

Sustainable Wetland Management in North Bihar Plain: A Geographical Assessment of Floodplain Ecosystem

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Abstract: Wetlands are dynamic transitional ecosystems between terrestrial and aquatic environments, performing essential ecological and socio-economic functions such as flood regulation, groundwater recharge, and biodiversity conservation. The North Bihar Plain, characterized by extensive alluvial floodplains, supports a large concentration of wetlands that are vital for sustaining rural livelihoods and maintaining regional hydrological balance. However, these ecosystems are increasingly threatened by siltation, encroachment, pollution, and unregulated land-use changes. The present study aims to assess the spatial distribution, ecological significance, and management challenges of wetlands in the North Bihar Plain from a geographical perspective. Using data from the National Wetland Atlas, district-level statistics, and GIS-based spatial analysis, the research quantifies wetland area and classifies them based on geomorphological and hydrological characteristics. The findings reveal that wetlands cover 259,930 hectares in North Bihar. The spatial pattern indicates a strong correlation between wetland density and the flood-prone basins of the Kosi, Gandak, and Burhi Gandak rivers. The study emphasizes the need for sustainable wetland management integrating scientific assessment, community participation and policy implementation. Strengthening institutional frameworks and adopting geospatial monitoring are essential for long-term conservation, ecological stability, and climate resilience of these floodplain ecosystems.

Key Words: Wetlands, Floodplain Ecosystem, North Bihar Plain, GIS, Sustainable Management, Hydrology.

1. INTRODUCTION:

Wetlands are dynamic ecosystems where land and water converge, characterized by saturated soils and the presence of standing water, either permanently or seasonally, creating unique habitats that support diverse flora and fauna. Geographically, they are transitional zones between terrestrial and aquatic environments, encompassing marshes, swamps, bogs, fens, and mangroves, shaped by local hydrology, climate, and topography. The Ramsar Convention (1971) defines wetlands as “areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters.” The U.S. Environmental Protection Agency (EPA) further describes them as areas where water is the primary factor controlling the environment and associated plant and animal life. These definitions highlight wetlands’ ecological and hydrological significance, serving as biodiversity hotspots, carbon sinks, and natural water regulators (Ramsar Convention Secretariat, 2013; EPA, 2023). Wetlands are among the most productive and biologically diverse ecosystems on Earth covering approximately 6% of the planet’s surface but their distribution is highly uneven due to variations in climate, topography, soil type, hydrology, and human activity. In North America, the United States and Canada host extensive wetlands such as the Everglades in Florida, the Prairie Pothole Region in the northern plains, and the Mackenzie River delta in Canada. In South America, the Pantanal—spanning Brazil, Bolivia, and Paraguay—is the world’s largest tropical wetland, while the Amazon floodplains support a vast network of seasonal wetlands. Africa is home to significant wetland systems such as the Okavango Delta in Botswana and the Sudd in South Sudan, which serve as critical habitats for diverse fauna and act as hydrological regulators. In Asia, wetlands are abundant in India, China, Bangladesh, and Southeast Asia; notable examples include the Sundarbans mangrove forest across India and Bangladesh, the Loktak Lake in Manipur, and Poyang Lake in China. Australia and Oceania feature coastal and inland wetlands, including Kakadu National Park in the Northern Territory and extensive mangrove systems along tropical coastlines. Europe’s wetlands are concentrated in the Danube Delta, the Camargue in France, and the Wadden Sea along the North Sea coast, reflecting both natural riverine and coastal processes. Wetlands are dynamic

landscapes that are shaped by hydrological cycles, geomorphology, and climate variability, making them particularly sensitive to anthropogenic pressures such as drainage for agriculture, urbanization, industrial pollution, and climate change, which have caused a global decline of 64–71% of wetland area since 1900 (Davidson, 2014). Recognizing their ecological, economic, and cultural importance, the international community established the Ramsar Convention on Wetlands in 1971, which now protects over 2,400 sites covering more than 250 million hectares worldwide, promoting sustainable use and conservation of wetlands of international significance (Ramsar Secretariat, 2024).

India possesses an extensive and diverse network of wetlands due to its varied physiographic, climatic, and hydrological conditions. Wetlands in India are distributed across almost all ecological regions — from the snow-fed Himalayan highlands to the arid zones of Rajasthan, the fertile Indo-Gangetic plains, and the extensive coastal belts of peninsular India. According to the *National Wetland Atlas (MoEFCC, 2024)*, India has more than 3,60,000 wetlands covering an area of about 15.26 million hectares, constituting roughly 4.6% of the country's geographical area. These wetlands are broadly categorized into inland wetlands (freshwater systems) and coastal wetlands (marine and brackish water systems), apart from numerous man-made wetlands such as reservoirs, tanks, and ponds. In the Himalayan region, states like Jammu & Kashmir, Himachal Pradesh, and Uttarakhand host high-altitude glacial and alpine wetlands such as Wular Lake, Dal Lake, Pangong Tso, and Tso Moriri, which serve as important habitats for migratory birds and sources of freshwater. The Indo-Gangetic plains, encompassing states like Punjab, Haryana, Uttar Pradesh, Bihar, and West Bengal, contain extensive floodplain wetlands and oxbow lakes formed by the meandering of major rivers such as the Ganga, Yamuna, and Ghaghara. Notable examples include Kanwar Lake (Bihar), Keoladeo National Park (Rajasthan), and East Kolkata Wetlands (West Bengal). These wetlands support agriculture, fisheries, and water recharge, forming the backbone of rural livelihoods. In the peninsular and coastal regions, wetlands are associated with deltas, estuaries, backwaters, and mangrove forests. The Chilika Lake in Odisha, India's largest brackish water lagoon, and Vembanad-Kol Wetland in Kerala are among the most prominent Ramsar Sites. Along India's 7,500 km coastline, extensive mangrove ecosystems such as the Sundarbans (West Bengal), Muthupet (Tamil Nadu), and Godavari-Krishna delta (Andhra Pradesh) serve as natural barriers against cyclones and coastal erosion. The western coast, particularly Gujarat, hosts the Gulf of Kachchh and Gulf of Khambhat, known for their intertidal mudflats, salt marshes, and mangrove habitats. In central and southern India, states like Madhya Pradesh, Maharashtra, and Karnataka are characterized by numerous man-made and natural wetlands, including reservoirs, tanks, and lakes such as Bhojtal (Bhopal) and Lonar Lake (Maharashtra). In the arid and semi-arid regions of Rajasthan and Gujarat, ephemeral wetlands like Sambhar Salt Lake and Little Rann of Kachchh form during monsoons and support salt production and seasonal bird migrations.

Overall, the eographical distribution of wetlands in India mirrors the nation's physical diversity and hydrological complexity. While the northern and eastern plains host freshwater and floodplain wetlands, the peninsular and coastal regions contain brackish and marine systems. However, these ecosystems are increasingly threatened by encroachment, pollution, siltation, and land-use changes. Sustainable management through GIS-based monitoring, community participation, and policy enforcement under frameworks like the *Wetlands (Conservation and Management) Rules, 2017* is vital for their protection and restoration.

2. WETLANDS IN BIHAR:

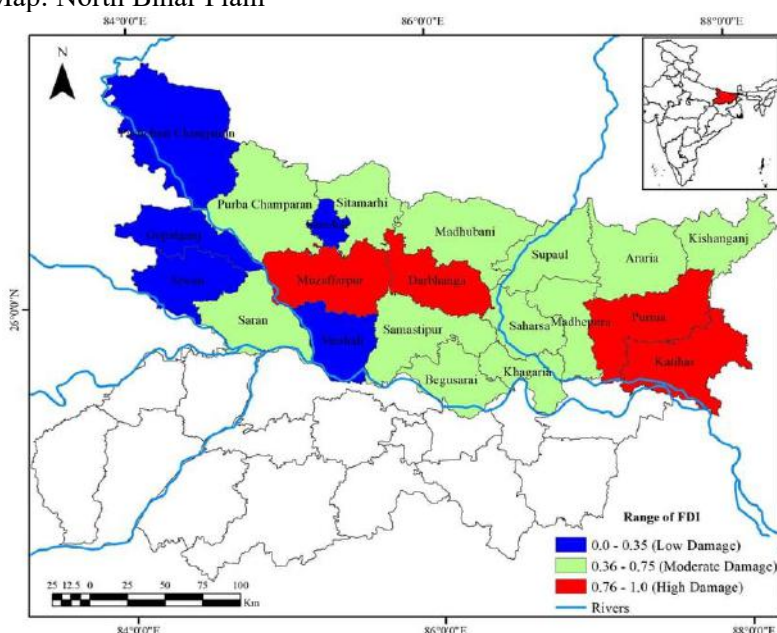
Wetlands in Bihar are integral to the state's Indo-Gangetic floodplain ecosystem, shaped by the meandering rivers like the Ganga, Gandak, Kosi and others covering an estimated 200,000–300,000 hectares across marshes, oxbow lakes, and seasonal floodplains. These wetlands, including freshwater lakes and riverine depressions, form in low-lying alluvial plains, absorbing monsoon floods that inundate 70% of Bihar's land annually. Kabartal (Kanwar Lake) in Begusarai, Asia's largest oxbow lake at 2,620 hectares, is a prime example, formed by the Burhi Gandak River's ancient meanders; designated Bihar's first Ramsar site in 2020, it supports 221 bird species, including 58 migratory waterfowl along the Central Asian Flyway, such as the critically endangered sociable lapwing and Baer's pochard, alongside 165 plant and 394 animal species. Other key sites include Kanwar Lake Bird Sanctuary, Gogabil Lake in Katihar (a vital fish habitat), and Vikramshila Gangetic Dolphin Sanctuary in Bhagalpur, home to endangered Ganges river dolphins. In September 2025, Gokul Jalashay in Buxar—an oxbow lake on the Ganga's southern edge—and Udaipur Jheel in West Champaran, supporting over 150 species of birds, mammals, fish, and amphibians, were added as Ramsar sites, bringing Bihar's total to five. These wetlands bolster biodiversity, recharge groundwater, and sustain fisheries yielding millions in livelihoods, while mitigating floods and droughts. Yet, they face acute threats: encroachment for agriculture has shrunk Kabartal from 6,786 hectares in 1984 to 2,032 by 2012; water abstraction, damming, and pollution from untreated sewage degrade water quality; invasive species like water hyacinth clog waterways; and climate-induced erratic monsoons exacerbate drying. Conservation lags, with only partial implementation of the *Wetlands (Conservation and Management) Rules, 2017*. The Bihar State Wetland Authority's 2023 recommendations for four sites underscore

urgency, but integrated restoration—desilting, hydrological connectivity, and community involvement—is essential to preserve these ecological lifelines for Bihar's resilience and global biodiversity (Ramsar Convention Secretariat, 2025; MoEFCC, 2023).

3. STUDY AREA:

The North Bihar Plain, a vital segment of the Indo-Gangetic Plain, stretches across the northern part of Bihar, India, bordered by the Himalayan foothills to the north and the Ganges River to the south. Spanning 21 districts like East Champaran, West Champaran, Muzaffarpur, Sitamarhi, Madhubani, Darbhanga, Katihar, khagaria, Begusarai and Supaul, it covers 5247118 hectare of fertile alluvial terrain. Formed by sediment deposits from rivers like the Kosi, Gandak, Bagmati, and Burhi Gandak, the plain is characterized by its flat topography, with elevations rarely exceeding 100 meters above sea level. These rivers, originating in the Himalayas, create a dynamic landscape prone to annual flooding, particularly during the monsoon, due to heavy siltation and shifting river courses, earning the Kosi the moniker "Sorrow of Bihar." The region's fertile loamy soil supports intensive agriculture, with rice, wheat, maize, sugarcane, and lentils as staple crops, sustaining a dense rural population. However, flooding poses significant challenges, disrupting livelihoods and infrastructure. Ecologically, it hosts wetlands like the Kanwar Lake Bird Sanctuary, though deforestation and urbanization threaten biodiversity. The North Bihar Plain is crisscrossed by irrigation canals, such as the Triveni and Koshi canal systems, enhancing agricultural productivity but also reflecting human efforts to manage the region's volatile hydrology. Culturally, it is a vibrant region with a rich history, dotted with ancient sites and diverse communities, making it a critical yet challenging part of Bihar's geography.

Location Map: North Bihar Plain



4. OBJECTIVES OF THE STUDY:

- To map and analyze the spatial distribution of wetlands across the North Bihar Plain
- To assess the contribution of each district to the total wetland area in North Bihar and identify high- and low-density wetland zones.
- To examine the hydrological and geomorphological factors influencing wetland formation, persistence, and decline in the region.
- To evaluate the ecological significance of wetlands, including biodiversity support, flood regulation, groundwater recharge, and carbon sequestration.
- To propose sustainable wetland management strategies, including restoration, desilting, hydrological connectivity, and community participation.
- To provide a geographical framework for future planning and policy-making aimed at balancing ecological, social, and economic interests in North Bihar wetlands.

5. DATABASE AND METHODOLOGY:

The database and methodology of this study are grounded in a combination of secondary data analysis, geospatial techniques, and field-based assessments to examine wetlands in the North Bihar Plain. The primary database comprises district-wise information on wetland area, total geographical area, and percentage distribution, derived from the National Wetland Atlas (MoEFCC, 2024), Census of India 2011, and reports published by the Bihar State Wetland Authority. Hydrological, topographical, and administrative boundary data were obtained from the Survey of India (SOI) topographic sheets and remote sensing satellite imagery (Landsat and Sentinel datasets) to delineate wetland extents and classify their spatial distribution. Wetlands were categorized by percentage share in total wetland area and proportion to district geographical area, following the standard classification schemes used in wetland geography and GIS-based environmental studies. spatial visualization techniques using GIS were employed to map wetland distribution, identify flood-prone zones, and examine the relationship between hydrological networks and wetland density. Additionally, qualitative interpretation considered geomorphology, river dynamics, flood frequency, and land-use patterns to contextualize wetland distribution in relation to human and ecological factors. Cross-validation was performed using published research articles, Ramsar site documentation, and field observations reported in secondary studies to ensure accuracy and reliability. This integrative database and methodology allow for a comprehensive geographical assessment of wetlands in North Bihar, facilitating insights into their distribution, ecological significance, and the need for sustainable management within floodplain ecosystems.

Floodplain Wetlands of North Bihar: The floodplain ecosystem of North Bihar is a dynamic and fertile region shaped by the rivers Ganga, Kosi, Gandak, Bagmati, and Mahananda. Seasonal flooding enriches the soil with alluvial deposits, supporting extensive agriculture and diverse biodiversity. Wetlands, ponds, and oxbow lakes form vital habitats for fish, birds, and aquatic plants. However, recurrent floods also cause displacement and damage to infrastructure. Despite these challenges, the floodplain sustains rural livelihoods through farming, fishing, and livestock rearing. Sustainable management and flood control measures are essential to balance ecological stability with socio-economic development in the flood-prone plains of North Bihar. Here a detailed description of wetland of north Bihar is presented.



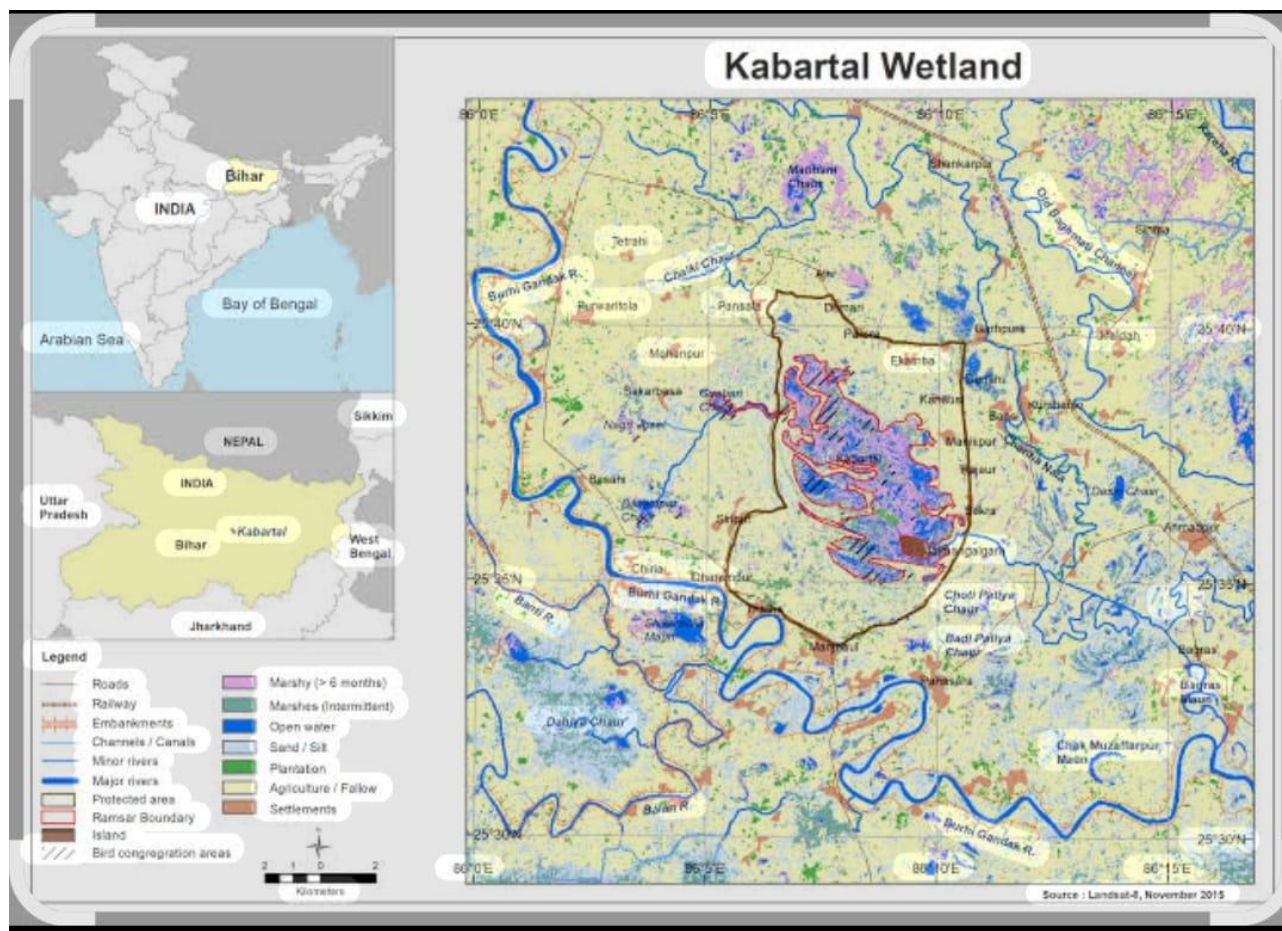


Table No. 1
Distribution of Wetlands in the districts of North Bihar Plain - 2020

District	Total Geographical Area (in hectare)	Total Wetland Area (in hectare)	Percentage to Total Geog. Area of district	Percentage to total Wetland area of North Bihar Plain
Katihar	291349	31011	10.64	11.94
West Champaran	484351	21697	4.48	8.35
Saran	264887	21170	7.99	8.15
Begusarai	187828	20365	10.84	7.84
Supaul	238603	19285	8.08	7.42
Vaishali	201449	17148	8.51	6.60
Samastipur	262390	15022	5.72	5.78
East Champaran	431715	12477	2.89	4.80
Purnea	313883	12401	3.95	4.77
Saharsa	164559	12086	7.35	4.65
Khagaria	149342	11979	8.02	4.61
Kishanganj	189080	10954	5.79	4.21
Muzaffarpur	315351	10490	3.33	4.04
Madhubani	353498	8958	2.53	3.45
Darbhanga	254077	8709	3.43	3.35
Gopalganj	203774	7122	3.49	2.74
Siwan	224410	7105	3.17	2.73
Araria	271712	4157	1.53	1.61
Madhepura	179589	3539	1.97	1.36

Sitamarhi	221891	2601	1.17	1.00
Sheohar	43475	1476	3.39	0.57
Total	5,247,118	259,930	--	100.00

Source: MoEFCC, 2024 and CENSUS OF India -2011

The analysis of Table No. 1 indicates a marked spatial disparity in the distribution of wetlands across the districts of the North Bihar Plain. Katihar district ranks first with 31,011 hac. (10.64%), accounting for 11.94% of the total wetland area of the region, followed by West Champaran (21,697 hac; 4.48%) and Saran (21,170 hac; 7.99%). Begusarai also exhibits a high wetland proportion (10.84%) owing to the flood-prone Ganga–Burhi Gandak basin. Supaul (19,285 hac; 8.08%) and Vaishali (17,148 hac; 8.51%) show extensive wetlands due to recurrent flooding by the Kosi and Gandak rivers, while Samastipur (15,022 hac; 5.72%) contains mainly seasonal wetlands. East Champaran (12,477 hac; 2.89%) and Purnea (12,401 hac; 3.95%) together contribute nearly 10% of the total wetlands, reflecting the influence of wide floodplains and low drainage gradients. Saharsa (12,086 hac; 7.35%) and Khagaria (11,979 hac; 8.02%) are also prominent wetland districts within the Kosi basin. Kishanganj (10,954 hac; 5.79%) and Muzaffarpur (10,490 hac; 3.33%) show moderate wetland coverage, while Madhubani (8,958 hac; 2.53%) and Darbhanga (8,709 hac; 3.43%) have witnessed wetland decline due to agricultural expansion. Gopalganj (7,122 hac; 3.49%) and Siwan (7,105 hac; 3.17%) possess smaller wetland tracts, mainly oxbow lakes along the Gandak River. In contrast, Araria (4,157 hac; 1.53%), Madhepura (3,539 hac; 1.97%), Sitamarhi (2,601 hac; 1.17%), and Sheohar (1,476 hac; 3.39%) have very limited wetland areas, reflecting better drainage and intensive land use. Overall, the wetland distribution demonstrates a clear east–central concentration pattern, where low-lying floodplains and high flood frequency favor wetland development, while the northern and western districts exhibit lesser wetland density due to improved drainage and agricultural reclamation.

The distribution of wetlands in North Bihar Plain, when examined in terms of their percentage contribution to the total wetland area of the region, reveals distinct spatial variations and hydrological influences. Katihar district occupies the foremost position, contributing 11.94% of the total wetlands of North Bihar Plain, highlighting its extensive floodplain conditions and poor drainage along the Mahananda–Ganga confluence. West Champaran follows with 8.35%, its wetlands largely formed by the Gandak and its tributaries. Saran ranks third with 8.15%, where the Ganga–Gandak interfluvium supports numerous oxbow lakes and marshes. Begusarai contributes 7.84%, benefitting from the backwater effects of the Ganga and Burhi Gandak rivers, while Supaul accounts for 7.42%, reflecting the Kosi River’s dynamic depositional activity. Vaishali contributes 6.60%, followed by Samastipur (5.78%), both lying in the Gandak–Burhi Gandak basin, where frequent inundations sustain wetland ecosystems. East Champaran (4.80%) and Purnea (4.77%) share nearly equal contributions, denoting the transition between upland and floodplain areas. Saharsa (4.65%) and Khagaria (4.61%) together form an important wetland belt of the Kosi basin. Moderate contributors include Kishanganj (4.21%), Muzaffarpur (4.04%), and Madhubani (3.45%), reflecting partial flood influence and human encroachment. Darbhanga (3.35%), Gopalganj (2.74%), and Siwan (2.73%) hold small but locally significant wetlands linked with abandoned river channels. The lower contributors — Araria (1.61%), Madhepura (1.36%), Sitamarhi (1.00%), and Sheohar (0.57%) — collectively represent less than 5% of the total wetland area, indicating relatively higher elevation and improved drainage. Overall, the pattern shows that over half of North Bihar’s total wetlands are concentrated in a few eastern and central districts, emphasizing the geomorphic control of major river systems like the Kosi, Gandak, and Ganga in shaping the region’s wetland distribution.

Table No. 2

Class categories: Showing the share of district in total Wetland area of North Bihar Plain

Share of district in total Wetland area of North Bihar	Class Category	No. of Districts	Name of the District
< 2 Percent	Very Low	04	Sheohar (0.57), Sitamarhi (1.00), Madhepura (1.36), Araria (1.61)
2 – 4 Percent	Low	04	Siwan (2.73), Gopalganj (2.74), Darbhanga (3.35), Madhubani (3.45)
4 – 6 Percent	Moderate	07	Muzaffarpur (4.04), Kishanganj (4.21), Khagaria (4.61), Saharsa (4.65), Purnia (4.67), East Champaran (4.80), Samastipur (5.78)

> 6 Percent	High	06	Vaishali (6.60), Supaul (7.420), Begusarai (7.84), Saran (8.15), West Champaran (8.35), Katihar (11.94)
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Source: On the basis of Table No.1

Table No. 2 classifies the districts of North Bihar Plain according to their share in the total wetland area, revealing a distinct spatial pattern of wetland concentration influenced by physiographic, hydrological, and land-use factors. The very low category (<2%), comprising Sheohar, Sitamarhi, Madhepura, and Araria, indicates districts where wetlands are scarce due to comparatively higher elevation, better drainage, and intensive agricultural land use. These areas are less affected by prolonged waterlogging and floods. The low category (2–4%), represented by Siwan, Gopalganj, Darbhanga, and Madhubani, includes districts of the western and central parts where wetlands are largely confined to isolated oxbow lakes and residual depressions formed by shifting river channels, reflecting moderate floodplain activity. The moderate category (4–6%), covering seven districts — Muzaffarpur, Kishanganj, Khagaria, Saharsa, Purnea, East Champaran, and Samastipur, marks a transitional belt between the well-drained uplands and the flood-prone lowlands. Here, wetlands are more extensive due to seasonal inundation from major rivers like the Kosi, Burhi Gandak, and Mahananda, yet subject to growing anthropogenic pressures. The high category (>6%), including Vaishali, Supaul, Begusarai, Saran, West Champaran, and Katihar, signifies the core wetland zone of North Bihar Plain, collectively accounting for the largest proportion of regional wetlands. These districts lie along the active floodplains of the Ganga, Kosi, and Gandak river systems, where recurring floods, low relief, and poor drainage favor wetland formation and persistence. Thus, the classification underscores a clear hydrological gradient from the wetland-rich eastern and central floodplains to the relatively drier and well-drained northern and western fringes highlighting the role of geomorphology, river dynamics, and human intervention in shaping the wetland geography of North Bihar.

Sustainable Wetland Management Strategies in North Bihar Plain : The North Bihar plain, encompassing districts like Supaul, Saharsa, Darbhanga, and Katihar, including floodplain lakes, chauras, and oxbow formations along rivers such as the Kosi and Gandak. These ecosystems are crucial for biodiversity, supporting over 30 indigenous fish species, groundwater recharge, flood control, and livelihoods for millions. However, threats like siltation, agricultural encroachment, pollution, and climate variability have led to a 70% decline in aquatic species. Sustainable management requires integrated approaches focusing on conservation, fisheries enhancement, hydrological restoration, and community participation. Drawing from recent analyses, the following strategies outline a pathway for resilience.

Holistic Conservation Planning: Begin with comprehensive mapping and zoning of wetlands to delineate core conservation zones, buffer areas, and sustainable use sectors. This involves using satellite imagery and geostatistical methods to assess hydrological connectivity and biodiversity hotspots, such as Kabar Tal and Kusheshwar Shthan. Enforce seasonal fishing bans during monsoons to protect breeding grounds, and conduct regular audits of fish genetic diversity to prevent inbreeding. Integrate wetland inventories into river basin plans, prioritizing Ramsar sites for protection against urbanization. This strategy ensures long-term ecosystem health, reducing biodiversity loss by maintaining natural habitats and supporting migratory birds and amphibians. By collaborating with bodies like the Bihar State Wetland Authority, mapping can identify threats like agricultural runoff, enabling targeted interventions that balance human needs with conservation.

Promotion of Indigenous Species Aquaculture: Shift focus to culturing native species like Rohu, Catla, Magur, Singhi, and Pabda, which command 3-5 times higher market prices than exotics. Establish community-managed hatcheries for seed production from wild brooders, reducing pressure on natural stocks. Domesticate high-value species such as river prawns and ornamentals for export, using bio-secure systems to avoid genetic dilution. This approach not only meets Bihar's fish demand deficit of over 3 lakh tons but also conserves endemic biodiversity. In North Bihar floodplains, pilot programs in districts like Supaul can integrate ranching to restock endangered species like Chitala, fostering a "blue revolution" through sustainable yields without habitat alteration.

Eco-Friendly Culture-Based Fisheries: Adopt low-input polyculture in open wetlands, combining grass carp with bottom feeders like Mrigal for yields of 600-1,200 kg/acre, using organic fertilizers like cow dung to prevent eutrophication. In peripheral zones, implement semi-intensive ponds with six-species mixes to utilize all trophic levels, achieving 25-30 quintals/acre. Advanced techniques like biofloc and recirculating aquaculture systems (RAS) can be applied in marshy areas for air-breathing fish, minimizing waste and water use. These methods suit North Bihar vegetation-rich chauras, ensuring production without degrading water quality, while integrating rice-fish farming enhances food security for local communities.

River-Wetland Connectivity Restoration: Reestablish linkages between rivers like the Kosi and wetlands via controlled spillways and bypass structures to facilitate natural water flow, nutrient cycling, and fish migration. This

restores breeding grounds, supports wild seed dispersal, and mitigates flood risks by allowing sediment flushing. In areas affected by embankment breaches, such as the 2008 Kosi event, hydrological budgeting can identify reconnection points to prevent stagnation and biodiversity loss. Long-term benefits include improved groundwater recharge and resilience against climate-induced droughts, crucial for North Bihar's floodplain dynamics.

Community-Led Monitoring and Governance: Empower fisher cooperatives and local institutions to oversee wetland management, including water quality testing, biodiversity monitoring, and enforcement of regulations under Bihar's Wetland Rules. Train communities in sustainable practices, such as using larger mesh nets to spare juveniles, and involve them in decision-making through participatory audits. This reduces illegal encroachments and poaching, while fostering ownership among marginalized groups. In districts like Darbhanga, cooperatives can manage leasing and revenue sharing, ensuring equitable benefits and aligning with national schemes like NPCA for integrated governance.

Integrated Pest and Nutrient Management: Promote buffer zones with rice-fish integration around wetlands to curb agrochemical runoff, which impairs fish reproduction and avian habitats. Adopt precision farming techniques to minimize fertilizer use, balancing agriculture with wetland health. Monitor xenobiotics and implement organic alternatives in catchment areas to prevent pollution. This strategy is vital in North Bihar, where agricultural expansion threatens 20-30% of wetland areas annually, safeguarding species diversity and supporting sustainable irrigation from these ecosystems.

Silt and Sediment Control Measures: Address excessive siltation (e.g., 43 Mt/year in Lower Kosi) through catchment-scale afforestation, check dams, and contour bunding to reduce upstream erosion. Downstream, conduct selective dredging in hotspots like Supaul (755 million m³ extractable sediment), recycling silt for embankments, backfilling, and habitat islands. Propose value chains for commercial utilization, such as in roads and ceramics, with models involving government-private partnerships. This turns silt from a hazard into a resource, preserving wetland depth and preventing shrinkage, while creating jobs under schemes like MNRGA.

Climate-Resilient Restoration Techniques: Restore degraded wetlands using native macrophytes for carbon sequestration and flood buffering, alongside floating gardens in chaurs to adapt to erratic monsoons. Create habitat islands from dredged silt to enhance biodiversity on floodplains. Incorporate environmental impact assessments (EIA) for all interventions, focusing on resilient species stocking. In North Bihar, these techniques build adaptive capacity against rising floods and droughts, aligning with SDG 13 for climate action.

Eco-Tourism and Diversified Livelihoods: Develop low-impact eco-tourism in sites like Kabar Lake, with birdwatching trails, homestays, and guided tours to generate alternative income. Train locals in crafting from wetland reeds and prawn farming, reducing over-reliance on capture fisheries. Integrate with inland waterways development for sustainable transport and tourism. This diversifies livelihoods in flood-prone areas, alleviating pressure on resources while promoting cultural heritage.

Policy and Capacity Building Frameworks: Advocate for policies merging wetlands into Ganga basin management, with funding from NMCG and international aid. Launch training programs on eco-friendly gears and awareness campaigns for stakeholders. Establish research hubs for ongoing monitoring and adaptive strategies, including Nepal coordination for transboundary rivers. This framework ensures scalable implementation, achieving UN SDG 14 through multi-stakeholder collaboration.

6. CONCLUSION:

The wetlands of the North Bihar Plain form a vital component of the region's floodplain environment, supporting rich biodiversity, regulating hydrological cycles, and sustaining rural livelihoods. This study reveals that wetland distribution is uneven, with higher concentrations in the eastern and central districts such as Katihar, Purnia, and Samastipur, where geomorphology and frequent flooding create favorable conditions. However, rapid urbanization, agricultural expansion, siltation, and unregulated resource extraction have led to widespread degradation of these ecologically sensitive areas.

Sustainable management of wetlands requires an integrated approach combining scientific planning, local participation, and effective policy implementation. Restoration of natural drainage, conservation of aquatic habitats, promotion of traditional yet eco-friendly practices, and the use of geospatial technologies for continuous monitoring are crucial steps toward long-term sustainability.

Ultimately, conserving the wetlands of North Bihar is both an ecological and developmental necessity. Protecting these dynamic ecosystems will not only enhance biodiversity and water security but also strengthen climate resilience and livelihood stability. Through coordinated efforts among government agencies, research institutions, and local communities, the floodplain wetlands of North Bihar can serve as a model for sustainable wetland management in eastern India.

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