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Impact of wetland degradation on biodiversity and livelihoods in Mangalajodi: An assessment using factor analysis and discriminant analysis

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Abstract

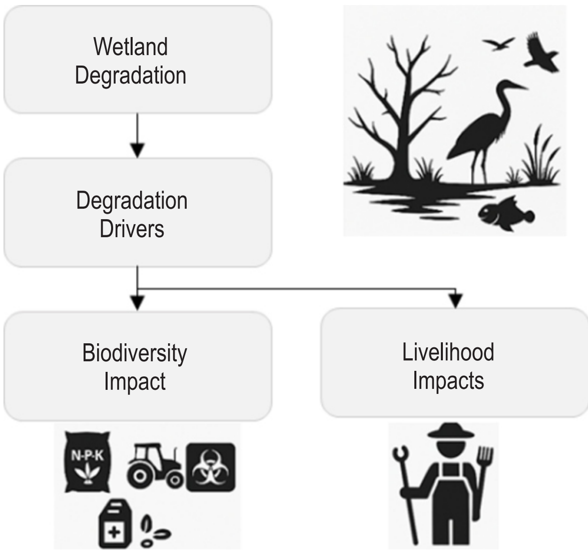
Aim: Wetland degradation from pollution, overuse, and habitat loss disrupts ecological balance, reduces avian biodiversity, and threatens local livelihoods reliant on farming, fishing, grazing, and eco-tourism. This study investigates the impact of wetland degradation on biodiversity and livelihoods in Mangalajodi, Odisha, a crucial ecosystem known for its migratory birds.

Methodology: Data were collected from 372 respondents using a structured Likert-scale survey. Both quantitative (through structured interview schedule) and qualitative (through checklist of Focus Group Discussions) data were collected. The quantitative responses were analysed using factor analysis and discriminant analyses to identify key drivers of wetland degradation and to assess their impact on biodiversity and livelihoods.

Results: Four primary drivers of wetland degradation were identified: fertilizers and pesticides, adjacent aquaculture, medical waste, and pollution/conflicts. These factors have significantly affected migratory bird populations, agricultural productivity, fish availability, and grazing resources. Fertilizer runoff and aquaculture pollution emerged as the most critical contributors to biodiversity loss and reduced livelihoods.

Interpretation: The findings emphasize the need for collaborative frameworks involving local authorities and international organizations, such as UNEP, to safeguard biodiversity and support livelihoods. Integrating socio-economic considerations into conservation strategies is essential for addressing environmental challenges and ensuring sustainable development in Mangalajodi.

Key words: Biodiversity loss, Discriminant analysis, Factor analysis, Livelihoods, Wetland degradation,



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Introduction

Wetlands are invaluable ecosystems providing critical ecological, economic and cultural services. They regulate water flow, offer flood and storm protection, stabilize shorelines, recharge groundwater, and filter pollutants and sediments (Ganapathi *et al.,* 2024). Beyond ecological roles, they support agriculture, supply water, and offer resources like timber, peat and grazing land. Additionally, wetlands sustain livelihoods, preserve cultural traditions and promote recreation and tourism, contributing to food and nutritional security (Nayak and Bhushan, 2022). However, with the decline in biodiversity, these essential services are compromised, exacerbating poverty and vulnerability among local populations. According to the Edge Effect Theory by Leopold (1933), habitat fragmentation increases the interface between different ecosystems, leading to changes in species composition, species interactions and biodiversity loss (Millstein, 2024). Habitat fragmentation and pollution disrupt wetland ecosystems, reducing biodiversity and affecting sensitive species like migratory birds (Davidson and Finlayson, 2019; Ramsar, 2018).

This degradation significantly impacts communities that rely on wetlands, diminishing resources such as crops, fish, pasture, thereby threatening the livelihoods and food security (Musasa and Marambanyika, 2020; Roy *et al.,* 2025). For instance, Sarkar *et al.* (2020) highlighted that pollution and resource depletion in Indian wetlands have led to reduced incomes among local farmers and fishermen, exacerbating poverty and resource conflicts within these communities. Naik and Sharma (2021) observed that ecological deterioration in India's Ramsar sites has led to substantial biodiversity loss and disruption of ecosystem functions. Recently, Ghosh *et al.* (2024) documented how degradation of the East Kolkata Wetlands has directly reduced livelihood opportunities for marginalized communities reliant on fisheries and agriculture. The absence of effective governance mechanisms and inadequate local participation in conservation efforts have also been identified as critical policy gaps (Ayambire *et al.,* 2025; Bezeng *et al.,* 2025; Pop *et al.,* 2025). Moreover, Yadav *et al.* (2024) emphasized the importance of adopting an interdisciplinary framework to integrate ecological restoration with socio-economic well-being.

Wetlands are threatened by both natural and human-induced factors, which include hydrology, geomorphology, geology, soil, and climate, each playing a crucial role in maintaining ecological balance. However, human activities have significantly altered these ecosystems, leading to various anthropogenic impacts. These impacts stem from agricultural, urban, industrial, and recreational (tourism) activities, along with forest exploitation, land-use changes, and in-stream modifications (Zaimes *et al.,* 2011; Kumar *et al*., 2025). Such disturbances contribute to habitat degradation, water pollution, and biodiversity loss, posing serious threats to the sustainability of wetland environments. (Balasundaram *et al.,* 2025; Daoun *et al.,* 2024; Diwate *et al.,* 2025). Wetlands face multiple threats, including agriculture, erosion, sewage, dams, industry, aquaculture and climate change (Ballut-Dajud *et al.,* 2022). Agricultural intensification and water diversions harm biodiversity and disrupt services like fisheries and soil health (Shukla *et al.,* 2021). Pollution from waste and agrochemicals accelerates degradation through nutrient overload (Akinnawo, 2023). Declining water quality and exotic species increase extinction risks and harm human health, agriculture and water systems (Ghosh *et al.,* 2024; Bhowmik, 2022). Wetland loss in India occurs due to multiple factors, including agricultural conversion, deforestation, and hydrologic alterations like dam construction and water diversion. Other significant threats include inundation, defoliation, watershed changes, excessive water extraction, pollution and wetland consolidation.

The East Kolkata Wetlands are under stress from pollution, habitat conversion, invasive species, and ineffective policy enforcement, resulting in a decline in fish stocks and the loss of vital ecological functions (Kumar *et al.,* 2023). In the peri-urban Dankuni wetlands of Eastern India, factory encroachments and disrupted hydrological flows have severely reduced biodiversity and ecosystem services, posing serious challenges to dependent communities (Adhya and Banerjee, 2022). Similarly, in Assam's Maguri-Motapung Beel wetland, overexploitation, siltation, and invasive species have led to diminishing resources such as thatch, fish and fodder, thereby undermining local livelihoods and tourism (Bhatta *et al.,* 2016). The wetlands of Mount Abu in Rajasthan have experienced spatial shrinkage and reduced ecosystem productivity due to land use changes and pollution (Imdad *et al.,* 2023). Additionally, major wetlands like Chilika, Kolleru and Vembanad suffer from eutrophication and declining freshwater inflows, linked to resource enclosure, social marginalization, and weak institutional frameworks (Narayanan and Venot, 2009).

Studies in Odisha by Singhar and Gundimeda (2024), showed that over-reliance on wetland resources and environmental degradation have led to resource conflicts and increased vulnerability among marginalized communities. Chilika Lake, Asia's largest brackish water habitat, supports local economies through fisheries and tourism (Pattnaik, 2024), but faces pressures from population growth, poverty and unsustainable use. Mangalajodi wetland, located on the northern fringes of Chilika Lake in Odisha, supports over 250 bird species during the migratory season from September to March, including approximately 125 migratory species. This ecological hotspot is renowned for its rich avifaunal diversity, with several species classified as endangered or near-threatened by the International Union for Conservation of Nature (IUCN). Expert consultations conducted in the region revealed regular sightings of the Black-tailed Godwit (*Limosa limosa*), listed as Near Threatened, and the Asian Dowitcher (*Limnodromus semipalmatus*), categorized as globally Vulnerable. Occasional appearances of the Baer's Pochard (*Aythya baeri*), a Critically Endangered species, further highlight the ecological sensitivity of the area. Other notable migratory birds include the Ferruginous Pochard (*Aythya nyroca*) and the River Tern (*Sterna aurantia*), both listed as Near

Threatened. Besides, the migratory bird species like Bartailed Godwit, Ruddy Turn Stone, Red Knot, Greater Sand Plover, Broad billed Sandpiper and Pallas Fish Eagle to Mangalajodi earlier, are found to be not coming in recent years. The wetland currently faces escalating threats from anthropogenic pressures such as fertilizer runoff, pollution from adjacent aquaculture activities, and improper waste disposal (Chatterjee *et al.,* 2024). Experts emphasized that such degradation is accelerating the decline in the presence and frequency of these sensitive species. This calls for urgent conservation action, as the disappearance of these birds not only represents biodiversity loss but also undermines the ecotourism and livelihood opportunities critical to the surrounding communities (Sources: Based on expert interviews conducted in Mangalajodi for this study, 2024).

Community-driven conservation in Mangalajodi has shown promise, with local involvement helping reduce pollution and restore bird habitats (Schismenos *et al.,* 2019). However, the lack of integrated policies addressing both biodiversity and socio-economic impact limits effectiveness. Wetland policies in India often focus on environmental goals without adequately considering the social and economic needs of local communities (Prusty *et al.,* 2019). Despite significant research on wetland degradation globally, there is a paucity of studies that integrate ecological, social, and economic analyses in the Indian context (Bassi *et al.,* 2014), particularly for sites like Mangalajodi, where human-environment interactions are complex and socio-economic dependencies are high. In light of the above, this study was conducted to investigate the impact of wetland degradation on biodiversity and livelihoods in Mangalajodi, Odisha, an important wetland ecosystem.

Materials and Methods

Study area: Mangalajodi, located in the Khordha district of Odisha, India, is an important wetland ecosystem of immense ecological, economic and cultural importance (Fig. 1). Located on the northern edge of Chilika Lake, Mangalajodi serves as a key habitat for over 200 resident and migratory bird species (Couple, 2022). Due to its rich biodiversity, it has been designated as an Important Bird Area (IBA) and plays a crucial role in India's wetland conservation strategies. Spread over an area of approximately 10 sq. km, Mangalajodi consists of shallow water bodies and supports diverse aquatic flora and fauna. The local community mainly fisherfolk, small farmers, and artisans rely heavily on the wetland for their livelihoods. Women also play a key role by crafting traditional handicrafts using wetland resources. In recent years, bird-watching tourism has become a vital income source, drawing ecotourists and conservationists worldwide (Samal and Dash, 2024). However, despite its ecological and economic significance, Mangalajodi faces growing threats from human-induced environmental degradation (Reddy, 2020).

Data collection methods and Analytical approach: In this study, the data was collected using structured interviews and a five-point Likert scale survey based on 23 statements related to wetland degradation and its effects on biodiversity and livelihoods. These statements were developed through

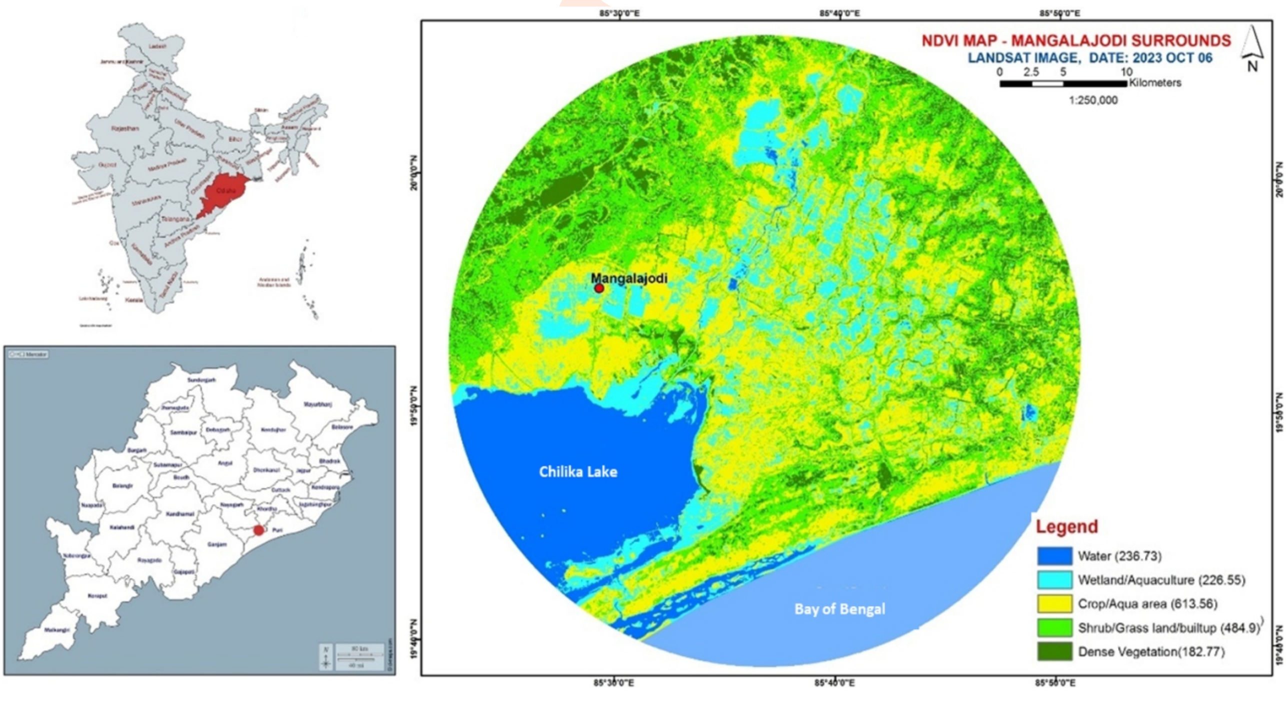

Fig. 1: Mangalajodi map by Chilika Lake in Odisha, India (Source: Landsat Image).

consultations with experts, community members, and local stakeholders to ensure contextual relevance. The sample comprised 372 households from five villages in Mangalajodi, selected from a total of 1,485 households involved in the Indian Grameen Services (IGS) project. A mix of purposive and simple random sampling ensured representation of those reliant on wetlands while maintaining fairness and reliability in data collection. Data analysis involved a two-step analytical framework. First, factor analysis was used to identify key factors contributing to wetland degradation. Discriminant analysis was later conducted to assess the impacts of these degradation factors on livelihood indicators. The dependent variables included key livelihood outcomes such as cropland productivity, fish availability, grazing land quality and migratory bird abundance. The discriminant analysis provided insights into how each degradation factor uniquely affected these livelihood indicators. By combining qualitative inputs from the community with quantitative analysis, this methodology enabled a comprehensive assessment of the impacts of wetland degradation in Mangalajodi.

Results and Discussion

To identify the underlying factors contributing to wetland degradation in Mangalajodi and their implications for biodiversity and local livelihoods, a structured 23-item Likert-scale survey was employed. The statements captured various aspects of environmental degradation and socio-economic changes. The data, refined through consultations with experts, farmers, fishermen and local officials, were subjected to factor analysis for dimensional reduction and pattern identification. Principal Component Analysis (PCA) with Varimax rotation (Schreiber, 2021) was used as the extraction method, as it is effective in reducing complex datasets into interpretable components while retaining maximum variance. PCA helps uncover the latent structure of variables by grouping them into principal components that represent distinct dimensions. Based on the extraction threshold, 16 variables were retained, while those with lower significance were excluded. The rotated component matrix revealed four prominent dimensions contributing to wetland degradation namely, fertilizer and pesticide use, adjacent aquaculture, medical waste, and pollution and conflict offering a robust analytical framework for understanding the complex interactions affecting the Mangalajodi wetland ecosystem.

The suitability of data for factor analysis was confirmed by a high Kaiser-Meyer-Olkin (KMO) value of 0.924, indicating excellent sampling adequacy (Kaiser, 1974), and a significant Bartlett's test of sphericity ($\chi^2 = 4135.178$, df = 253, $p < 0.05$), confirming meaningful correlations among variables (Bartlett, 1954) (Table 1). Principal Component Analysis (PCA) revealed that 58.628% of the total variance could be explained by four factors with eigenvalues greater than 1 (Table 2). The scree plot further supported this, as the curve leveled off after fourth factor, indicating a natural cutoff (Fig. 2). These results validate the dimensional reduction and factor retention approach applied in the analysis.

The first factor, fertilizers and pesticides exhibited high loadings on variables related to their impact on water quality (0.814), fish availability (0.737), migratory birds (0.706), and other flora and fauna (0.668). This indicates a significant association between agricultural pollutants and biodiversity loss in the wetland ecosystem. The second factor, adjacent aquaculture, was associated with the impacts on fish availability (0.814), migratory birds (0.670), grazing land (0.663), water quality (0.603), and other plants and animals (0.521). These loads reflect the adverse impacts of aquaculture activities on wetland resources, including habitat disruption and water pollution. The third factor, medical waste, had high loads on water quality (0.790), fish availability (0.685), migratory birds (0.577), and other plants and animals (0.468), emphasizing the detrimental impact of improper medical waste disposal on environmental health and biodiversity. Finally, the fourth factor, pollutants and conflicts, refers to variables such as pollution from motorized boats (0.839), general wetland pollution (0.815), and conflicts over wetland use among local users (0.665). These results highlight the role of human activities and social conflicts in exacerbating wetland degradation. Together, these four factors explain the primary dimensions of environmental degradation in Mangalajodi and provide the basis for understanding its broader impacts on biodiversity and livelihoods (Table 3).

The findings indicate that siltation from upstream deforestation and agricultural runoff has significantly altered the wetland's hydrology, thus reducing its water-holding capacity and changing the composition of aquatic vegetation. This physical degradation has affected fish breeding grounds and foraging sites for wetland-dependent species, leading to seasonal fluctuations and habitat loss for migratory birds (Qiu *et al.,* 2025). Further analysis showed that regions with high agricultural activity had elevated nitrogen and phosphorus concentrations, directly correlating with reduced fish availability and declining bird populations. Medical waste, including pharmaceuticals, has led to the bioaccumulation of toxic substances in aquatic organisms, further affecting the food chain. Additionally, the study found a marked increase in water hyacinth and other invasive macrophytes, which have altered dissolved oxygen levels, leading to hypoxic conditions unsuitable for many native fish species. These combined alterations have significantly modified the physical, chemical and biological aspects of the wetland, contributing to substantial degradation (Bhowmik, 2020). Discriminant analysis was used to assess the impact of identified factors on biodiversity and livelihood indicators including

Table 1: KMO and Bartlett's Test

Kaiser-Meyer-Olkin measure of sampling adequacy.		**.924**
Bartlett's Test of Sphericity	Approx. Chi-Square	4135.178
	df	253
	Sig.	.000

Source: Interview Schedule Data

Table 2: Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.911	38.742	38.742	8.911	38.742	38.742	4.937	21.464	21.464
2	2.073	9.014	47.756	2.073	9.014	47.756	3.729	16.212	37.677
3	1.419	6.168	53.924	1.419	6.168	53.924	2.531	11.003	48.679
4	1.082	4.704	58.628	1.082	4.704	58.628	2.288	9.949	58.628
5	.988	4.294	62.923						
6	.817	3.552	66.475						
7	.711	3.091	69.566						
8	.693	3.012	72.577						
9	.676	2.937	75.515						
10	.650	2.828	78.343						
11	.572	2.486	80.829						
12	.539	2.341	83.170						
13	.521	2.264	85.434						
14	.463	2.014	87.448						
15	.422	1.833	89.281						
16	.390	1.696	90.977						
17	.369	1.605	92.582						
18	.339	1.472	94.054						
19	.317	1.378	95.432						
20	.297	1.291	96.723						
21	.279	1.215	97.937						
22	.255	1.109	99.047						
23	.219	.953	100.000						

Extraction Method: Principal Component Analysis. Source: Interview Schedule Data

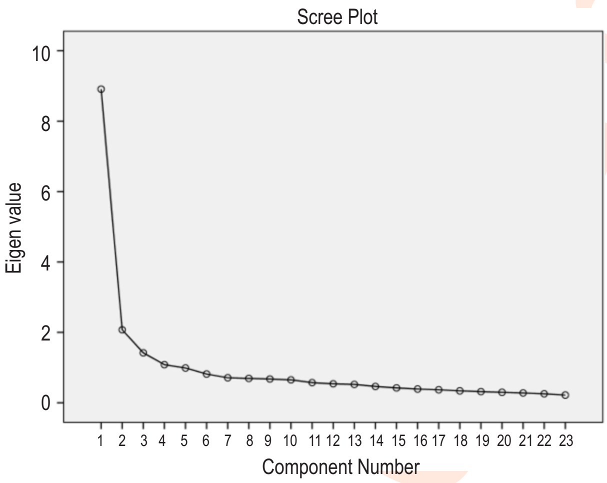

Fig. 2: Scree plot.

migratory bird availability, agriculture land, fish availability and grazing land (Table 4). Discriminant analysis revealed that the predictive variables had the most significant impact on group 2, specifically agriculture land. The mean values of these variables ranged from 12.88 for pollution and conflict to 16.65 for fertilizers and pesticides, indicating a significant impact on cropland and its conditions. These high indices also indicate that environmental degradation factors exert a strong influence on agricultural outcomes, most likely due to the impact of these pollutants on bird habitats in wetlands adjacent to these croplands and the subsequent movement and destruction caused by birds in these areas (Fig. 3). In addition, for groups 3 and 4 fish availability and grazing land, the impact of predictive variables was moderate, as reflected by their relatively close mean values. In contrast, the first group (migratory birds), showed the lowest mean values among all groups. For this group, the mean effect of the predictor variables ranged from 4.60 for fertilizers and pesticides to 9.80 for pollution and conflicts. While pollution and medical waste affect bird populations, their effects appeared to be more significant for agriculture and rangelands.

The term “valid N (listwise)” refers to respondents with complete data for all relevant variables in each livelihood category. Using listwise deletion ensured consistent analysis by excluding incomplete responses. Sample sizes varied by category: 5 for migratory birds, 17 for agriculture, 181 for fish, and 169 for grazing land. Overall, 372 respondents provided complete data, ensuring reliable statistical analysis. The analysis revealed that the fertilizers and pesticides have the strongest discriminating effect on biodiversity and livelihood groups, followed by medical waste and adjacent aquaculture. Pollutants and conflicts, while statistically significant, exhibited the weakest

Fig. 3: Images showing the effects of biodiversity and livelihood degradation in the Mangalajodi (Source: Authors).

Table 3: Rotated Component Matrix

	Component			
	1	2	3	4
Impact_on_water_quality_(fertilizers)	.814			
Impact_on_fish_availability_(fertilizers)	.737			
Impact_on_migratory_birds_(fertilizers)	.706			
Impact_on_other_flora/fauna_(fertilizers)	.668			
Poor_management_and_lack_of_enforcement_of_environmental_conservation_laws_lead _to_uncontrolled_exploitation_and_degradation_of_wetland_resources				
There_is_conflict(s)_on_the_wetland_use_with_the_users_from_outside_the_local_villages				
Runoff_from_agriculture_fields_degrades_the_wetland				
Impact_on_grazing_land_(medical_waste)				
Impact_on_grazing_land_(fertilizers)				
Impact_on_fish_availability_(adjacent_aquaculture)		.814		
Impact_on_migratory_birds_(adjacent_aquaculture)		.670		
Impact_on_grazing_land_(adjacent_aquaculture)		.663		
Impact_on_water_quality_(adjacent_aquaculture)		.603		
Impact_on_other_flora/fauna_(adjacent_aquaculture)		.521		
Overfishing_and_hunting_especially_of_endangered_species_or_during_breeding_seasons_ disrupts_the_ecological_balance_and_reduces_the_numbers_of_key_species				
Impact_on_water_quality_(medical_waste)			.790	
Impact_on_fish_availability_(medical_waste)			.685	
Impact_on_migratory_birds_(medical_waste)			.577	
Impact_on_other_flora/fauna_(medical_waste)			.468	
Transportation_by_motorised_boats_through_wetland_has_polluted_the_wetland				.839
Wetland_degradation_led_to_further_pollution/water_quality				.815
There_is_conflict(s)_on_the_wetland_use_among_different_local*_users				.665
The_wetland_is_being_encroached				

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

discriminating power (Table 5). These findings highlight the differential impact of degradation factors on ecological and livelihood outcomes. Discriminant analysis revealed three functions, Function 1 (Eigenvalue = 0.305, Canonical Correlation = 0.483) demonstrated that 83.6% of the variance served as the primary driver of group differentiation. Functions 2 and 3 explained 10.6% and 5.8% of the variance, with weaker canonical correlations, contributing limited additional discrimination. The squared canonical correlations indicated that 23%, 3.72% and 2.07% of the variance in group separation were explained by the respective functions (Table 6). Wilks' Lambda tests for all three functions were statistically significant ($p < 0.05$), confirming the discriminant power of four independent variables across biodiversity and livelihood groups (Table 7).

Wetlands are essential for achieving key UN Sustainable Development Goals. They support SDG 6 by purifying water and sustaining groundwater levels, and contribute to SDG 13 by serving as carbon sink that help combat climate change. They are vital for SDG 15 (Life on Land) by preserving biodiversity, providing habitats, and supporting species conservation. Wetlands also support SDG 11 by mitigating flood risks, boosting

Table 4: Group statistics: loss of biodiversity and livelihood

Loss of biodiversity and livelihood		Mean	Std. Deviation	Valid N (listwise)	
				Unweighted	Weighted
Migratory birds	Fertilizer and pesticide	4.6000	1.34164	5	5.000
	Adjacent aquaculture	7.6000	3.71484	5	5.000
	Medical waste	5.8000	2.04939	5	5.000
	Pollution and conflicts	9.8000	4.38178	5	5.000
Agricultural crops	Fertilizer and pesticide	16.6471	4.96162	17	17.000
	Adjacent aquaculture	16.3529	5.75479	17	17.000
	Medical waste	16.0000	4.30116	17	17.000
	Pollution and conflicts	12.8824	2.39485	17	17.000
Availability of fish	Fertilizer and pesticide	12.7017	3.10545	181	181.000
	Adjacent aquaculture	14.2431	3.68729	181	181.000
	Medical waste	13.9282	2.89642	181	181.000
	Pollution and conflicts	11.7127	1.72089	181	181.000
Grazing lands	Fertilizer and pesticide	14.4675	2.13540	169	169.000
	Adjacent aquaculture	16.1716	3.28962	169	169.000
	Medical waste	14.8876	2.07431	169	169.000
	Pollution and conflicts	11.6805	1.31553	169	169.000
Total	Fertilizer and pesticide	13.5753	3.17457	372	372.000
	Adjacent aquaculture	15.1263	3.84507	372	372.000
	Medical waste	14.3495	2.86186	372	372.000
	Pollution and conflicts	11.7258	1.66948	372	372.000

Source: Interview Schedule Data

Table 5: Tests of equality of group means

	Wilks' Lambda	F	df1	df2	Sig.
Fertilizer and pesticide	.776	35.318	3	368	.000
Adjacent aquaculture	.884	16.050	3	368	.000
Medical waste	.838	23.748	3	368	.000
Pollution and conflicts	.960	5.150	3	368	.002

climate resilience, and promoting sustainable urban development. (Mishra *et al.,* 2024). The study conducted in Mangalajodi revealed that wetland degradation is driven by a complex interplay of natural and anthropogenic factors, profoundly impacting biodiversity and local livelihoods.

The Flood-Pulsing Theory (Junk *et al.,* 1989) explains how periodic inundation influences wetland ecosystems, affecting species composition and nutrient distribution. The disruption of this natural hydrological cycle due to anthropogenic pressures can significantly impact biodiversity and ecosystem resilience in wetlands like Mangalajodi. Factor analysis identified fertilizers, pesticides, adjacent aquaculture, medical waste, pollutants, and conflicts as the key drivers of degradation. These findings align with the previous studies that emphasize the detrimental impacts of agricultural pollutants, aquaculture activities, and improper waste management in disrupting wetland ecosystems and depleting biodiversity (Chatterjee *et al.,* 2024, Kumar *et al.,* 2023). The analysis revealed significant impacts of these factors on livelihood indicators. Agricultural land, with mean values ranging from 12.88 for pollution and conflict to 16.65 for fertilizers and pesticides, emerges as the most affected, highlighting how environmental degradation undermines crop yields and land quality. Moderate impacts were noted on fish availability and grazing land. The displacement of migratory birds underscores the intricate relationship between biodiversity loss and agricultural vulnerabilities.

The significant impact of these factors on key livelihood indicators such as migratory bird numbers, crop yields, fish availability, and grazing pastures underscores the major environmental, social, and economic vulnerabilities faced by local communities. These findings also highlight the urgent need for targeted conservation strategies to address the Mangalajodi wetland ecosystem. Effective measures could include regulating the use of fertilizers and pesticides in adjacent agricultural areas, promoting sustainable aquaculture practices that reduce habitat disruption and pollution (Kong *et al.,* 2020) and implementing

Table 6: Summary of canonical discriminant functions

Eigenvalues				
Function	**Eigenvalue**	**% of Variance**	**Cumulative %**	**Canonical Correlation**
1	.305[a]	83.6	83.6	.483
2	.038[a]	10.6	94.2	.193
3	.021[a]	5.8	100.0	.144

a. First 3 canonical discriminant were used in the analysis

Table 7: Wilks' lambda

Test of Functions	Wilks' Lambda	Chi-square	df	Sig.
1 through3	.723	119.240	12	.000
2 through3	.943	21.547	6	.001
3	.979	7.684	2	.021

appropriate waste management systems to mitigate the flow of medical and other pollutants into the wetland (Mumtaz *et al.,* 2024). International collaboration, facilitated by UNEP, is essential to address migratory bird challenges in Mangalajodi, promoting sustainable solutions that balance biodiversity conservation with agricultural and livelihood concerns. Additionally, community-based homestay programs can enhance local economies by boosting ecotourism, preserving traditional handicrafts, and fostering direct community engagement with visitors. These initiatives, along with training in hospitality and environmental management, can improve tourism standards, reduce economic migration, and diversify income sources, reducing reliance on unsustainable wetland-dependent livelihoods while ensuring economic resilience.

This study provides critical insights into the need for adaptive ecosystem management frameworks that integrate scientific research, community participation, and robust policy support. These frameworks should prioritize biodiversity restoration and livelihood resilience to ensure the long-term sustainability of the Mangalajodi wetlands. Coordinated conservation efforts, enhanced governance, and active community engagement are crucial for preserving these invaluable ecosystems for future generations.

In conclusion, the study underscores the interconnected challenges of wetland degradation, biodiversity loss, and livelihood decline in Mangalajodi. Using factor and discriminant analyses, it identifies key anthropogenic drivers and their impacts on ecological and socio-economic indicators. It emphasizes the need for integrated, community-based conservation strategies that align environmental sustainability with livelihood resilience. The findings are highly relevant for policymakers, conservationists, and development planners seeking evidence-based interventions. Moreover, the framework offered is replicable for other ecologically sensitive wetland regions facing similar pressures.

Future research should adopt an interdisciplinary approach, combining environmental science, socio-economics, and climate modeling to deepen our understanding of wetland ecosystems. Investigating the effects of climate change on biodiversity and the subsequent impacts on local livelihoods is crucial. Additionally, assessing the effectiveness of community-based conservation initiatives, such as ecotourism and sustainable aquaculture, could provide actionable insights for policy development. This study serves as a foundation for designing strategies that balance biodiversity restoration with livelihood resilience, emphasizing the importance of adaptive management frameworks to ensure sustained ecological integrity and community well-being of Mangalajodi and other wetlands.

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Authors' contribution: All authors made substantial contributions to the conception, design, analysis, and interpretation of the research findings; **D. Jena and A. Daoun:** Conceptualized the study, contributed to data collection, analysed the data, and drafted the manuscript; **N.R. Parida:** supervised the study, guided the methodological approach, and critically revised the manuscript for intellectual content; **S. Dash and V.V. Giri:** Assisted in data analysis and interpretation; **P. Mishra, S. Das and S.K. Jena:** Contributed to data collection, literature review, and manuscript editing.

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