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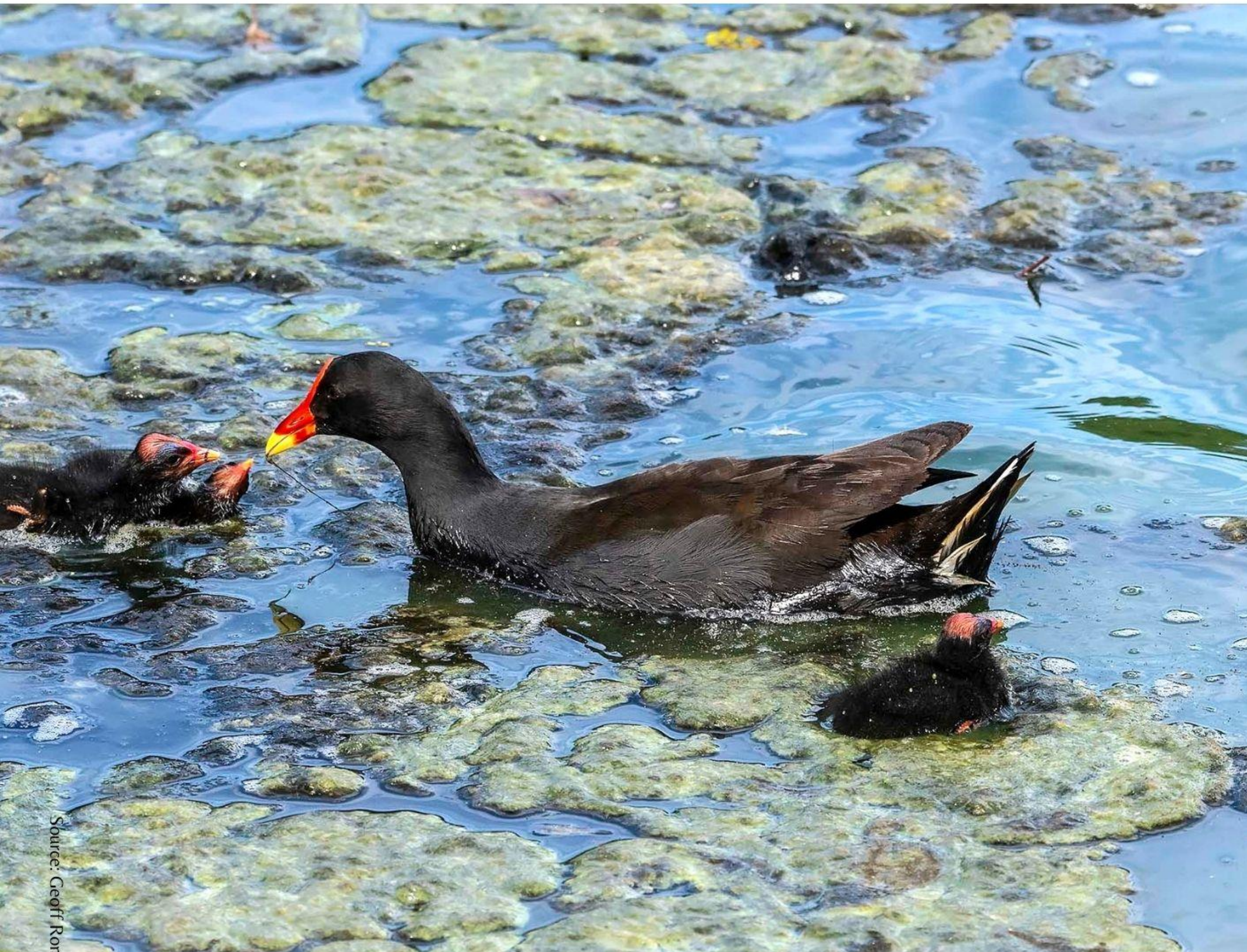

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Vulnerability of Wetlands to Climate Change

Special Guidance

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CONTENT

An overview of the spatio-temporal variation of the Gangetic riverine wetlands – diaras along the Patna urban agglomeration

1. Introduction

The Indo-Gangetic Plain, 2525 km long, is the cradle of Indian civilization and it is hardly a wonder that the river Ganges is one of the most revered rivers in the world. An elongated, shallow, and asymmetrical fore-basin with a gentle easterly slope, trending in the west-east direction as a response to the Himalayan orogeny, the basin is a repository of six distinct regional geomorphic episodes ranging from the Late Pleistocene to the recent Holocene which is manifested in its myriad cyclic phases of sedimentation ranging from shallow marine to estuarine and deltaic to fluvial to the recent. (Dewey and Bird, 1970; Suess, 1893-1909; Singh, 1996; Sinha and Sarkar, 2009).

The riparian state of Bihar is bisected by the holy Ganges, which is in its old stage as it lazily moves to keep its date with the Bay of Bengal and as such the geomorphology is characterized by numerous but ever-changing shapes, sizes, and locations of doabs or diara lands and Ox-bow lakes not to mention the bowl-shaped depressions- tals /chaurs and massive flood plains along natural levees or banks on either side. Although the jury is still out with respect to the extent of diaras and tals in the state, conservative estimates peg them at 0.863 mha and 80000 -100000 ha respectively. The state government has also listed nine chaurs/tals/riverine wetlands in the state covering an estimated 12,500 ha as protected areas with specific qualifying as bird sanctuaries owing to their rich fauna of the winged variety.

Mr. L.S.S. O'Malley, an ICS of erstwhile Bihar and Orissa, wrote in the Gazetteer of Patna in 1907, "From June-September under the combined effect of the melting Himalayan snows and the monsoon rains, it becomes a mighty stream several miles wide. Many broken columns under the pressure of flooded river create chars /chuawar (wetland) and diaras, valuable government assets".

The rain-bearing winds of the south-west monsoon characterized by its rate, frequency, and total precipitation in the catchment areas in this part of the subcontinent is responsible for the volume of discharge in the Ganges-Brahmaputra River system, which has been estimated at 1.7 X 10^9 Tons (Milliman and Meads, 1983). The heavy discharge in the Ganges river system, inclusive of its tributaries, is concomitant with unwieldy baggage of sediments, which is deposited on its onward journey choking the channel and initiating bank line erosion in its wake. Pattanayak and Dayal (2012) have candidly mapped the cycle of bank line shifts characterized by erosion and deposition along the bank in the last four decades.

The phases of degradation and aggradation have long served as tools to demystify the secret (upheavals) of channel geomorphology of a particular reach (Garde, 2006;

Mondal and Satpathi, 2012) and are usually limited by monsoon conditions and characterized by sediment supply. The Late Quaternary climate changes in India are marked by phases of weak and strong monsoon, which is manifested by episodic responses of aggradation and reduced sediment supply and degradation, incision and increased sediment supply to ocean respectively (Rajaguru et al., 1993; Mishra et al., 2003; Singhvi and Kale, 2009). However, remote satellite imagery coupled with geographical information system has proved to be a game-changer of sorts by leveraging spectral and radiometric analysis capacity of RSI for providing fresh insights with respect to fluvial geomorphic systems in space and time and analytical and data integration capability of GIS (Walsh et al., 1998; Ghosh, 2012; Ghoshal et al., 2010).

Faced with the scourge of a burgeoning population and depleting resources fuelled by an inherent ambition to play catch up, 'Development', a much-abused term in recent times, has been used as the proverbial sword to reclaim hitherto lush virgin green-lands and water bodies to cater to our greed. As a result, it is hardly surprising that a number of these virgin lands and water bodies have been reclaimed for agriculture and related activities at the best or have been transformed into concrete jungles at the worst. A large number of dried up water bodies reclaimed as barren land parcels are currently serving as landfill sites. The age-old bureaucratic approach of "one size fits all" results in encouragement and application of dry-land farming techniques where water reigns the roost for a larger part of the year. So instead of following the age-old countryside wisdom of promoting pisciculture as means of livelihood, the government ends up wasting limited resources by teaching local farmers and peasants about the advanced methods of 'rice farming '. It appears that the 'blind spot' for wetlands endures, which has given its right place would have been nothing short of a boon for the poor and the entrepreneurs besides shoring up the fragile ecology of the region already doomed by the unrealistic flood control regime.

According to Dr. Ashok Ghosh, Chairman of BSPCB, around 75% of water bodies and wetlands in the state have vanished. Till the 1980s, more than 2.50 lakh ponds were in the state which came down to less than 90 thousand presently. Further, he added, the water bodies and wetlands are allowed to die an unnatural death. Kabar Lake in Begusarai, one of the largest freshwater lakes of South Asia, is an archetypical case of water bodies vanishing due to human interference".

2. Methodology

2.1 Study Area

The study area encompasses a 35.85 km long stretch (25042’15” N - 25037’28” N latitude and 84051’51” E - 85012’31” E longitude) of the Ganges nested between the upstream confluence point of the Sone in the west and the downstream point of the Gandhi Setu in the east. The two main tributaries, the peninsular origin, river Sone and the Himalayan origin river Gandak join the Ganges along its South and North banks, hereafter flowing in a SW-NE direction and NNW-SSE respectively. Further, downstream beyond the study area, it is met by the river Punpun. In the study area, the aggraded land of diara and Patna Urban agglomerated land with the aforementioned coordinates under reference was measured.

***Figure 1**: Location map of study area*

2.2 Data analysis

The data used is 'Landsat Multispectral Imagery' from the year 1975, 1990, 2000, 2005, 2010, and ESRI world imagery 2014 from Arc map 10.1 user database. The GIS software used is Arc GIS v 10.1 (2012 release). The base map used is DeLorme - world base map provided by ESRI. For each of the imagery, major stable aggraded landforms were measured using 'Area Measure Tool' from the GIS software, besides any part, which is joined with either of the banks by any means is not taken into account as such landforms are not defined as ‘Diaras’. Numbering is done separately for each image on a random basis starting downstream from the west. Overlaying of imaging is done whenever required.

3. Results and discussion

Table 1 represents the extents of aggradations of the river Ganges in the study area from 1975 to 2014 as per measurements.

Table 1: Total aggraded area as per the measurements

Sl No	Year of Imagery	No of fragment	Area (Km2)
1	1975	4	74.40
2	1990	7	204.58
3	2000	9	205.03
4	2005	10	239.05
5	2010	12	215.70
6	2014	6	254.44

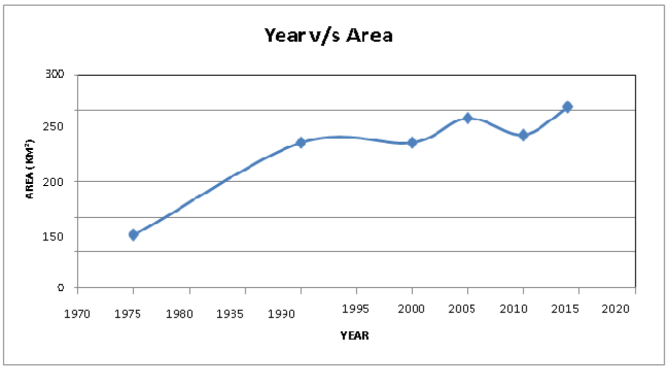

Figure 2*: Time series of aggradations in the study area*

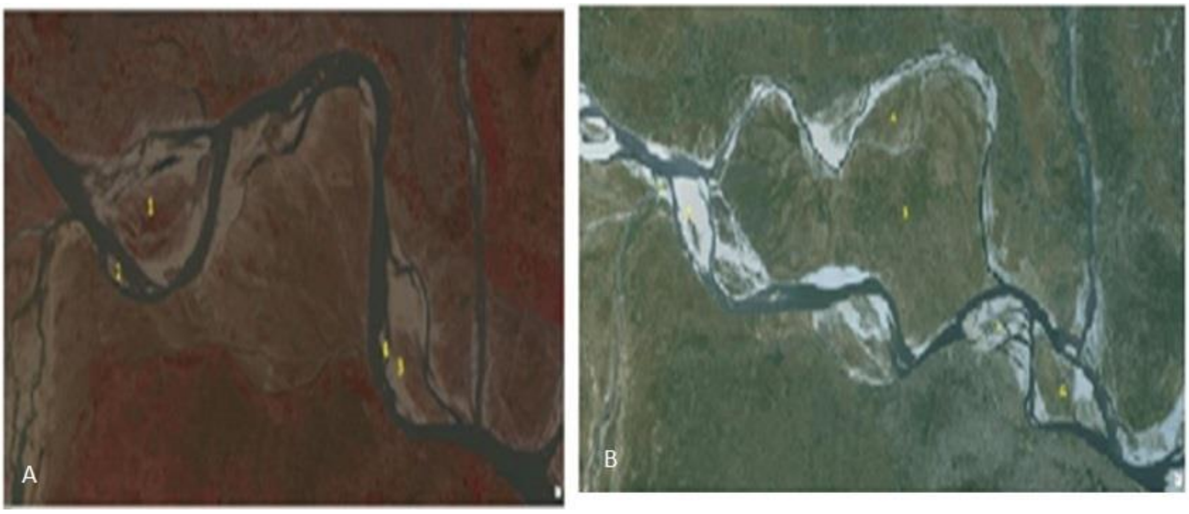

Figure 2: *Difference between Diaras through LANDSAT Multispectral Imagery of 1990 (A) and 2014 (B) through ESRI world imagery*

The time-series graph of the aggraded land area shows an increasing trend of fluvial aggradation in the study area during the year 1975, 1990, 2000, and 2014, due to the decreased flow of the river Ganges, which results in the deposition of the sediment load of the river Sone and the river Gandak in the adjoining Diara region while a decrease in the area of Diara is observed in 2010, when the flow of the Ganges is high, which is not conducive to the deposition of sediments.

4. Conclusions

The findings are consistent with the fact that a spell of unsuccessful monsoon and drier weather enhances the sediment supply resulting in a greater sediment load in the river initially. Aggradation takes place in the area in which the supply of sediments is greater than the amount of material that the system is able to transport. Conversely, during a successful monsoon, the soil is bound to the roots more firmly and sediment is in short supply initially. However, the greater volume of discharge of the river results in the inundation of regions across the natural levees, and the concomitant degradation leads to a greater supply of sediments to the ocean.

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Impacts of urbanization and encroachments in urban wetlands: A case study of Ganga riparian wetlands of the city of Patna

Abstract

Urbanization is the increase in the proportion of people living in towns and cities due to the migration of people from the rural area. The development in urban areas causes wetlands loss of more than 60%. In fact, urbanization is an inevitable trend of human society, and necessary for modernization. At the same time, it has a severe impact on the wetlands ecosystem. Wetlands were estimated to occupy around 8.6 million sq. km, which is 6.4% of the surface of the earth, out of which about 4.8 million sq. km are found in the tropic and sub-tropic regions. In the 19th century, it was found that approximately 50% of the world's wetlands are lost. Some of the major anthropogenic activities leading to loss of the wetlands are urbanization, drainage for agriculture, and water system regulation. The construction and development activities due to urbanization like excavation, filling, draining, and so forth, are the major destructive methods resulting in a significant loss of wetland spatial extent. The wetlands are under tremendous pressure and need effective measures for their rejuvenation. This present study enumerates the different causes and impacts of urbanization on wetlands by taking the example of Patna's urban character.

1. Introduction

Wetlands are characterized by the interaction between the terrestrial system and the aquatic system. The wetlands could be considered as the world's most productive ecosystem. Wetlands provide many functions and services within local watersheds along with economic values in communities. Indeed, the Wetlands offer habitat for numerous birds and other wildlife and provide recreational opportunities. The wetlands ecosystem changed a lot in watershed due to the effects of urbanization.

The health of urban wetlands can be recovered in terms of water quality by eliminating pollutants, reducing flood damage by checking and storing excess water coming from flood and insulating shorelines from erosion through absorbing storm surges. Urban reformation applies remarkable effects on the architecture and operation of wetlands, chiefly through modulating the hydrological and sedimentation regimes, and the dynamics of nutrients and chemical pollutants. Multiple investigations have reported the fading of indigenous species in urban settings (Faeth et al. 2005; Clergeau et al. 2006). Environment of urban areas can also promote the infiltration of invasive species, which further add up to loss of indigenous biodiversity (Shochat et al. 2006). A lot of changes in the wetlands ecosystem is due to change in the watershed and effects of urbanization.

1.1 Impacts of urbanization on wetlands

The urban wetlands, whether coastal, riparian, or lacustrine estuarine, the impacts are caused due to intervention in its watershed. Firstly, the creation and evolution of wetlands are repressed by hydrological cycle. The living and chemical properties of wetlands are impacted by hydrological regimes, Hence the process of production and convergence of runoff altered significantly in the watershed of urban areas. This results in the degradation of wetland's function on runoff regulation and maintenance of ecosystem productivity. Secondly, there are a large number of pollutants including sediment loadings, heavy metals, nutrients, bacteria, and so on in urban surface runoff, which cause an important impact on the wetlands water environment, aquatic organisms, and wildlife habitats. The urban reformation also minimizes the aboriginal species of the plants and enhances newly introduced species of plant. Moreover, the drinking water can be polluted and then causes health problems in humans. Thirdly, urbanization induced climate change that impacts hydrology of wetlands, quality of water, hydrological cycle, energy balance, biogeochemical cycle, plant species, and the ecological operation of wetlands (Zheng, 2008).

1.2 Direct impacts on urban wetlands

The direct impacts can be considered as the activities that are directly located on-site of wetland area. These could be land-use change from wetlands to non-wetlands activities, agriculture, construction activities, encroachments, dredged filled or drained, solid waste disposal, water, and soil water disposal grazing, industrial waste disposal, water transport, tourism activities, etc. All the activities increase sedimentation, hence affect the depth of wetland or main waterbody, which increases flooding in urban areas. The activities like wastewater disposal, use of fertilizers in agricultural practices increases eutrophication which is a form of water pollution. It fosters the proliferation of algae (algal bloom) and other plants in the water, after overcrowding crops up and these plants species compete for sunlight, oxygen and space. The definition of the eutrophication can be given as the mechanism by which a waterbody achieves a high level of nutrients, particularly phosphates and nitrates. This initially promotes aquatic plant growth, but later plants disappear leaving the stage to algae blooming. When the algae die and decompose, elevated amount of organic matter and decaying microorganisms diminish the available oxygen in water, inducing the death of other organisms, such as fish. The activities, such as grazing also affect habitat loss of floral and faunal biodiversity (Figure 01). The collection of wetland products like fish, lotus seeds, water chestnuts, etc. also increases direct pressure on wetlands, hence disturbs the wetlands ecosystem. Taking account of a cultural and religious point of view, the immersion of idol or other religious offerings also degrades the aesthetic value and increases sedimentation.

1.3 Indirect impacts on urban wetlands

Indirect impacts are caused by increased stormwater and pollutants generated by urbanization within a wetland's contributing drainage area or watershed area that stress the wetland ecosystem community. It is caused mainly by non-point sources of pollution due to different activities in an urban watershed. Since the wetlands are often placed at the low point of topography of a watershed, they are frequently influenced by activities in upland areas. The indirect impacts could be through carrying of pollutants by a surface flow of stormwater to main wetland streams, pollution of wetlands water through pollutants entering through biogeochemical cycles. The population density in the urban watershed of wetlands also caused decreased recreational activities and tourism activities in wetland sites, impacting disturbance in migratory and local birds. As wetlands are known for biodiversity in terms of migratory birds, the impact of urbanization also decreases the total number of birds visited.

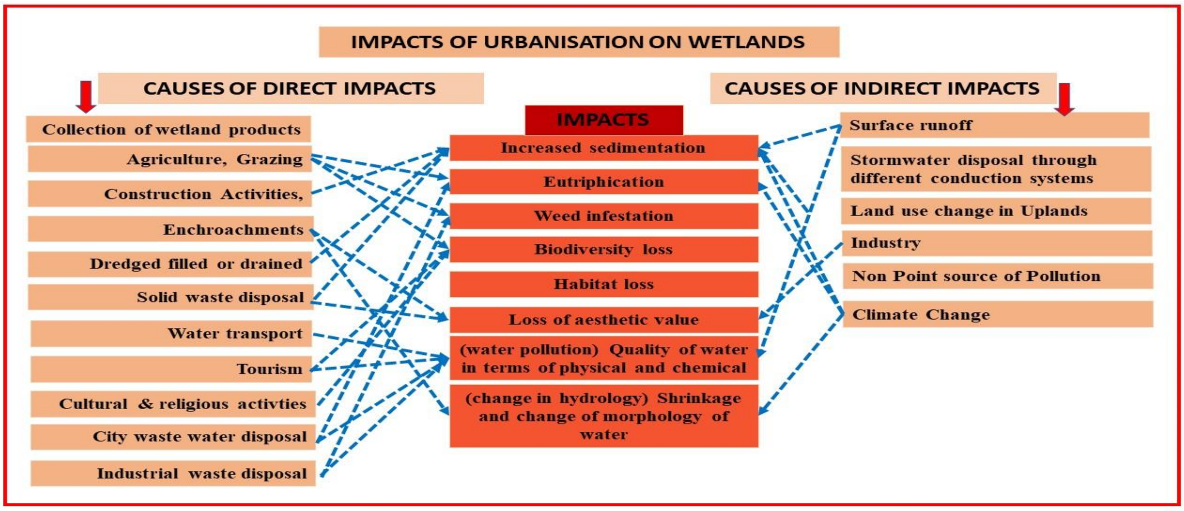

***Figure 1**: Impacts of Urbanization on Urban Wetlands*

Source: Barman, 2020

2. Methodology

The methodology adopted for the study is a literature study, site visit, and analysis. The observational data is collected in the form of notes, photographs, and drawings. The collected data is analyzed and correlated with literature studies.

2.1 The study area

Patna is the capital and the largest city of Bihar with cartographic co-ordinates as 25.6°N 85.1°E, with a mean elevation of 174 ft. (53 m). The population of Patna was 1.68 million in 2011, which makes it the 19th most populous city in India. Patna is one of the earliest dawn of civilization in term of tradition and history. The modern city of

Patna is located on the South of Ganges. The city is approximately 35 km (22 miles) in length and 16 to 18 km (9.9 to 11.2 miles) wide. The important feature of the geography of Patna is the location at the junction of the rivers; it has a slender strip of slightly high land around 8 km in breadth along the South of Ganga and has very productive soil and alluvial arable plains in the remaining portions. The Ganga river, in Patna, has meandered and migrated northwards in the Patliputra area (Sahu and Saha, 2014). This migration has resulted in the deposition of the earth on the south [right] bank of the river and created a massive space of a few hundred hectares between the line of urban reformation and the operating river passage. The detailed study area is selected a riparian wetland stretch of Ganga in the city of Patna. A detailed study has been conducted in a stretch in the urban fringe of Patna city which is also proposed for riverfront development under smart city mission.

***Figure 2**: River Ganga in Patna*

Source: Google Map

2.2 Observations and analysis

The city of Patna is spread alongside the river Ganga from west to east. Through its course of time, the river edges have been developed in Ghats due to religious and cultural impacts. The city beautification projects including the construction of Ganga Driveway, bridges, Ghats, etc. have been coming up as a result of urbanization. The stretch of the Ganga in Patna has never been considered as the part of Riparian ecosystem. Due to urbanization and development projects taking up in Patna Ganga Riparian, wetlands are in tremendous anthropogenic pressure and degraded conditions. The area around the stretch of Ganga river and its southern bank of Patna is mostly surrounded by government institutional buildings, residential buildings, convention, public halls, market areas, colleges, transport transit points, and commercial markets. The linear stretch of riverbank has transformed the adjoining urban fabric in a similar fashion of linear low-rise development. The Bans Ghat, Buddha Ghat, and collectorate Ghat are 3 places of public activity while the rest stretch is bounded by different public institutions and few residential areas. There are many direct and indirect causes of impacts of urbanization. There is also unauthorized development of colonies along the bank near the Bans Ghat and Collectorate Ghat which are polluting the environment of the river. The floristic survey of the proposed site witnesses scattered growth of grasses (mainly weeds), rooted hydrophytes, emerging hydrophytes, shrubs in an undisturbed area where human movement is absent and trees leaning over river water. Commonly seen shrubs and grasses are Congress grass, Lantana, Eipatorium, Solanum, and Datura. This is mainly due to better survival rates, higher seed production, and fast-growing in comparison to other herbs. The species of grasses reported along the banks are Cyanodon dactylon, Achyranthes aspera, Saccharum sponticum, Vetiveria zizanoides, Ludwigia parviflora, Rungia repens, etc. These are primarily documented above the water level, in an unperturbed area. Rooted hydrophytes are reported along the banks, where the water level is less than a foot of water has receded after flooding.

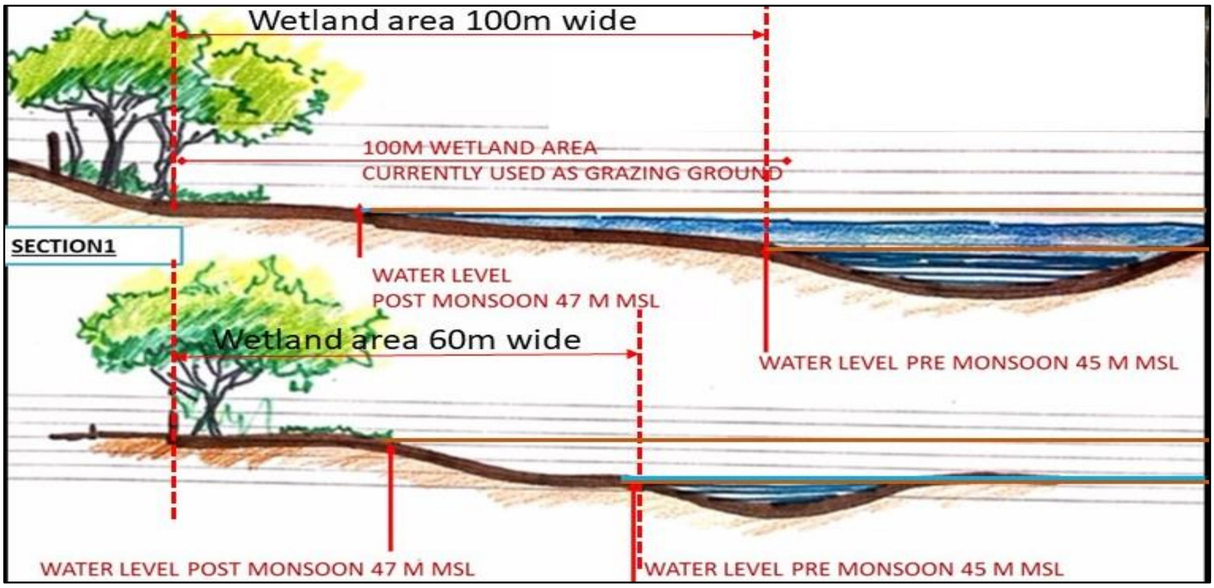

Figure 3: *Wetland distribution of Patna, Sections at different stretches of Study Area Bans Ghat to collectorate ghat*

3. Results

3.1 Direct impact of urbanization in ganga riparian wetlands

The main direct causes of Impacts of Urbanization in Patna are basically land-use change, religious and cultural, massive construction activities of both ghats and encroachments, grazing, agricultural activities, solid waste disposal, waste and sewer water disposal.

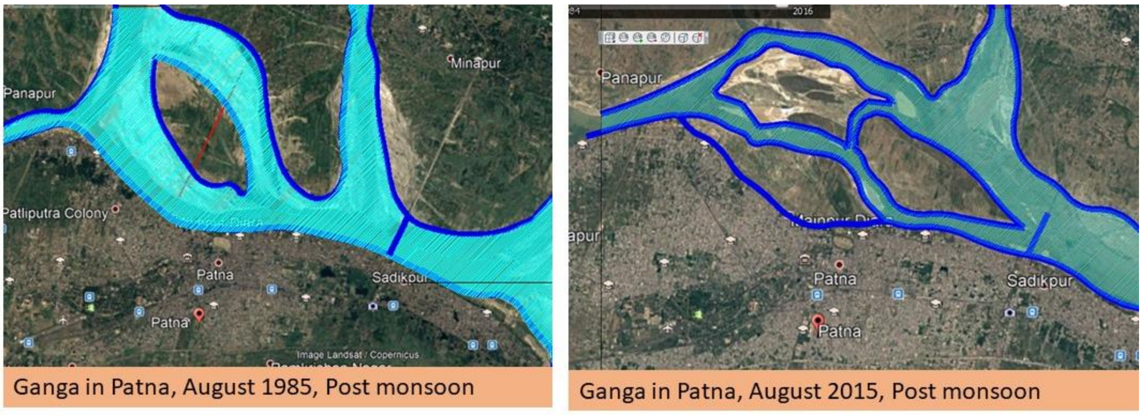

Figure 4: *A comparative study of Change in wetland size in 30 years showing wetland shrinkage*

Source: Barman, 2020

3.2 Land use change for water bodies and urbanization

As the city is very old with historical importance, the fringe along the city is all occupied with residential and government institutional buildings. This impacts the river with day to day activities, which causes partly biodiversity and habitat loss to floral and faunal biodiversity. The existing river bank is bounded on the southern end by public buildings and unauthorized settlements, which creates a close boundary to the riverfront that is not accessible to general citizens. On the northern end, Lokanayak Ganga Path or Ganga Driveway is situated, which is a planned 21.5 kilometer-long (13.4 mi) road expressway across the river Ganga between Digha and Deedarganj in Patna. There is a big stretch of wetland between these two sections of the river which is serviced by a small stream of Ganga diverted near Digha Ghat. The water level is quite low in the summer season while during monsoons the flow is high.

Figure 5*: Encroached settlements, River edge, Waste water disposal and residential settlement*

Source: Barman, 2019

3.3 Collection of wetland products, grazing and agricultural activities

The part of wetlands beyond Bans ghat is being used for extensive agricultural purposes. The use of fertilizers and other agricultural processes increasing siltation in the river Ganga main channel which may cause a flood-like situation. The increased agricultural activities also affect biodiversity and increase weeds like water hyacinth

(Jalkumbhi) in those areas. It is also noted that due to agricultural activities the migratory and local birds do not get free space for feeding and breeding.

Encroachments are a predominant activity found all along the stretch. The construction of temporary structures by bamboo can be found all along the stretch and a few of them are permanent buildings also. (Figure 6) The encroachments also enhance solid waste, sewerage, and wastewater disposal activities along the wetlands zone. The water near this fringe is observed grey in color and with reduced transparency.

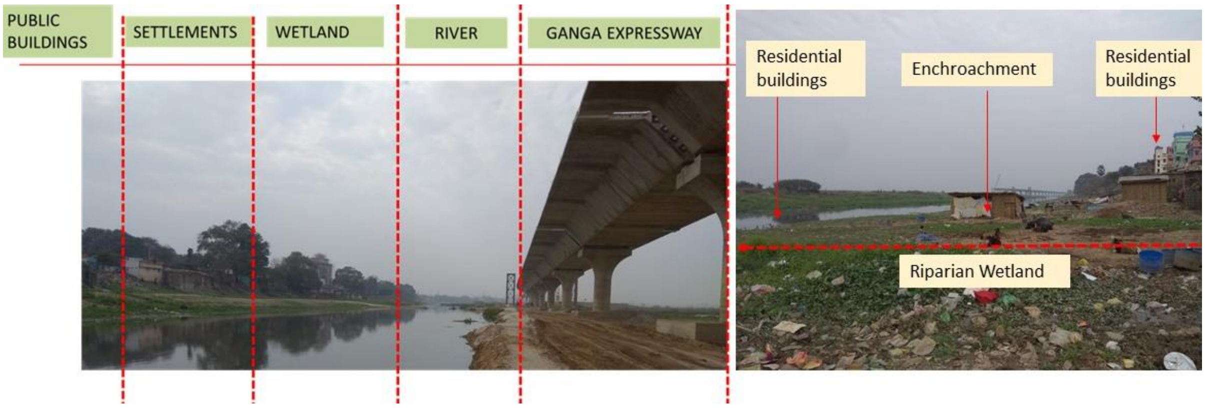

Figure 6*: Section showing different segments along wetland, degraded scenario of the Wetland*

Source: Author

3.4 Solid waste disposal

It is also observed that part of the riparian wetlands has also become garbage dumps or solid waste disposal sites for people living in nearby fringe areas. The Patna Nagar Nigam in general does not practice garbage collection by going for individual door-to-door collection in adjoining areas of the riverfront area. The residents, institutions, and shopkeepers of these areas throw their garbage at the identified points along the main Ashok Rajpath road. There is a dumping of solid waste on road by mobile vendors for the absence of community bins and regular waste collection. Further, there are dairy units and settlements along the ghats, who dispose of their waste directly into the river.

3.5 Wastewater and sewerage disposal

There is a severe problem with drainage in the city. There are closed drains along the main arterial road of Ashok Rajpath while open drains in internal roads. The small local drains are also present in few places which get clogged in monsoon. The drains get choked and overflow due to encroachment on roadsides. This results in water logging in adjoining areas during rainy seasons. The major issue is the flow of untreated drain water directly into the river with all the waste of nearby areas. There is an old sewerage system existing in the area with linkage to public buildings, households, and shops. There is a lack of public toilets and urinals for the local vendors, shopkeepers, and commuters in the zone. Disposal of raw sewage from settlements and slums along the river bank is very common including the open defecation along the edge.

It is also noted that the stormwater drains (Nallah) of the city also carries wastewater from a few parts of the city and due to lack of sewerage system it disposes of in the river itself. The greywater falling into the river is observed to be a prominent phenomenon near Bans Ghat.

Figure 7*: An wetland of Ganga formed at a distance from 500 m from southern River bank in study area, it is thriving to sustain due to sedimentation of construction activities*

Source: Barman 2019

3.6 Development and construction activities

The construction of the Ganga Expressway is currently creating the most destructive impact on these riparian wetlands. The huge sedimentation of construction activities

Figure 8*: Construction of expressway causing narrowing of channel and wetland*

Source: Barman 2019

has divided the mainstream and the character of wetlands is getting lost. Due to which, shrinkage of wetlands along with main waterbody shrinkage is also observed. This can be also noted that the main course of Ganga is now swiftly moving away from its banks in the stretch of Patna city. The construction activities have caused a threat to its biodiversity also. It could also be observed that the river Ganga has already shifted 2.5 – 3.5 km from most Ghats in Patna in recent years due to man-made interference (Figure 5).

3.7 Religious and Cultural Activities

As Ganga is considered as the holy river in Hindu religion and the city inhabitants remain engaged with the river for different religious activities. The disposal of religious offerings and gatherings are also causing degradation to the wetlands.

4. Discussion and conclusion

As the wetland ecosystem provides various services to mankind, the cost of replacing the lost ecological services of wetlands can be expensive, assuming they can be replaced at all. The community that loses wetlands services may need to invest in costlier drinking water treatment, stormwater management, and flood control infrastructure. Retaining and conserving its existing ecosystem is always a better solution than investing in infrastructure. The present status is not a site-driven or localized concern, but it is a story of every urban wetland. A collaborative effort should have been made to avoid the adverse impact of urbanization to wetlands and it should be a primary concern for policymakers. Wetlands should be used to provide solution inside the urban and peri-urban background that can alleviate risks from climate change, support production of food for an expanding population, and stimulate income through tourism and recreation (Ramsar, 2013).

All the development should be oriented towards conserving and restoring the wetlands ecosystem. The socioeconomic profile and culture of the region is also a predominant local cause of different degradation pattern. There is a need for an interdisciplinary decision-making system to address these problems, which can be adopted at a very wide range of academic disciplines that do not generally mingle with each other – herpetology, hydrology, botany, ecology of landscape, conservation biology, management of wildlife, management of storm water, toxicology, and wetlands etc. The upcoming development works could be focused on wetlands restoration and conservation with biodiversity and habitat establishments. As wetland plants play an important role in remediating contaminants causing pollution, adopting phytoremediation techniques through the ecological design process may balance the ecosystem and give a sustainable ecological solution. These techniques could also be seen as a purpose of designing habitat corridor, biodiversity regeneration through environmental design processes with collaborative design interventions by a landscape architect, ecologist, environmental planners, environmental engineers, and many more. After all, a healthy wetlands ecosystem could be a healthy lifeline for urban dwellers. There are many examples of wetlands restoration and wetlands conservation in riparian wetlands like - Weiliu Wetland Park in China, Yanweizhou Wetland Park in Jinhua. Such examples can be studied and reviewed for further development activities and policymaking. “Handbook for Integrating Urban Development and Wetland Conservation, (2018)” by Ramsar also gives guidelines for such kind of development which can be easily followed for a better future and mankind.

***Figure 9**: (A) Yanweizhou Park: A resilient Landscape, (B) Weiliu wetland park*

Source: Topos, 2015; Landazine, 2019

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The vulnerability of wetlands to climate change

1. Introduction

As per the Ramsar Convention, the natural water bodies and man-made wetlands together constitute the wetland ecosystem in India. The climate change scenario makes wetlands one of the most threatened habitats of the world. Wetlands in India, as in other parts of the world are increasingly facing multiple environmental and anthropogenic pressures. The fast-expanding human population, large-scale changes in land use, burgeoning developmental projects and improper management of watersheds have all caused a considerable decline of wetland resources of the country. The threat of conversion of wetlands to agricultural, industrial, and various urban developmental projects also added to the loss of wetland areas in the country. These unsustainable developments have led to hydrological disruption, pollution, and their consequent effects on existing wetlands. Unsustainable levels of fishing and grazing activities have also resulted in the degradation of wetlands. These are the major threat to the wetland ecosystem in addition to the unavoidable threat from changing climate scenarios. According to NWIA (National Wetland Inventory and Assessment 2011) the total area under wetland in the country is estimated as 15.260 MHa, which accounts for 4.63% of the geographical area. Besides streams and rivers, the total area of wetlands is determined to be 10 MHa. The distribution of wetlands based on the states reflected that Lakshadweep covers 96.12% of the geographic area classified under wetlands, Andaman and Nicobar Islands (18.52%), Daman and Diu (18.46%), and Gujarat (17.56%). The other states with high proportion of wetlands are – Puducherry with 12.88%, West Bengal with 12.48%, Assam with 9.74%, Tamil Nadu with 6.92%, Goa with 5.76%, Andhra Pradesh with 5.26%, and Uttar Pradesh with 5.16%. (http://iictenvis.nic.in/Database/Wetlands,Wetlandecosystemsforhumanhealth_1452.aspx?format).

1.1 Perceived threats

The position of wetlands within hydrologic landscapes determines the vulnerability of any wetland to changes in climate. Mainly the flow behaviour of ground water and surface water and by the interaction of atmospheric water, surface water, and ground water for any given locality or region defines boundary conditions of any hydrological landscapes. The mountainous, flat coastal, high plain and plateau, riverine, broad basins of interior drainage, and dune and hummocky glacial are the six major hydrological landscapes. Ground study of these landscapes suggests that the vulnerability of all wetlands to climate change fall between two extremes: the landscapes, which primarily depend on precipitation as the source of the supply of water are significantly vulnerable, and those, which depend chiefly on discharge from regional ground system of the flow of water are the least vulnerable, because of the buffering quantity of huge ground systems of flow of the water to climate change. A water balance study based on precipitation, evaporation, and percolation by IIT Delhi (Gosain et al. 2006) on thirteen major river basins of India suggested that under changed climate scenario only four major river basins i.e., Mahanadi, Brahmani, Ganga and the Godavari would remain as a surplus basin (Gosain et al. 2006). Rest all nine river basins (Cauvery, Narmada, Tapi, Krishna, Pennar, Mahi, Luni, and Sabarmati) and wetlands associated with it are likely to suffer from the deficit basin effect. Silting of deltas due to soil erosion making wetlands prone to overflow in high rainfall areas due to extreme rainfall event are also threat for wetlands (Syvitski et al. 2014). According to India State of Forest Report, 2019, there are total of 62,466 wetlands with 3.83% of its recorded forest area in India. A total of 37 sites in India have been recognized under the convention as Ramsar sites till February 2020. There are 5,55,557 small wetlands (less than 2.25 ha) in the country. West Bengal has the highest number of small wetlands (138707). Only 26 of these wetlands have been designated as Ramsar Sites (Ramsar, 2018). Bihar is situated in the Ganga river basin with river dividing it in the middle. Out of 38 districts, 21 are in North Bihar and 17 in South Bihar. The state of Bihar is known for its extensive network of rivers and associated water bodies like floodplains wetlands (comprising of an oxbow lake, meanders, and seasonal floodplain), reservoirs, ponds, and tanks. The state has over 4416 wetlands with around 130 wetlands having an area of over 100 hectares (National Wetland Atlas of Bihar, 2010) and is mostly fed by rainwater. West Bengal has sixteen major wetlands in the state, out of which one (East Kolkata Wetland) is designated as the Ramsar site. The state of Odisha has at least 78,440 wetlands fed mainly by rainfall in topographical depressions and four doabs (Mahanadi-Kathjhori-Debi, Mahanadi-Chitrotpala-Luna-Birupa-Brahmani, Luna-Chitrotpala, and area to the East of high-level canal). Out of 78,440 wetlands, 66,174 are with an area of 2.25 ha or less are small in the category. The total coverage of wetlands has been estimated at 6,90,904 ha in Odisha. All these wetlands are mainly increased to 38998 ha during 1998-99 from 29330 ha in 1988-89 (30% increase) and are still increasing mainly due to basin of Mahanadi and Brahmani river basin and are mainly rain-fed.

In the state of Bihar, which has over 4416 wetlands has 628 x 103 ha surface waterlogged area, i.e. 10.57% of command area (5939 x103 ha) and spread over 132 command areas. Land surface with floods throughout the year covers 2.95% of the waterlogged area in all the command areas. Gandak command has a maximum total waterlogged area (212 x 103 ha), Eastern Kosi irrigation scheme (116 x 103 ha) and modernization of Sone scheme (82 x103ha; Chowdary et al. 2008). These major freshwater resources provide life to the wetland ecosystems in Bihar. The adverse climate change scenario, reduced or excess water flow, or flood due to extreme climate events, as well as the influx of deteriorating water quality in wetlands are a major concern for the overall health of these wetlands. These freshwater bodies are often subjected to stress due to the extensive land use in their catchments leading to tapered inflows. Excessive diversion of water for agriculture is yet another major problem to keep wetlands to its full brim. Lack of conformity and conflict among government policies in socio-economy, environmental protection, ecological conservation, development planning are among the reasons for the deteriorating condition of these water bodies.

The most important function of wetlands is that it refills, recharges, and filters groundwater and is the basic source of drinking water in urban areas. It supports the life of a range of flora and fauna providing ecological services. However, poor water quality of the 'runoff' laden with overflown fertilizer and pesticide from agricultural fields and poorly maintained sewerage in urban areas located in catchment areas add to the poor health of wetlands. On the other hand, many of them act as the 'sink' for untreated effluents from urban settlement and dump of even solid wastes. In coastal areas, the mangrove wetlands prevent flood and prevent extreme damages during a cyclone or flood.

1.2 Framework for Wetland Management

Inventory creation and management and cataloguing of wetlands is the first step in formulating the strategy of wetland management under a climate change scenario. For characterizing wetlands, the information should be collected and collated under subheads: (i) The description of the study area along with catchment or watershed area and drainage network; (ii) Water Management: Hydro-meteorological data analysis; survey, delineation, and mapping of the wetlands. Maintaining the hydrological balance of wetlands is of paramount importance. Additionally, filtration of the river water has been hampered greatly by deforestation. It's high time steps are taken to improve the source of freshwater, so as to maintain the health of wetlands in catchment of Mahanadi river; (iii) Identification of the effluent discharge sources, their quality assessment, and their control; (iv) Land use and land cover study of the wetlands; (v) Bio-diversity survey; (vi) Analyses of socio-economic scenario and livelihood opportunities and development of Institutional infrastructures (Srivastava, et al 2020).

As a result of climate change, reduced flow of water during lean season and the more frequent onset of extreme weather events like drought, low pressure-induced depression rainfall are major perceived threats for maintaining the health of wetlands. Maintenance of hydrological balance of wetlands is a major challenge under such scenario. There comes the importance of overall catchment management mentioned in the framework above. Policy guidelines are necessary for curbing encroachment of natural drainage basins to maintain inflow and outflows from the wetlands. Once natural water balance in the wetland is established, along with suitable catchment management protocol as per the above framework, we shall be able to restore the health of wetlands to a large extent.

2. Conclusion

Policy and action plans for flood control, urbanization in catchment areas of wetlands affecting water flows into wetlands, removing demographic pressure on wetlands like excessive commercial fisheries, preventing the use of wetlands as an outlet for untreated sewerage, repair, renovation, and restoration of wetlands are going to play important roles in sustaining the health of the dwindling wetlands under changing climate scenarios. Almost everything in the environment, like change in climate and issues related to it, is interlinked. Therefore, an improved framework of wetland development will not only assist farmers because a majority of them depend on wetlands for irrigation purposes, but will also provide ecological services for overall long-term improvement of the environment for its stakeholders.

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Kanwar Wetland, North Bihar – It's situation and threats

1. Introduction

Wetlands are considered to be an important linkage between the water bodies and land. Different definitions being used to define wetlands as lands transitional between the terrestrial and the aquatic eco-systems where the water table is usually at or near the surface (Mitsch and Gosselink 1986). The wetlands are the areas of fen, marsh, water or peatland, either natural or artificial, perineal or seasonal, with water that is flowing or static, fresh and include the areas of marine water (Ramsar Convention, 1971).

Wetlands remain the most important source for survival of different flora and fauna. It has been estimated that about 6 percent of the land surface of the world has wetlands which are distributed in all climatic zones of the earth except the Antarctica region. India with its vast geographical extent supports large and diverse wetland classes, among which some are very unique. Wetlands, variously estimated to be occupying 1-5 percent of the geographical area of India, support about a 5th of the known biodiversity (National Wetland Atlas, 2011). At present, according to the Ramsar Convention, India has a total of 37 protected wetlands distributed in different sites of India.

1.1 Wetlands and its importance

Wetlands remain the home of major flora and fauna and also remain an important part of the environment. A single wetland performs many important functions of ecological services and maintains the natural functioning of the nearby area as well as environmental and social services. It maintains food web, provides nursery and protection for the development of many small birds, mammals, amphibians, reptiles, fishes, insects, etc. whose survival not possible in general conditions. It remains home to migratory birds, helps in the filtering of sediments and nutrients caused due to pollution in water. Most importantly, it acts as a flood-control system, recharges groundwater, maintains nutrient cycling, provides drinking water, helps in aquaculture, acts as a carbon sink, helps in climate change, fodder, fuel and in providing a source of livelihood and recreation to local people.

Table 01: As per the Millennium Ecosystem Assessment (2005) the ecological services provided by wetlands:

	Services	**Components**
1.	Provisioning	Food, Fresh water, Fibre and fuel, Biochemical (medicine), Genetic materials
2.	Regulating	Climate regulation, Water regulation (hydrological flows), Water purification and waste treatment, Erosion regulation, Natural hazard regulation, Pollination
3.	Cultural	Spiritual and inspirational, Recreational, Aesthetic, Educational
4.	Supporting	Soil formation, Nutrient cycling

1.2 Wetlands in Bihar

The wetlands with a total of 4,416 major and 17,582 small wetlands with less than 2.25 ha, have been found (National Wetland Atlas: Bihar, 2011). The state has 4.4% with a total of 4,03,209 ha of its geographical area under wetlands (Fig 1). The total wetlands in all the districts include lakes/ ponds, ox-bow lakes/cut-off meanders, riverine wetlands, waterlogged areas, river/stream, tanks/ponds, and wetland (<2.25 ha). River Ganga also passes through the middle of the state from west to east, which remains the suitable site for wetland formation in Ganga's flood plain. Altogether 12 districts come in flood plains of Ganga viz. Begusarai, Bhagalpur, Buxar, Katihar, Khagaria, Lakhisarai, Munger, Patna, Purnia, Saran, Sheikhpura, and Vaishali. According to the National Plan for Conservation of Aquatic Eco-systems' (NPCA) for holistic conservation of lakes and wetlands, Bihar is identified to have 3 major wetlands: Kabar lake, Barilla, and Kusheshwar Asthan.

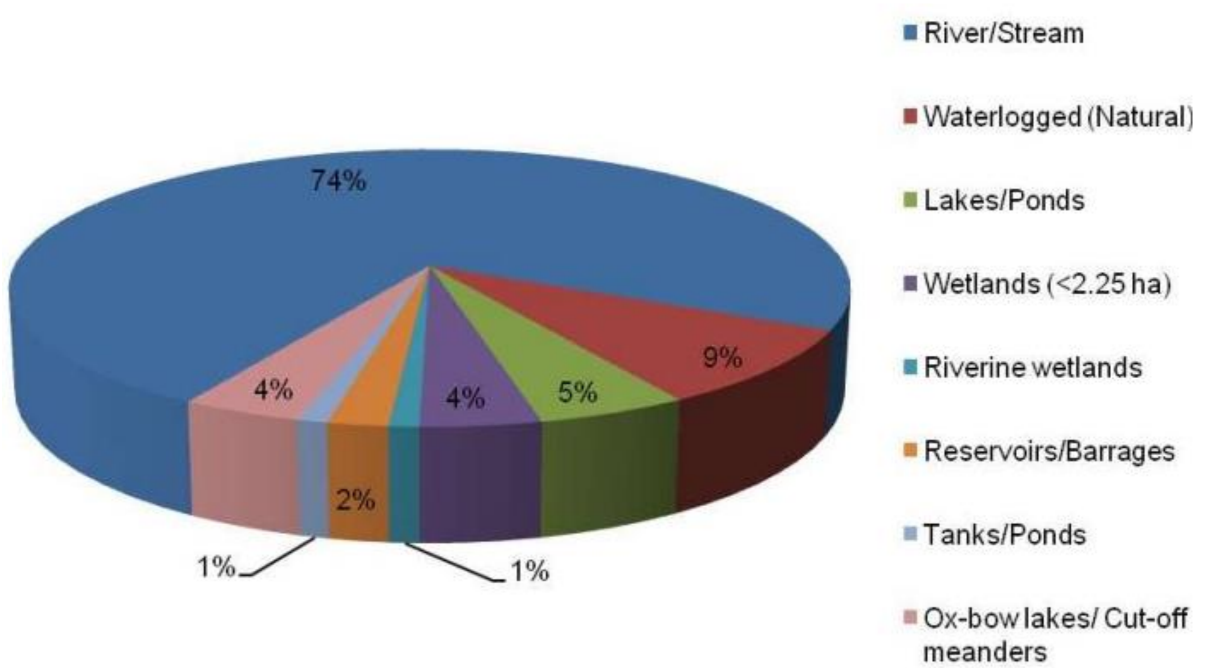

***Fig.1**: Types of wetland distribution in Bihar*

Source: National Wetland Atlas: Bihar, 2011

But with time and improper management of wetlands, the condition of wetlands is deteriorating due to anthropogenic activities like encroaching lands for agriculture, pollution, etc. Such activities are not only degrading the wetland, rather also affecting those species which are completely dependent on it for their survival. One of such deteriorating wetlands is Kabar Taal or Kanwar Lake in North Bihar.

1.3 Scenario of the Kanwar lake

Kanwar Lake or Kabar Taal/Jheel/Wetland is a recognized bird wildlife sanctuary, located 22 km north-west of Begusarai in North Bihar. It is Asia's largest freshwater ox-bow lake which is residual, formed due to meandering of the Gandak river, a tributary of Ganga, in the geological past. Once it was a heaven for migratory birds, but today it is a dying wetland ecosystem (Figure 02).

Fig.2: *A view of Kanwar Wetland*

Source : http://birderPics.com

Once the wetland covered about 6,786 ha in 1984, which reduced to 6,043.825 ha in 2004 (Ghosh et al. 2004). In a similar manner in 2012, the lake area had reduced to a mere 2,032 ha (Kumar & Pandey, 2017). The area has been notified under the Wildlife (Protection) Act of 1972 to control poaching of birds, and has also been declared a protected zone by the Bihar government in 1986, and later the Government of India declared it a bird sanctuary in 1989. The authorities had also notified 15,000 acres in the area as a wetland, which makes it six times bigger than the Keoladeo National Park in Bharatpur, Rajasthan. For revival, legal protection has been provided to this wetland, which is still not enough as the shrinking paces fast.

A study conducted to determine the land cover change of Kanwar wetland for the period of 1990, 2010 and 2015 clearly showed the changes occurring within the area in Fig.3 (Ranjan & Priyanka, 2018). A drastic change is visible in the analysis of open water present within the wetland area.

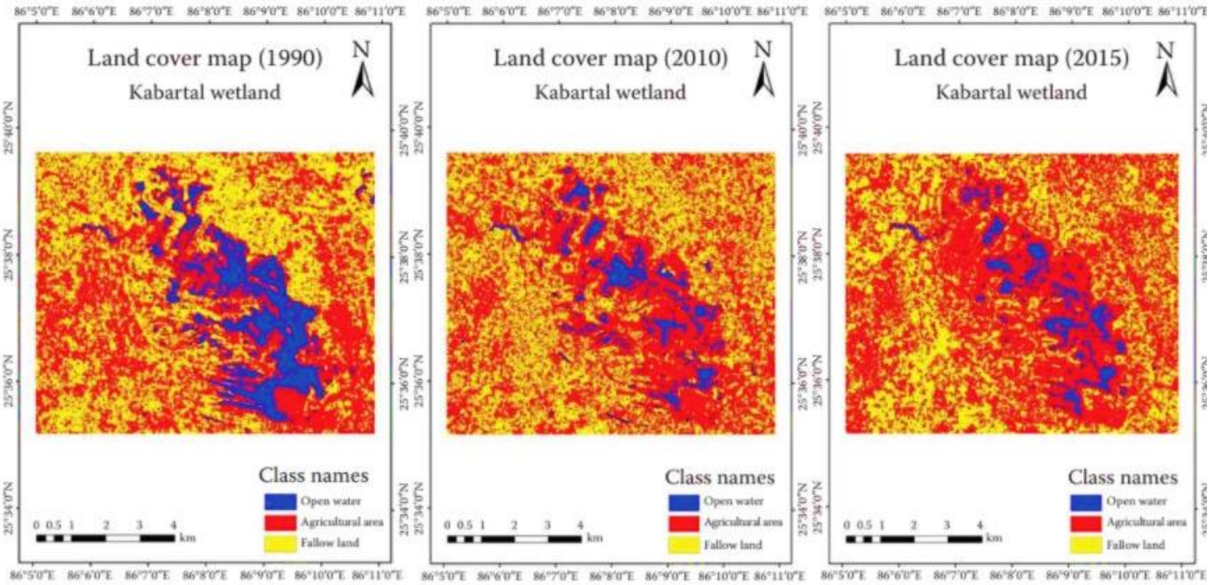

Fig.3*: Change occurred in Kanwar wetland in 1990, 2010, 2015 via Land cover map*

Source : Ranjan & Priyanka, 2018

1.4 Impact on birds

Kanwar wetland is also the habitat for many critically endangered bird species like Oriental White-backed Vulture, which belongs to vulnerable category and other bird species like Long-billed Vulture, Greater Adjutant stork, Greater Spotted Eagle, Lesser Kestrel, Sarus Crane, Painted Stork, Black-bellied Tern, etc. belongs to near-threatened category.

Till the 1980s, the wetland was one of the largest breeding grounds for migratory birds. But now, due to poaching and trapping activities, a steep decline in the bird population has been observed in this area. The use of poisonous pesticides in farming also poses a major threat to the birds in the area.

Besides all these, this area is once known to host 106 species of resident birds and 59 species of migratory birds, besides 41 species of fish. But now all of this is in trouble as the wetland is gradually dying.

***Fig.4**: (a) & (b) degrading condition of Kanwar wetland.*

(Source : DownToEarth)

1.5 Emerging challenges to the Wetland

- The excessive agricultural practices result in land encroachment of wetland and reduce its area. And such practices use pesticides/ chemical fertilizers, which during monsoon season lead to runoff from land to water by increasing the nutrient (nitrogenous and phosphate) content in the water body and called eutrophication of wetland.
- The process of eutrophication will not only degrade the open water body, but it will also shrink the total land area of the wetland.
- In addition, the depth of the wetland is also declining rapidly due to an infestation of aquatic weeds such as Phragmatis and Hydrilla due to high nutrient content (Ranjan & Priyanka, 2018).
- According to Saviour Alluvial Ecological Establishment (SAEE) Society, a massive inflow of silt is also decreasing the depth of the lake, and about every year 3.8 cm of silt is deposited in the lake.
- Due to anthropogenic activities along with agriculture, the excessive discharge of Sulphate in the water body from municipal is also affecting the biogeochemical cycle occurring within the lake (Ghosh et al., 2004).
- Continuous extensive deforestation, overgrazing, and overexploitation of biomass for fuel, fodder, and timber have stripped the land of its natural vegetation cover, resulting in erosion (Ghosh et al., 2004).
- The illegal encroachment of lake beds by farmers and local people has reduced the size of the wetland.

2. Conclusions

Wetlands are one of the most important naturally occurring inland water bodies. It maintains the biodiversity of an area. But they need to be protected from anthropogenic activities with proper conservation, restoration, and management plan. Not only the government and non-government organizations, even the local people should be made aware of the need to protect and conserve the wetlands and their ecosystem. Because once they degraded, it would be very tough to bring them back to their naturally occurring form.

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Wetlands Highlights

Bihar gets its first and India's 39th wetland of international importance – 'Kabartal Lake'

Kabartal, also known as Kanwar Jheel, in Begusarai, Bihar has finally been recognized as a wetland of international importance under Ramsar Convention in October 2020. It is the first wetland in Bihar and 39th in India to be recognized as a wetland of international importance. Nevertheless, Kabartal is one of the most important wetlands in Bihar. Apart from Kabartal in Bihar, 10 more wetlands in India have been recognized as wetlands of international importance under the Ramsar Convention in last one year, including one from Maharashtra, three from Punjab and six from Uttar Pradesh.

Source : https://south-asia.wetlands.org/news/kabartal-and-asan-conservation-reserve-designated-as-ramsar-sites/

Photo credit: south-asia.wetlands.org

Wetland of International Importance

CONVENTION ON WETLANDS
CONVENTION SUR LES ZONES HUMIDES
CONVENCIÓN SOBRE LOS HUMEDALES

This is to certify that

Kabartal Wetland

has been designated as a

Wetland of International Importance

and has been included in the List of Wetlands of International Importance established by Article 2.1 of the Convention. This is site No: 2436

Date of designation: 21 July 2020

Martha Rojas Urrego
Secretary General
Convention on Wetlands

Other Indian wetlands recognized as wetlands of international importance

Lonar Lake

Soor Sarovar

Asan Wetland

Lonar Lake in Buldhana, Maharashtra, Soor Sarovar Lake in Agra, Uttar Pradesh and Asan Barrage in Dehradun, Uttarakhand have been recognized as wetlands of international importance by India under the Ramsar Convention. The Lonar Lake was created by the impact of a meteorite on basalt bedrock thousands of years back. It covers an area of about 77.69 hectares and 365 hectares around the lake, which had been declared as a wildlife sanctuary by the State Forest Department in June 2000. On the other hand, Soor Sarovar Lake covers around 713 hectares and is home to hundreds of bird species (migratory and local), reptiles with more than 300 pythons, and hundreds of fish species. It was declared as a bird sanctuary in 1991 and now as a wetland of international importance. The Asan Conservation Reserve is spread over 444 hectares converging with the

Yamuna river in Dehradun. Its habitat supports almost 330 bird species, including Reading Headed Vulture, White Rumped Vulture, Baer's Pochard, and 49 fish species with endangered Putitor Mahseer. Almost 10 more Indian wetlands were enlisted under the Ramsar Convention in January 2020. After the addition of 4 more wetlands in October 2020, the list includes a total of 41 wetlands of India as wetlands of international importance.

Source : https://economictimes.indiatimes.com/news/politics-and-nation/india-names-lonar-lake-sur-sarovar-as-wetlands-of-international-importance/articleshow/79240659.cms

https://www.jagranjosh.com/general-knowledge/ramsar-sites-in-india-1605708327-1

The Centre has asked States and UTs to set up Wetlands Authority

Photo credit: un-ihe.org

The Ministry of Environment, Forest and Climate Change has notified a new Wetland Conservation Rules in January 2020, which restrain the expansion or establishment of industries, and disposal of wastes of construction and demolition in the wetlands. The ministry has directed the States and Union Territories to set up an authority, which will prepare the strategies for conservation and beneficial use of wetlands within their jurisdiction. According to the directives from the ministry, the state authorities will be headed by the Minister of State Department of Environment, Forest and Climate Change and will be responsible for undertaking measures for elevating the awareness and sensitization among the local communities on the importance of wetlands.

Source : https://economictimes.indiatimes.com/news/environment/centre-notifies-new-wetland-conservation-rules-asks-states-uts-to-set-up-authority/articleshow/73161225.cms?from=mdr

The Bihar State Wetlands Authority resolved to rectify the land use classification of wetlands

Kabartal Lake

As per the directions from the Ministry of Environment, Forest and Climate Change, New Delhi, under the new Wetland Conservation Rule, a State Wetland Authority has been set up in Bihar. After the establishment of the Bihar State Wetland Authority, a meeting under the chairmanship of Mr. Sushil Kumar Modi, Hon'ble Minister, Department of Environment, Forest and Climate Change was held on 28 August 2020. Under the category of wastelands of Bihar Soil and Water Conservation and Land Development Act 1970, measures for minimizing these unproductive lands, including waterlogged areas, have been decided to be propelled by funding wetland drainage programs. The authority has updated the land records and effectively removed the wetlands from the category of wastelands and placed them under a new category named 'wetlands'. It has also been decided by the State Wetland Authority to constitute a review process, which includes all the developmental processes relating directly or indirectly to wetlands. The Principal Secretary, Department of Environment, Forest and Climate Change emphasized that different departments need to incorporate wetlands in their development plans and processes. Very recently, Kabartal Lake has been recognized as a wetland of international importance with the efforts of Bihar State Wetland Authority and Wetlands International. Moreover, the Kabartal has been given high priority by the Authority for its conservation and wise use as supported by all the members of the Authority. The meeting was represented by different departments, including water resources, tourism, agriculture, fisheries, environment and forest, and other research institutions.

Source : https://south-asia.wetlands.org/news/bihar-state-wetlands-authority-resolves-to-update-land-records-by-removing-wetlands-from-the-wastelands-category/

Important Events

Launch of Gaya and Muzaffarpur Clean Air Action Plan Reports

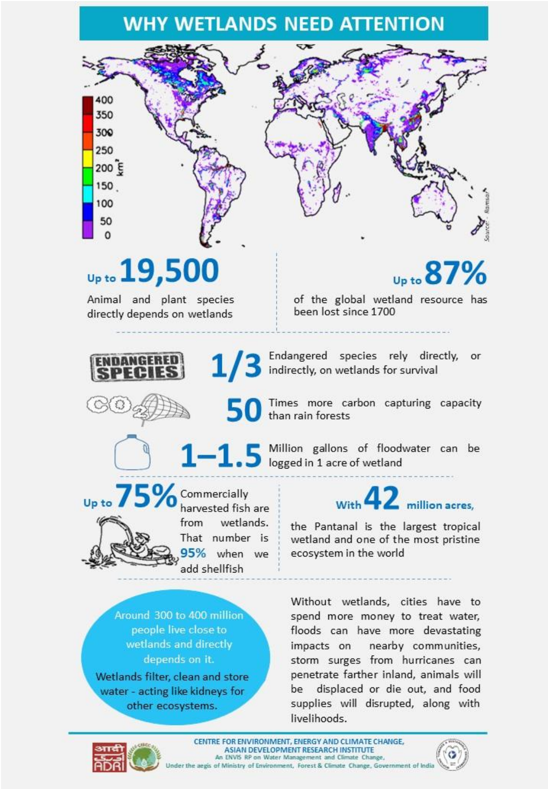
Launch of the GCAAP & MCAAP Reports September 23, 2020

The reports of 'Gaya and Muzaffarpur Clean Air Action Plan (GCAAP & MCAAP)' were launched on September 23, 2020 by Hon'ble Deputy Chief Minister of Bihar Shri Sushil Kumar Modi. The virtual launch programme was organized by the Centre for Environment Energy and Climate Change (CEECC) - ADRI. Along with launching of the reports, there was also a special lecture on air quality management in Bihar and a discussion on the implementation strategies, challenges and way forward on GCAAP and MCAAP in Bihar's context.

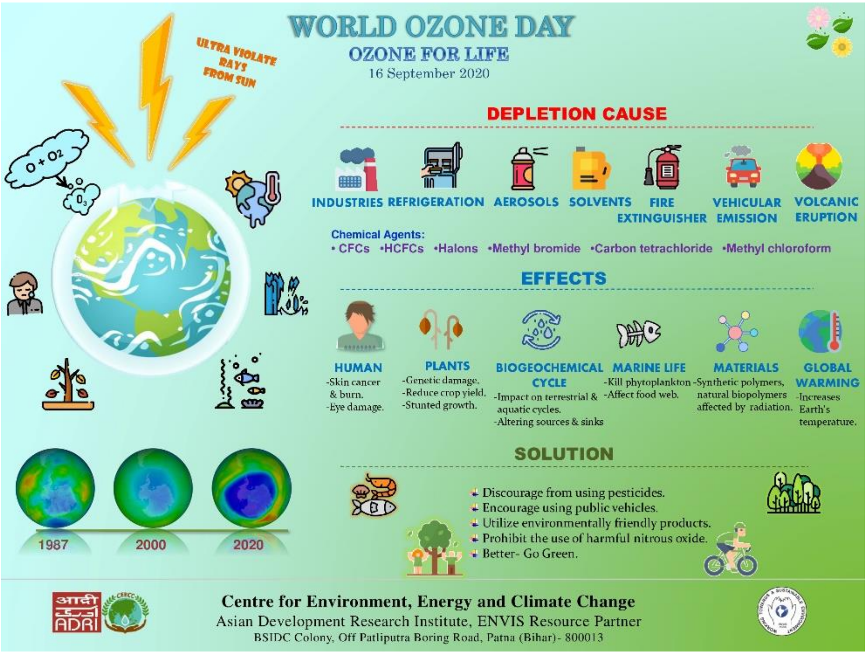
Virtual Seminar on 'Vulnerabilities of Wetlands and its Impact on Climate Change'

The Centre for Environment Energy and Climate Change (CEECC) – ADRI organized a virtual seminar on **'Vulnerabilities of Wetlands and Its Impact on Climate Change'** on December 04, 2020. The objectives of the virtual seminar were to highlight the scientific as well as practitioners perspective on degrading wetlands, to highlight the prospects of wetlands and its impact on climate change, and to gather inputs on devising a roadmap for the long-term sustainability of wetlands management in the Bihar's context. The virtual seminar consisted of interdisciplinary subject experts to discuss the complexity and way forward to the vulnerability of wetlands in the Indian context. Furthermore, the speakers of the virtual seminars were Dr. Ashok K. Ghosh, Chairman, Bihar State Pollution Control Board, to discuss vulnerabilities of wetlands, Dr. Meenakshi Dhote, Professor, School of Planning and Architecture, New Delhi, to discuss vulnerabilities of urban wetlands, Dr. Ritesh Kumar, Director, South-Asia Wetlands International to discuss the impact of wetlands on climate change and Mr. Dipak Kumar Singh, Principal Secretary, Department of Environment, Forest and Climate Change, Government of Bihar, Patna to discuss Government's perspective on degrading wetlands and management in Bihar along with Dr. Prabhat P. Ghosh, Director, CEECC-ADRI.

Infographics on 'Why Wetlands need attention' developed by CEECC-ADRI



Infographics on 'World Ozone Day' developed by CEECC-ADRI



Updates

Green Skill Development Programme

This year, the Centre conducted the GSDP course on 'Water Budgeting and Auditing' (WBA). So far under GSDP, out of 76 enrolled candidates, 67 completed the training programme successfully and were provided a certificate by the Ministry of Environment, Forest and Climate Change, Government of India.

Ongoing GSDP Courses

With some new additions, the ongoing programmes are:

a. Pollution Monitors: Air and Water Pollution – this is the second batch of the training programme. This batch has candidates from Bihar, Jharkhand and West Bengal.

b. ETP, STP, CETP: Operation and Maintenance – this is the second batch of the training programme. This batch has candidates from Bihar and Punjab.

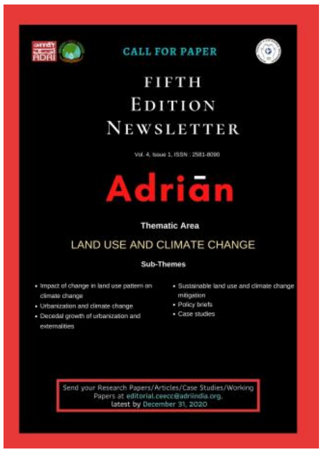
Upcoming GSDP Courses

a) Water Budgeting & Auditing (NSQF level 6, 200 hours)
b) Emission Inventory (NSQF level 6, 130 hours)
c) Value addition and Marketing of NTFPs: Bamboo Crafts (NSQF level 5, 400 hours)
d) Bird Identification and Basic Ornithology (NSQF level 5, 160 hours)
e) Sustain and Enhance Technical Knowledge in Solar Energy Systems (NSQF level 5, 260 hours)
f) Value Addition & Marketing of NTFPs - Bee Keeping (NSQF level 4, 200 hours)
g) Waste Management (NSQF level 6, 300 hours)

For more, please visit: http://www.gsdp-envis.gov.in/Index.aspx

Emission Survey

CEECC-ADRI has planned to conduct a survey for developing an emission inventory of the transport sector of Patna. The survey aims to collect data of fleets plying on roads and develop an emission inventory for the air pollution load.



Upcoming Newsletter

The fourth volume of Adrian will be on 'Land Use and Climate Change'.

Virtual Lecture Series

The Centre is going to organize a lecture series to discuss some of the prevailing issues around wetlands and some other issues, with special reference to Bihar. Other topics include 'Current trends used in the analysis of climate change study in the context of Bihar', 'Potential of wetlands for alternative livelihood in Bihar', and 'Impact of urbanisation on urban flooding'.

Newsletter Subscription Form

Please fill up the form and send back by post or email.

Adrian – An ENVIS Newsletter on Climate Change and Disaster Risk Reduction

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