Chapter 1
Restoration, Construction, and Conservation of Degrading Wetlands: A Step Toward Sustainable Management Practices

Ibha Suhani, Monika, Barkha Vaish, Pooja Singh, and Rajeev Pratap Singh

Abstract In the current scenario, the world is facing various water-related issues, for instance, water shortage, degradation of water resources, pollution of aquatic systems, and proliferation of waterborne diseases. Moreover, the condition is getting worse in the developing economies because of the integrated effect of anthropogenic activities, escalating demand of resources, and the population explosion. In various developed countries, traditional centralized sewage treatment systems were used for combating water pollution. With the advancement of technologies, wastewater treatment (WWT) systems like activated sludge process, membrane separation, membrane bioreactors, etc. are being employed for treatment of water pollution. However, these expensive systems are not feasible enough for the widespread application along with they are not capable to treat water according to WWT standards. Thus, it is imperative to shift toward the natural way of water purification. In order to meet this demand, protection, restoration, and sustainable use of natural wetlands are essential because of being big reservoir of water on the earth. The present chapter comprehensively describes the importance of natural and artificial wetland (constructed wetland) for human beings toward achieving sustainable environment in a simple, manageable, and cost-effective way.

Keywords Wetland · Wastewater · Constructed wetland · Sustainability · Restoration

---

I. Suhani · Monika · B. Vaish · R. P. Singh (✉)
Department of Environment and Sustainable Development, Institute of Environment and Sustainable Development (IESD), Banaras Hindu University (BHU), Varanasi, India

P. Singh
Department of Science, Institute of Computer Science and Technology, SHEPA, Varanasi, India

A. K. Upadhyay et al. (eds.), *Restoration of Wetland Ecosystem: A Trajectory Towards a Sustainable Environment*,
https://doi.org/10.1007/978-981-13-7665-8_1

1 Introduction

Wetlands are described as “the lands of transition zone between aquatic and terrestrial ecosystems where the land is covered by shallow water” (Mitsch and Gosselink 1986). The worldwide intergovernmental treaty on wetlands signed at Ramsar, Iran, in 1971 includes marsh, fen, bog, peatland or flowing water, static water, and fresh, salty, or brackish water whether artificial or natural areas of marine water (the depth should be maximum 6 m at low tide) into the wetland (Bowman 2002). However, in the Ramsar Convention, paddy fields, river channels, and anthropogenic water bodies are not comprised in wetland. As wetlands have zoological, ecological, botanical, hydrological, and limnological importance, they are categorized as “wetlands of international importance” underneath the Ramsar Convention (Frazier 1999). The Ramsar Convention published an international report in 2013 in the Economics of Ecosystem and Biodiversity for Water and Wetlands, which emphasizes on the need of shifting our attitude toward wetland. The Ministry of Environment, Forest and Climate Change (MoEFCC) in the notification on 26th September, 2017, has described wetlands as vital bodies of the ecosystems which support abundant biodiversity and help in hydrological cycle. Wetlands provide a broad spectrum of services and resources to the community, such as flood mitigation, water storage and purification, aesthetic enrichment of landscapes, microclimate regulation, and cultural and social activities, for recreational prospects and supporting cultural heritage (Clarkson et al. 2013).

Currently, wetlands are shrinking due to urbanization, population growth, climate change, and land use alteration (Davis and Froend 1999; Ferrati and Canziani 2005; Sebastiá-Frasquet et al. 2014). This might stimulate the qualitative and quantitative characteristics of wetland ecosystems’ functions and services (Erwin 2009). Generally, wetlands are mainly influenced by the social (anthropogenic) pressures such as wastewater discharge, runoff from agriculture, and groundwater depletion by abstraction of groundwater for the utilization of urban water supply and other agricultural practices (Konikow and Kendy 2005). The majority of research has agreed that there is urgency for coordination in an attempt to restore, protect, and manage the wetland ecosystems (Hansson et al. 2005). To find the way for maintaining the sustenance of wetland and the nature, numerous authorities from governmental and nongovernmental levels should coordinate by forming policies and frameworks. In both, the developed and developing nations, various frameworks, policies, and regulations should be implemented to check the degradation of wetland.

1.1 Wetland Type (Ramsar Convention)

Under the umbrella of the Ramsar Convention, wetland types have been defined to aid sharp recognition of the wetland habitats that correspond to every Ramsar site (Table 1.1). Different codes have used to define wetland types. Ramsar sites are dependent upon the Ramsar Classification System for Wetland Type as approved by

Table 1.1 Wetland type and their description

Peatland	• Found all over the world are thick water-logged soil layer made up of dead and decaying plant material. • Include moors, mires, peat swamp forests, bogs, and permafrost tundra.
Rivers and Deltas	• Rivers originate as rain on high ground that flows downhill into creeks and streams. • Deltas are found on the lower reaches of rivers, where the flow of water slows down and spreads out into expanses of wetlands and shallow water.
Mangrove forests	• Crossroad where oceans, freshwater, and land meet. • Most complex ecosystems on the planet, growing under environmental conditions that would kill ordinary plants very quickly. • Found in tropical and subtropical regions in tidal areas, which are frequently inundated with salt water.
Wetlands in dry regions	• Characterised by seasonal rainfall. • Wetlands that retain water long after the rest of the landscape has dried out. • Include rivers, swamps, and lakes and springs that dry up for portions of the year
High altitude wetlands	• Store water from rain and glacial melt, feed groundwater stores, trap sediments and recycle nutrients, enhancing both the quantity and quality of water.
Arctic wetlands	• Wetlands are the main ecosystem in the Arctic. These peatlands, rivers, lakes, and shallow bays cover nearly 60% of the total surface area. • Store enormous amounts of greenhouse gases and are critical for global biodiversity. • They are also the main source of livelihoods for local indigenous peoples.
Coastal Wetlands	• Found in the areas between land and open sea that are not influenced by rivers such as shorelines, beaches, mangroves and coral reefs.
Shallow lakes and ponds	• Areas of permanent or semi-permanent water with little flow. • Include vernal ponds, spring pools, salt lakes and volcanic crater lakes. • Small, shallow, intermittently flooded depressions in grasslands or forests, and are often only wet in winter and early spring.
Bogs	• Almost all water in bogs comes from rainfall • These are waterlogged peatlands in old lake basins or depressions in the landscape • Unsuitable for agriculture, forestry or development they offer an undisturbed habitat for a wide range of species.
Marshes and Swamps	• Also known as palustrine wetlands, marshes, swamps and fens account for almost half of all wetlands throughout the world. • Marshes are one of the broadest categories of wetlands and in general harbour the greatest biological diversity.
Estuaries	• Area where rivers meet the sea and water changes from fresh to salt. include deltas, tidal mudflats and salt marshes.

Recommendation 4.7 and amended by Resolutions VI.5 and VII.11 of the Conference of the Contracting Parties (Table 1.2) (Plans et al. 2009).

2 Wetlands of India

The wetland of India has been categorized into following types (Prasad et al. 2002).

2.1 Himalayan Wetlands

This type of wetlands includes the parts of Central Himalayas, Eastern Himalayas, Ladakh, and Zanskar (Pangong Tso, Chantau, Tso Moriri, Noorichan, Hanley, and Chushul marshes) and few portions of Kashmir Valley (Dal, Anchar, Haigam, Kranchu, Malgam, Wular, and Haukersar lakes).

Table 1.2 Classification of wetlands

Marine/Coastal Wetlands

A	B	C	D	E
• Permanent shallow marine waters in most cases less than six metres deep at low tide; includes sea bays and straits.	• Marine sub-tidal aquatic beds; includes kelp beds, sea-grass beds, and tropical marine meadows.	• Coral Reefs	• Rocky marine shores; includes rocky offshore islands, sea cliffs.	• Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks.

F	G	H	I	J	K	Zk(a)
• Estuarine waters; permanent water of estuaries and estuarine systems of deltas.	• Intertidal mud, sand or salt flats	• Intertidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal brackish and freshwater marshes.	• Intertidal forested wetlands; includes mangrove swamps, nipah swamps and tidal freshwater swamp forests.	• Coastal brackish/saline lagoons; brackish to saline lagoons with at least one relatively narrow connection to the sea.	• Coastal freshwater lagoons; includes freshwater delta lagoons.	• Karst and other subterranean hydrological systems, marine/coastal

Inland Wetlands

L	M	N	O	P
• Permanent inland deltas	• Permanent rivers/streams/creeks; includes waterfalls.	• Seasonal/ intermittent / irregular rivers/streams/creeks.	• Permanent freshwater lakes (over 8 ha); includes large oxbow lakes.	• Seasonal/intermittent freshwater lakes (over 8 ha); includes floodplain lakes.

Q	R	Sp	Ss	Tp
• Permanent saline/brackish/alkaline lakes.	• Seasonal/intermittent saline/brackish/alkaline lakes and flats.	• Permanent saline/brackish/alkaline marshes/pools.	• Seasonal/intermittent saline/brackish/alkaline marshes/pools.	• Permanent freshwater marshes/pools; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season.

Ts	U	Va	Vt	W
• Seasonal/intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes.	• Non-forested peatlands; includes shrub or open bogs, swamps, fens.	• Alpine wetlands; includes alpine meadows, temporary waters from snowmelt.	• Tundra wetlands; includes tundra pools, temporary waters from snowmelt.	• Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils.

Xf	Xp	Y	Zg	Zk(b)
• Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils.	• Forested peatlands; peat swamp forests.	• Freshwater springs; oases.	• Geothermal wetlands	• Karst and other subterranean hydrological systems, inland

Human-made wetlands

1	2	3	4	5
• Aquaculture (e.g., fish/shrimp) ponds	• Ponds; includes farm ponds, stock ponds, small tanks; (generally below 8 ha).	• Irrigated land; includes irrigation channels and rice fields.	• Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture).	• Salt exploitation sites; salt pans, saline, etc.

6	7	8	9	Zk(c)
• Water storage areas; reservoirs/barrages/dams/impoundments (generally over 8 ha).	• Excavations; gravel/brick/clay pits; borrow pits, mining pools.	• Wastewater treatment areas; sewage farms, settling ponds, oxidation basins, etc.	• Canals and drainage channels, ditches.	• Karst and other subterranean hydrological systems, human-made

Adapted from Plans et al. (2009)

"Floodplain" here is used to denote one or more wetland types that might comprise instances from the R, Ss, Ts, W, Xf, and Xp or from other wetland categories. Few examples of floodplain wetlands are shrublands, woodlands, forests, and seasonally inundated grassland (including natural wet meadows). Floodplain wetlands are not listed as a specific wetland type herein

2.2 Indo-Gangetic Wetlands

Through the whole stretch from the river Indus at one end of west to Brahmaputra at the other end of east, there lies the largest wetland system in India called the Indo-Gangetic floodplain. The wetlands of the Indo-Gangetic plains and the Himalayan Terai are included in this type of wetlands.

2.3 Coastal Wetlands

The lagoons, mangroves, and massive intertidal expanses are included in the coastal type of wetlands. These are stretched along the 7500 km coastline in West Bengal, Orissa, Tamil Nadu, Andhra Pradesh, Karnataka, Goa, Kerala, Gujarat, and Maharashtra. This category of wetland includes Andaman and Nicobar Islands, Gulf of Mannar, Lakshadweep, Gulf of Kutch, and Sundarbans of West Bengal.

2.4 Deccan

Several tanks for storing water and numerous trivial and huge reservoirs along with few natural wetlands in nearly each town in the associated region are included in this category of wetland ecosystem (Fig. 1.1).

Fig. 1.1 Different types of wetlands of India (**a**) Indo-Gangetic wetland, (**b**) coastal wetland, (**c**) Himalayan wetland

3 Importance of Wetlands

Wetlands have significant socioeconomic importance like wildlife resource, tourism, energy resource, and water supply. The services and products supported by wetlands are noteworthy. There is a very broad spectrum of services and resources provided by wetlands to humans (Engelhardt and Ritchie 2001). They provide shelter, food, shellfish, livestock fodder, fish and fuel wood, medicinal plants, building materials, honey, beeswax, etc. Straightforwardly or circumstantially wetlands support people by their different functions and values. The biological, environmental, and fiscal values of wetlands are of great importance, which are directly affected by humans. Several valuable operations/services carried out by wetlands are as follows.

3.1 Water Quality

Wetlands have a very dynamic role in storing water and improving the quality of water (Clarkson et al. 2013). They purify water, revive groundwater, and also control the frequency of runoff in urban areas. Many plants growing in wetlands act as filters by doing the cleansing role for the downstream environment (Engelhardt and Ritchie 2002). So, wetlands are regarded as the kidneys of the ecosystem (Mitsch and Gosselink 1986).

3.2 Flood Control

Wetlands help in attenuating flood and decreasing the effect of flood. They maintain the groundwater levels all through the low rainfall periods (Roulet 1990). Riverbanks and shorelines are well stabilized by wetlands of that area. They play a vigorous role in checking coastal erosion by buffering the shorelines against erosion, besides also helping in alleviating the effect of natural disasters by absorbing the tidal forces (Wondie 2010).

3.3 Wildlife Habitat

As every wetland is unique in their climatic and topographic conditions, they have specific environmental conditions which provide vulnerable and endangered communities (Brinson and Malvárez 2002). They are the areas of great importance from the perspective of wildlife habitat as they have no less wildlife species than a forest habitat.

3.4 Recreation, Education, and Resources

As wetlands are the landscapes which add beauty in nature, they provide bird watching, recreational activities of fishing, boating, etc. They play a foremost part in tourism for the recreation of society, for habitat, and for supporting cultural heritage (Clarkson et al. 2013). From the perspective of education, wetlands are interesting environmental resource of carbon sequestration, disaster management, nutrient removal, biodiversity maintenance, and toxic retention (Zedler and Kercher 2005).

4 Growing Threat to Wetland Ecosystem

As wetlands are often depicted as kidneys of the landscape, this directly means it helps in biodiversity maintenance (Mitsch and Gosselink 1986). The change in the physicochemical properties of wetland mainly relies on the climate condition, nutrient availability, and topographic and hydrological conditions. The biotic response depends on the physicochemical modifications in the wetland (Gosselink and Turner 1978). From the past few decades, humans have ignored the importance of wetland ecosystems. The rapid population, land use patterns, and demands of resources have led in the degradation of wetlands. Pollution of wetlands by agricultural runoffs and domestic and industrial wastes have headed towards the major destruction to the wetland ecosystems.

Due to urbanization, demand of resources, and land use changes, wetlands are facing major troubles (Boyer and Polasky 2004). The developmental pressure is increasing day by day leading to the degradation of the wetland ecosystems. The urban water supply demand has led to over withdrawal of underground water which causes salinization and reduction in the water table of the region (Prasad et al. 2002). There are considerable ecological, biological, and economical losses due to unplanned developments. Different anthropogenic activities like agriculture, road construction, industries, residential developments, resource extraction, and disposal of wastes are a main cause of long-term losses and ecological disturbances in the wetland ecosystems (Prasad et al. 2002). The agricultural activities like irrigation by construction of dams, canals, and reservoirs have altered the hydrological conditions of the associated wetlands (Russi et al. 2013). The different hydrological activities like diversion of streams and rivers, transport of water to arid regions, changes in the drainage patterns, and construction of canals have led to the significant degradation of wetlands in the associated regions.

Wetlands are also largely affected by deforestation, as it leads in the removal of the topmost layer of the earth leading to soil erosion and siltation problems (Smith et al. 2016; Zhao et al. 2006). Besides, the unrestricted dumping of toxic wastes from industries and sewage has led in the deterioration of physiochemical properties of wetlands, giving rise to eutrophication and destruction of aquatic ecosystem of the related wetland (Russi et al. 2013). Climate change like the change in precipitation patterns, global warming, increased CO_2, increase in the occurrence of storm floods and droughts, and sea level rise could also badly affect the wetland ecosystems (Chen et al. 2003). The plant species like water hyacinth and *Salvinia* has threatened the Indian wetlands, as these species absorb the underground water and also clog the waterways (Prasad et al. 2002).

5 Strategies of Restoration and Conservation

Wetlands are considered as one of the most fertile but endangered ecosystems of the world (Cherry 2012; Maltby 1991). Extensive uses, as well as exponential population growth, have made this ecosystem more deteriorating and vulnerable to environmental changes (Zedler 2003). Anthropogenic pressure (i.e., land use change, inappropriate use of water resources, burgeoning development projects) is the well-known reason of the decline in wetland resources (Ducks Unlimited Canada 2010). In contemporary time, wetlands are modifying continuously for the human needs, and the current wetland's declining rate in India can move toward severe environmental consequences. Around 74% of the rural populations (Anon 1994) are reliant on resources coming from the wetland. Land use conversion from wetland to agricultural, industrial, and various urban development results in substantial losses in the form of hydrological perturbations, pollution, and their effects (Turner et al. 1994). In the context of Indian biodiversity, numerous flora and fauna are reliant on wetlands or their products (Prasad et al. 2002).

To control these problems, restoration practices are not the only options but the ultimate necessity. Along with various biological restoration practices, the practices of natural hydrological conditions of wetlands are able to reconstruct the physicochemical properties like the degree of the substrate, pH, nutrient availability, anoxia, sediment properties, and soil salinity (Prasad et al. 2002). These modifications lead to a change in physicochemical environment, which also promotes to change in biotic feedback in the wetland (Gosselink and Turner 1978). Hydrological conditions in wetlands modify even slightly which can lead toward huge change in response to biota richness, species composition, and ecosystem productivity. There are some restoration methodologies for wetland as described by various authors (Pfadenhauer and Klötzli 1996; Klimkowska et al. 2007):

i. *Fen depth*: Fen depth has been necessary since we assumed that most of the organic material will soon be lost anyway at peat depths of less than 1 m.
ii. *Rewetting potential*: The rewetting potential is chosen as a criterion because one has to be sure that sufficient water is available in the area to allow permanent flooding and the purpose of a wetland as a sink can be restored. Assessment of rewetting potential is specifically important and must include the entire catchment area of the wetland to be restored.
iii. *Presence of suitable target species*: The third major criterion, the occurrence of target species, is more relevant when areas cannot be rewetted sufficiently. In

that case, the existence of characteristic fen or fen meadow species is important for carrying out a more flexible plan, in which several development goals must be pursued simultaneously. It may take some time before the site conditions of the restoration area meet the requirements of the target species.

5.1 Use of GIS and Remote Sensing in Wetland Management

Remote sensing data accomplished with geographic information system (GIS) is a significant tool for wetland restoration and management. The application encloses water resource assessment, flood management, hydrologic modeling, reservoir capacity surveys, water quality mapping and monitoring, and assessment and monitoring of the environmental effects of water resources project (Adam et al. 2010; Jonna 1999).

i. *Water Resource Management*

Abundant of thematic maps on the hydro-geomorphological features, slope, elevation, surface water bodies, and land use are performed by remote sensing and GIS. It has been initiated for the action plan for water source development (Adam et al. 2010; Ozesmi and Bauer 2002). The result may also reveal that the underground potential basin is moderate to good (Rao 1997). Utilization of satellite remote sensing data and aerial photointerpretation impressively support in planning groundwater reconnaissance and help in discovering the sources by recognition of geomorphological units.

ii. *Flood Zonation Mapping*

Satellite data source is utilized for the demarcation of flood-risk zone and flood-inundated regions. Temporal data promote to get correct ground facts about the status of restoration and conservation projects of wetland. IRS 1 C/D WIFS data having 180 km spatial resolution and high temporal consecutiveness has helped in demarcating the zonation of flooding areas of large river bodies. This helps in designing for basin- and state-wise flood inventories.

iii. *Water Quality Analysis and Modeling*

Water quality analysis has been proceeded through using the relationship between chlorophyll-a, reflectance, and suspended solid concentration. Remote sensing data is utilized for the analysis of water quality factors and modeling. In the near-infrared wavelength range, the quantity of suspended solids content is directly proportional to the reflectance. Due to the temporal and spatial resolution of satellite data information of the point of discharge and source of pollution, the inflow of sewage can be regularly examined. By means of IRS LISS-II data, the suspended load in estuarine waters was inspected (Adam et al. 2010; Sasmal and Raju 1996).

There was some program initiated by WWFs for the conservation and restoration of wetland which helps to improve water access, efficiency, and allocation for people and the environment. This program promotes water stewardship, climate change adaptation, and water safety and mainly emphasizes habitat protection. Working with the Ramsar Convention, international river basin, national governments, non-governmental organization, and institutions play a dynamic role for wetlands includes (WWF):

- Assisting execution of international agreements and treaties on biodiversity and wetlands
- Encouraging payments for environmental services (PES) for funding freshwater ecosystem facilities
- Evaluating and growing the representativeness of freshwater habitats in protected area systems
- Forming freshwater conservation setups
- Restoring serious freshwater habitats

5.2 Specific Techniques for Conservation

Wetland restoration technique involves modification in hydric soil condition, hydrophytic plant communities, and hydrologic conditions. Wetland functions that happened on fragmented wetland site before to moderation to the extent operable. Wetland conservation strategies involve restoring endemic, native plant and animal communities (Faulkner et al. 2011). Minimization of soil erosion is the primary reason of the most commonly applied practice, residue management, conservation crop management, no-tillage/strip tillage, conservation cover, afforestation, reduction of land use change, reduction of overgrazing, and increase in vegetative cover and irrigation (Faulkner et al. 2011).

Degradation and depletion of sea grass in a coastal wetland, which is often caused by erosion which leads to eutrophication or dredge-and-fill activities, is commonly restored by transplantation (Burkholder et al. 2007; Fonseca et al. 1994). The suitable place and donor population for replacement should receive more focus on the significant expense (Bastyan and Cambridge 2008). Along with that, seeding techniques and mechanical planting have also been used as a possible solution to restore sea grass loss (Paling et al. 2009; Van Katwijk et al. 2009).

To resolve the complication of degraded wetlands caused by *Spartina alterniflora* invasions in the Yangtze River Delta, some are the examples especially in Chongming Dongtan wetland; methods that involve breaking of rhizomes, cutting, digging and tillage, and waterlogging as well as biological substitution with *Phragmites australis* proved effective (Liu et al. 2013; Yuan et al. 2008).

6 Preparation Needed Before Starting a Restoration Project

Before beginning a restoration project, pre-preparation step should be needed enlisting of this first one: locate the degraded wetland and identify the key indicators to decide the potential of replacement, restoration, and regulation. Along with ecological restoration, elemental method should be acknowledged to estimate the feasibility of conserving the damaged ecological, hydrological, and chemical processes. The social feasibility and ecological rationality should be used to predict and identify the crucial regions and pattern of ecological conservation and restoration (Zhao et al. 2016).

Ecological restoration endeavors are frequent part of an international framework that purposes to achieve local and global restoration targets (such as the Aichi Biodiversity Targets and EU biodiversity targets), for which inhabitants afford the expense (Adams et al. 2010; Kari and Korhonen-Kurki 2013). In literature related to conservation, the idea has been referred to as the “parks versus people” debate, where safeguarding global biodiversity through so-called fortress restoration. This fortress restoration is on one end of the spectrum, and a focus on refining local people is at the other end (Miller et al. 2011; Southworth et al. 2006). To safeguard nature restoration and conservation areas from resource exhaustion of resource are necessary. Because of such limitations, people have been moved or denied access to the resources, frightening their rights and livings (Brockington and Wilkie 2015).

To stimulate support for wetland restoration and foster sustainable use of wetland restore areas, an intended approach is obligatory. Increasing realization of the problem and enhancing awareness can be a needful strategy to promote public sensitization for wetland conservation. Reflecting upon the concept of Festinger (1957), Kollmuss and Agyeman (2002) suggest the proposal that the public may show a conflict against nonconforming information, meaning that “information that boosts our current values and conceptual frameworks is readily acknowledged, whereas information that controverts or excavate our thoughts and beliefs are avoided or not able to recognize at all.” This means that the pros and cons of wetland restoration should be “framed” in ways that reverberate with the people (Groffman et al. 2010).

The public may be empathetic toward the restoration and conservation of wetland and its ecosystem. In reality, when it comes to daily practice and actual environmental behavior, activities that conflict with biodiversity conservation still gain priority (Samantha et al. 2016). This emphasizes the importance of wetland restoration projects to identify trade-offs and collaboration, making them better capable of dealing with both competing and complementary targets (Mitsch and Gooselink 2000). As expressed by McShane et al. (2011), by actively involving with scientists, regional users and environmentalists can raise sensitization for wetland restoration projects, which is expected to enhance the accomplishment of wetland restoration and conservation (Cooke et al. 2013).

7 Constructed Wetland (CW): An Attempt to Optimize Wildlife Conservation and Restoration

Generally, for treating wastewater, constructed and engineered wetlands are designed in such a way to look like natural wetland to remove various contaminants or improve the water quality along with conservation of resources (Vymazal 2013; Saeed and Sun 2012). These systems chiefly encompass substrates, vegetation, water, soil, and microorganisms (Badhe et al. 2014). They employ complex processes involving physicochemical and biological mechanisms (Upadhyay et al. 2016). It has been noticed since long that the CW treat a variety of wastewater with the help of plants and microbes. On the basis of macrophytes present in the wetland, it can be categorized as under (Brix 1993):

1. Free-floating macrophyte-based systems: In this type of CW, free-floating plants remove the pollutants which are present in dissolved form (Upadhyay et al. 2016).
2. Emergent macrophyte-based systems: This system plays a critical role as the rhizomes of the plant produce suitable required environment for nutrient removal process (Hofmann 1991). The rhizome helps in bacterial growth by providing surface for filtration of solids. The aerenchymatous rhizomes supply oxygen and create oxidized microenvironment in anoxic soil that subsequently increases decomposition of organic matter and nitrification.
3. Submerged macrophyte-based systems: These systems are less suited for the treatment of raw sewage and therefore utilized as tertiary treatment step for improving the effluent quality or treating eutrophic natural water. The species that have been employed for the above purposes are *Ulva lactuca*, *Ceratophyllum* spp., *Elodea canadensis*, *Cladophora* spp., *Myriophyllum* spp., *E. nuttalli*, *Enteromorpha* spp., *Egeria densa*, *Potamogeton* spp., etc.

The designing of CW is based on the flow of water, i.e., vertical flow (VF), horizontal flow (HF), surface flow, and subsurface flow (Ali et al. 2013). The water hydrology and the substrates used in CW (clay, sand, rock, peat, zeolite, gravel, etc.) provide a wider range of habitat for the growth of different types of microorganism like bacteria, fungi, and algae (Cui et al. 2010; Wu et al. 2014). The microorganism growing in the designed CW ultimately degrades the pollutants present in wastewater, thereby releasing large amounts of nitrogen, phosphorus, and other organic and inorganic contaminants. These contaminants were further utilized by plants for their growth and development (Rai et al. 2013). The growth of plants acts as a house of different wildlife animals. The conservation and restoration of wetland through CW can be dealt with the following points:

- CW facilitates the growth of different groups of microorganisms in a single habitable niche.
- CW purifies a variety of wastewater coming from different resources which directly affects the nature of natural wetland.

- The growth of plants may act as nesting sites for birds and other insects.
- CW may recharge groundwater and inhibits soil erosion.
- CW may assist in flood control and vegetation loss and provide shelter to different wildlife animals.

8 Conclusions

In the past few decades, scientists and managers have identified the multiple values and functions of wetlands. Wetlands have generally been called as “kidneys of the landscape” because of their capability to transmute and store organic content. For this reason, various types of constructed wetland are employed to deal with wide range of wastewater all over the world. Many efforts are put into investigation in the advancement and refinement of CW technology. Further researches are needed to optimize design criteria for all sorts of CWs. Also, scientific studies are much needed for the improvement of long-term performance capabilities and operational problems related with the systems.

Acknowledgments The authors are thankful to the Dean and Head, Department of Environment and Sustainable Development, and Director, Institute of Environment and Sustainable Development, Banaras Hindu University, for providing necessary facilities. RPS is thankful to the Department of Science and Technology for providing financial support (DST-SERB P07-678). BV is also thankful to the Council of Scientific and Industrial Research for awarding Senior Research Fellowship.

References

Adam E, Mutanga O, Rugege D (2010) Multispectral and hyperspectral remote sensing for identification and mapping of wetland vegetation: a review. Wetl Ecol Manag 18:281–296

Adams VM, Pressey RL, Naidoo R (2010) Opportunity costs: who really pays for conservation. Biol Conserv 143:439–448

Ali H, Khan E, Sajad MA (2013) Phytoremediation of heavy metals—concepts and applications. Chemosphere 91(7):869–881

Anon (1994) World resources 1994–1995. A report by the world resources institute. Oxford University Press, New York

Badhe N, Saha S, Biswas R, Nandy T (2014) Role of algal biofilm in improving the performance of free surface, up-flow constructed wetland. Bioresour Technol 169:596–604

Bastyan GR, Cambridge ML (2008) Transplantation as a method for restoring the seagrass *Posidonia australis*. Estuar Coast Shelf Sci 79:289–299

Bowman M (2002) The Ramsar Convention on wetlands: has it made a difference. Yearbook of International Co-operation on Environment and Development, pp 61–68

Boyer T, Polasky S (2004) Valuing urban wetlands: a review of non-market valuation studies. Wetlands 24:744–755

Brinson MM, Malvárez AI (2002) Temperate freshwater wetlands: types, status, and threats. Environ Conserv 29:115–133

Brix H (1993) Wastewater treatment in constructed wetlands: system design, removal processes, and treatment performance. In: Moshiri GA (ed) Constructed wetlands for water quality improvement. Lewis Publishers, Boca Raton, pp 9–22
Brockington D, Wilkie D (2015) Protected areas and poverty. Philos Trans R Soc B 370(1681):20140271
Burkholder JM, Tomasko DA, Touchette BW (2007) Seagrasses and eutrophication. J Exp Mar Biol Ecol 350:46–72
Chen KL, Zhang XH, Lu Y (2003) Climate change and wetland. Wetl Sci 1:73–77
Cherry JA (2012) Ecology of wetland ecosystems: water, substrate, and life. Nat Educ Knowl 3:16
Clarkson BR, Ausseil AGE, Gerbeaux P (2013) Wetland ecosystem services. Ecosystem services in New Zealand: conditions and trends. Manaaki Whenua Press, Lincoln, pp 192–202
Cooke GD, Welch EB, Peterson SA (2013) Lake and reservoir restoration. Elsevier
Cui L, Ouyang Y, Lou Q, Yang F, Chen Y, Zhu W, Luo S (2010) Removal of nutrients from wastewater with *Canna indica* L. under different vertical-flow constructed wetland conditions. Ecol Eng 36:1083–1088
Davis JA, Froend R (1999, Jun 1) Loss and degradation of wetlands in southwestern Australia: underlying causes, consequences and solutions. Wetl Ecol Manag 7(1–2):13–23
Ducks Unlimited Canada (2010) Southern Ontario wetland conservation analysis. Report prepared by Ducks Unlimited Canada
Engelhardt KA, Ritchie ME (2001) Effects of macrophyte species richness on wetland ecosystem functioning and services. Nature 411:687
Engelhardt KA, Ritchie ME (2002) The effect of aquatic plant species richness on wetland ecosystem processes. Ecology 83:2911–2924
Erwin KL (2009) Wetlands and global climate change: the role of wetland restoration in a changing world. Wetl Ecol Manag 17:71
Faulkner S et al (2011) Effects of conservation practices on wetland ecosystem services in the Mississippi Alluvial Valley. Ecol Appl 21(sp1):S31–S48
Ferrati R, Canziani GA (2005, Jul 25) An analysis of water level dynamics in Esteros del Ibera wetland. Ecol Model 186(1):17–27
Festinger L (1957) A theory of cognitive dissonance. Stanford University Press
Fonseca MS, Kenworthy WJ, Courtney FX, Hall MO (1994) Seagrass planting in the southeastern United States: methods for accelerating habitat development. Restor Ecol 2:198–212
Frazier S (1999) Ramsar sites overview. Wetlands International, Wageningen
Gosselink JG, Turner RE (1978) The role of hydrology in freshwater wetland ecosystems. In: Good RE, Whigham& DF, Simpson RL (eds) Freshwater wetlands: ecological Processes and management potential. Academic, New York, pp 63–78
Groffman PM, Stylinski C, Nisbet MC, Duarte CM, Jordan R, Burgin A, Previtali MA, Coloso J (2010) Restarting the conversation: challenges at the interface between ecology and society. Front Ecol Environ 8(6):284–291
Hansson LA, Brönmark C, Anders Nilsson P, Åbjörnsson K (2005) Conflicting demands on wetland ecosystem services: nutrient retention, biodiversity or both? Freshw Biol 50(4):705–714
Hofmann K (1991) The role of plants in sub-surfaces flow constructed wetlands. In: Ecological engineering for wastewater treatment. Stensund (Sweden)
Jonna S (1999) Remote sensing applications to water resources: retrospective and Perspective. In: Adiga S (ed) Proceedings of ISRS National symposium on remote sensing applications for natural resources, Dehradun, pp 368–377
Kari S, Korhonen-Kurki K (2013) Framing local outcomes of biodiversity conservation through ecosystem services: a case study from Ranomafana, Madagascar. Ecosyst Serv 3:32–39
Klimkowska A, Van Diggelen R, Bakker JP, Grootjans AP (2007) Wet meadow restoration in Western Europe: a quantitative assessment of the effectiveness of several techniques. Biol Conserv 140(3–4):318–328
Kollmuss A, Agyeman J (2002) Mind the gap: why do people act environmentally and what are the barriers to pro-environmental behavior? Environ Educ Res 8(3):239–260

Konikow LF, Kendy E (2005) Groundwater depletion: a global problem. Hydrogeol J 13(1):317–320
Liu L, Liu Y-h, Liu C-x, Wang Z, Dong J, Zhu G-f, Huang X (2013) Potential effect and accumulation of veterinary antibiotics in *Phragmites australis* under hydroponic conditions. Ecol Eng 53:138–143
Maltby E (1991) Wetland management goals: wise use and conservation. Landsc Urban Plan 20(1–3):9–18
McShane TO, Hirsch PD, Trung TC, Songorwa AN, Kinzig A, Monteferri B, Mutekanga D, Van Thang H, Dammert JL, Pulgar-Vidal M, Welch-Devine M (2011) Hard choices: making trade-offs between biodiversity conservation and human Well-being. Biol Conserv 144(3):966–972
Miller TR, Minteer BA, Malan LC (2011) The new conservation debate: the view from practical ethics. Biol Conserv 144(3):948–957
Mitsch WJ, Gosselink JG (1986) Wetlands. Van Nostrand Reinhold, New York
Mitsch WJ, Gosselink JG (2000) The value of wetlands: importance of scale and landscape setting. Ecol Econom 35(1):25–33
Ozesmi SL, Bauer ME (2002) Satellite remote sensing of wetlands. Wetl Ecol Manag 10(5):381–402
Paling EI, Fonseca M, van Katwijk MM, van Keulen M (2009) Seagrass restoration. Coastal wetlands: an integrated ecosystem approach, pp 687–713
Pfadenhauer J, Klötzli F (1996) Restoration experiments in middle European wet terrestrial ecosystems: an overview. Vegetation 126(1):101–115
Plans S et al (2009) Strategic framework and guidelines for the future development of the list of Wetlands of International Importance of the Convention on Wetlands (Ramsar, Iran, 1971)
Prasad SN, Ramachandra TV, Ahalya N, Sengupta T, Kumar A, Tiwari AK, Vijayan L (2002) Conservation of wetlands of India-a review. Trop Ecol 43(1):173–186
Rai UN, Tripathi RD, Singh NK, Upadhyay AK, Dwivedi S, Shukla MK, Mallick S, Singh SN, Nautiyal CS (2013) Constructed wetland as anecotechnological tool for pollution treatment for conservation of ganga river. Bioresour Technol 1(148):535–541
Rao HVN (1997) Restoration of Ulsoor Lake, Bangalore. In: Proceedings of one – day workshop on lakes for Bangalore water needs – beautification and pollution prevention, Environment Association of Bangalore, pp 20–24
Roulet NT (1990) Hydrology of a headwater basin wetland: groundwater discharge and wetland maintenance. Hydrol Process 4(4):387–400
Russi D, ten Brink P, Farmer A, Badura T, Coates D, Förster J, Kumar R, Davidson N (2013) The economics of ecosystems and biodiversity for water and wetlands. IEEP, London, p 78
Saeed T, Sun G (2012) A review on nitrogen and organics removal mechanisms in subsurface flow constructed wetlands: dependency on environmental parameters, operating conditions and supporting media. J Environ Manag 112:429–448
Samantha SK et al (2016) Public support for wetland restoration: what is the link with ecosystem service values? 36:467–481. https://doi.org/10.1007/s13157-016-0755-6
Sasmal SK, PLN Raju (1996) Monitoring suspended load in estuarine waters of Hooghly with satellite data using PC based GIS environment. In: Proceedings of National symposium on coastal zone management
Sebastiá-Frasquet MT, Altur V, Sanchis JA (2014) Wetland planning: current problems and environmental management proposals at supra-municipal scale (Spanish Mediterranean Coast). Water 6:620–641
Smith P, House JI, Bustamante M, Sobocká J, Harper R, Pan G, West PC, Clark JM, Adhya T, Rumpel C, Paustian K (2016) Global change pressures on soils from land use and management. Global Chan Biol 22:1008–1028
Southworth J, Nagendra H, Munroea Darla K (2006) Introduction to the special issue: are parks working? Exploring human–environment tradeoffs in protected area conservation. Appl Geogr 26(2):87–95
Turner BL, Meyer WB, Skole DL (1994) Global land-use/land-cover change: towards an integrated study. Ambio Stockholm 23(1):91–95

Upadhyay AK, Bankoti NS, Rai UN (2016, Mar 16) Studies on sustainability of simulated constructed wetland system for treatment of urban waste: design and operation. J Environ Manag 169:285–292

Van Katwijk MM, Bos AR, de Jong VN, Hanssen LSAM, Hermus DCR, de Jong DJ (2009) Guidelines for seagrass restoration: the importance of habitat selection and donor population, spreading of risks, and ecosystem engineering effects. Mar Pollut Bull 58:179–188

Vymazal J (2013) The use of hybrid constructed wetlands for wastewater treatment with special attention to nitrogen removal: a review of a recent development. Water Res 47:4795–4811

Wondie A (2010) Improving management of shoreline and riparian wetland ecosystems: the case of Lake Tana catchment. Ecohydrol Hydrobiol 10:123–131

Wu S, Kuschk P, Brix H, Vymazal J, Dong R (2014) Development of constructed wetlands in performance intensifications for wastewater treatment: a nitrogen and organic matter targeted review. Water Res 57:40–55

Yuan L, Zhang LQ, Xiao DR, Zhang J, Wang RZ, Yuan LQ, Gu ZQ, Chen X, Ping Y, Zhu ZC (2008) A demonstration study using the integrated technique of cutting plus waterlogging for the control of *Spartina alterniflora*. Acta Ecol Sin 28:5723–5730

Zedler J (2003) Wetlands at your service: reducing impacts of agriculture at the watershed scale. Front Ecol Environ 1:65–72

Zedler JB, Kercher S (2005) Wetland resources: status, trends, ecosystem services, and restorability. Annu Rev Environ Resour 30:39–74

Zhao S, Peng C, Jiang H, Tian D, Lei X, Zhou X (2006) Land use change in Asia and the ecological consequences. Ecol Res 21:890–896

Zhao Q, Bai J, Huang L, Gu B, Lu Q, Gao Z (2016) A review of methodologies and success indicators for coastal wetland restoration. Ecol Indic 60:442–452