 11.07 percent under cultivation and minimal urban impact. However, by 1998, cultivated land plummeted to just 1.31 percent**,** likely due to increased swamp formation **(**22.43 %**)** and expansion of water bodies, hinting at early signs of stress from sedimentation and flooding.

From 1998 onward, the trend reversed. Cultivation resurged reaching 6.71 percent by 2008 and continuing to grow into 2024 reflecting intensified agricultural encroachment, especially paddy farming near the lake shore. While this growth indicates human re-engagement with the land, it also correlates with increased runoff of chemical fertilizers and pesticides, triggering eutrophication and siltation. Urban expansion in areas like Hallanchowk, Pame and Khapaudi has added impervious surfaces, boosting polluted runoff containing sediments, nutrients and hydrocarbons. These pressures have destabilized the ecosystem's hydrology and nutrient balance.

The Phewa Lacustrine Wetland is currently exposed to a range of interrelated threats that compromise its ecological stability and long-term sustainability. One of the most pressing issues is land encroachment, as areas surrounding the wetland increasingly converted for agricultural use and human settlement. Although Nepal's Water Resources Strategy (2002) provides a legal framework for wetland protection and its implementation remains weak. Fragmented management and poor enforcement have allowed ongoing illegal land conversion and unchecked spread of invasive species, underscoring the urgent need for more effective governance and coordinated conservation efforts.

- Legally demarcate the boundaries of the Phewa Wetland and lake buffer zones using GPS and satellite mapping.
- Create a well-resourced and empowered Phewa Lake and wetland Conservation Committee to oversee planning, protection, monitoring and enforcement.

- Ensure the committee coordinates across sectors like agriculture, urban development, tourism and local governance for integrated management.
- Ban or strictly limit the use of chemical fertilizers and pesticides in farming areas near the lake.
- Encourage sustainable and organic farming methods and create vegetative buffer strips to absorb runoff.
- Construct check dams and sediment traps, especially at key tributaries like Harpan Khola to reduce silt flow during the monsoon.
- Restore riparian vegetation and stabilize degraded stream banks in overgrazed areas such as Pame and Bhakunde.
- Strictly prohibit solid and liquid waste discharge into the lake.
- Impose penalties on illegal dumping and reward compliant waste management behavior.
- Implement targeted removal and biological control programs for invasive species like water hyacinth.
- Regulate urban sprawl through zoning and land-use planning, integrate wetland-sensitive urban design.
- Fallow the Ramsar Convention, committing to the global framework for conserving wetlands as a safeguard for biodiversity, water regulation, and human well-being.
- Launch long-term awareness and education campaigns to inform residents and tourists about the ecological role of the wetland.
- Use remote sensing, GIS, and drone technology to monitor land use, vegetation cover and hydrology in real-time.
- Develop a Wetland Health Index to track changes in key ecological indicators like water quality, habitat area and biodiversity.

Conclusion

The Phewa Wetland, a vital ecological and socio-economic resource in Nepal, is facing serious and accelerating degradation due to unchecked human activity. Between 1979 and 2024, the wetland area shrank unstable, driven by agricultural expansion, urban sprawl, sedimentation, and weak policy enforcement. Once dominated by water bodies and natural wetland zones, land use data from 1979 to 2024 shows a shift toward increased cultivation and built-up areas, leading to severe ecological stress. Major threats include nutrient overloading from agrochemicals, unchecked sedimentation especially from Harpan Khola, rapid urban development and the spread of invasive species like water hyacinth. These pressures have caused eutrophication, habitat loss and declining biodiversity. The degradation is further worsened by illegal land conversion, poor waste management, overgrazing and the lack of coordinated wetland governance. Despite legal frameworks such as Nepal's

Water Resources Strategy (2002), enforcement remains weak and fragmented. If this trend continues, Phewa risks transitioning into a terrestrial landscape, permanently losing its ecological functions, economic value, and role in biodiversity conservation. The degradation of Phewa Wetland can still be reversed with urgent, coordinated action. This includes clear boundary demarcation, strict regulation of agrochemicals and urban growth, restoration of riparian areas, invasive species control, and improved waste and sediment management. Community engagement, along with modern monitoring tools like GIS and drones, is essential for long-term protection and informed decision-making. Protecting the Phewa Wetland is not only crucial for Pokhara's environment and tourism economy but also for Nepal's broader ecological stability. With coordinated policies, local stewardship and science-based conservation strategies, this wetland can be restored and preserved as a resilient ecosystem for future generations.

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