Present Status, Conservation, and Management of Wetlands in India

Vandana Shan, S. K. Singh, and A. K. Haritash

Abstract Among various types of aquatic ecosystems, wetland is highly productive and efficient one which provides direct as well as indirect services to human beings. And these services of wetland ecosystem account around fifty percent of the overall global ecosystem values and ranks first among all of them. The ever-growing needs for freshwater have exerted great pressure on wetland ecosystem. Also, in last few decades, a bunch of activities such as accelerated urbanization, industrialization, technological advancement in agricultural sectors along with changed land use pattern have unfortunately threatened the uniqueness of wetlands and affected their ecological, economical, and biological identity. Due to various natural and anthropogenic activities, wetland occupied areas throughout the world are decreasing and declining its water quality. Indian wetlands cover around 4.1 million hectares (excluding irrigated agricultural lands, rivers, and streams) of land area, from which 1.5 million hectares are natural and 2.6 million hectares are man-made. Interest in sustainable use and adaptive management of wetlands has increased in the last few years. Based on the available information, wetlands are facing problems like inadequate information and uneven management of these valuable systems. A conceptual framework is highly required for wetland management which should include all the major issues affecting the wetland status, trends, management scenario and related responses, technical input and data management, respectively. This paper mainly reviews the present status, conservation and management plans for Indian wetlands concentrating on various threats and their possible sources to wetland regions and also focuses to investigate major factors responsible for overutilization of wetland wealth and various management practices for their present and future usage in sustainable way.

Keywords Wetland · Threats · Conservation · Sustainable use · Management plans

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R. Al Khaddar et al. (eds.), *Advances in Energy and Environment*, Lecture Notes in Civil Engineering 142, https://doi.org/10.1007/978-981-33-6695-4_22

1 Introduction

Water is most important commodity which sustains life on planet earth. Even a large part of earth surface is covered with water but a very less amount of water is accessible for human use. And that amount of water is available in various lentic (lakes, ponds) and lotic (stream, river) ecosystems. Wetlands are one of the highly productive and valuable ecosystems among them. Wetlands are transitional zone between permanently wet (water) and generally dry environment (land), where water is usually found closed to the surface and soil is temporarily or permanently covered with shallow water [31]. According to Indian context, Ramsar Convention [40] stated about various water bodies (natural and anthropogenic) like rivers, lakes, mangroves, ponds, agricultural fields, water reservoirs, canals, etc. This is also one of the most biologically diverse ecosystems on the earth surface as it provides natural habitats to wide varieties of plant and animal species [16]. Wetlands are freshwater resources and provide many ecological, economic, cultural, aesthetical and supportive services that are important for human society [51]. In addition, wetlands provide feeding, resting, and breeding place for wildlife and are important habitat for water fowl and various migratory birds [41]. In recent years, there has been increasing recognition of wetlands in context of providing various regulating, provisioning, supporting, and cultural services. Inland water is known the most endangered ecosystem on the earth and it is predicted that more 50% of the world's wetlands would have been vanished by 2030. Increasing demand of water use is due to increasing rate of population growth, so uphill task to protect and conserve our ecosystem resources for their sustainable use. Even after all these, services providing wetlands are under the threat of extinction or degraded by poor management and unsustainable use which ultimately declined their benefits significantly. Wetlands, being the most threatened habitats of the world, are facing tremendous anthropogenic pressures posing degradation in quality and quantity of water resources [17] and the catchments areas found in their vicinity. Burgeoning human population, unplanned urbanization [12], changes in land use/land cover [10, 15] at large scale, fast-moving activities and continued overexploitation of resources has drastically reduced in number of wetland resources in India. A number of significant losses like hydrological alterations, lowering in water table, contamination of underground water resources with organic and inorganic pollutants, sprout of water borne diseases [24, 35], etc. have been observed. In order to conserve wetland productivity and biodiversity, sustainable use of its resources is highly required by human beings. To understand the vitality of these ecosystems need of advance research is highly required in planning and implementation of a national strategy. And this can only be possible by collective efforts and collaboration of planners, managers, owners, occupiers, and stakeholders. The scientific knowledge further will lead in setting priorities and in framing appropriate planning processes to achieve sustainable approach/results in conservation of these productive ecosystems and help in mitigation of pollution. In addition more research emphasis on the physical, socioeconomic, and institutional factors is needed which directly influence present wetlands

conditions and their use [28]. The present paper includes the wetland values, distribution in varied geographical conditions, threats, conservation of wetlands, and their sustainable management plans.

2 Global Wetlands Scenario

97.5% of the total water in the hydrosphere is situated in the oceans as saline water that constitutes two-thirds of the earth's surface [47]. Wetlands constituted nearly 6.4% of the earth's surface which includes bogs, fens, swamps, and flood plains with 30%, 26%, 20%, and 15%, respectively (Table 1). The water resource distribution throughout the world and continentwise distribution is given in Tables 1 and 2, respectively [9, 47]. Wetlands are distributed globally in each continents of world except Antarctica (Fig. 1.) where bog, fen, freshwater marsh, bog, swamp forest, mire, and peat lands are types of palustrine, lacustrine have lakes, pans, and saline wetlands and estuarine represents coastal wetlands [26].

According to recent report published by the Economics of Ecosystems and Biodiversity (TEEB), the world has lost around half of its wetlands in just the last 100 years,

Table 1 Global water resources distribution

Water resource	Area (millionsq.km)	Volume (mill.cu.km)	Total water (%)	Freshwater (%)
Ocean	361	1338	97.47	–
Freshwater	–	35	2.53	–
Ice	16	24	1.76	69.1390
Ground water	–	10.5	0.76	30.0710
Lakes (excluding saline lakes)	1.5	0.09	0.007	0.2769
Rivers	–	0.02	0.0002	0.0079
Wetlands (Marshes, swamps, lagoons, flood plains, etc.)	2.6	0.1	0.0001	0.0039

Table 2 Freshwater resources distribution in continents

Freshwater type	Africa	Europe	Asia	Australia	North America	South America
Lakes	30,000	2027	27,782	154	25,623	913
Rivers	195	80	565	25	250	1000
Reservoirs	1240	422	1350	38	950	286
Groundwater	5,500,000	1,600,000	7,800,000	1,200,000	4,300,000	3,000,000
Wetlands	341,000	–	925,000	4,000	180,000	1,232,000

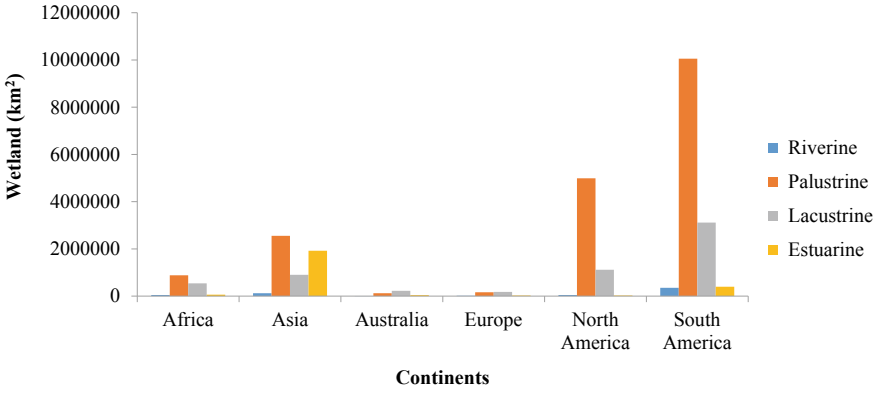


Fig. 1 Wetland area distribution in various continents except Antarctica

Table 3 Wetland density (km^2) excluding reservoirs and Ramsar sites [26] and wetland loss (%) [10] in various continents

Continent	Wetland density (km^2)	Wetland loss (%)
Africa	0.051	43
Asia	0.085	83.7
Australia	0.051	44.3
Europe	0.037	71
North America	0.25	36.5
South America	0.094	NA

and it was found that out of 25 million square kilometers of wetlands that existed in 1900 just 12.8 million square kilometers now remain. The rate of destruction varies geographically and is higher in East Asia with annual rate of 1.6% per year. Wetland losses have been found larger and faster for inland wetlands as compared to coastal wetlands. As compared to Europe and North America, the rate of wetland loss has observed high in Asia with fast and large-scale conversion [10]. Table 3 represents wetland density (km^2) excluding reservoirs and Ramsar sites [26] and percentage wetland loss [10] in various continents.

3 Indian Scenario

Most of the Indian wetlands have depth below six meter. And presently most of Indian lakes are being degraded by the problems of siltation and encroachment. Some of them are Wullar lake of Kashmir, Chilka lake in Orissa, Kolleru lake in Andhra Pradesh, and man-made Sukhna lake in Chandigarh. In last two decades, the water holding capacity of most of these lakes has also decreased. The other most important reason for degradation of water quality in most popular lakes of country, Srinagar's

Table 4 Indian wetland distribution according to wetland inventories of India

Sr. No.	Inventory list	Year	Total wetlands		Total wetlands	
			Natural	Anthropogenic	Natural	Anthropogenic
1	WWF and AWB	1989 &1993	Not identified	–	58.3	–
2	MoEF, GoI	1990	2167	65,253	1.45	2.59
3	Wetlands of India (Space Applications Center)	1998	1815	49,249	1.45	2.27

Source [15, 50]

Dal lake and Loktak lake of Manipur is eutrophication (nutrient enrichment) and weed infestation which have threatened the ecological functioning and biodiversity of these lakes. In Harike lake (Punjab), water hyacinth is spreading at alarming rate and infested about 75% of the wetland area. Extensive and unsustainable utilization of natural resources, for example, (excessive fishing) in the catchment areas of wetlands has created noticeable nuisance to aquatic life (waterfowls) in this lake. Loktak lake situated in southern part of Manipur valley is the largest natural lake in eastern India which is seriously threatened due to unwisely use of resources in its catchment and unplanned land use practices. Most of the lake is choked with various invasive species, e.g., *Eichhornia crassipes, Typha angustata, Hydrilla verticillata,* and *chara* spp. Problems of increased pollution, loss of biological diversity and available natural resources and reduction in water-spread areas are mainly resulted by various anthropogenic activities. The water-spread area and number of water bird species (pelicans, storks, and flamingos) of Kaliveli (Tamil Nadu) have reduced mainly due to encroachment by paddy fields and poaching for meat, respectively, and resulted in their migration. A number of lakes have also shrunk on account of repossession for agriculture, e.g., Kolleru lake of Andhra Pradesh, Deepar beel of Assam, Pyagpur and Sitadwar Jheels of Uttar Pradesh, and Hokarsar lake of Kashmir (Table 4).

4 Distributions and Classification of Wetlands in India

India comprises a large geographical spread and varied topography along with wide range of weather conditions which support large and highly diverse wetland classes with unique characteristics. Indian climate ranges from cold arid Laddakh to the warm arid Rajasthan, with a coastline of over 7500 km, with its major river systems and mountains. In India, most of the Indian wetlands are linked with famous rivers, Ganges, Cauvery, Krishna, Godavari, Tapti, and their tributaries directly or indirectly linked with major river systems and their tributaries. About 1–5% of geographical

Table 5 Aerial estimates of typewise national wetland inventory and assessment

Sr. No.	Wetland type	Wetland area (ha)	Wetland area (%)
1	River/stream	5,258,385	34.5
2	Reservoir/barrage	2,479,754	16.2
3	Intertidal mud flat	2,413,642	15.8
4	Tank/pond	1,310,443	8.6
5	Lake/pond	729,532	4.8
6	Wetlands	555,557	3.6
7	Mangrove	471,407	3.1
8	Waterlogged-natural	316,091	2.1
9	Aquaculture pond	287,232	1.9
10	Lagoon	248,277	1.6
11	Creek	206,698	1.4
12	Salt marsh	161,144	1.1
13	Salt pan	148,913	1.0
14	Coral reef	142,003	0.9
15	Waterlogged-man-made	135,704	0.9
16	High-altitude wetland	124,263	0.8
17	Ox-bow lakes/cutoff meander	104,124	0.7
18	Riverine wetland	91,682	0.6
19	Sand/beach	63,033	0.4
20	Salt pan-inland	13,698	0.1
	Total	**15,260,572**	**100**

Source National Wetland Atlas, Space Applications Centre, ISRO, Ahmedabad, March 2013

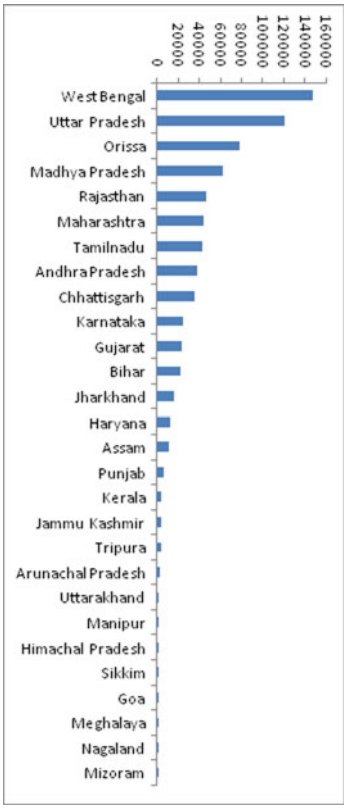
region of country is occupied by wetlands alone. India is at fifth position in category of mega biodiversity zone (MoEF 2010) (Table 5).

Of an estimated 4.1 million hectares (excluding irrigated agricultural lands, rivers, and streams) of wetlands, 1.5 million hectares are natural and 2.6 are man-made, while 6750 km^2 areas of coastal wetlands are mainly occupied by mangroves. Indian wetlands are mainly classified in two main categories, inland and coastal wetlands according to definition devised under the Ramsar Convention and these are further divided into two categories as: natural and man-made. Ox-bow lakes, high-altitude wetlands, riverine wetlands, and waterlogged area, river/stream are natural inland wetland and creeks, sand/beach, intertidal mud flats, salt marsh, mangroves, and coral reefs comes under the category of coastal natural wetlands (Table 6).

However reservoir/barrages, tanks/ponds, salt pans, and aquaculture ponds are examples of inland man-made wetlands and coastal man-made wetlands category, respectively. Majority of man-made wetlands are found in regions of South India in form of tanks and these tanks have constructed in each and every village for human consumption and besides this act as resting, nesting, and breeding site for a variety of

Table 6 Statewise number of wetlands in India [5]

Sr. No.	State	No. of wetlands
1	West Bengal	147,826
2	Uttar Pradesh	121,242
3	Orissa	78,440
4	Madhya Pradesh	62,618
5	Rajasthan	46,748
6	Maharashtra	44,714
7	Tamil Nadu	42,978
8	Andhra Pradesh	38,514
9	Chhattisgarh	35,534
10	Karnataka	25,276
11	Gujarat	23,891
12	Bihar	21,998
13	Jharkhand	15,690
14	Haryana	11,970
15	Assam	11,178
16	Punjab	6430
17	Kerala	4354
18	Jammu Kashmir	3651
19	Tripura	3415
20	Arunachal Pradesh	2653
21	Uttarakhand	994
22	Manipur	708
23	Himachal Pradesh	641
24	Sikkim	553
25	Goa	550
26	Meghalaya	426
27	Nagaland	421
28	Mizoram	234



avifauna. Statewise wetland distribution in India follows the trend of Lakshadweep > Andaman and Nicobar Islands > Daman and Diu > Gujarat > Puducherry > West Bengal > Assam with 96.12%, 18.52%, 18.46%, 17.56%, 12.88%, 12.48%, 9.74%, respectively, with maximum geographical area to minimum geographical area in different union territories and states. States like Mizoram, Haryana, Delhi, Sikkim, Nagaland, and Meghalaya the extents of wetland are less than 1.5% [46].

The total estimated wetland area in India is 15260572 ha [46] (Table 5) which turns out to be 4.63% of the geographic area. The summary area statistics shows that inland: natural wetlands dominate with about 43% followed by inland: man-made

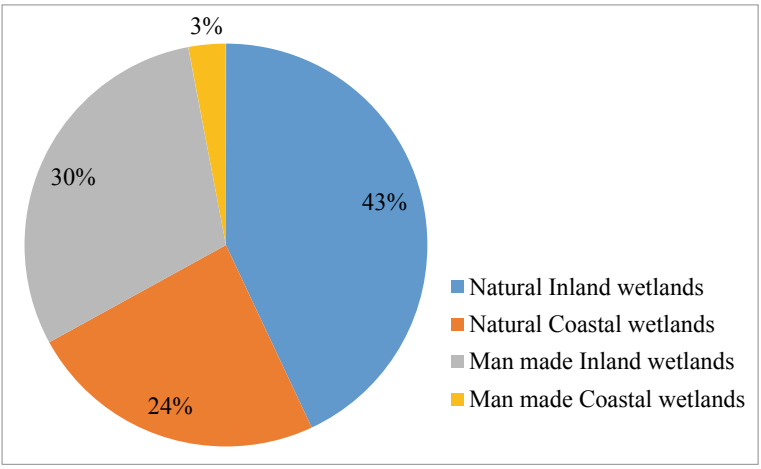


Fig. 2 Categorywise distribution of wetlands in India. (*Source* Aerial estimates of national wetland inventory and assessment based on Resource sat- 1 LISS-III data on 1: 50,000 scale)

wetlands (30%) and coastal: natural wetlands (Fig. 2). The sizewise distribution of wetlands (Fig. 3) reveals that large size wetlands (> 10,000 ha) constitute 49% followed by the wetland between 100 and 10,000 ha (37%).

Typewise statistics (Table 7) reveals that river/stream is the dominate type with 34.5% of the wetland area followed by reservoir/barrage (16.3%), intertidal mudflat (15.8%), and lagoon (8.6%). Rest of the each wetland type comprised less than 5% of wetland area.

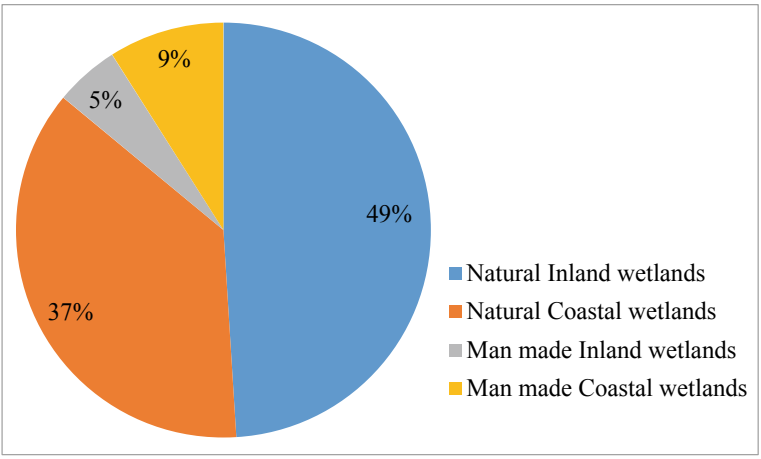


Fig. 3 Sizewise distribution of wetlands in India. (*Source* Aerial estimates of typewise national wetland inventory and assessment based on Resource sat- 1 LISS-III data on 1: 50,000 scale)

Table 7 Types of wetlands in Indian states and union territories*

State code	State	Geographic Area	Wetland Type																			Sub-total	Wetland (<2.25ha)	Total
			1101	1102	1103	1104	1105	1106	1201	1202	1203	1204	2101	2102	2103	2104	2105	2106	2107	2201	2202			
			Lake/ pond	Ox-bow lake/ Cut-off meander	High altitude wetland	Riverine wetland	Waterlogged (Natural)	River/ Stream	Reservoir/ Barrage	Tank/ Pond	Waterlogged (Man-made)	Salt pan	Lagoon	Creek	Sand/ Beach	Intertidal mud flat	Salt Marsh	Mangrove	Coral Reef	Salt pan	Aquaculture pond			
		(sq. km.)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)
35	Andaman & Nicobar Islands*	8249	45	-	-	-	-	6571	280	16	-	-	56	1777	10063	12399	6029	66101	49378	-	-	152715	94	152809
28	Andhra Pradesh	275045	21843	-	-	-	2714	385839	404499	201677	4178	-	47407	9594	15891	31767	4002	41486	-	17725	240474	1429096	18037	1447133
12	Arunachal Pradesh	87658	18	520	11422	-	8146	134244	164	95	-	-	-	-	-	-	-	-	-	-	-	154609	1119	155728
18	Assam	78438	51257	14173	-	4258	47141	637164	2833	921	544	-	-	-	-	-	-	-	-	-	-	758291	6081	764372
10	Bihar	91689	20281	16172	-	2118	34878	298408	8612	4822	336	-	-	-	-	-	-	-	-	-	-	385627	17582	403209
4	Chandigarh*	114	160	-	-	-	-	167	-	14	-	-	-	-	-	-	-	-	-	-	-	341	9	350
22	Chhattisgarh	135194	-	26	-	174	-	179088	90389	40226	240	-	-	-	-	-	-	-	-	-	-	310143	27823	337966
25	Daman & Diu*	112	-	-	-	-	-	380	125	88	-	-	24	-	204	1054	57	63	-	63	-	2058	10	2068
26	Dadra & Nagar Haveli*	487	-	-	-	-	-	732	1286	13	-	-	-	-	-	-	-	-	-	-	-	2031	39	2070
7	Delhi*	2966	49	-	-	-	380	1074	479	260	228	-	-	-	-	-	-	-	-	-	-	2470	301	2771
30	Goa	3702	499	6	-	-	-	9362	2363	396	17	41	-	-	519	3286	-	1752	-	2929	-	21170	167	21337
24	Gujarat	197841	23550	6	-	-	20660	275877	248979	73873	13951	1295	22289	149898	6508	2260365	144268	90475	33547	90878	8823	3465242	9708	3474950
6	Haryana	49663	801	24	-	-	1412	17025	1775	7573	3339	-	-	-	-	-	-	-	-	-	-	31949	10529	42478
2	Himachal Pradesh	55673	52	-	387	-	47	55558	41817	134	30	-	-	-	-	-	-	-	-	-	-	98025	471	98496
1	Jammu & Kashmir	222111	13762	-	109170	9594	-	231597	25132	6	-	-	-	-	-	-	-	-	-	-	-	389261	2240	391501
20	Jharkhand	79714	3204	83	-	1629	231	97743	48177	5688	61	8	-	-	-	-	-	-	-	-	-	156824	13227	170051
29	Karnataka	191791	638	-	-	1051	2045	179731	213527	222030	2403	-	72	97	1897	1663	-	967	-	812	2779	629712	13864	643576
32	Kerala	38863	2643	-	-	410	20305	65162	26167	2435	-	-	38442	80	2354	-	-	-	-	-	-	157998	2592	160590
31	Lakshadweep*	828	-	-	-	-	-	-	-	-	-	-	23674	-	733	-	-	-	55179	-	-	79586	0	79586
23	Madhya Pradesh	308414	208	93	-	7	157	315526	392455	64768	-	-	-	-	-	-	-	-	-	-	-	773214	44952	818166
27	Maharashtra	307748	9003	15	-	2	284	299730	368135	208669	310	-	-	41636	4873	22249	614	30238	-	7025	71	992854	21668	1014522
14	Manipur	22327	39123	64	-	-	3525	16677	856	187	-	-	-	-	-	-	-	-	-	-	2643	63075	541	63616
17	Meghalaya	22420	501	461	-	1272	1028	24841	1562	150	5	-	-	-	-	-	-	-	-	-	-	29820	167	29987
15	Mizoram	21087	185	-	-	-	133	13497	27	-	-	-	-	-	-	-	-	-	-	-	-	13842	146	13988
13	Nagaland	16521	3	9	-	-	423	19254	1547	41	-	-	-	-	-	-	-	-	-	-	-	21277	267	21544
21	Orissa	153845	712	728	-	980	12925	223522	189972	29301	934	-	89023	-	6046	25514	-	23395	-	1726	19952	624730	66174	690904
34	Puducherry*	492	1120	-	-	-	20	2113	-	867	-	-	-	212	809	505	66	285	-	-	194	6191	144	6335
3	Punjab	50362	1934	373	-	306	2032	59864	11858	3526	1341	-	-	-	-	-	-	-	-	-	-	81234	5049	86283
8	Rajasthan	342269	38269	-	-	-	16856	312570	190600	151027	7636	12283	-	-	-	18950	-	-	-	-	-	748191	34123	782314
11	Sikkim	7096	15	-	3050	-	-	4131	-	-	-	-	-	-	-	-	-	-	-	-	-	7196	281	7477
33	Tamil Nadu	130409	316091	-	-	127	3928	136878	56419	237613	10811	-	25057	3404	9798	33164	6108	7315	3899	22889	10739	884240	18294	902534
16	Tripura	11040	300	387	-	-	2946	7420	3320	186	-	-	-	-	-	-	-	-	-	-	-	14559	2983	17542
5	Uttarakhand	53566	2081	63	142	-	9	80133	20319	108	211	-	-	-	-	-	-	-	-	-	-	103066	816	103882
9	Uttar Pradesh	240928	122531	51371	-	61100	76263	607315	105641	33263	87694	-	-	-	-	-	-	-	-	-	-	1145178	97352	1242530
19	West Bengal	88805	58654	19550	82	8654	56603	559192	22672	20470	1435	71	-	-	3338	2726	-	209330	-	4866	1557	969200	138707	1107907
	Total	**329467**	**729532**	**104124**	**124253**	**91682**	**315091**	**5258385**	**2481987**	**1310443**	**135704**	**13698**	**246044**	**206698**	**63033**	**2413642**	**161144**	**471407**	**142003**	**148913**	**287232**	**14705015**	**555557**	**15260572**

Source [47]

Distribution of different types of wetlands in Indian states and union territories is given in Table 6.

5 Significance of Wetlands

Wetlands are obligate biodiversity support system and habitats for a wide range of rare, endangered, and threatened species of flora and fauna. They are well known as kidney of landscape and buffer zone. Besides this, wetlands provide various provisional, regulating, cultural, and supportive services [39] as discussed below.

5.1 Provisioning Services

Wetland ecosystems provide a large variety of natural products like food grain, fruits, raw materials for industries, timber, and firewood production and also provide resources for medicinal, ornamental, and genetic use. Also, these are known buffer zone which help in storage of storm water and retention of excess water during flood. Wetlands also provide water for domestic, industrial, and agricultural use. A number of well-known Indian lakes, e.g., Kolleru (Andhra Pradesh); Vembanad (Kerala) Chilka (Orissa); Khabartal (Bihar); Loktak (Manipur); Nalsarovar (Gujarat); Nainital (Uttarakhand); Dal lake (Jammu and Kashmir); Deepor Beel (Assam); and Carambolim (Goa), are main source of domestic, agricultural, and irrigational services and also provide tourism, fisheries, and recreational services [22]. Due to extraction of medicine from medicinal plants and other materials from biota, they are also having biochemical importance.

5.2 Regulating Services

Wetlands are highly important in maintaining essential ecological processes and life support systems. As a large source of and sink of greenhouse gases, they help in carbon sequestration and also useful in regulating local and regional temperature. They also influence other climatic conditions like gaseous exchange and precipitation. During excess rainfall, they keep proper continuous hydrological flow, maintaining water quality, and enhancing ecosystem productivity for both, humankind as well as for aquatic biota. Wetlands are the main primary source for recharging ground water aquifers by storing excess rainwater. They are known as natural filters as they remove a large amount of organic and inorganic contaminants from water, consisting harmful pathogens (bacteria and viruses) from waste water and sewage and heavy metals and hazardous waste generated from industries. They act as a buffer zone during periods of excessive rainfall and absorb suspended impurities like solids and

nutrient under soil surface. In addition, they are useful in erosion regulation, natural hazard regulation, and pollination. Wetlands are habitat of a number of native and migratory bird species as these provide resting and nesting place to them. Rann of Kutch, coastal areas in Gujarat, and Bharatpur wild life sanctuary in Rajasthan are well-known habitat of around 1200–1300 species of migratory birds (equivalent to 24% of total Indian bird species [1] from western and European countries during winter season.

5.3 Cultural and Amenity Services

Cultural service is the broad term used for spiritual interest which wetlands provide such as inspirational approach toward human culture, spiritual enrichment, intellectual development, science and education, cultural and historic information, religious experience, and education throughout recreation. It comprises knowledge systems, social relations, aesthetic values, and appreciation of nature. Pushkar lake (Rajasthan) and Ramappa lake (Telangana) are closely related to the local culture. Wetlands are becoming an increasingly important economic resource which offers chances for outdoor recreation and environment friendly tourism. Besides providing an aesthetic experience for the privileged, ecotourism helped out in alleviating poverty in major regions of the world and proven success for enhancing human well-being.

5.4 Supporting Services

Wetlands provide habitat for a large species of flora and fauna and support their biological and genetic diversity. Soil formation and reservation, biomass generation, atmospheric oxygen production, nutrient and water cycling, and serving habitat are some of supporting services which are provided by wetlands to large variety of plants and animal species for their entire life time. In regime of wetlands, plants flourish and produce a variety of products. Wetlands play an important role in supporting food chains which further help in maintaining ecological balance in nature [23]. Majority of water ecosystems in India support a large biological diversity of almost all taxonic groups (flora and fauna). A rich species biodiversity of endemic and endangered species are preserved and supported by freshwater ecosystems in southern India. Loktak lake in North eastern region is nesting and breeding ground for endangered Sangai [44] and supports 75 and 120 species of phytoplanktons and rotifers, respectively, and Western Ghats provides habitat to around 24% of endemic aquatic plants species. Due to highly divergent ecological characteristics, the capital Delhi has achieved second most position after Nairobi. During winter season, more > 450 bird species are observed in Delhi alone. Red-crested pochards, white-tailed lapwing,great white pelicans; and Orphean warbler are some of these migratory birds species usually sighted in capital region [25].

6 Threats to Wetlands

India is second most populous country of the world and yet constitutes very little portion (around 2.4%) of the earth's surface. Wetlands are one of the most threatened habitats of the world that are subjected to both human and natural forces. Hydrologic cycle, rising sea level, natural succession, sedimentation, subsidence, drought, hurricanes, weed infestation, and soil erosion are some of natural processes which influence proper functioning of wetland. Wetland's spatial extent, due to rising sea level, is dependent on local factors. Due to burgeoning population and increasing anthropogenic activities (industrial and agricultural), Indian wetlands are facing great pressure of their extinction and degradation. Improper use of watersheds, large-scale change in land use cover and constructional projects have all caused dramatically reduction in wetland resources in our country. Extinction and degradation of highly useful wetlands result in various environmental and ecological issues, which directly affect the social and economic prosperity of associated population [34]. It has been estimated that in every single minute, one hectare of the world's wetlands is turning degenerated.

6.1 Urbanization

Wetlands situated near urban areas are facing expanding developmental pressure for various man-made activities. Urban wetlands are major source of freshwater supplies for public. Open land/wetland situated in urban center or suburban centers is treated as wasteland and transformed into various development activities. Local governments are responsible for zoning wetlands for light industry or residential housing. Urban wetlands have become ineffective in maintaining water quality and flood abatement due to various ongoing developmental activities in adjoining uplands. Urban development and industrial development have declined the wetlands area and due to poor water holding capacity of concrete, water runoff from the land surface and increase the risk of flood [38] due to increasing the flow rate of rivers after heavy rainfall. Also, various pollutants bring together with increased runoff and degrade water quality. Effluents from industries and untreated sewage from sewage treatment plants [6, 27] are usually dumped in wetland which leads to various disease causing microorganisms [24].

6.2 Anthropogenic Activities

Various man-made activities are responsible for deterioration of water quality [12] in lake and in catchment areas. Direct disposal of untreated sewage waste and solid waste is highly responsible for water quality deterioration in wetlands [37]. Direct

and indirect disposal of solid waste (biodegradable and toxic non-biodegradable) and immersion of idols have affected the physical, chemical, and biological properties of water in wetlands. Bathing, washing clothes, recreation, and navigation with motorized boats also affect the biota in wetlands. Exploitation of biological and physical resources of lakes and wetlands by dredging, harvesting of aquatic crop and vegetation, and fishing have caused interminable ecological and economic losses. Due to unmanaged urban, agricultural and industrial activities, wetlands have been depleted and altered causing their completely loss [32, 41]. Most of the human settlements are situated in catchment areas of urban and suburban wetlands and lakes which are facing both liquid and solid waste from these regions. In urban areas, large amount of pollutants and waste find their ways through storm water. But in rural areas, due to presence of natural vegetation in catchment area is facing different level of stress. Catchment devoid of vegetation, caused by excessive grazing and cultivation of vegetation, is highly susceptible for soil erosion. Due to soil erosion, upper fertile soil moves with runoff. In agricultural catchments, the degradation is caused due to excessive addition of fertilizers and non-biodegradable pesticides and silts due to surface and subsurface runoff.

6.3 Agricultural Activities

Increased population and advanced civilization have reduced vast stretches of wetlands, lakes, and floodplains of rivers and converted them into paddy fields with substantially increased in their spatial extent in India [14]. Due to easy access of water, the rich Gangetic floodplains are known highly rich cultivated regions all over the world. About 34,000 ha in Kolleru lake have been lost in Andhra Pradesh due to transformation of natural wetlands into agricultural land. Due to increased agricultural activities to support large number of population, excessive synthetic fertilizers are being used last few years which move with surface run off in wetlands and nearby water resources and caused enrichment of lake (Eutrophication) [4, 33]. In last twenty years, the irrigated land has been increased by 1506 km^2, showing approximately 50% increase in the area [3]. In last few decades, increasing water demand to irrigate crops in water deficient regions has been increased considerably leading to large number of canals, dams, and reservoirs construction resulting in advanced irrigation pattern and altered wetland hydrology in India. Hydrology of the wetland is significantly altered due to construction of a large number of reservoirs, dams, and canal in water scare regions. In certain extent, construction of reservoirs, dams, and canals increased economic prosperity of nation by converting wetlands and mangrove forests into pisciculture and aquaculture ponds instead their altered physiological and ecological characteristics.

6.4 Hydrologic Activities

Diversion of streams and rivers flow by constructing dams and reservoirs for water transportation to downstream arid zones for irrigation has changed the direction of water flow and drainage pattern which have substantially degraded the wetlands of that particular region. For example, in Gujarat, water drain from western Himalayan mountains in Satluj river is diverted via canal system to the dry zones of the state along with the neighboring state Rajasthan for providing water for irrigation to cash crops which have altered in the physicochemical characteristics of the soil and created various ecological problems like invasion of alien plant species, salinization, water scarcity in regional zones, and elimination of culturally sustainable life styles. Change in hydrological regime caused by human interference has resulted in changes in natural drainage [18]. Natural drainage of water bodies has also altered due to many anthropogenic activities in their catchment areas. Due to isolation of rivers and lakes from their flood plain zones lead to lower in water tables, decreased groundwater recharge and also increased human activities in flood plain zones caused increased flooding potential in lower zones due to faster flood water drainage. Migratory birds which usually visit to Bharatpur bird sanctuary have to force for alternate water bodies, e.g., Bhindawas Bird Sanctuary for nesting and breeding [20]. Moreover, change in structural, functional characteristics, and value of wetlands has transformed hydrology in urban and rural regions.

6.5 Change in Land Use Cover

Changed land use pattern has resulted in degradation of wetlands [8, 37] and decreased availability and production of a variety of valuable resources like fuel, fodder, fishes, medicine, honey, shell fish, and various chemicals. Along with this economic harm, a number of problems related to changes in land use have also been accelerated like accumulation of silt in bottom water bodies, soil erosion, and water pollution with unwanted wastes. Excessive and over withdrawal of ground water has decreased the water table level by 1.5 to 2.0 m making the situation worse in most of the regions. Change in hydrological conditions further resulted in increased soil erosion which eliminated a number of wetlands in directly in urban regions by filling them. Excessive ground water withdrawal has further raised the problems of soil salinity with reduced crop production which significantly accelerated the economic loss to the nation.

6.6 Deforestation

Major changes in water quality and quantity were observed in last few decades mainly due to deforestation. The rate of degradation of wetlands was noticed faster and larger as compared to forests. Removal of large number of plants and trees in the catchment area leads to removal of fertile soil and soil deposition over bottom surface of various water bodies. Mangroves, special type of wetlands, are being replaced to obtain farming lands and formation of fish ponds for rearing fishes, are significantly affecting their ecological properties. Mangrove forests are valued for their direct and indirect uses [2]. Altered land use pattern and advanced pisciculture have substituted large mangrove region into agricultural land and affected hydrology of wetlands.

6.7 Pollution

Only one-third of the total domestic wastewater generated from urban areas in India is treated and rest untreated is disposed in various natural and man-made water reservoirs affecting their water quality. River Yamuna passes through six big cities and a huge amount of untreated sewage and industrial waste is dumped daily in this river. A large proportion of untreated sewage and wastewater from metro city, Delhi, alone is discharged into Yamuna river which constitutes 78 percent of the total pollution load that flows every day in the river. Also, Bellandur lake in Bengaluru is also facing the problem related to industrial effluents discharged from nearby industries leading to increased problems of eutrophication in lake [33]. Excessive accumulation of nutrients in lakes has polluted freshwater by decreasing oxygen content and created nuisance and make them dead after some time [42]. Point source (emanating from an identifiable source like sewage and industrial effluent) and non-point sources (emanating from a diffuse source like agriculture and urban areas) are two main prominent sources for wetland pollution. A number of lakes and wetlands have lost due to improper and excessive use of their resources without their conservation [45].

6.8 Invasive Species

Introduction of invasive or alien species has threatened many of Indian wetlands by clogging water ways and fast uptake of nutrients in comparison to their native Indian species. Water hyacinth and salvinia are examples of mostly invaded exotic plant species. Due to changed habitats, these invasive plants species grow fast over native plants. Due to fast uptake of nutrients by exotic species, wetlands have lost a large number of native species of animals and plants. In late 1960, the problem of weed infestation in India has raised with free floating species of salvinia in Kakki reservoir of Kerala.

6.9 Climate Change

In reports of UNESCO [48] it was stated that climate change is expected to become main driver causing drastic change and loss in wetland ecosystems. Due to change in climatic conditions, water level has risen in Tsomoriri lake in Laddakh, due to which important breeding islands of various endangered migratory birds species would be submerged leading to their extinction. It was estimated that 1 m rise in sea water due to climate change will disappear coastal and saline wetlands with 84% and 13%, respectively. A number of climatic conditions, viz. change in rainfall pattern,fluctuated storms frequency; increased air temperature; unexpected droughts, and floods; excessive greenhouse gases (CO_2, CH_4, CFCs, etc.) concentration; and sea level rise, have also affected the ecological functioning of wetlands. Climate change acts both, boon and curse for wetlands. Paddy fields are also a type of wetlands and a large source of methane, a green house gas causing global warming. Rapidly increasing population in India has caused change in the landscape and topography, which is continuously affecting the water and wetland resources and making the regions less habitable by humans, animals.

7 Ramsar Sites in India

The Ramsar Convention is an intergovernmental treaty including 171 contracting parties. The main objective of convention is conservation and sustainable use of all wetlands at local, regional, and national level [36] and advice various contracting parties to produce wetland inventories, to adopt various wetland policies, to conduct research and monitoring within wetland areas. 2323 wetland sites were described in Ramsar list contributing over 248 million hectares throughout the world with their International importance. In 1981, India became signatory to the Ramsar Convention, mainly on the Waterfowl Habitat. Chilika lagoon and Keoladeo National Park in Orissa and Rajasthan states were designated first two Ramsar sites in India in 1981 significantly based on waterfowl habitats. In 2012, total 26 wetlands have been designated as Ramsar sites in India with maximum number in 2002. As India has various types of wetlands depending on their size, area, and importance, there are some criteria of selection of sites for Ramsar designation. India has 27 sites designated as Wetlands of International Importance (Ramsar Sites), with a surface area of 689, 131 ha in 2019. But on January 28, 2020, Ramsar Convention declared ten more new wetland sites, Nandur Madhameshwar of Maharashtra, Keshopur-Miani, Beas Conservation Reserve and Nangal from Punjab**,** and Nawabganj, Parvati Agra, Saman, Samaspur, Sandi, and Sarsai Nawar are from Uttar Pradesh as sites of national importance from India with surface area of 1,067,939 ha.

8 Conservation of Wetlands

Conservation is management of resources to maximize efficiency of use, minimize wastage and preservation for future. In India efforts to conserve wetlands had begun in 1987 and still various attempts are being done for wetland protection and conservation with the government's help using biological methods instead of engineering methods. It was observed that initiation of national wetland-mapping project provided an integrated approach on conservation. Various national committees were constituted for recommending the government regarding implementation of appropriate policies and management plans for conservation of wetlands, mangroves, and coral reefs. Steering committees should be set in each state including representatives from various government and non-government departments, research institutions, and universities for successful execution of these policies.

8.1 Ramsar Convention

The Ramsar convention is named after the name of city Ramsar in Iran where the convention was ratified in 1971. Main aim of the convention was to aware nations for conservation and wise use of wetlands without affecting its quality and quantity. India is also signatory to the Ramsar convention. Presently, India has 37 sites designated as Wetlands of International Importance (Ramsar sites).

8.2 National Wetland Conservation Programme (NWCP)

National Wetland Conservation Programme was implemented in 1985. The main aim of the plan is to set effective policies and guidelines for conservation and management of wetlands in the country to avoid their loss and deterioration. Several lakes were covered under this program. 115 wetlands were identified from 24 states and 2 union territories of India for their conservation and management. But due to differences noticed in implementing activities needed for conservation of wetlands and lakes, a distinct National Lake Conservation Plan was started for restoration and conservation of urban and suburban lakes degraded by man-made activities. According to Ministry of Environment and Forests [29], under this plan, only 10 lakes were recognized initially for their conservation and management.

8.3 The Central Wetlands (Conservation and Management) Rules

They were introduced in 2010 for effective management and preservation of wetlands across the country. According to new rules in 2017, state government has authority to keep an eye on prohibited activities in wetland areas along with their identification and notification.

8.4 National Environment Policy 2006

National Environment Policy, 2006, first time noticed the wetlands degradation due to various anthropogenic and natural factors and no proper legislative system for conservation of wetland were regulated in the country. So it was highly recommended to enforce legal system for identification and management of valuable wetlands, to avoid their further degradation and increase their restoration [28]. Further, the policy advocated in developing a national inventory of such wetlands implemented a wide spectrum of policies and plans for wetland conservation and their environmental impact assessment (EIA). Central government notified the Wetlands (Conservation and Management) Rules, 2010 based on the directives of National Environment Policy, 2006 and recommendations made by National Forest Commission and under the chairmanship of Secretary, Environment and Forest, Central Wetlands Regulatory Authority (CWRA) has been constituted. Besides this, for examining management action plans of newly identified wetlands, an Expert Group on Wetlands (EGOW) has also been constituted. The rules put restrictions on the activities such as reclamation, setting up industries in vicinity, discharge of untreated effluents, manufacture or storage of hazardous substances, any permanent construction, and solid waste dumping within the wetlands.

8.5 National Plan for Conservation of Aquatic Ecosystems (NPCA)

NPCA plan was initiated for both wetlands and lakes and implemented in 2015 by merging National Wetlands Conservation Programme (NWCP) and the National Lake Conservation Plan (NLCP). This plan was sponsored by center. Its main objective is to provide strong policy framework to State Governments for their effective management.

8.6 Education and Capacity Building

The meaning of capacity building is increase in knowledge, skills and attitudes of people and their development at individual, organizational, and institutional level. Ministry of Environment and Forests has noticed that proper trained manpower in different fields, viz. research institutions, economic and social administrative is required for effective management and conservation of wetlands. Conservation of rivers and lake is a multidisciplinary course, sponsored by MoEF, at Indian Institute of Technology, Roorkee, with various coordinating departments like hydrology, civil engineering, and management, for capacity building of state, local, and central government officers for conservation of water bodies and their ecology.

8.7 Legal and Regulatory Framework

In India, a number of policy and legislative measures (Table 8) influenced wetland conservation directly or indirectly.

Provisions under these acts/stringent laws include conservation, restoration of ecologically sensitive regions along with protection of water quality and increasing the biodiversity of flora and fauna in various environmental ecosystems (terrestrial and aquatic) of country.

Table 8 Indian legal and regulatory framework

Sr. No.	Legal framework/stringent law	Year
1	National Policy And Macro level Action Strategy on Biodiversity	1999
2	National Conservation Strategy and Policy Statement on Environment and Development	1992
3	Wildlife (Protection) Amendment Act	1991
4	Coastal Zone Regulation Notification	1991
5	Environmental (Protection) Act	1986
6	Forest (Conservation act)	1980
7	Maritime Zone of India (Regulation and fishing by foreign vessels) Act	1980
8	Water (Prevention and Control of Pollution) Act	1977
9	Territorial Water, Continental Shelf, Exclusive Economic Zone and other Marine Zones Act	1976
10	Water (Prevention and Control of Pollution) Act	1974
11	Wildlife (Protection) Act	1972
12	The Indian Forest Act	1927

9 Conclusion

The present study concludes that the wetlands are backbone of economy and human society as these ecosystems provides a large extent of services to mankind and help in keeping ecological balance with human needs. But now current status of wetlands is matter of concern that must be discussed, understood, and acted upon to ensure their protection, restoration, and conservation. For this, an integrated approach in terms of planning, execution, and monitoring of various wetland regions should be practiced along with effective collaboration with, experts in hydrologist, watershed management, ecologist, economist, planners, and decision makers for their proper management of resources as well as efficient and sustainable use. Awareness for wetland restoration and their conservation at local level is prerequisite condition. Public awareness by educational programs about the wetland importance in rural areas, colleges, schools, and among local people should be practiced to spread awareness about importance of wetlands and their need for conservation. Present study also stated that the various conservation and management plans practiced by government so far, for large National and Ramsar sites, were resulted likely to be ineffective and unrealistic to meet the desired goals. Small wetlands were totally neglected under these government conservation plans. So a common whole of government policy should be exercised for conservation of both, large as well as small wetlands by decentralizing power of center to states along with district too. Only proper care and efficient management of wetlands can ensure its sustainability otherwise continued mismanagement and depletion of the same will dead to crisis for life on this planet.

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