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Community-Driven Wetland Rejuvenation and its Impacts on Hydrology, Biodiversity and Livelihoods in a Flood-Prone Region of Gorakhpur, Uttar Pradesh, India

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ABSTRACT

Floodplain wetlands play an important role in hydrological regulation, biodiversity conservation and livelihood support in monsoon-dominated river basins. They are also increasingly recognized as critical Nature-based Solutions (NbS) that contribute to climate adaptation, flood moderation, groundwater recharge, carbon sequestration and livelihood resilience, particularly for vulnerable rural communities in climate-sensitive landscapes. However, increasing climate variability and anthropogenic disturbances are adversely affecting the ecological functions and ecosystem services provided by these wetlands. The present study evaluates the hydrological, ecological and livelihood impacts of a community-driven wetland rejuvenation intervention implemented at the Mirhiriya wetland in the Rapti River basin of Gorakhpur, eastern Uttar Pradesh, India. Major restoration activities included selective de-siltation, restoration of hydrological connectivity, removal of invasive aquatic vegetation and conservation of a vegetated Natural Filtration System (NFS). Pre- and post-intervention assessments conducted during January 2024 and January 2026 indicated substantial improvement in wetland functioning following restoration. Water depth in the central wetland increased by 54.55%, while the spatial extent of waterlogging decreased by 48.62%. Water quality improved considerably, and aquatic macrophyte richness increased from 4 to 10 species, while fish species richness increased from 4 to 8 species following rejuvenation. Wetland rejuvenation also enhanced livelihood opportunities through improved fisheries and wetland resource utilization among local communities. The findings demonstrate that community-driven wetland rejuvenation can function as an effective nature-based solution for improving ecological resilience and livelihood security in flood-prone agricultural landscapes.

Keywords Floodplain wetland, Wetland rejuvenation, Nature-based solutions, Hydrological restoration, Biodiversity recovery, Community participation, Climate resilience.

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INTRODUCTION

Floodplain wetlands are important ecological systems that regulate hydrological processes, support biodiversity and sustain rural livelihoods in monsoon-dominated river basins (Mitsch and Gosselink 2015, Junk *et al.* 2014). These wetlands function as natural buffers by storing excess runoff, reducing flood peaks and improving groundwater recharge, providing ecosystem services such as fisheries, fodder and edible vegetation (Ministry of External Affairs Report, Govt. of India 2005). Wetlands also support diverse plant communities and contribute significantly to local livelihoods and ecosystem stability (Boru *et al*. 2024). However, increasing climate variability, recurrent floods and anthropogenic disturbances have been found to accelerate wetland degradation in many regions, affecting their ecological functions and ecosystem services (Intergovernmental Panel on Climate Change (IPCC) 2021).

The Rapti River basin in eastern Uttar Pradesh is highly vulnerable to seasonal flooding and prolonged waterlogging, which adversely affects agricultural productivity and livelihood security of small and marginal farmers (Saharia *et al.* 2025). Over the time, many floodplain wetlands in this region have experienced silt accumulation, obstruction of natural drainage and proliferation of invasive aquatic vegetation such as *Eichhornia crassipes*, resulting in reduced storage capacity and disrupted hydrological functioning (Zedler and Kercher 2005). Consequently, wetlands that previously acted as flood-regulating systems have increasingly become sources of persistent inundation and ecological degradation.

Wetland rejuvenation through nature-based approaches has emerged as an effective strategy for improving hydrological regulation, biodiversity conservation and climate resilience (Singh and Sinha 2022, Mitsch and Gosselink 2015). In particular, community participation in wetland management is considered essential for ensuring long-term sustainability, strengthening local stewardship and enhancing livelihood opportunities (Agarwal 2010). Despite growing recognition of wetland restoration, field-based studies integrating hydrological improvement, biodiversity recovery and livelihood outcomes in flood-prone agricultural landscapes remain limited.

In recent years, indicator-based wetland assessment frameworks such as Wetland Health Cards promoted under Ministry of Environment, Forest and Climate Change (MoEFCC) wetland conservation and management initiatives have gained importance for evaluating ecological conditions, hydrological functioning and management effectiveness of wetlands. However, their application in community-driven floodplain wetland rejuvenation studies integrating hydrological, ecological and livelihood dimensions remains limited.

The present investigation evaluates a community-driven wetland rejuvenation intervention implemented at the Mirhiriya wetland in the Rapti River basin of Campierganj Block of Gorakhpur District, Uttar Pradesh, India. The study assesses changes in water-holding capacity, water quality, biodiversity and livelihood outcomes following restoration. The findings provide evidence on the role of wetland rejuvenation as a nature-based solution for enhancing ecological resilience and livelihood security in flood-prone rural landscapes.

Unlike many previous wetland restoration studies that primarily focus either on hydrological or ecological aspects, the present study integrates hydrological improvement, water quality enhancement, biodiversity recovery and wetland-dependent livelihood outcomes within a single community-driven restoration framework in a flood-prone agricultural landscape of eastern Uttar Pradesh. The study further demonstrates the role of interconnected floodplain wetlands as nature-based solutions for climate adaptation and local livelihood resilience under recurrent flood conditions.

MATERIALS AND METHODS

Study area

The study was conducted at the Mirhiriya wetland (27.028571° N, 83.207054° E), a floodplain-associated wetland located in Campierganj Block of Gorakhpur district, Uttar Pradesh, India, within the River Rapti basin. The wetland system comprises three interconnected ponds receiving surface runoff

Table 1. Key characteristics of the Mirhiriya wetland system.

Parameter	Description
Location	Campierganj Block, Gorakhpur district, Uttar Pradesh, India
River basin	Rapti River basin
Catchment area	29.29 ha
Wetland system	Three interconnected wetlands
Major inflow sources	Surface runoff and village drains
Flood influence	Seasonal backflow from Rapti River
Main intervention	Community-driven wetland rejuvenation
Major activities	De-siltation, hydrological restoration and invasive vegetation removal

and village wastewater through drainage from surrounding settlements. The region experiences recurrent monsoon flooding and prolonged waterlogging, which frequently affect agricultural activities and *Rabi* season cultivation.The key characteristics of the Mirhiriya wetland system are summarized in Table 1.

The region experiences a humid subtropical climate characterized by hot summers and monsoon rainfall during June–September. Average annual rainfall in the region ranges between 1,100–1,400 mm, with frequent flooding caused by monsoon runoff and backflow from the Rapti River (IMD 2020). The surrounding landscape is dominated by smallholder agriculture with low-lying flood-prone fields.

The elevation and contour characteristics of the study area are shown in Fig. 1.

Hydrological setting and spatial analysis of the wetland system

The Mirhiriya wetland drains a low-lying catchment area of approximately 29.29 ha comprising agricultural fields and village settlements. Surface runoff and village drainage from surrounding habitations, including Khajurgawan (27.032456° N, 83.211116° E), Baraipar (27.039865° N, 83.209912° E), Bahboliya (27.029925° N, 83.209956° E) and Mirhiriya village (27.030075° N, 83.204948° E), are naturally directed towards the interconnected wetland system through topographic gradients from the north and north-west to the south and south-east.

The drainage channels and natural flow paths convey storm runoff and domestic wastewater into the wetland system, primarily through Wetland-1, located in the south-western part of the wetland system, and Wetland-2, which functions as the central storage wetland. Prior to intervention, silt accumulation and reduced storage capacity disrupted drainage flow and

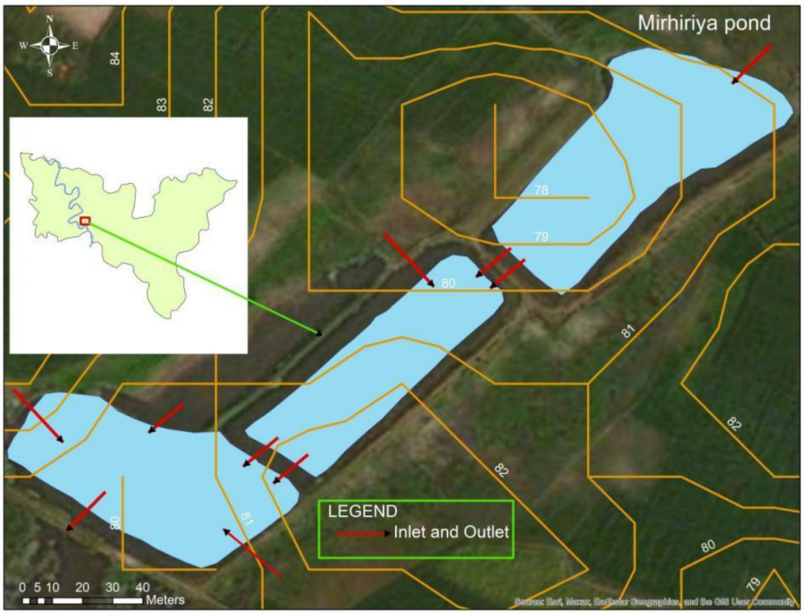

Fig. 1. Elevation and contour map of the Mirhiriya wetland showing topographic gradients and surface drainage patterns.

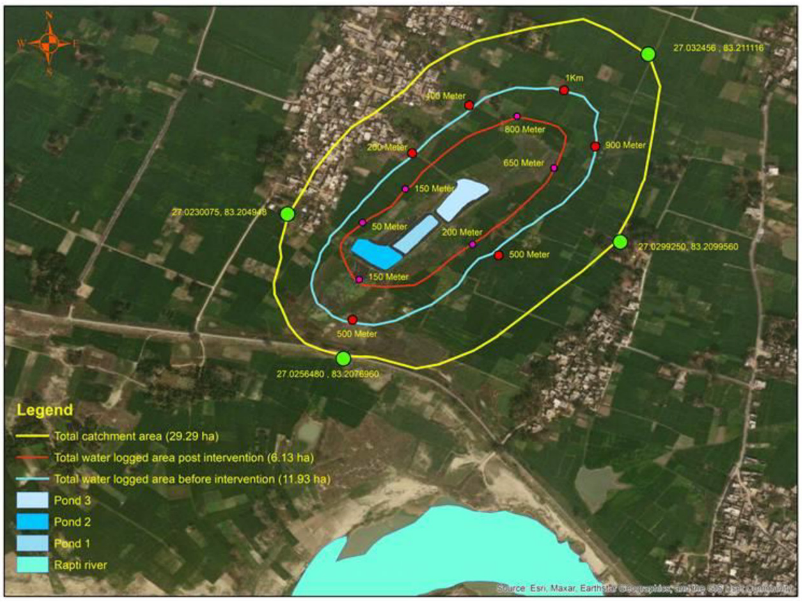

Fig. 2. Spatial analysis of the Mirhiriya wetland system showing catchment extent, interconnected wetlands and reduction in waterlogged area following wetland rejuvenation intervention.

caused frequent overflow into adjacent agricultural fields, resulting in prolonged waterlogging during the post-monsoon period.

Spatial analysis was carried out using thematic mapping and contour-based interpretation to assess drainage pathways, hydrological connectivity and extent of waterlogged areas before and after intervention.

Spatial analysis and thematic mapping were carried out using QGIS/ArcGIS software based on field GPS observations, drone imagery and contour interpretation. Elevation and drainage characteristics were assessed using Digital Elevation Model (DEM)-based contour analysis to identify runoff pathways, low-lying zones and hydrological connectivity among the wetlands.

The spatial distribution of drainage pathways, storage zones and waterlogged areas is illustrated in Fig. 2.

Wetland rejuvenation intervention

A community-driven wetland rejuvenation intervention was implemented under the Strengthening, Upscaling & Nurturing Local Innovations for Livelihood (SUNIL) programme under the Science for Equity Empowerment and Development (SEED) Division of Department of Science and Technology, Government of India. The initiative was undertaken to improve hydrological efficiency and ecological functions of the wetland. Major interventions included selective de-siltation and excavation of the central wetland (Fig.1) to enhance water-holding capacity, restoration of hydrological connectivity through hume pipes and removal of invasive aquatic vegetation (*Eichhornia crassipes*).

Selective de-siltation was carried out primarily within the central storage zone of Wetland-2 to restore water-holding capacity and improve internal drainage regulation. Excavated sediments were deposited along selected bund sections for stabilization. Hydrological connectivity among the wetlands was restored through installation of hume pipes and clearance of obstructed flow channels.

The naturally vegetated inlet zone was conserved as a natural filtration system (NFS) for partial treatment of wastewater inflows. A village wetland management committee (5 members) was formed for mobilizing community participation and post-intervention management and sustenance.

Water quality and hydrological assessment

Pre- and post-intervention assessments were conducted during the post-monsoon periods of January 2024 and January 2026 to evaluate changes in water depth and water quality of the wetland system. Water samples were collected from three representative locations within the wetland system during both sampling periods. At each location, composite surface water samples were collected in triplicate using pre-cleaned polyethylene bottles. Physicochemical parameters including pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), total dissolved solids (TDS) and total suspended solids (TSS) were analyzed following standard methods (APHA 2017).

Water depth measurements were recorded using a graduated measuring rod at fixed sampling points within the peripheral and central zones of Wetland-2.

Biodiversity assessment

Aquatic vegetation, fish, amphibians, reptiles, birds and associated fauna were surveyed during the pre-intervention (post-monsoon, January 2024) and post-intervention (post-monsoon, January 2026) periods through field observations and community interactions. Aquatic vegetation was assessed using quadrat sampling (1 m × 1 m) at randomly selected locations across the wetland margins and shallow-water zones. Fish diversity was assessed through field observations, community catch records and opportunistic sampling during the post-monsoon period. Avifaunal surveys were conducted during morning (0600–0900 h) and evening (1600–1800 h) observation periods using direct visual encounter methods. Bird identification was carried out using standard field guides, while aquatic vegetation and fish species were identified based on standard taxonomic references and local expert consultation. Biodiversity indices, including species richness, Shannon-Wiener diversity index, Simpson's diversity index and evenness, were calculated to evaluate ecological changes following wetland rejuvenation.

Statistical analysis

Descriptive statistical analysis was performed to compare pre- and post-intervention variations in hydrological, physicochemical and biodiversity parameters of the wetland system. Mean values and percentage changes were calculated for water depth and water quality parameters. Biodiversity indices including Shannon–Wiener diversity index (H′), Simpson's diversity index (1–D) and Pielou's evenness index (J′) were calculated using standard ecological formulae. Biodiversity status and community structure were evaluated using standard ecological indices. Species richness (S) was determined as the total number of species recorded within the sampling period. The Shannon–Wiener diversity index (H′) was calculated as:

$$H' = -\Sigma\,(pi \ln pi)$$

where *pi* represents the proportion of individuals belonging to each species.

Simpson's diversity index (1–D) was calculated as:

$$1 - D = 1 - \Sigma\,(pi^2)$$

where *pi* represents the relative abundance of each species.

Species evenness was assessed using Pielou's evenness index (J′), calculated as:

$$J' = H' / \ln(S)$$

where H′ is the Shannon–Wiener diversity index and S is the total number of species recorded.

These indices were used to evaluate changes in species diversity, dominance and distribution patterns following wetland rejuvenation.

The study primarily focused on comparative ecological assessment of pre- and post-intervention conditions using descriptive statistical approaches.

Wetland ecosystem health assessment

Wetland ecosystem condition before and after intervention was additionally evaluated using a Wetland Ecosystem Health Card framework developed based on hydrological, ecological, biodiversity and governance-related indicators. The assessment framework broadly aligned with indicator-based wetland assessment approaches promoted under MoEFCC wetland conservation and management initiatives.

Livelihood assessment

Changes in wetland-based livelihood activities were assessed through semi-structured household interactions, focus group discussions and field observations involving nearly 50 households located around the wetland. These marginalized communities largely depend on wetland resources for their primary production based-livelihoods and supplementary income. The assessment focused on small, marginal and women farmers, and landless households engaged in wetland-based activities.

The study documented livelihood activities associated with the wetland ecosystem, including fishing, basket making using MOOJ grass (*Saccharum munja*), handicraft production from *Eichhornia* biomass and access to cultivable land during the *Rabi* season. Special attention was given to the availability and utilization of edible wetland vegetation, particularly water spinach (*Ipomoea aquatica*), which is commonly harvested and sold by local households as a supplementary source of food and income. Changes in the availability and use of these wetland resources before and after rejuvenation were evaluated to assess the livelihood benefits associated with wetland restoration.

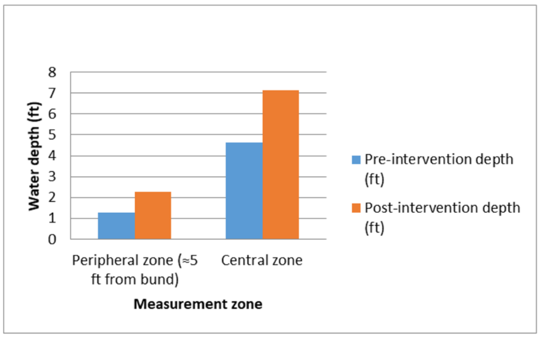

Fig. 3. Comparison of pre- and post-intervention water depth in Wetland-2.
Note: "Comparison of pre- and post-intervention water depth is shown in Fig. 3."

Table 2. Changes in water depth of Wetland-2 before and after wetland rejuvenation intervention.

Measurement zone	Average depth (pre-intervention) (ft)	Average depth (post-intervention) (ft)	Increase (ft)	Increase (%)
Peripheral zone (≈5 ft from bund)	1.27	2.26	0.99	77.95
Central zone	4.62	7.14	2.52	54.55

Note: "Changes in water depth before and after intervention are presented in Table 2."

RESULTS

The wetland rejuvenation intervention resulted in noticeable improvements in hydrological and ecological conditions, as well as livelihood enhancement and community benefits at the Mirhiriya wetland.

Hydrological improvements following wetland rejuvenation

Changes in water depth and water-holding capacity of the central wetland (Wetland-2)

Selective de-siltation and excavation of Wetland-2 substantially enhanced the storage capacity of the wetland system. Average water depth increased in both the peripheral and central zones during the post-intervention period, indicating improved water retention and regulated surface water storage.

In the peripheral zone (approximately 5 ft from the bund), average water depth increased from 1.27 ft to 2.26 ft, representing an increase of 77.95%. Similarly, in the central zone, water depth increased from 4.62 ft to 7.14 ft, corresponding to an increase of 54.55% following intervention (Table 2).

The enhanced storage capacity reduced uncontrolled overflow and prolonged waterlogging in adjacent agricultural fields during the post-monsoon

Table 3. Physicochemical water quality parameters of the Mirhiriya wetland during pre- and post-intervention periods.

Parameter	Pre-intervention (Mean)	Post-intervention (Mean)	Unit
pH	7.05	7.20	–
Total solids	843.22	801.00	mg/L
TSS	133.41	117.11	mg/L
TDS	705.83	683.70	mg/L
COD	22.25	12.42	mg/L
BOD	23.26	9.41	mg/L
DO	3.66	4.31	mg/L

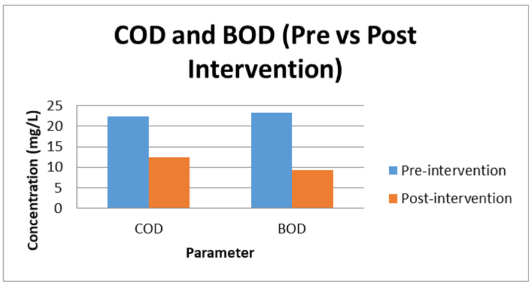

Fig. 4. Comparison of pre- and post-intervention COD and BOD levels.

period. Comparison of pre- and post-intervention water depth is presented in Fig. 3.

Improved drainage and reduction in waterlogged area following wetland rejuvenation

Spatial analysis indicated that the pre-intervention waterlogged area extended to approximately 11.93 ha around the wetland periphery and adjoining farmlands. Following selective de-siltation, excavation and restoration of hydrological connectivity among the wetlands, the waterlogged area was reduced to 6.13 ha, representing a reduction of approximately 48.62% (Fig. 2).

The results indicate that wetland rejuvenation, strengthened its regulatory ecosystem services through increased internal flow regulation, enhanced water-holding capacity and reduced uncontrolled inundation within the surrounding agricultural landscape, thereby restoring agricultural lands for cultivation.

Ecological improvements following wetland rejuvenation

Changes in water quality

Water quality analysis revealed noticeable improvement in the physicochemical condition of the wetland following rejuvenation. Post-intervention observations indicated reductions in organic pollution load and suspended solids, along with improved oxygen availability within the wetland system.

Table 4. Aquatic macrophytes and associated wetland flora recorded during pre- and post-intervention periods at the Mirhiriya wetland.

Sl. No.	Species	Scientific name	Life form	Pre-intervention (No./quadrat)	Post-intervention (No./quadrat)
1	Eichhornia	*Eichhornia crassipes*	Free-floating	16	2
2	Marsilea	*Marsilea quadrifolia*	Rooted floating	0	17
3	Water plantain	*Alisma plantago-aquatica*	Emergent	4	2
4	Sessile joyweed	*Alternanthera sessilis*	Semi-aquatic herb	8	8
5	Water lily	*Nymphaea* sp.	Rooted floating	0	6
6	Azolla	*Azolla pinnata*	Free-floating	0	68
7	Nitella	*Nitella* sp.	Submerged (charophyte algae)	0	19
8	Hydrilla	*Hydrilla verticillata*	Submerged	0	12
9	Nut sedge	*Cyperus* sp.	Semi-aquatic (sedge)	26	6
10	Ipomoea aquatica	*Ipomoea aquatica*	Semi-aquatic herb	0	34

Table 5. Marginal vegetation recorded during pre- and post-intervention periods at the Mirhiriya wetland.

Sl. No.	Plant name	Scientific name	Habit	Pre-intervention	Post-intervention
1	Doob grass	*Cynodon dactylon*	Creeping perennial grass	40	51
2	Sessile joyweed	*Alternanthera sessilis*	Semi-aquatic herb	12	23
3	Munj grass	*Saccharum munja*	Tall perennial grass	5	7

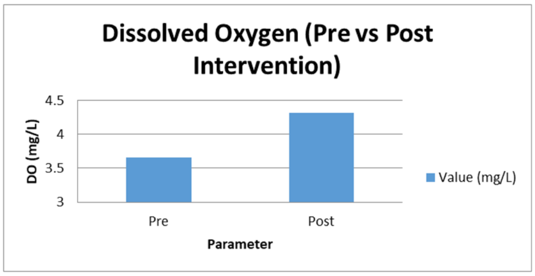

Fig. 5. Comparison of dissolved oxygen (DO) levels before and after intervention.

Mean biochemical oxygen demand (BOD) decreased from 23.26 mg/L during the pre-intervention period to 9.41 mg/L after intervention, while chemical oxygen demand (COD) declined from 22.25 mg/L to 12.42 mg/L. Similarly, total suspended solids (TSS) and total dissolved solids (TDS) showed moderate reductions during the post-intervention period. In contrast, dissolved oxygen (DO) increased from 3.66 mg/L to 4.31 mg/L following rejuvenation, indicating improved aeration and ecological condition of the wetland water.

The pH of the wetland remained near neutral during both sampling periods, showing only minor variation. Overall, the observed changes indicate improvement in water quality and ecological functioning of the wetland system following restoration. Water quality parameters before and after intervention are presented in Table 3, while comparative variations in COD, BOD and dissolved oxygen levels are illustrated in Figs. 4 and 5.

Changes in wetland biodiversity following Rejuvenation

Aquatic macrophytes and associated wetland flora

Aquatic and semi-aquatic vegetation exhibited substantial improvement in species richness and community composition following wetland rejuvenation. Pre-intervention conditions were largely dominated by invasive *Eichhornia crassipes* and sedges (*Cyperus* sp.), whereas post-intervention observations recorded increased occurrence of rooted floating, submerged and emergent macrophytes, indicating improved habitat heterogeneity and ecological condition of the wetland ecosystem.

Table 6. Fish species abundance recorded during pre- and post-intervention periods at the Mirhiriya wetland.

Sl, No.	Species	Scientific name	Pre-intervention (Individuals recorded)	Post-intervention (Individuals recorded)
1	Walking catfish	*Clarias batrachus*	0	6
2	Striped snakehead	*Channa striata*	0	11
3	Spotted snakehead	*Channa punctata*	6	12
4	Climbing perch	*Anabas testudineus*	4	3
5	Stinging catfish	*Heteropneustes fossilis*	0	9
6	Spiny eel	*Mastacembelus armatus*	9	16
7	Small barb	*Puntius/Pethia* spp.	7	6
8	Minor carp	*Labeo* spp.	0	18

Several aquatic plant species, including *Marsilea quadrifolia, Nymphaea* sp., *Hydrilla verticillata, Nitella* sp. and *Azolla pinnata,* were recorded only during the post-intervention period. In contrast, the abundance of *Eichhornia crassipes* decreased markedly after rejuvenation. Increased occurrence of submerged and rooted macrophytes suggests improvement in hydrological conditions and water quality within the wetland system.

Aquatic and semi-aquatic vegetation recorded during pre- and post-intervention periods is presented in Table 4.

Marginal vegetation

Vegetation cover and density along the wetland bunds increased following rejuvenation. Increased abundance of grasses and semi-aquatic herbs, particularly *Cynodon dactylon, Alternanthera sessilis* and *Saccharum munja,* was observed during the post-intervention period. Enhanced vegetation growth along the bunds contributed to improved slope stabilization, reduced soil erosion and increased habitat availability for insects and small fauna around the wetland margins.

The regeneration of *Saccharum munja* (MOOJ grass) is particularly important from a livelihood perspective, as it is traditionally used by local communities for basket making and other handicraft

Table 7. Amphibians and aquatic macrofauna recorded during pre- and post-intervention periods at the Mirhiriya wetland.

Sl. No.	Species (Common name)	Scientific name	Pre-intervention	Post-intervention
1	Indian bull frog	*Hoplobatrachus tigerinus*	Present (Moderate)	Present (High)
2	Paddy frog	*Fejervarya limnocharis*	Rare	Present (Moderate)
3	Apple snail	*Pila globosa*	Present (Low)	Present (Moderate)
4	Freshwater mussel	*Unio* spp.	Rare	Present (Low)
5	Freshwater crab	*Paratelphusa* spp.	Present (Low)	Present (Moderate)
6	Freshwater prawn	*Macrobrachium* spp.	Rare	Present (Moderate)

Table 8. Aquatic insect groups recorded during pre- and post-intervention periods at the Mirhiriya wetland.

Sl. No.	Group	Order	Pre-intervention	Post-intervention
1	Dragonfly larvae	Odonata	Rare/Not seen	Present (Common)
2	Damselfly larvae	Odonata	Rare	Present (Occasional)
3	Chironomid larvae	Diptera	Present (Few)	Present (Common)
4	Water beetle larvae	Coleoptera	Not seen	Present (Few)
5	Mayfly nymphs	Ephemeroptera	Not seen	Present (Few)

activities. Bund vegetation recorded during pre- and post-intervention periods is presented in Table 5.

Fish diversity and biodiversity indices

Fish diversity and abundance increased substantially following wetland rejuvenation. Post-intervention observations recorded higher species richness and increased abundance of several native fish species, indicating improvement in aquatic habitat quality and hydrological connectivity within the wetland system.

Species such as *Clarias batrachus, Channa striata, Heteropneustes fossilis* and *Labeo* spp., which were absent during the pre-intervention period, were recorded after rejuvenation. The abundance of *Mastacembelus armatus* and *Channa punctata* also increased during the post-intervention period. These changes suggest improved habitat suitability, water retention and ecological functioning of the wetland.

Fish species abundance recorded during pre- and post-intervention periods is presented in Table 6.

Biodiversity indices further indicated improvement in fish community structure following intervention. Species richness increased from 4 to 8, while the Shannon–Wiener diversity index increased from 1.35 to 1.94. Similarly, Simpson's diversity index increased from 0.73 to 0.86, reflecting enhanced

Table 9. Soil fauna recorded during pre- and post-intervention periods at the Mirhiriya wetland.

Sl. No.	Fauna	Category	Pre-intervention	Post-intervention
1	Earthworm	Soil macro-invertebrate	Present (Moderate)	Present (Common)
2	Termite	Soil insect	Present (Few)	Present (Moderate)
3	Ant	Soil insect	Present (Moderate)	Present (Common)
4	Millipede	Soil macro-fauna	Not observed	Present (Few)
5	Spider	Soil arthropod	Rare	Present (Moderate)
6	Soil insect larvae	Soil fauna	Rare	Present (Few)

Table 10. Reptiles recorded during pre- and post-intervention periods at the Mirhiriya wetland.

Sl. No.	Species	Scientific name	Pre-intervention	Post-intervention
1	Checkered keelback	*Xenochrophis piscator*	Observed	Present (Few)
2	Indian flapshell turtle	*Lissemys punctata*	Rare	Present (Few)
3	Garden lizard	*Calotes versicolor*	Present (Few)	Present (Few)
4	Common house lizard	*Hemidactylus flaviviridis*	Present (Moderate)	Present (Few)

Table 11. Bird species recorded during pre- and post-intervention periods at the Mirhiriya wetland.

SL No.	Species	Scientific name	Habitat	Pre-intervention	Post-intervention
1	Egret	*Egretta* spp.	Wetland	Present (Few)	Present (Common)
2	Heron	*Ardea* spp.	Wetland edge	Not observed	Present (Moderate)
3	Cormorant	*Phalacrocorax* spp.	Open water	Not observed	Present (Few)
4	Waterhen/Moorhen	*Amaurornis/Gallinula* spp.	Marsh	Rare	Present (Moderate)
5	Kingfisher	*Alcedo atthis*	Wetland	Not observed	Present (Few)
6	Rock pigeon	*Columba livia*	Terrestrial	Present (Common)	Present (Common)
7	Crow	*Corvus splendens*	Terrestrial	Present (Common)	Present (Common)
8	Purple sunbird	*Cinnyris asiaticus*	Wetland edge	Not observed	Present (Moderate)
9	Sarus crane	*Antigone antigone*	Wetland/agriculture	Not observed	Present (Common)
10	Black drongo	*Dicrurus macrocercus*	Wetland edge	Present (Few)	Present (Common)

species diversity and reduced dominance within the fish community. Although Pielou's evenness index showed a slight decline from 0.97 to 0.93, the values remained relatively high, indicating balanced species distribution after rejuvenation.

Amphibians, aquatic macrofauna and other faunal groups

Occurrence of amphibians, aquatic macrofauna, aquatic insects and semi-aquatic reptiles increased during the post-intervention period, indicating improvement in habitat quality and ecological condition of the wetland ecosystem. Pollution-sensitive aquatic insect groups such as mayfly nymphs were recorded only after restoration, suggesting improved water quality and habitat heterogeneity. Increased occurrence of soil macrofauna and semi-aquatic reptiles further reflected improvement in shoreline microhabitats and ecological functioning of the wetland system.

Amphibians, aquatic macrofauna, aquatic insects, soil fauna and reptiles recorded during pre- and post-intervention periods are presented in Tables 7–10.

Birds

Avifaunal diversity increased markedly following wetland rejuvenation, with increased occurrence of wetland-dependent bird species during the post-intervention period. Improved habitat quality, shallow-water availability and enhanced food resources likely contributed to increased avifaunal presence within the wetland ecosystem. The post-intervention occurrence of the Sarus crane (Antigone antigone), an important wetland-associated bird species, further indicates recovery of shallow wetland habitats and ecological functioning of the wetland landscape.

Bird species recorded during pre- and post-intervention periods are presented in Table 11.

Biodiversity indices of fish and aquatic vegetation

Biodiversity indices of fish and aquatic vegetation communities indicated substantial ecological improvement following wetland rejuvenation. Increased species richness and diversity values reflected enhanced habitat heterogeneity, improved ecological stability and reduced dominance within the wetland ecosystem. Although slight reductions in evenness were observed in post-intervention communities, overall species distribution remained relatively balanced following restoration.

Table 12. Comparative biodiversity indices of fish and aquatic vegetation communities during pre- and post-intervention periods at the Mirhiriya wetland.

Community	Period	Species Richness (S)	Shannon–Wiener Index (H′)	Simpson's Diversity (1–D)	Evenness (J′)
Fish community	Pre-intervention	4	1.35	0.73	0.97
Fish community	Post-intervention	8	1.94	0.86	0.93
Aquatic vegetation community	Pre-intervention	4	1.20	0.64	0.86
Aquatic vegetation community	Post-intervention	10	1.71	0.82	0.74

Table 13. Livelihood outcomes associated with wetland rejuvenation at the Mirhiriya wetland.

Livelihood activity	Beneficiary group	Pre-intervention status	Post-intervention outcome
Fishing	Small and marginal farmers	Limited	Increased fishing opportunities
Basket making (MOOJ grass)	Women groups	Practiced by few women of the community (10–15)	Increased participation (30–45 women)
Handicraft production (*Eichhornia-based*)	Women groups	Absent	Newly introduced
Leafy vegetables (Karmua saag / *Ipomoea aquatica*)	Landless households	Seasonal availability	Increased availability
Rabi cultivation	Small farmers	Waterlogged fields	Improved access to cultivable land

Biodiversity indices of fish and aquatic vegetation communities before and after intervention are presented in Table 12.

Wetland ecosystem health assessment

The overall Wetland Ecosystem Health Score improved from 0.58 (Very Low/F category) during the baseline assessment in January 2024 to 0.82 (Good/B− category) during the post-intervention assessment in January 2026, indicating substantial improvement in hydrological condition, ecological quality and wetland governance following rejuvenation.

Livelihood outcomes following wetland rejuvenation

Wetland rejuvenation contributed to improved livelihood opportunities and enhanced utilization of wetland resources among small and marginal farmers, women and landless households dependent on the Mirhiriya wetland. Improved water regulation and reduction in prolonged waterlogging increased access to cultivable land during the *Rabi* season.

Fishing activities increased following improvement in water availability and fish diversity within the wetland system. Regeneration of wetland vegetation, particularly *Saccharum munja* (MOOJ grass), supported basket-making activities among local women groups, while handicraft production using *Eichhornia* biomass emerged as an additional livelihood activity after intervention.

The availability of edible wetland vegetation, particularly water spinach (*Ipomoea aquatica*), locally known as Karmua saag, also increased during the post-intervention period, contributing to household nutrition and supplementary income for wetland-dependent communities. Livelihood outcomes following wetland rejuvenation are presented in Table 13.

DISCUSSION

Hydrological improvement and flood buffering

Selective de-siltation and restoration of hydrological connectivity substantially improved water storage and internal flow regulation within the Mirhiriya wetland system. Improved hydrological functioning reduced prolonged inundation in adjacent agricultural fields and enhanced the flood-buffering capacity of the wetland landscape during the post-monsoon period (Fig. 2).

Restoration of interconnectivity among the three wetlands facilitated regulated movement and temporary storage of runoff, thereby strengthening the flood-buffering function of the wetland system. Similar hydrological functions of floodplain wetlands in regulating runoff and reducing flood impacts have been widely reported in earlier studies (Singh and Sinha 2022, Junk *et al.* 2014, Mitsch and Gosselink 2015).

The observed reduction in waterlogged area further demonstrates the importance of wetland rejuvenation in improving local drainage efficiency and enhancing agricultural resilience in flood-prone landscapes. Restoration of natural storage and drainage pathways through wetland management is increasingly recognized as an effective nature-based strategy for flood mitigation and climate adaptation (IPCC 2021).

The study further demonstrates the usefulness of indicator-based Wetland Health Card approaches for monitoring restoration outcomes and supporting community-based wetland management in flood-prone landscapes.

Ecological recovery following wetland rejuvenation

Water quality improvement and role of the natural filtration system

The reduction in biochemical oxygen demand (BOD) and chemical oxygen demand (COD), together with increased dissolved oxygen (DO), indicates improvement in water quality following wetland rejuvenation. The slightly higher BOD value than COD during the pre-intervention period may indicate the predominance of biodegradable organic matter in the wetland system. Conservation of the inlet zone functioning as a Natural Filtration System (NFS), comprising Typha species and other locally adapted wetland vegetation, contribute to sediment retention, nutrient uptake and partial bio-remediation of domestic wastewater, prior to its entry into the wetland system (Fig. 6).

The interconnected wetland configuration and overflow (OVF) pathways further facilitated regulated movement and temporary retention of runoff and wastewater within the system, thereby improving hydraulic retention and natural filtration processes. Vegetation-mediated filtration by emergent wetland macrophytes such as Typha spp. is widely recognized as an effective mechanism for decentralized wastewater treatment and ecological restoration in wetland ecosystems (Vymazal, 2011, Mitsch and Gosselink 2015).

The observed improvement in physicochemical parameters suggests that restoration of hydrological connectivity and vegetative filtration enhanced overall ecological functioning and water quality within the wetland system.

Biodiversity recovery following wetland rejuvenation

Wetland rejuvenation resulted in positive ecological response reflected through increased aquatic vegetation diversity, improved fish community structure and greater occurrence of wetland-dependent fauna.

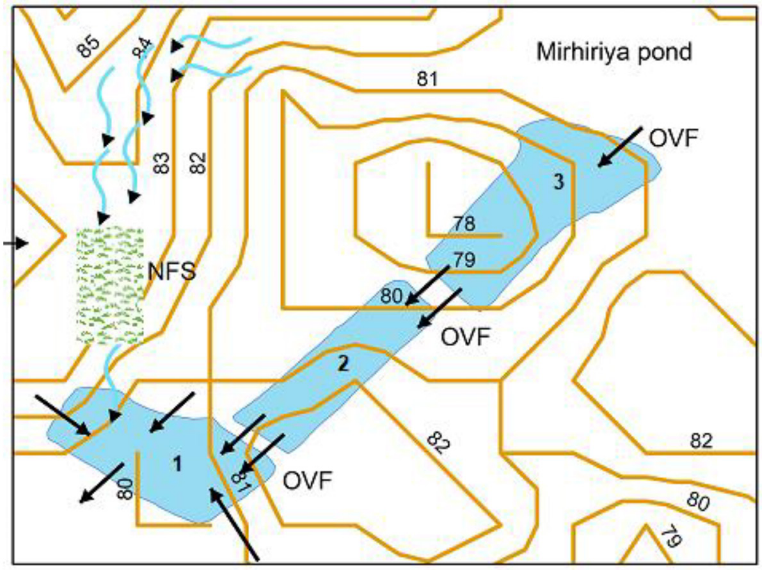

Fig. 6. Schematic representation of the Mirhiriya wetland system showing interconnected wetlands, contour gradients, overflow (OVF) pathways and the vegetated Natural Filtration System (NFS) comprising Typha spp. and other local wetland vegetation facilitating wastewater filtration and regulated flow movement.

Fig. 7. Pre- and post-intervention condition of the Mirhiriya wetland and associated livelihood activities: (A) wetland condition prior to intervention showing dense infestation of Eichhornia crassipes; (B) post-intervention wetland condition with restored open water and increased avifaunal presence; (C) fish catch recorded following wetland rejuvenation and (D) post-monsoon condition of the rejuvenated wetland showing improved water spread and storage.

Reduction in invasive vegetation and restoration of hydrological connectivity enhanced habitat heterogeneity and ecological stability within the wetland ecosystem. Increased occurrence of amphibians, aquatic insects and wetland-associated birds further indicated improvement in habitat quality and ecosystem functioning following restoration. Similar ecological responses following wetland restoration have been reported in earlier studies (Zedler and Kercher 2005, Mitsch and Gosselink 2015).

While several earlier studies have independently reported hydrological or ecological benefits of wetland restoration, the present study provides integrated evidence of simultaneous improvement in water regulation, biodiversity and wetland-based livelihoods under a community-managed restoration approach in an intensively cultivated floodplain landscape.

Livelihood improvements and community benefits

Wetland rejuvenation generated multiple livelihood benefits for wetland-dependent communities through improved access to fisheries, wetland vegetation resources and associated income-generating activities (Fig. 7). Community participation in restoration and post-intervention management strengthened local stewardship and sustainable utilization of wetland resources. Integration of community participation with wetland restoration is increasingly recognized as an important component of sustainable ecosystem management and climate resilience (Agarwal 2010. Barman *et al.* 2025).

Implications for climate adaptation and sustainable wetland management

The present study demonstrates that community-driven wetland rejuvenation can function as an effective and sustainable nature-based solution for enhancing ecological resilience and climate adaptation in flood-prone agricultural landscapes. The relevance of such interventions is particularly important in low-lying floodplain regions of eastern Uttar Pradesh that frequently experience recurrent floods, localized heavy rainfall events and prolonged waterlogging conditions associated with poor drainage gradients. Restoration of hydrological connectivity, wetland storage capacity and ecological functioning improved flood buffering, ecosystem stability and wetland-dependent livelihood opportunities. These findings highlight the multifunctional role of restored wetlands in supporting

Fig. 8. Drone view of the rejuvenated Mirhiriya wetland system showing restored water-holding capacity, interconnected wetland structure and surrounding agricultural landscape supporting hydrological regulation and climate-resilient ecosystem management.

environmentally sustainable rural development and climate-resilient ecosystem management.

Integration of wetland restoration with community participation and local resource-use practices can support climate adaptation and sustainable management of floodplain ecosystems in monsoon-dominated river basins. Scaling up similar wetland rejuvenation initiatives through convergence with watershed development, rural livelihood and climate adaptation programmes may strengthen ecosystem resilience, biodiversity conservation and livelihood security in vulnerable floodplain regions.

The restored wetland landscape and interconnected hydrological structure of the Mirhiriya wetland system are illustrated in Fig. 8.

Study limitations and future scope

The present study primarily represents post-monsoon observations and short-term ecological responses following wetland rejuvenation. Long-term seasonal monitoring and detailed hydrological assessment may further improve understanding of ecosystem dynamics and sustainability of restoration outcomes in floodplain wetland systems. The study was primarily based on comparative field observations and descriptive ecological assessment; therefore, long-term replicated monitoring may further strengthen statistical interpretation of restoration outcomes.

Conclusion and policy implications

The study demonstrated that community-driven wetland rejuvenation showcases the potential of locally led adaptation approaches where local knowledge-based participation, and ecosystem stewardship collectively strengthen climate resilience. Selective de-siltation and restoration of hydrological connectivity enhanced water-holding capacity, reduced prolonged waterlogging and improved functioning of the ecological cycle of wetland system.

Wetland rejuvenation contributed to increased diversity of aquatic vegetation, fish and wetland-dependent birds, indicating substantial ecological recovery following intervention. Restoration activities also generated livelihood benefits for small and marginal farmers, women and landless households through improved fishing opportunities, handicraft production and enhanced access to cultivable land during the *Rabi* season.

The findings highlight the importance of wetland rejuvenation as a nature-based solution for integrated flood management, biodiversity conservation and climate adaptation in flood-prone agricultural landscapes. Wetlands should be recognized not merely as ecological assets but as critical climate-resilient infrastructure supporting biodiversity, disaster risk reduction, and livelihood security. Mainstreaming community-based wetland restoration within watershed development, rural livelihood and climate adaptation programmes can strengthen ecosystem resilience, environmental sustainability and livelihood security in monsoon-dominated regions.

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