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# Ecological Regeneration of Wetland: Case Study of Kanwar Lake, Begusarai

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## ABSTRACT

The wetlands are the partially water-submerged environments that are highly productive, and support fauna and flora species in significant numbers that are dependent for their survival on the organic production of wetlands. Kanwar Lake is situated about 22 kilometers to the northwest of Begusarai. The Gandak River, a tributary of the Ganges, meanders across the area, creating the largest oxbow lake in Asia. It is a natural body of water that is significant on many different levels, including ecological, floral, faunal, geomorphological, and zoological. In 1989, the state government of Bihar designated Kanwar as a protected area for avian species. It has been considered a Ramsar site since 1987, but the wetland was not one of the 13 designated sites. In 1984, the lake's area was 6,786 hectares (ha), but by 2004, it had shrunk to 6,043.825 ha. Only 2,032 hectares remained of the original lake area by 2012. Wealthy farmers and locals have rapidly colonized the lake bed. Lake biodiversity has declined as weeds have grown across the wetland. Widespread deforestation, overgrazing, unsustainable agricultural methods and over-exploitation of biomass for wood, fodder, and timber have stripped the land of its natural vegetative cover and exacerbated erosion. The research deals with the ecological study of the area and how urbanization has caused impacts on it. It focuses on how this has caused the deterioration of the lake and the measures for restoring the lake ecology, safeguarding the trend of urbanization. After analyzing the major key issues and analyzing the issues at the edge of the lake and around the Manjhaul, some of the major findings conclude that there is a need for stormwater management of the whole city, restoration of Kanwar wetland, and industrial control around the lake.

## INTRODUCTION

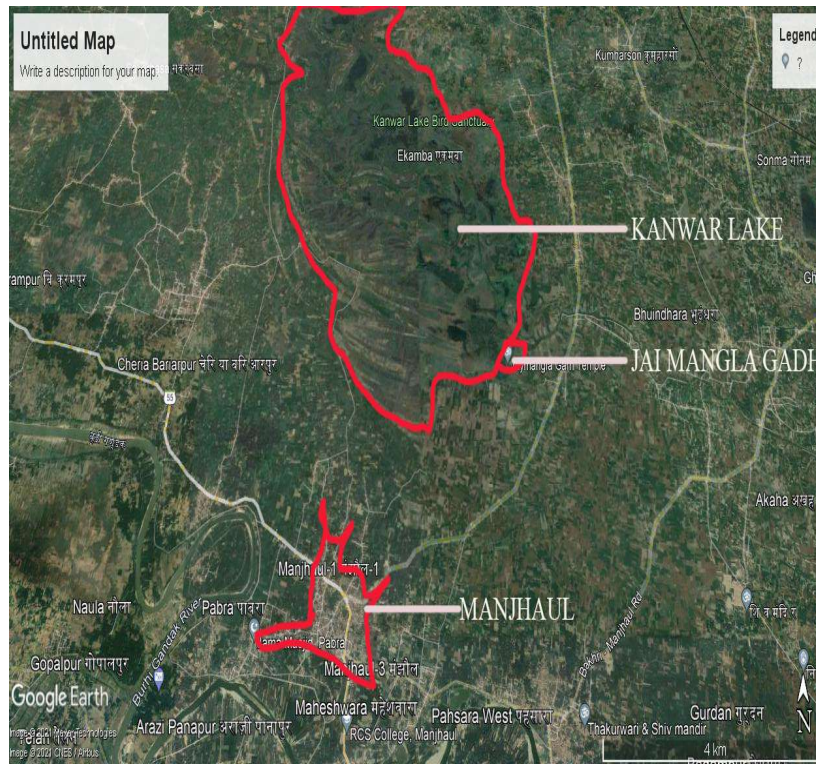
The wetlands are environments that are highly productive, and support fauna and flora species in significant numbers that are dependent for their survival on the organic production of wetlands (Desta et al. 2012). These wetlands, which were earlier used for hunting and fishing, are taken as wastelands and are used for residential, industrial development, and agricultural land by draining and filling (Patrick 1994). Despite having great ecological importance, they are continuing to be degraded, and the main reason is anthropogenic activities (Johnson 2012). These are vulnerable and fragile ecosystems that are in alarming condition and are extinguished because of intensive agricultural and industrial practices (Gattenlöhner et al. 2004). Reviving the wetland will include the functions of re-establishment and natural site reconstruction, which have been degraded and are losing their identity as vital ecosystems (Johnson 2012).

With a surface area of 67.37 $km^2$ and a distance of 22 km from Begusarai, Kanwar Lake in Bihar is Asia's largest freshwater oxbow lake. The Gandak River, a tributary of the Ganges, meanders across the area, creating the largest oxbow lake in Asia (Sharma 1993). It is approximately three times the size of the Bharatpur Sanctuary. It is an important, extremely ecological, floral, faunal, geomorphological, and natural water body. On Tuesday, June 20, 1989, the state government of Bihar designated Kanwar as a protected area for avian species (Singh et al. 2021). It has been considered a Ramsar site since 1987, but the wetland was not one of the 13 designated as having international significance in 2002. According to a 2007 study (Ambastha et al. 2007), in recent years, the Ramsar Convention has come to govern internationally significant wetlands (Chandra et al. 2023). Every year, birds from all across Central Asia and the Himalayan areas come here to spend the winter. The marsh also provides a large number of plant and animal life throughout the year (Prasad 2016). The government has designated 15,000 acres as a wetland in the region. The lake's depth and surface area expand during the rainy season thanks to runoff from neighboring communities, including Jaimanglagarh, Rajour, Parora, Narainpur, Sonbasa, Kumbhi, and others. Still, the lake significantly decreases in size during the dry seasons of winter and summer. In 1984, the lake's area was 6,786 hectares (ha), but by 2004, it had shrunk

to 6,043.825 ha. As of 2012, the lake's area was down to about 2,032 hectares.

Kanwar Lake provides a haven for numerous endangered, fragile, and near-threatened species, including the Oriental white-backed vulture (Kumar 2013). Up until the 1980s, the lake served as a major stopover for migrating birds. However, poachers and trappers have taken control in modern times, drastically reducing bird populations. Birds in an area may be in danger from poisonous chemicals used in farming. To prevent more land transactions, this wetland is essential. Large amounts of silt washing into the lake have reduced its depth. Each year, about 3.8 centimeters of silt are added to the lake. Lake biodiversity has declined as weeds have grown across the wetland. Widespread deforestation, overgrazing, unsustainable agricultural methods, and over-exploitation of biomass for wood, fodder, and timber have stripped the land of its natural vegetative cover and exacerbated erosion. Wealthy farmers and locals have rapidly colonized the lake bed (Kumar & Vardhan Pandey 2017). The lake is bordered on the west and south by the Burigandak River and on the north and east by the N.E. Railway line from Samastipur to Khagaria. The lake was created by a cut in the Burigandak River's meander, which occurred in the vast plains of a deep alluvial region. The average rainfall is 1000-1800 mm. The island of Jai Manglagadh, also known as Monkey Island, is located in the southeast corner of the lake and covers about 34 square kilometers. Fig. 1 depicts the lake area and the adjoining island Jai Manglagadh, and the nearby subdivision of Manjhaul.

The historical significance of the Jaimangla temple on the Kanwar lake's bank is well known. A number of artifacts from the distant past have been discovered in the region. Artifacts from the Post Suguna period, including terracotta, glazed ware, an iron sickle, and more, were unearthed. Many coins from the Tuglak period were also unearthed there. Not only have these artifacts been found in the fort town, but so have a large number of cannon balls. An ancient temple dedicated to the goddess "Jaimangal" (also known as Durga or Bhavani) is located within the walls of the fort of the same name. Because of this, the hill known as "Jaimangal Temple and Jaimangal Fort" on the shore of the lake is rich in history. Several significant archaeological artifacts have been discovered in the area, including a Northern Blackware vessel, a terracotta head, and pieces of idols carved from Cherts and Basalts. In addition, the earthen seals discovered at the sites indicated that they belonged to the Gupta period, which ruled from approximately 400 to 600 AD. Several archaeological finds, including Northern Black ware,




(Source: Google Earth).

Fig. 1: Settlements of Jaimanglagadh, Manjhaul subdivision, and Kanwar lake.

Terracotta heads, and fragments of idols made of Cherts and Basalts, have been discovered in the region. These structures belonged to the Gupta dynasty when they were constructed (about 400-600 AD; the earthen seal confirms this).

## MATERIALS AND METHODS

The case of Kanwar Lake was taken, and a detailed analysis was done, finding the issues that are leading to its degradation. The analysis is done with the identification of wetland functions and values and the working of the wetland. Further, with the data collection and site study, which included understanding the conditions of the place, sampling, interviews, surveys, observations, maps were generated, and the urban layer analysis and morphological layer analysis were done to identify the current situation on the ground in the year 2021. Further, the issues have been identified with different tools like Chord diagrams, cause and effect diagrams, issue mapping, and issue impact matrix. Further, a vision is provided with proposals for the regeneration.

## RESULTS

### Ecological Evolution and Shrinking of Kanwar Lake

It has shrunk by 66% since 2004, with just 30% of the initial coverage area remaining, as measured in 1984. Loss of natural vegetation cover due to deforestation, overgrazing, unsustainable agricultural practices and excessive biomass harvesting for fuel, feed, and lumber. Due to the widespread use of chemical fertilizers, pesticides and herbicides in nearby farm fields, the wetland's water quality has drastically declined. Untargeted hunting has historically harmed the winter vacationing population. The wetland currently has no legal boundaries. This creates a rivalry between the two groups, the Sahnis, and the farmers. Sahnis depend on fishing for a living, and they want the wetland to be flooded all year so they can fish all year.

The ecological history of the Kanwar Lake is as follows:

1801- Village survey

1895- Verdict of Calcutta High Court for fishing and trapping rights

1962- Cleaning of drainage canal

1965-66- More cultivation and more crops due to cleaning of the drainage canal. More land came out of submergence, but the canal silted soon

1972- Bird capturing prohibited

1986- Fishing, buying, selling, and poaching on land was banned under the Wildlife Protection Act of 1972

1987- Flood: A dam on river Bagmati collapsed upstream. The flood again cleaned the drainage canal.

1989- 20 June - declaration of Kanwar Lake bird sanctuary

1992-93 Survey of land after creation of Bird sanctuary

1994-95 Cleaning of weeds in the drainage canal

### Biodiversity in Lake

The ecological diversity of plants, birds, fish, and some ordinary creatures in Kanwar Lake is highly rich. There have also been found about 106 macrophytes, phytoplankton and hydrophytes. Some 60 of the 106 known bird species were migratory birds, whereas the remainder were common or local. About 120 species of macrophytes are known to exist in and around the lake. Rather than some of the native trees, internal shrubs and grasses are abundantly found on the Jaimanglagarh Island with plantings of forest departments, such as Arjun (Terminalia arhuna) and Sisso (Dalbergia sissoo) (Prasad 2016). Sometimes, these trees are good for birds as they protect them. Some varieties of fish, insects, mollusks etc. are also prevalent. Although the lake region has decreased as a result of land invasions for agricultural and residential uses, which adversely affects organisms, some of them are endangered because of many human activities interfering with their life cycle.

### Flora and Fauna

It has an abundance of plant and animal life, including many different kinds of Imili, Neem, Bamboo, Sohar, Babool, Sissoo, Khajur, Shirish, etc. (Prasad 2016). Fig. 2 depicts the existing flora in the area. More than 40 kinds of fish can be found in the waters of Kanwar Lake, which visitors to the Kanwar Lake Bird Sanctuary frequently spot. Reptiles such as the Indian Cobra, Indian Krait, Tortoise, Water Snake, Dhaman, and many sorts of Lizards; mammals such as the Musk Deer, Palm Squirrel, Leopard, Himalayan Black Bear, Common Mongoose, Rhesus Macaque, Indian Fox, Barking Deer, Jackal, Nilgai (Prasad 2016) and more. As depicted in Fig. 3 beautiful birds such as the Crested Serpent Eagle, Yellow Throated Sparrow, Purple Rumped Sunbird, Magpie Robin, Tailor Bird, Red Wattled Lapwing, Black Winged Kite, Long Billed Vulture, Black Drongo, Jungle Babbler, Swallow, Oriental White-Backed Vulture, Painted Snipe, Bush Lark, Spotted Owlet, Palm Civet, and others can be spotted here.

### Usage of Lake

Lakes are an extremely valuable habitat for both humans and animals. Even though most wetland-related activities are shared rather evenly among different communities, some

(Source: Author)

Fig. 2: Image showing the different types of Flora present at the lake.

(Source: Author)

Fig. 3: Image showing the different types of fauna present at the lake.

do differ slightly. These communities depend heavily on agriculture and livestock for subsistence as shown in Fig. 4, with a range of 21.4–43.3 percent of annual income going towards fodder sourced from the Kanwar Lake. This means that the people of the villages in the vicinity of Kanwar Lake use the wetland system there mostly to grow feed for their animals. Grazing animals are common in these regions because they were once utilized to cultivate fodder.

Conversely, fish are plentiful in a wetland ecosystem. Again, a sizeable percentage of the locals use this marsh for fishing (13.3-25.0%, to be exact) as shown in Fig. 5. The majority of homes also participate in plant processing and other derivatives businesses in addition to these mainstay industries. Khajahnpur, closest to the Kanwar wetland system, has the highest concentration of this kind of activity, but it is widespread throughout the region. The settlements almost equally share in the use of Kanwar Lake's wetland environment. The obvious inference is that the majority of the local population relies on agricultural and animal processing. As a result, the Kanwar Lake wetland system is highly valued in the area. The locals of Jai Mangla Gadh island also utilize this body of water to

(Source: Author)

Fig. 4: Image denoting the agricultural activity in the lake.

(Source: Author)

Fig. 5: Image denoting the fishing activity in the lake.

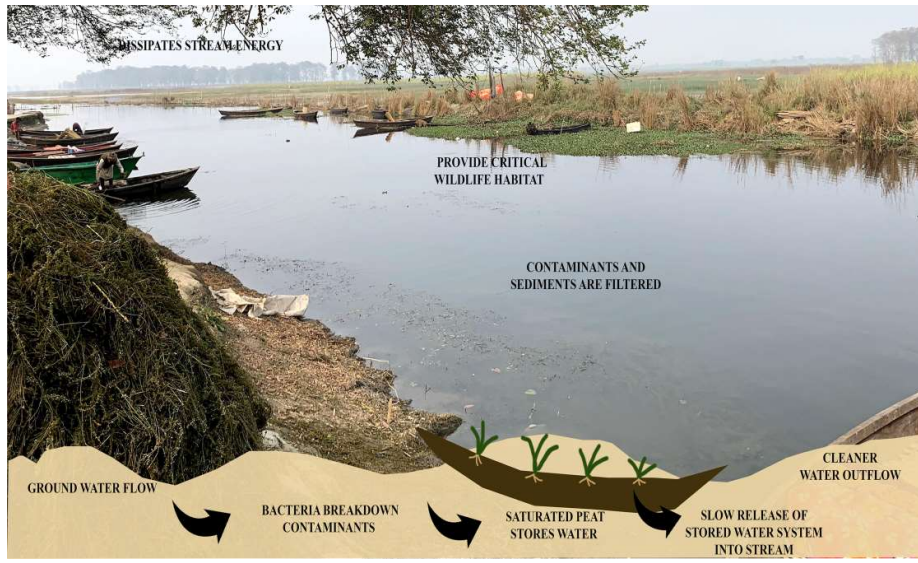
clean their dishes and laundry. The villagers use the lake as a washroom and for drinking water. The sewage waste has been disposed of in the lake of the sub-urban settlement of Manjhaul.

## DISCUSSION

### Functions and Values of Kanwar Lake

**Functions:** Relying on breeding and migrating birds and mammals for food, water, and shelter, production of sugarcane, rice and mustard, surface water nitrogen and phosphorus removal via biogeochemical cycling. Instead of releasing it into the atmosphere as carbon dioxide, which would have a warming effect on the planet's temperatures, peat bogs sequester carbon inside their line and preserve (peat) plant biomass. Growth of primary producers and consumers. Hydrological cycling revives stores and releases water in various ways.

**Values:** Recreational value for bird watching, photography and hunting fish, Societal value as habitats for fish, wildlife and plants. Primary habitats of wetlands depend on them for survival. Seasonal inhabitants of food, water and cover are plentiful. Cultural value as it has a temple on the island with great significance from the Gupta dynasty. Economic value for commercial fish catch and crops like rice and sugarcane. Too much surface runoff carrying pollutants and




(Source: Author)

Fig. 6: Image showing the Working of Kanwar wetland as its disruption is the cause of degradation.

sediments degrading the lake. Educational value as diversity for research opportunities.

### Working at Kanwar Wetland

The wetland values have dissipating energy, which lessens the speed of the stream. It acts as a natural sponge that recharges groundwater, controls erosion, absorbs water, provides wildlife habitat, breaks contaminants, and filters it. Fig. 6 depicts the working of the wetland where due to the lost connection from the canal, the freshwater is not released and thus hampers the working of the wetland.

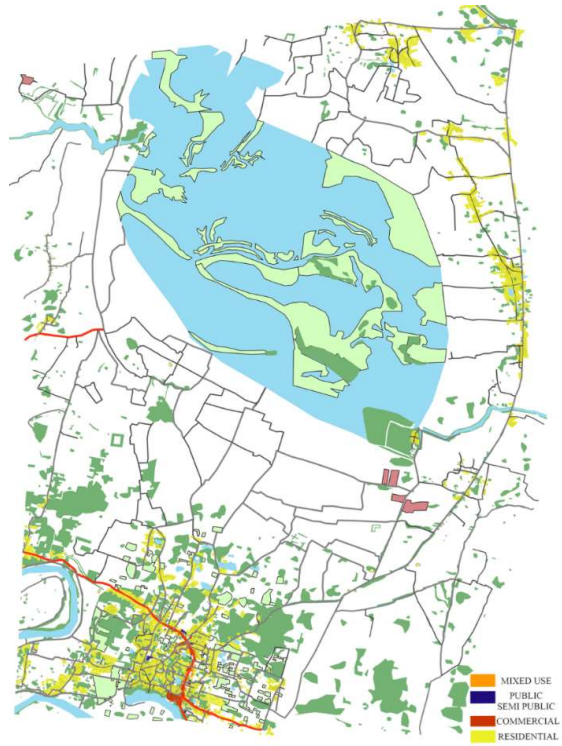
### Morphological Study

In land cover and land use, the cropland increased from 2005 to 2016 on a larger scale, the wetland has been decreasing with a decrease in fallow land and the plantation is increasing trend. Fig. 7 depicts the existing built use of sub-division Manjhaul which is majorly residential, as about 95% is residential. The only commercial buildings are found on the primary road and this road has only commercial and mixed-use buildings on it. Few mixed-use and commercial buildings can be found in the Manjhaul market lane. Some public semi-public buildings can be found throughout the division. All the villages that surround the Kanwar Lake including the Jai Manglagadh Island are residential. Medium-rise buildings can be found mostly in the Manjhaul settlement, and a good amount of low-rise buildings are also found. Mostly low-rise buildings are found in the adjoining villages and few medium-rise buildings can be found and the Jai Manglagadh Island has low-rise buildings. Talking about the road hierarchy, three types of roads are found: the primary road, i.e. is. 10-15m, the secondary road, i.e., 4-6m, and the tertiary road, i.e., 1.5-2.5m wide. The whole site has 73% unbuilt area and 27% built-up area. On the site, two types of open spaces are found, which are the green areas and the agricultural land. A good amount of green areas are found in the Manjhaul settlement and green areas and a good amount of agricultural land are found in the Kanwar Lake.

### Habitat of Birds

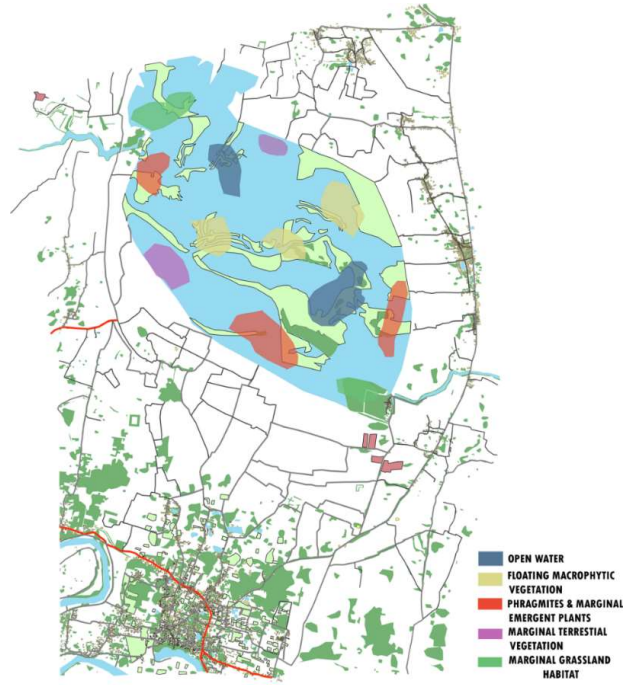
Five kinds of habitat are found in the Kanwar Lake which are depicted in Fig. 8.

1. **Open water:** The Podicipedidae, Phalacrocoracidae, Threskiornithidae, Anatidae, Rallidae, Jacanidae, Strigidae and Alcedinidae are habitats for birds found in the open water.
2. **Floating macrophytic vegetation:** Phalacrocoracidae, Threskiornithidae, Rallidae, Laridae, Alcedinidae and Sturnidae are the habitats of birds found in floating macrophytic vegetation.
3. **Phragmites and marginal emergent plants:** Aradeidae, Ciconidae, Threskiornithidae, Anatidae, Jacanidae, Haemantopidae, Rostratulidae, Recurvirostridae, Glareolidae and Laridae are the habitats of birds found in phragmites and marginal emergent plants.
4. **Marginal terrestrial vegetation:** Aradeidae, Accipetridae, Phasnidae, Apodidae, Dicruridae, Upupidae and Sturnidae are the habitats of birds found in marginal terrestrial vegetation.



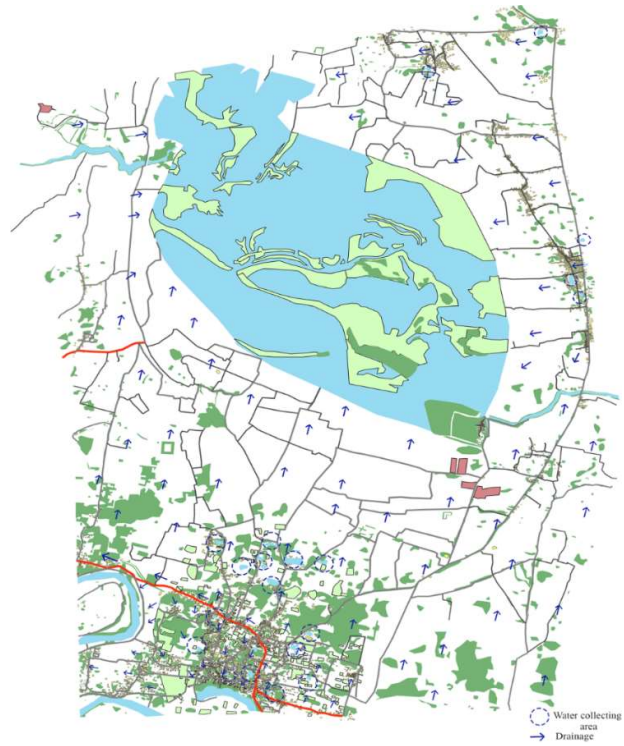

(Source: Author)

Fig. 7: Map showing the built use, which majorly shows the residential area.




(Source: Author)

Fig. 8: Map depicting the five types of habitats in the lake.




(Source: Author)

Fig. 9: Map depicting the drainage flow, which is towards the north of the lake.

5. **Marginal grassland habitat:** Aradeidae, Ciconidae, Accipetridae, Rostratulidae, Glareolidae, Apodidae, Dicruridae, Upupidae and Sturnidae are the habitats of birds found in marginal grassland habitats.

### Drainage of the City

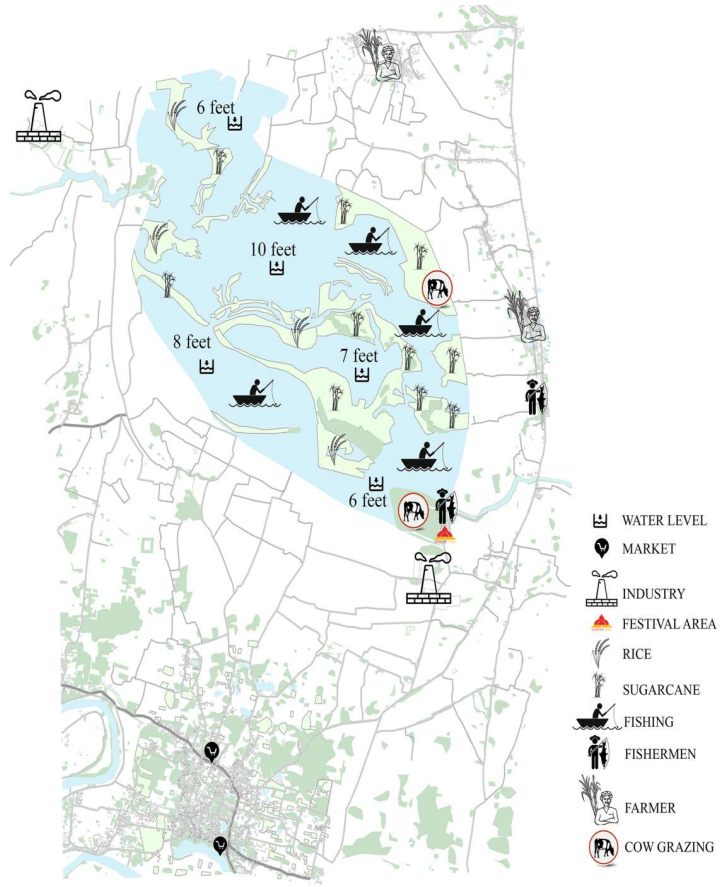
The drainage of the city is towards the north and goes into Kanwar Lake as depicted in Fig. 9. The Manjhaul settlement has a partial drainage system on the primary road but lacks in the other parts and all the overflow drainage goes directly into the Kanwar Lake. The ponds are present in the city and all the overflow waters are collected in those ponds and then overflow into the Kanwar Lake.

### Activities in and Around the Lake

Fig. 10 depicts the detailed activities in and around the lake while showcasing the depth of the lake. The crops found around the lake area are sugarcane, rice (paddy crop), and mustard, but only sugarcane and rice plantations can be found in the lake area. Fishing activities can be found in some front parts of the lake area, while the fishermen are found living in the Jai Manglagadh area and the adjacent Rajouri village. The grazing grounds are found next to the lake, as the villagers are using it for their cattle grazing. The farmers who practice agriculture live in the nearby villages, and industries are found near the lake, which disposes of waste in the lake. At the Jai Manglagadh island, the Kabar Mahotsav is organized every year for the upliftment of the local people to showcase their talent and discuss the issues related to Kanwar Lake. The market area is far away from the lake and is the main Manjaul market, which is 7 km away from the lake. The water depth of the lake varies from 10 feet to 6 feet. The central part of the lake has the highest water depth of 10 feet and the starting and ending parts has the lowest water depth.

### Issues Leading to the Dying of the Lake

The issues that are leading to the deterioration and shrinking of the lake are the presence of agricultural activity happening in the lake area and the dead remains of the left-over plants that are decayed in the water. The people have made embankments on the canal to restrict the flow of water so that they can practice fishing activity in the lake, and this closing of canals leads to floods in the nearby areas. Kanwar Lake has a good quantity of snails in the water and the shells of snails are thrown at the side of the lake as waste, leading to deterioration of the side and water quality. The waste from the sub-division Manjahul and Jai Mangla Gadh is thrown at the lake site,




(Source: Author)

Fig. 10: Map depicting the different activities taking place in and around the lake.

deteriorating the water quality. The dead remains of the plants can be found floating in the lake, which is deteriorating the water of the lake. The lake is used as a washroom by the nearby villagers and for washing clothes, utensils, and themselves. Overfishing activity has led to the loss of biodiversity, and the agriculture and water quality have led to the loss of habitats. The overgrazing on the sides of the lake led to the loss of habitats. There are factories present on the edges of the lake surface whose remains are discharged into the lake, polluting and leading to its shrinkage. The waste generated by the tourists at the Jai Mangla Gadh temple area is directly thrown into the lake, and because of this, water cannot be found in the area and the lake is degrading. The eutrophication is taking place in the river. The sewage wastewater of the sub-urban settlement Manjhaul and Jai Mangla Gadh village is flushed into the lake, hence leading to its contamination. The issues are mapped in the Fig. 11.

The major issues found in the area are industrial development, agriculture, human disturbance, pollution, weather and climate change, and trapping and hunting.

Fig. 12 depicts the detailed issues found in the area which are threatening the lake. Industrial development includes extraction of soil from the lake, brick kiln and their wastes dumped in the lake and alcohol production discharge. Agriculture includes the deterioration of water quality, extinction of birds and decaying of remains of crop cultivated. The human disturbance includes embankments by fishermen, boating and encroachment of land for cultivation and tourism at Jai Manglagadh Island. Pollution includes sewage disposal from the village, Sewage flow of settlement Manjhaul, dumping of waste, washing of clothes, bathing, and Agriculture waste. Weather and climate change which includes shrinking of lakes, shrinking of habitats and floods. Trapping and hunting, which includes fishing and hunting of migratory birds.

Fig. 13 depicts the factors by which the habitats were affected like eutrophication, siltation, degraded water quality, etc. which caused the changes in habitats leading to habitat shrinkage.

The below-mentioned causes and effects have been

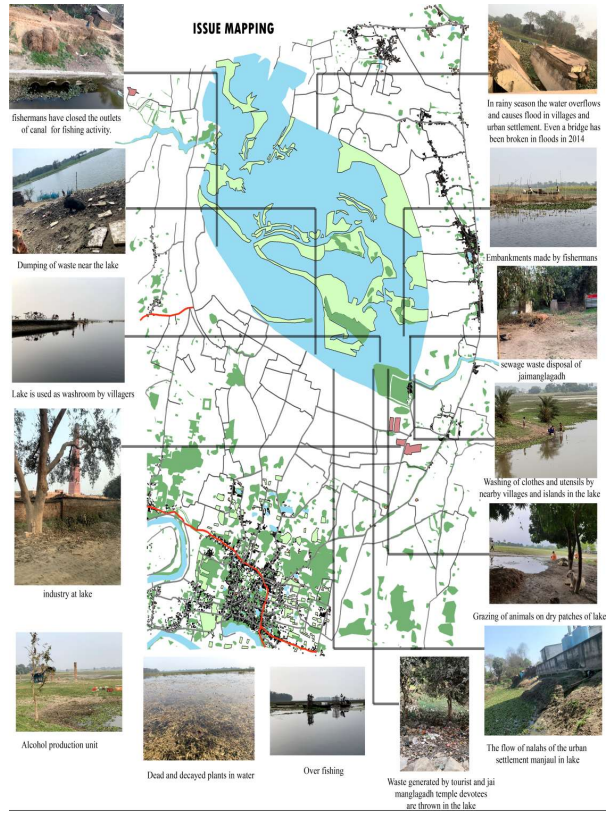



Fig. 11: Issues mapping.

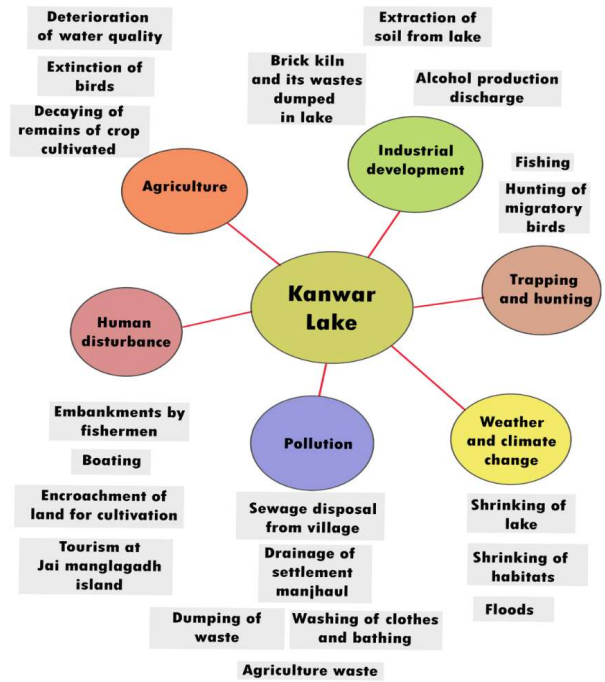



Fig. 12: Image showing the major issues threatening the lake.

identified from the cause-and-effect diagram showcased in the Figs. 14, 15 and 16.

The lake was shrinking because of the disposal of waste, encroachment, use of agricultural pesticides and extraction of soil. The changing of habitats was because of eutrophication, human presence, decayed vegetation, reduced water levels, hunting, and encroachment. The shrinking of habitats was because of water quality, heavy siltation, extensive deforestation, encroachment, unsustainable agriculture practices and reduced water quality. The canal dried because the inlets were blocked, intentionally choking the canals by fishermen's embankments and accumulation of sand. There is no development in the area because of lack of leadership, no interest in government, land conflict between landlord and fishermen, and dispute over ownership. Degradation of lakes is because of the disposal of sewage, fishing, decaying of crops, extraction of soil, embankments and encroachments, and industrial discharge.

The water quality results in the shrinkage of habitats, shrinkage of lakes, change in habitats, loss of biodiversity, loss of migratory birds, extinction of birds and loss of wetlands and more marshy land. The pollution results in water quality degradation, extinction of birds, health disorders, and loss of biodiversity. Industrial development leads to the shrinkage of lakes and water pollution. Agriculture activity leads to shrinkage, change in habitats, loss of Lake Biodiversity, and water pollution. Human intervention like grazing leads to the degradation of shallow water habitats, and waste disposal leads

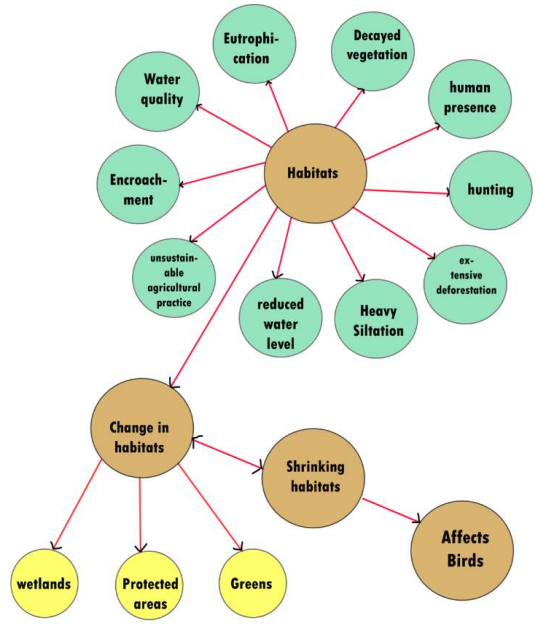



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Fig. 13: Image showing the reasons for the change in habitats and its effect.

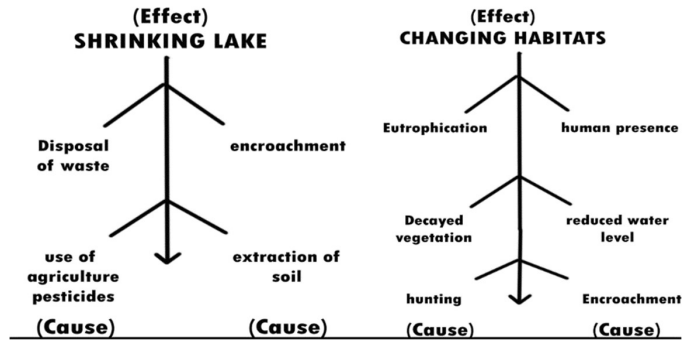


Fig. 14: Cause and effect of shrinking of the lake and changing of habitats.

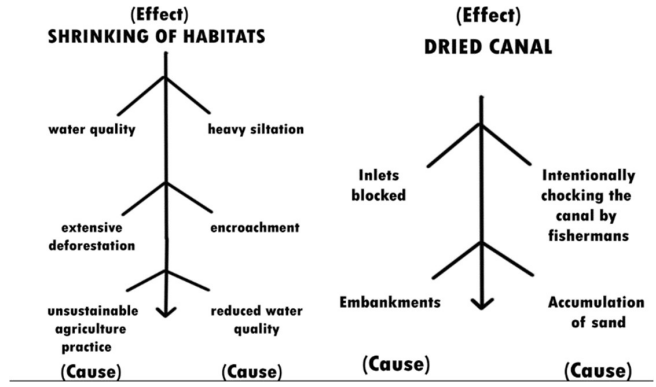


Fig. 15: Cause and effect of shrinking of habitats and drying of the canal.

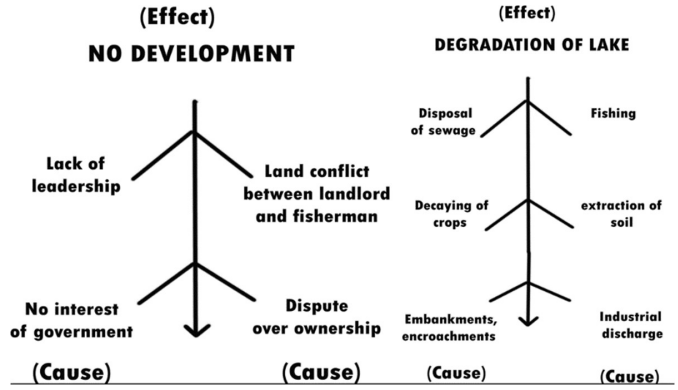


Fig. 16: Cause and effect of no development taking place and degradation of lake.

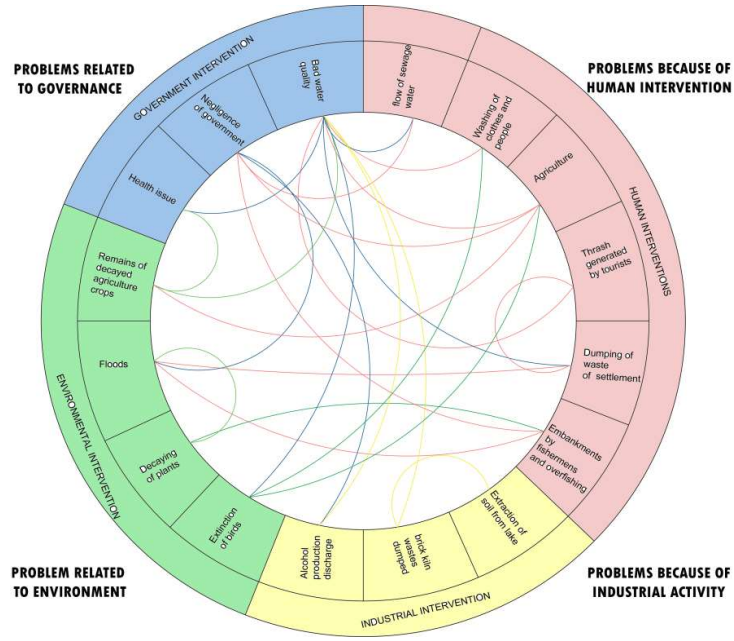


Fig. 17: Chord diagram depicting the issues which are majorly human intervention, government negligence, environmental and industrial intervention.

Table 1: Issues and their impact in the lake.

| Issues | Impact |
|---|---|
| Water quality | Shrinkage of habitat |
| | Shrinkage of lake |
| | Change in habitats |
| | Loss of biodiversity |
| | Loss of migratory birds |
| | Extinction of birds |
| | Loss of wetland and more marshy land |
| Pollution | water quality degradation |
| | Extinction of birds |
| | Health disorders |
| | Loss of biodiversity |
| Industrial development | Shrinkage of lake |
| | Water pollution |
| Agriculture | Shrinkage of lake |
| | Change in habitats |
| | Loss of lake biodiversity |
| | Water pollution |
| Human intervention | |
| Grazing | Degradation of shallow water habitats |
| Waste disposal | Degradation of water quality and weed infestation |
| Fishing | Floods |
| | Contamination of water |
| | Trapping |
| | Degradation of lake |
| Encroachment | Floods |
| | Shrinkage of lake |
| | Change in habitats |

to the degradation of water quality and weed infestation. The major issues were identified by linking all the listed problems in the form of a chord diagram by dividing the issues of the area into four broader sections as mentioned in Fig. 17. A detailed issue impact matrix explains the issues and the impacts they had on the lake and the surrounding area showcased in the Table 1.

## CONCLUSIONS

Hence, the detailed analysis of Kanwar Lake has been studied with respect to morphology, ecology, terms of values and functions, etc, and various issues have been identified with the help of different tools. The major issues that came across were because of agriculture, human disturbances, industrial development, pollution, trapping and hunting, and weather and climate change. These issues led to degraded water quality and caused the shrinking of the lake, shrinking of habitats in the lake, change in habitats, loss in biodiversity, loss of migratory birds, extinction of birds, health disorders, etc. Agriculture and fishing activity was very prominent and were one of the major reasons for the dying of the lake. The sewage flow of the urban settlement Manjhaul flows in the lake, which degrades the water quality.

After analyzing the major key issues and analyzing the issues at the edge of the lake and around the Manjhaul, some of the major findings conclude there is a need for stormwater management of the whole city, restoration of Kanwar wetland, and industrial control around the lake. Some recommendations are provided below with the vision to conserve and revive the lake ecology by providing better infrastructure and livelihood to upgrade the economy and tourism of the region.

1. Decontamination of the water and protection of wetlands by regulating the use of water quality standards and revival of the canal for the functioning of the watershed and minimizing flooding.
2. Regulation of industrial development around the lake through policy and master plan
3. Demarcation of sanctuary area and regulation of land use practice and restoration of hydrological connectivity and creation of buffer zone for eco-restoration.
4. Improvement of the human habitations like drinking water, sanitation and solid waste management with proper drainage channels for settlements and Promotion of ecological and cultural tourism with proper waste management
5. Community involvement and active participation for restoration and Promotion and recognition of economic values of wetland ecosystem services and biodiversity and enforcement of land control regulation.
6. Buffer zone to be provided across the lake so that filtered water gets into the lake with the provision of cropland to reduce the agricultural activity in the lake.
7. Further, for recreation and water purification, Wetland Parks and floating wetlands should be provided. For the development of the area, community centers and restaurants should be provided for tourists.

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## REFERENCES

Ambastha, K., Hussain, S.A. and Badola, R. 2007. Resource dependence and attitudes of local people toward conservation of Kabartal wetland: A case study from the Indo-Gangetic plains. Wetlands Ecol, Manag., 15(4): 287-302. https://doi.org/10.1007/s11273-006-9029-z

Chandra, K., Bharti, D., Kumar, S., Raghunathan, C., Gupta, D., Biswajit, A. and Chowdhury, R. 2023. Ramsar wetlands of India. Rec. Surv. India, 123(1S): 1-15. DOI: 10.26515/rzsi/v123/i1S/2023/172458

Desta, H., Lemma, B. and Fetene, A. 2012. Aspects of climate change and its associated impacts on wetland ecosystem functions: A review. J. Am. Sci., 8(10): 81.

Gattenlöhner, U., Marion, H.R. and Sabine Jantschke, E. 2004. Reviving Wetlands – Sustainable Management of Wetlands and Shallow Lakes. Global Nature Fund, Germany, pp. 1-136.

Johnson, B.A. 2012. Ecological Restoration of the Wairio Wetland, Lake Wairarapa: Water Table Relationships and Cost-Benefit Analysis of Restoration Strategies. Master Thesis. Victoria University of Wellington, Kelburn, Wellington, New Zealand, pp. 1-24

Kumar, M. 2013. Resource inventory analysis of Kabartal wetland. Int. J. Res. Hum. Social Sci., 8(1): 13-26.

Kumar, R. and Vardhan Pandey, V. 2017. Kanwar Lake: A Dying Wetland Ecosystem. International Conference on Environment and Ecology, ICCE, 27-29 March 2017, St. Xavier's College, Ranchi, Confederation of Indian Universities, New Delhi, pp. 111-127.

Patrick, W.H. 1994. From wastelands to wetlands. J. Environ. Qual., 23(5): 892-896.

Prasad, B. 2016. The World's Largest Oxbow Lake Kanwar Lake. WISA, South Asia, pp. 1-163.

Sharma, U.P. 1993. Origin, geomorphology and current trends of terrestrialisation of Kawar Lake (Begusarai), Bihar: A typical wetland system of India. SIL Proceed., 25(2): 804-810. https://doi.org/10.1080/03680770.1992.11900255

Singh, A.M., Sathya, M., Verma, S. and Agam Kumar, S.J. 2021. Assessment of anthropogenic pressure and population attitude for the conservation of Kanwar Wetland, Begusarai, India. In: Singh, P., Singh, R., Singh, V.K. and Bhadouria, R. (eds), Pollutants and Water Management, Wiley, NY, pp. 22-46.