Content available at: https://www.ipinnovative.com/open-access-journals

Journal of Pharmaceutical and Biological Sciences

Journal homepage: https://www.jpbs.in/

Review Article

Ramsar wetlands: Critical zones for maintenance for ecological equilibrium

Shivam Dubey [1]*

[1] *Rani Durgavati Vishwavidyalaya, Jabalpur, Madhya Pradesh, India*

ARTICLE INFO

Article history:
Received 23-10-2024
Accepted 28-11-2024
Available online 09-01-2025

Keywords:
Sustainable development
Wetlands
Biomonitoring
Ramsar sites
Ecosystem

ABSTRACT

Wetlands are essential for preserving the global hydrological cycle, controlling the climate, preserving ecosystem diversity, and ensuring human well-being. Humans can benefit directly from wetland ecosystems in terms of economic value in addition to indirect benefits. As a result, it is among the most significant and fruitful ecosystems. But in previous ages, people didn't value wetlands; instead, they saw them as a haven for mosquitoes, disease-carrying insects, and places to die. This led to the loss of many wetlands worldwide.

1. Introduction

A wetland is a special kind of semi-aquatic habitat in which the groundcovers are continually or periodically saturated with water throughout many years or decades. Particularly in the soils, flooding causes oxygen-poor processes to occur.[1] Because the roots of their vegetation have adapted to oxygen-poor waterlogged soils, wetlands are distinct from other terrestrial or aquatic ecosystems and constitute a transitional zone between waterbodies and dry lands. Among the most biologically diverse ecosystems, they support a broad array of aquatic and semi-aquatic plants and animals and frequently have better water quality because plants filter out excess nutrients like phosphorus and nitrates.

1.1. Ramsar site: What Is It?

According to the definition given by ramsar.org, a Ramsar site is a wetland site that has been designated as being of international importance under the auspices of The Ramsar Convention. Under UNESCO's auspices, the Ramsar Convention,[2] commonly known as "The Convention on Wetlands," is an international environmental agreement that was signed on February 2, 1971, in Ramsar, Iran. Once enough countries accepted it, it went into effect on December 21, 1975. Regarding the preservation of wetlands and the prudent, sustainable use of their resources, it calls for both domestic and international action. Ramsar designates wetlands of global significance, particularly those that serve as habitat for waterbirds. According to the data, as of October 2024, 635,845,060 acres were being protected with the involvement of 172 countries under 2523 Ramsar sites globally. Their primary goal is to preserve and responsibly utilize wetlands that have been identified as Ramsar areas. Each continent has a different distribution of the these 2523 wetlands of international importance.[2] Africa has the largest area of sites, whereas Europe possesses the most sites. Numerous issues, such as pollution, the use of biological resources, the alteration of natural systems, and agriculture and aquaculture, have an impact on more than half of the sites.

"Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of

* *Corresponding author.*
E-mail address: shivamdubey20@gmail.com (S. Dubey).

https://doi.org/10.18231/j.jpbs.2024.019

marine water the depth of which at low tides does not exceed six meters" comprise a wetland, according to the Ramsar Convention. Additionally, "wetlands may include riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands," according to Article 2.1 of the Convention, which protects cohesive sites.

Inland wetlands, marine or coastal wetlands, and man-made wetlands are the three types of wetlands recognized by the Ramsar Convention.[3] The sites that contain both natural and artificial inland wetlands are included in the category of inland wetlands. However, the marine or coastal wetlands comprise both natural and man-made wetland habitats, as well as locations that are both natural and coastal. The aforementioned three wetland types are further divided into forty-three subtypes by the Ramsar Convention.[4] There are inland wetlands, such as permanent and seasonal rivers, inland deltas and floodplains, permanent and seasonal lakes and ponds, marshes, freshwater swamps, and peatlands; human-made wetlands, such as reservoirs, barrages, and dams; aquaculture ponds; excavations and burrow pits; wastewater treatment ponds; irrigation canals, ditches, irrigation ponds, and rice fields; and marine and coastal wetlands, such as open coasts, coral reefs, estuaries, tidal flats, mangroves, and coastal lagoons. These wetland forms frequently blend into one another and the broader landscapes due to their hydrological and ecological connections (Figure 1). Therefore, wetlands ought to be regarded as a component of the coastal zone or river basin. River wetlands, as well as marine and coastal wetlands, are the types of wetlands that have the greatest impacts on biodiversity and the ecosystem.

India has a wide distribution of Ramsar Sites. As of October 2024, India accounts for 85 Ramsar sites. According to the Ramsar Convention, these wetlands are considered to be of "international importance".[2] The Indian government defines wetlands as places like paddy fields and river channels that are not utilized for commercial reasons, as stated in The Wetlands (Conservation and Management) Rules of 2017. The World-Wide Fund for Nature-India lists wetlands as one of India's most vulnerable habitats. The nation's wetlands have been harmed by invasive species, excessive development, road construction, salinization, excessive flooding, water pollution, and vegetation loss.[5] The total geographical area of the Ramsar Sites is approximately 13,32,746.24 hectares. Tamil Nadu has more Ramsar Sites than any other Indian state (18).[6] A complete state wise distributed list of Ramsar Sites in India is compiled as (Table 1) and their distribution across the country is depicted as (Figure 2).

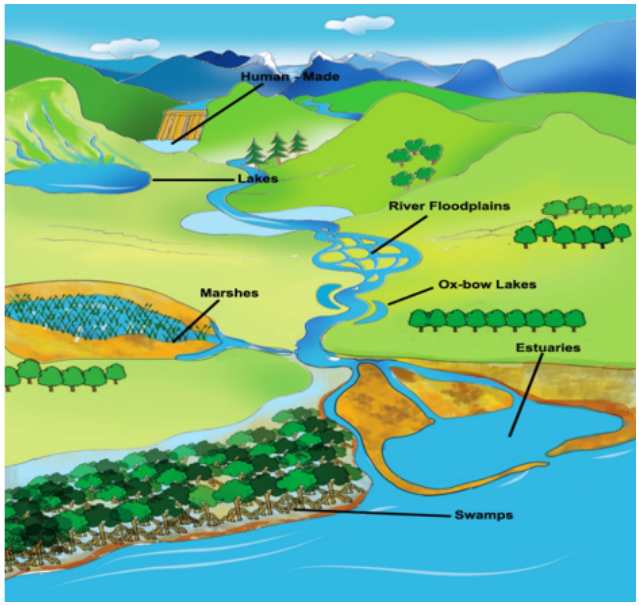

Figure 1: Major Wetland types
Source: https://indianwetlands.in/wp-content/uploads/2021/01/SS_2.3-1.png

2. Discussion

Ramsar Sites are essential to preserving the natural equilibrium. Wetlands are essential to the hydrological cycle and have a major impact on controlling water flow and quality, even though they only make up 2.6% of the planet's surface area.[7] Wetlands are also a vital source of nutrients and energy for many aquatic and terrestrial ecosystems, producing more than 20% of the earth's organic carbon.[8,9] They are the ideal habitat for a variety of species since they have access to enough food and water.[10,11] Numerous essential ecological services, including water purification, flood control, biodiversity preservation, food production, and carbon sequestration, are offered by wetlands.[12] The sustainable development goals are achieved in part by the execution of the Ramsar Strategic Plan.[13] Since rice is a staple food for around three billion people and is farmed in wetland paddies, these sites aid in the fight against world hunger.[14] By controlling sediment transport, they also aid in the stabilization of coastal zones, land creation, and drought reduction.[15,16] Wetlands serve as carbon sinks, and coastal wetlands mitigate the effects of sea level rise by controlling erosion and serving as storm surge buffers. The water, carbon, and nitrogen cycles would be drastically changed in the absence of wetlands.[14]

Table 1: State wise distributed list of ramsar sites in India(As on October, 2024)

S. No.	State Location	Name of Site	Date of Declaration	Area (Km)
1	Andhra Pradesh	Kolleru Lake	19.8.2002	901
2	Assam	Deepor Beel	19.8.2002	40
3	Bihar	Kabartal Wetland	21.07.2020	26.2
4	Bihar	Nagi Bird Sanctuary	11-10-2023	20.6
5	Bihar	Nakti Bird Sanctuary	11-10-2023	33.3
6	Goa	Nanda Lake	06.08.2022	0.42
7	Gujarat	Khijadia Wildlife Sanctuary	13.04.2021	5.12
8	Gujarat	Nalsarovar Bird Sanctuary	24.09.2012	120
9	Gujarat	Thol Lake Wildlife Sanctuary	05.04.2021	6.99
10	Gujarat	Wadhvana Wetland	05.04.2021	6.3
11	Haryana	Bhindawas Wildlife Sanctuary	25.05.2021	4.12
12	Haryana	Sultanpur National Park	25.05.2021	1.43
13	Himachal Pradesh	Chandertal Wetland	8.11.2005	0.49
14	Himachal Pradesh	Pong Dam Lake	19.8.2002	156.6
15	Himachal Pradesh	Renuka Wetland	8.11.2005	0.2
16	Jammu and Kashmir	Hokera Wetland	8.11.2005	13.75
17	Jammu and Kashmir	Hygam Wetland Conservation Reserve	13.08.2022	8.02
18	Jammu and Kashmir	Shallbugh Wetland Conservation Reserve	13.08.2022	16.75
19	Jammu and Kashmir	Surinsar-Mansar Lakes	8.11.2005	3.5
20	Jammu and Kashmir	Wular Lake	23.3.1990	189
21	Karnataka	Aghanashini Estuary	31.01.2024	48.01
22	Karnataka	Ankasamudra Bird Conservation Reserve	31.01.2024	0.98
23	Karnataka	Magadi Kere Conservation Reserve	31.01.2024	0.54
24	Karnataka	Ranganathittu Bird Sanctuary	15.02.2022	5.18
25	Kerala	Asthamudi Wetland	19.8.2002	61.4
26	Kerala	Sasthamkotta Lake	19.8.2002	3.73
27	Kerala	Vembanad Kol Wetland	19.8.2002	1513
28	Ladakh	Tso Kar Wetland Complex	17.11.2020	95.77
29	Ladakh	Tsomoriri Lake	19.8.2002	120
30	Madhya Pradesh	Bhoj Wetlands	19.8.2002	32.01
31	Madhya Pradesh	Sakhya Sagar	01.07.2022	2.48
32	Madhya Pradesh	Sirpur Wetland	01.07.2022	1.61
33	Madhya Pradesh	Yashwant Sagar	13.08.2022	8.23
34	Madhya Pradesh	Tawa Reservoir	08.1.2024	200.5
35	Maharashtra	Lonar Lake	22.7.2020	4.27
36	Maharashtra	Nandur Madhameshwar	21.6.2019	14.37
37	Maharashtra	Thane Creek	13.08.2022	65.21
38	Manipur	Loktak Lake	23.3.1990	266
39	Mizoram	Pala Wetland	31.08.2021	18.5
40	Odisha	Ansupa Lake	13.08.2022	2.31
41	Odisha	Bhitarkanika Mangroves	19.8.2002	650
42	Odisha	Chilka Lake	1.10.1981	1165
43	Odisha	Hirakud Reservoir	13.08.2022	654
44	Odisha	Satkosia Gorge	10.12.2021	982
45	Odisha	Tampara Lake	13.08.2022	3
46	Punjab	Beas Conservation Reserve	26.9.2019	64.29

Continued on next page

Table 1 continued

47	Punjab	Harike Lake	23.3.1990	41
48	Punjab	Kanjli Lake	22.1.2002	1.83
49	Punjab	Keshopur-Miani Community Reserve	26.9.2019	3.44
50	Punjab	Nangal Wildlife Sanctuary	26.9.2019	1.16
51	Punjab	Ropar Lake	22.1.2002	13.65
52	Rajasthan	Keoladeo Ghana NP	1.10.1981	28.73
53	Rajasthan	Sambhar Lake	23.3.1990	240
54	Tamil Nadu	Chitrangudi Bird Sanctuary	13.08.2022	2.6
55	Tamil Nadu	Gulf of Mannar Marine Biosphere Reserve	04.08.2022	526.7
56	Tamil Nadu	Kanjirankulam Bird Sanctuary	13.08.2022	0.97
57	Tamil Nadu	Karaivetti Bird sanctuary	31.01.2024	4.53
58	Tamil Nadu	Karikili Bird Sanctuary	04.08.2022	0.58
59	Tamil Nadu	Koonthankulam Bird Sanctuary	11.08.2021	0.72
60	Tamil Nadu	Longwood Shola Reserve Forest	31.01.2024	1.16
61	Tamil Nadu	Pallikaranai Marsh Reserve Forest	04.08.2022	12.48
62	Tamil Nadu	Pichavaram Mangrove	04.08.2022	14.79
63	Tamil Nadu	Point Calimere Wildlife and Bird Sanctuary	19.8.2002	385
64	Tamil Nadu	Suchindram Theroor Wetland Complex	13.08.2022	0.94
65	Tamil Nadu	Udhayamarthandapuram Bird Sanctuary	04.08.2022	0.44
66	Tamil Nadu	Vaduvur Bird Sanctuary	13.08.2022	1.13
67	Tamil Nadu	Vedanthangal Bird Sanctuary	04.08.2022	0.4
68	Tamil Nadu	Vellode Bird Sanctuary	04.08.2022	0.77
69	Tamil Nadu	Vembannur Wetland Complex	04.08.2022	0.2
70	Tamil Nadu	Nanjarayan Bird Sanctuary	16.1.2024	1.26
71	Tamil Nadu	Kazhuveli Bird Sanctuary	16.1.2024	51.52
72	Tripura	Rudrasagar Lake	8.11.2005	2.4
73	Uttar Pradesh	Bakhira Wildlife Sanctuary	29.06.2021	28.94
74	Uttar Pradesh	Haiderpur Wetland	8.12.2021	69.08
75	Uttar Pradesh	Nawabganj Bird Sanctuary	19.9.2019	2.25
76	Uttar Pradesh	Parvati Agra Bird Sanctuary	2.12.2019	7.22
77	Uttar Pradesh	Saman Bird Sanctuary	2.12.2019	5.26
78	Uttar Pradesh	Samaspur Bird Sanctuary	3.10.2019	7.99
79	Uttar Pradesh	Sandi Bird Sanctuary	26.9.2019	3.09
80	Uttar Pradesh	Sarsai Nawar Jheel	19.9.2019	1.61
81	Uttar Pradesh	Sur Sarovar	21.8.2020	4.31
82	Uttar Pradesh	Upper Ganga River	8.11.2005	265.9
83	Uttarakhand	Asan Conservation Reserve	21.7.2020	4.44
84	West Bengal	East Kolkata Wetlands	19.8.2002	125
85	West Bengal	Sunderbans Wetland	30.1.2019	4230

Source: www.ramsar.org

Monitoring of Ramsar sites is very important. Supporting a wide variety of flora and fauna as well as several ecological niches, wetlands are among the most important elements of an ecosystem. Because of these sites' biological importance, it is essential to investigate changes in the amount of their flooding and suggest appropriate conservation actions. Even minor changes in the hydrologic regime can have a significant impact on the features and function of the ecosystem since wetland saturation and inundation are the most significant abiotic processes governing wetland area and function.[17] In order to comprehend the health and function of wetlands as well as the ecological services they offer, it is crucial to monitor the inundation dynamics of these areas. Inundation maps are crucial for assessing the condition of any wetland. They are frequently employed to analyze the current and historical conditions of wetlands, predict future developments, and comprehend the effects of natural occurrences, human resources, and climate change.[18–20] Additionally, they are helpful for biodiversity research and wetland management plans.[21] However, traditional in-situ methods of data collecting alone cannot provide comprehensive and timely wetland change detection and delineation.[22] When there is a shortage of personnel or for large or inaccessible areas, satellite imagery can be utilized to create inundation maps.[23]

One important source of information for tracking wetland dynamics is remote sensing. However, imaging radar has proven helpful in identifying water level changes in swamp forests[24] and mapping wetland inundation.[25] Wetland classification[26] and change detection[27–29] are two of the many wetland studies that have made use of Landsat data.[30,31] Comprehensive assessments of remote sensing datasets and methods for describing wetlands have been provided by Rundquist et al.[32] and others.

Wetland deterioration is a matter that is of significant consequences**.** Unfortunately, because of climate change and human activity, wetlands—one of the most vulnerable ecosystems—have seen severe losses and degradation on a global scale.[33,34] Given the intimate connection between wetlands and climate, any shifts in their behavior are a reflection of shifting weather patterns and vice versa.[35,36] A framework for the preservation and prudent use of wetlands is provided by the convention.[36] By conserving and responsibly exploiting wetlands through national and local initiatives as well as international collaboration, the treaty seeks to promote sustainable development on a global scale.[14]

Anthropogenic activities continue to be the main cause of water quality degradation despite several attempts to safeguard delicate marine and inland ecosystems.[37] Due to a lack of sewage treatment capacity, about 38,000 million gallons of untreated sewage water are released into Indian rivers every day.[38] It has been demonstrated that different aquatic environments are negatively impacted by the combination of anthropogenic activity and climate change.[39] The traditional method of monitoring water quality relies on on-site measurements, which are accurate but typically time-consuming and labor-intensive, making it challenging to continuously monitor water bodies.[40] Furthermore, because these estimations are restricted to point-to-point data, extrapolation frequently becomes generalized in the intricate ecological problems pertaining to water bodies.[41] A breakthrough for quick and simple comprehension of surface water quality was made possible by the use of satellite data products based on earth observation. At the regional or even global level, remote sensing data products offer spatially explicit and temporally frequent observations regarding the size and quality of water bodies[42,43]. Since the 1970s, when the Landsat series was launched, remote sensing techniques have been used to map the extent of inland waterbodies, including wetlands, and their water quality.[44]

Wetland change and wetland destruction are the two categories of wetland threat factors. Human settlements, the construction of transportation and service corridors, natural system modifications (such as vegetation removal/land conversion, dams, and water management/use), and the occupation of wetland areas by agriculture and aquaculture are the main factors affecting the land area.[3] The loss or degradation of wetlands in tropical and subtropical regions has increased as a result of their conversion to agricultural use.[45] The exploitation of water resources also contributes significantly to the degradation of inland wetlands. Around the world, many rivers are tightly regulated by dams to satisfy the increasing need for hydropower and irrigation. Here, "wetland loss" pertains to the literal diminution of wetland acreage, which can be attributed to human interference and change in the climate.[3]

The wetlands' ecosystem and land area are the primary items impacted. Lake wetlands and river wetlands are most affected by land area occupation, while marsh wetlands and river wetlands are most affected by water resource regulation. In addition, the wetlands that are most impacted by climate change are the lake wetlands and the marine/coastal wetlands. A third or so of the wetland locations have been artificially recreated. Nonetheless, it is discovered that the percentages of natural wetland sites that are unaffected or only impacted by one factor are typically higher than those of wetland sites that have both natural and artificial wetlands. Furthermore, compared to natural wetland sites, the proportions of wetland sites with both artificial and natural wetlands affected by three or four factors are typically higher.

3. Are Wetlands of any Economic Value ?

The wetlands are of great socioeconomic significance and are among the world's most productive and diversified

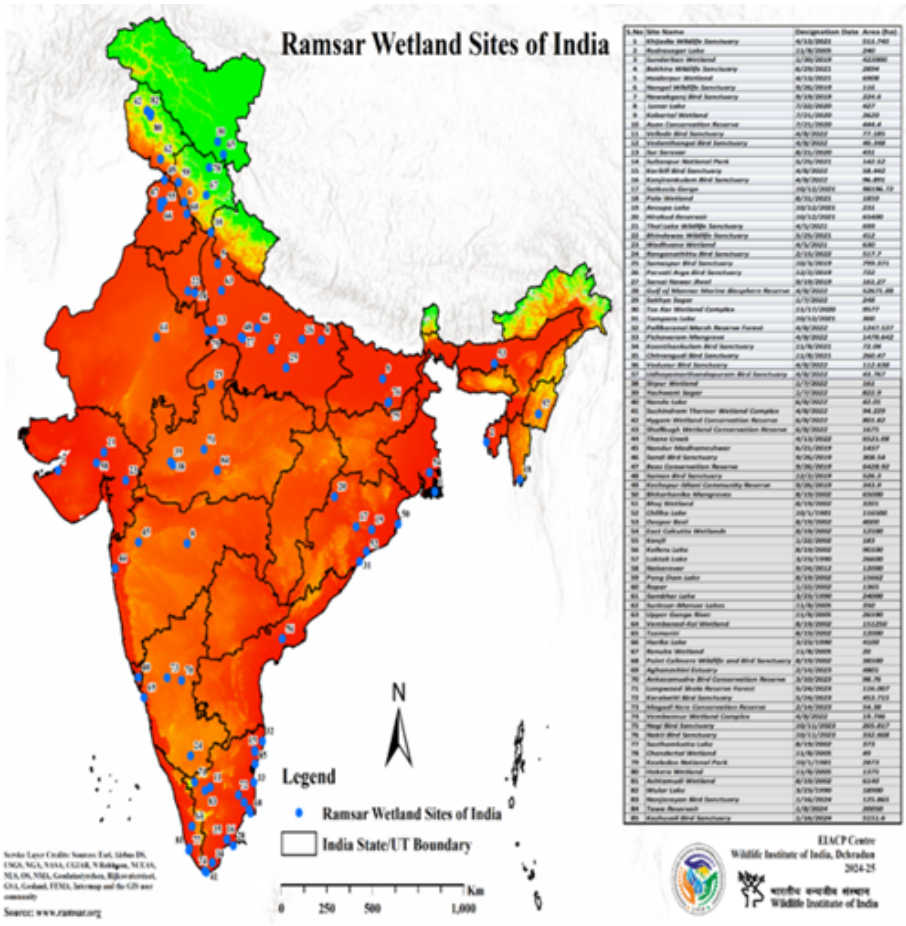

Figure 2: Map showing distribution of Ramsar Sites across India
Source: https://wiienvis.nic.in/WriteReadData/UserFiles/image/images/Ramsar%20Wetland%20Sites%20Map/Ramsar%20Sites%20October%202024.png)

ecosystems.[46] Both local populations and those living outside the perimeter can benefit from the many products and services that wetlands offer.[47] Millions of people worldwide depend on wetlands for a variety of commodities and services. In fact, the products and services promote biological variety, the life support system, and serve as a safety net and environmental insurance against the effects of ecosystem degradation and climate change. In the words of Ramachandra et al.[48], human actions have an influence on the biological, chemical, and physical processes of wetlands, which degrade the functioning of ecosystems and contribute to an overall reduction and degeneration of ecosystem functions as well as the financial significance of wetlands. According to estimates, wetland-related ecosystem services and direct goods are worth 14 trillion USD a year on a worldwide scale.[49] They supply fuel, food, fodder, and water for industrial, agricultural, and residential uses. Additionally, owing of their roles in the chemical and hydrological cycles, it also acts as the landscape's kidney. Wetlands are in danger because of watershed degradation and water diversion that alters water regimes, despite their vital role in preserving the ecosystem's health and supporting local residents' livelihoods. Wetlands have been lost or degraded in many regions of the world, primarily as a result of urbanization, agricultural usage, excessive local population exploitation, and poorly planned development projects.

Many studies on the economic value of wetlands have been conducted worldwide, but very few have examined the wetlands' overall economic contribution. According to Ramachandran et al.[48], the annual value of goods and services from wetlands was estimated to be the second highest, at 14785 USD/ha, based on the assessment of 17 ecosystem services in 16 biomes, with a focus on social welfare. According to a number of studies, the primary cause of inadequate management of these resources is the lack of a clear definition of the products and services provided by wetlands, as well as the true economic worth of those services and their significance to social welfare and the local and national economies.

3.1. What can be done to protect and revive the wetlands?

To conserve and restore wetlands, humans must adhere to natural law. There are number of steps that can be taken in order to protect these wetlands around the world. Firstly, designated wetland protection zones can be created in areas with protection or with less wetland features. They can also be preserved by creating coastal parks, forest parks, water conservancy scenic spots, water source protection zones, etc. Pollution restrictions can be established to rigorously regulate the overall quantity of pollutants released into the wetland in order to mitigate the impact on the wetland environment. Wetland management and river basin environmental management can be combined to accomplish this. Pollutant discharge from home sewage, industry, agriculture, and animal husbandry, among other sources, should be tightly restricted in the areas surrounding wetlands, rivers, lakes, and seas.

The boundaries of species diversity can be established for the influence on wetland biodiversity. It's critical to help rare creatures reproduce and to make sure their numbers don't decline. Limits of wetland ecological water can be established for the impact on wetland water supplies. Wetland management and river basin water resources management can be combined to accomplish this. Wetlands' ecological water amount can be safeguarded by meticulously regulating the quantity of water they receive from water bodies such as lakes and rivers. Climate prediction studies should be conducted in advance to assess the effects of climate change on wetlands. Given the long-term drought climate, it is important to ensure the ecological water amount of wetlands beforehand and to promptly implement the ecological water supply in water-deficient areas. Wetland drainage should be established as soon as possible to prevent the secondary biological effects of prolonged precipitation on wetland overflooding. More scientific laws, rules, and policies on wetland conservation should be swiftly created to clamp down and punish wetland degradation in order to guarantee the seamless execution of wetland management. Every nation and region should enact laws, rules, and policies that are in line with local growth because their national conditions differ greatly.

At last, but the most important step to be taken is to raise global citizens' knowledge of wetland conservation, expanding the breadth of wetland protection globally, and educating the public about wetland resource preservation and resource distress are all critical. Even though there are a specific number of wetlands on each continent that have ratified the Ramsar Convention, their combined area makes up less than nineteen percent of all wetlands worldwide. As a result, the Ramsar Convention urges additional wetlands worldwide to participate in its protection.

4. Conclusion

Ramsar sites are globally significant, but human activities and climate change continue to significantly impact them. Pollutants from waste, urban waste water, household sewage, industrial effluents, and agricultural effluents are the main causes. Wetland habitats are also impacted by human invasions and disruptions of leisure and tourism activities. Climate change and extreme weather are the primary natural factors. The most severely affected areas are around lakes, large interior rivers, and coastlines. Most wetlands are coastal and marine, with lake and marsh wetlands being most vulnerable. Economic growth and rising sea levels are the main causes of pollution and climate change's effects on marine and coastal wetlands.

5. Source of Funding

None.

6. Conflict of Interest

None.

References

1. Keddy PA. Wetland Ecology. 2nd ed. Cambridge University Press; 2010. p. 548.
2. National Report on the Implementation of The Ramsar Convention on Wetlands; 2024. Available from: https://www.ramsar.org/sites/default/files/documents/library/cop14nr_brazil_e.pdf.
3. Gardner R, Finlayson M. Global Wetland Outlook: State of the World's Wetlands and Their Services to People. Ramsar Convention; 2018. Available from: https://www.global-wetland-outlook.ramsar.org/.
4. Davidson NC, Finlayson CM. Extent, regional distribution and changes in area of different classes of wetland. *Mar Freshw Res*. 2018;69:1525–33.
5. O'Neill AR. Evaluating high-altitude Ramsar wetlands in the Sikkim Eastern Himalayas. *Glob Ecol Conser*. 2022;20(e00715):19.
6. Koshy J. Three more Ramsar wetland sites now in India, taking total to 85; 2024. Available from: https://www.thehindu.com/sci-tech/energy-and-environment/three-more-ramsar-wetland-sites-now-in-india-taking-total-to-85/article68524739.ece.
7. Davidson NC. How much wetland has the world lost? Long-term and recent trends in global wetland area. *Mar Freshw Res*. 2014;65(10):936–41.
8. Bar-On YM, Phillips R, Milo R. The biomass distribution on Earth. *Proc Natl Acad Sci*. 2018;115(25):6506–11.
9. Scheyer TM, Aguilera OA, Delfino M, Fortier DC, Carlini AA, Sánchez R, et al. Crocodylian diversity peak and extinction in the late Cenozoic of the northern Neotropics. *Nat Commun*. 2013;4:1907.
10. Kulshreshtha S, Sharma BK, Sharma S, Rajasthan IHO, Usa, Springer. The Ramsar sites of Rajasthan: Ecology and conservation of Sambhar Salt Lake. Jaipur and Keoladeo National Park, Bharatpur; 2013. p. 173–219.
11. Rathod DM, Parasharya BM. Odonate diversity of Nalsarovar Bird Sanctuary-a Ramsar site in Gujarat. *India J Threat Taxa*. 2018;10(8):12117–22.
12. Mitsch WJ, Bernal B, Hernandez ME. Ecosystem services of wetlands. *Int J Biodivers Sci Ecosyst Serv Manag*. 2015;11(1):1–4.
13. Jaramillo F, Desormeaux A, Hedlund J, Jawitz J, Clerici N, Piemontese L, et al. Priorities and Interactions of Sustainable Development Goals (SDGs) with Focus on Wetlands. *Water* . 2019;11(3):619.

14. Ramsar. Scaling up wetland conservation, wise use and restoration to achieve the Sustainable Development Goals; 2018. Available from: https://www.ramsar.org/sites/default/files/documents/library/wetlands_sdgs_e.pdf.
15. Poonia V, Jha S, Goyal MK. Copula based analysis of meteorological, hydrological and agricultural drought characteristics across Indian river basins. *Int J Climatol*. 2021;41(9):4637–52.
16. Mao D, Wang Z, Wang Y, Choi CY, Jia M, Jackson MV. Remote observations in China's Ramsar Sites: Wetland dynamics, anthropogenic threats, and implications for sustainable development goals. *J Remote Sens*. 2021;10(1-3):1–13.
17. Nestler J, Long K. Development of hydrologic indices to aid cumulative impact analysis of riverine wetlands. *Regul Riv Res Manag*. 1997;13(4):317–34.
18. Goyal MK, Gupta AK, Jha S, Rakkasagi S, Jain V. Climate change impact on precipitation extremes over Indian cities: Non-stationary analysis. *Technol Forecast Soc Change*. 2022;180:121685.
19. Dottori F. Increased human and economic losses from river flooding with anthropogenic warming. *Nat Clim Change*. 2018;8:781–6.
20. Inman VL, Lyons MB. Automated inundation mapping over large areas using Landsat data and Google Earth Engine. *Remote Sens*. 2020;12(8):1348.
21. Shirzaei M, Bürgmann R. Global climate change and local land subsidence exacerbate inundation risk to the San Francisco Bay Area. *Sci Adv*. 2018;4(3):9234.
22. Valenti VL, Carcelen EC, Lange K, Russo NJ, Chapman B. Leveraging Google Earth Engine user interface for semiautomated wetland classification in the Great Lakes Basin at 10 m with optical and radar geospatial datasets. *IEEE J Sel Top Appl Earth Obs Remote Sens*. 2020;13:6008–18.
23. Schumann G, Baldassarre D, and GB. The utility of spaceborne radar to render flood inundation maps based on multialgorithm ensembles. *IEEE Trans Geosci Remote Sens*. 2009;47(8):2801–7.
24. Lu Z, Crane M, Kwoun OI, Wells CJ, Rykhus R. C-band Radar Observes Water Level Change in Swamp Forests. *Sci chang World* . 2005;86(14):141–4.
25. & Lang M, & Kasischke E, Prince, & Pittman KS. Assessment of C-band synthetic aperture radar data for mapping and monitoring Coastal Plain forested wetlands in the Mid-Atlantic Region. U.S.A.; 2008.
26. Castañeda C, Ducrot D. Land cover mapping of wetland areas in an agricultural landscape using SAR and Landsat imagery. *J Environ Manage*. 2008;90(7):2270–7.
27. Baker C, Lawrence RL, Montagne C. Change detection of wetland ecosystems using Landsat imagery and change vector analysis. *Wetlands*. 2007;27(3):610–9.
28. Nielsen EM, Prince SD, Koeln G. Wetland change mapping for the U.S. mid-Atlantic region using an outlier detection technique. *Remote Sensing Environ*. 2008;112(11):4061–74.
29. Kassawmar NT, Rao KM, Abraha GL. An integrated approach for spatio-temporal variability analysis of wetlands: A case study of Abaya and Chamo lakes, Ethiopia. *Environ Monit Assess*. 2010;180(1-4):313–24.
30. Lunetta RS, Balogh ME. Application of multi-temporal LANDSAT 5 TM imagery for wetland identification. *Photogrammetric Eng Remote Sensing*. 1999;65(11):1303–10.
31. Thomas RF, Kingsford R, Hunter SJ. Landsat mapping of annual inundation (1979-2006) of the Macquarie Marshes in semi-arid Australia. *Int J Remote Sensing*. 2011;32(16):4545–69.
32. Rundquist DC, Narumalani S, Narayanan RM. A review of wetlands remote sensing and defining new considerations. . *Remote Sensing Rev*. 2001;20(3):207–26.
33. Fluet-Chouinard E, Stocker BD, Zhang Z, Malhotra A, Melton JR, Poulter B, et al. Extensive global wetland loss over the past three centuries. *Nature*. 2023;614:281–6.
34. Courouble M, Davidson N, Dinesen L, Fennessy S, Galewski T, Guelmami A, et al. 2021. Available from: https://static1.squarespace.com/static/5b256c78e17ba335ea89fe1f/t/61b8a904f3ceb458e9b5ca44/1639491853578/Ramsar+GWO_Special+Edition+2021%E2%80%93ENGLISH_WEB.pdf.
35. Haig SM, Murphy SP, Matthews JH, Arismendi I, Safeeq M. Climate-altered wetlands challenge waterbird use and migratory connectivity in arid landscapes. *Sci Rep*. 2019;9(4666):1–10.
36. Xi Y, Peng S, Ciais P, Chen Y. Future impacts of climate change on inland Ramsar wetlands. *Nat Clim Change*. 2021;11:45–51.
37. Kulk G, George G, Abdulaziz A, Menon N, Theenathayalan V, Jayaram C, et al. Effect of reduced anthropogenic activities on water quality in lake Vembanad. *India Rem Sens*. 2021;13(9):1631.
38. CPCB Directions issued under section 5 of EPA act, 1986 regarding treatment and utilization of sewage for restoration of water quality of river to metropolitan cities and states/UT capitals; 2015. Available from: http://www.indiaenvironmentportal.org.in/content/420116/directions-issued-under-section-5-of-epa-act-1986/.
39. Häder DP, Banaszak AT, Villafañe VE, Narvarte MA, González RA, Helbling EW. Anthropogenic pollution of aquatic ecosystems: emerging problems with global implications. *Sci Total Environ*. 2020;713:136586.
40. Quang NH, Sasaki J, Higa H, Huan N. Spatiotemporal Variation of Turbidity Based on Landsat 8 OLI in Cam Ranh Bay and Thuy Trieu Lagoon, Vietnam. *Water*. 2017;9(8):570.
41. Gholizadeh MH, Melesse AM, Reddi L. A comprehensive review on water quality parameters estimation using remote sensing techniques. *Sensors*. 2016;16(8):1298.
42. Huang C, Chen Y, Zhang S, Wu J. Detecting, extracting, and monitoring surface water from space using optical sensors: a review. *Rev Geophys*. 2018;56(2):333–60.
43. Sahadevan AS, Joseph C, Gopinath G, Ramakrishnan R, Gupta P. Monitoring the rapid changes in mangrove vegetation of coastal urban environment using polynomial trend analysis of temporal satellite data. *Reg Stud Mar Sci*. 2021;46(7):101871.
44. Klemas V, Borchardt JF, Treasure W. Suspended sediment observations from ERTS-1. *Rem Sens Environ*. 1971;2:205–21.
45. Niu Z, Zhang H, Gong P. More protection for China's wetlands. *Nature*. 2011;471:305.
46. Dodds WK, Wilson KC, Rehmeier RL. Comparing ecosystem goods and services provided by restored and native lands. *BioScience*. 2008;58(9):837–45.
47. Roy MB, Roy PK, Samal NR, Mazumdar A. Socio-economic valuations of wetland based occupations of lower gangetic basin through participatory approach. . *Environ Nat Resour Res*. 2012;2(4):30–44.
48. Ramachandra TV, Alakananda B, Rani A, Khan MA. Ecological and socio-economic assessment of Varthur wetland. *Bengaluru (India) Journal of Environmental Science and Engineering*. 2011;53(1):101–108.
49. Costanza R, Arge R, Groot RD. The value of the world's ecosystem services and natural capital. *Nature*. 1997;387(6630):253–260.

Author's biography

Shivam Dubey, Research Scholar https://orcid.org/0000-0002-2704-4260

Cite this article: Dubey S. Ramsar wetlands: Critical zones for maintenance for ecological equilibrium. *J Pharm Biol Sci* 2024;12(2):127-134.