Chapter 14
Nature-Based Solutions for Restoration of Freshwater Ecosystems: Indian Experiences

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Abstract In the wake of rapid environmental degradation including climate change, caused by various human activities, several concepts and approaches such as ecological restoration, ecological engineering, ecohydrology, ecosystem-based adaptation/mitigation, ecosystem-based disaster risk reduction, green infrastructure and ecosystem-based management, have been put forward during the past three decades for managing and restoring the natural and human-made ecosystems. More recently, the International Union for Conservation of Nature (IUCN) developed a new concept of Nature-based Solutions (NbS) which has been promptly promoted by the European Commission, World Bank and the UN-Water, among others. The NbS is projected to differ from the other concepts in its integrative, systemic approach to societal challenges and focus on human well-being and biodiversity benefits. The NbS approach is being applied to a wide range of issues—from agriculture and water resources to climate change as well as urban development. While the term 'NbS' has not yet been officially and formally used in India, many of the projects aimed at restoration and management, especially of freshwater ecosystems, have followed the elements of the NbS concept and approach, at least in some respects. This article briefly discusses the NbS approach in the context of freshwater ecosystems, and presents a few examples of its application to their restoration in India.

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14.1 Introduction

Water is one of the most important natural resources that determine the very existence of life on the planet Earth. It occurs in great abundance but about 97.5% of the total water on the Earth is saline or brackish and resides in the oceans (Shiklomanov 1993). Practically all of the fresh water is held in glaciers, polar ice caps, snow, and below the ground. Less than 0.3% of all freshwater on the Earth that is utilisable by humans for all their needs and is shared by numerous plants, animals and microbes dependent upon it, resides in rivers, lakes and wetlands which together occupy approximately 6% of the Earth's land surface. These freshwater ecosystems along with their enormous biodiversity provide immense valuable ecosystem services. However, various human activities, both on land and in water, severely impinge upon the water quantity, quality and the biodiversity, and in turn affect the ecosystem services of these freshwater ecosystems. It is now necessary to not only prevent further degradation but also to restore these ecosystems through various kinds on interventions. A variety of interventions, mostly based on engineering and grey infrastructure have been employed for the reduction and mitigation of the adverse impacts and as far as possible restoration of the ecosystems. It is in this context that the nature-based solutions are now proposed for meeting the objectives.

In this article, the emerging concept of Nature-based Solutions (NbS) are briefly examined together with its application to fresh water resources management and the state of degradation of freshwater ecosystems in India described. Then, the Indian experience with the restoration of rivers, lakes and wetlands using the principles and approaches relevant to NbS, discussed. It may be noted that the NbS is starting to appear in official or academic circles, but similar approaches developed in the past had been employed in India in many cases for mitigating environmental problems.

14.2 Nature-Based Solutions

During the past few years, various new concepts and approaches have been proposed that attempt to bring together several emerging ideas and extend them to a variety of natural and human-made ecosystems for their management. Some of them include ecological restoration, ecological engineering, ecohydrology, ecosystem-based adaptation/mitigation, ecosystem-based disaster risk reduction, green infrastructure and ecosystem-based management. These concepts and approaches emphasise upon the need to understand the structure and functioning of natural ecosystems, and how the human activities disrupt them with consequent impacts for humans themselves. They also stress upon the need for restoration activities that can lead to return to the earlier natural or near-natural state of the ecosystems.

The IUCN introduced the concept of Nature-based Solutions in its position paper to the United Nations Framework Convention on Climate Change (UNFCCC), (IUCN 2009), and promoted the concept by adopting it for its Programme for the period 2013–2016 that envisages ecosystem-based development and conservation using nature-based solutions for achieving the sustainable development goals (IUCN 2013). The IUCN defined it as, '*actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits*' (Cohen-Shacham et al. 2016). The concept soon found its way into policy and has been vigorously followed by the European Commission (2015) which states: '*Nature-based solutions aim to help societies address a variety of environmental, social and economic challenges in sustainable ways. They are actions inspired by, supported by or copied from nature; both using and enhancing existing solutions to challenges, as well as exploring more novel solutions, for example, mimicking how non-human organisms and communities cope with environmental extremes*' (see also, Maes and Jacobs 2015).

Although the concept of nature-based solution is still being debated and developed (Potschin et al. 2016), it has found wide support for application to a wide range of issues such as flood control, urban development and disaster risk management. As per Potschin et al., 'The term NbS first entered the mainstream scientific literature in early 2000s, in the context of solutions to agricultural problems-including Integrated Pest Management, Use of habitats to mitigate farm runoffs etc.' From mid 2000s, the concept also started appearing in works of industrial design and biomimicry and later from 2009, it was being related to methods for enhancing ecosystem resilience or adaptations. Eggermont et al. (2015) consider the nature-based solutions as the sustainable use of nature in solving societal challenges, Nesshöver et al. (2017) find in the NbS, an opportunity for: (a) transdisciplinary research into the design and implementation of solutions based on nature; and (b) overcoming a bias towards development alternatives with narrow perspectives that focus on short-term economic gains and effectiveness. Nesshöver et al. (2017) also state that the strength of the NbS concept lies in its integrative, systemic approach which prevents it from becoming just another 'green communication tool that provides justification for a classical model of natural resource exploitation and management measures'. Interestingly, a recent IIED Brief (2019; http://pubs.iied.org/17725IIED) on Nature based solutions to Climate Change adaptation, discusses only the Ecosystem-based adaptation (EbA), treating them as synonymous.

Very recently, Cohen-Shacham et al. (2019) have critically analyzed the strengths and weaknesses of the NbS comparing it with four other ecosystem-based approaches. They identified three distinguishing principles of NbS:

1. The NbS can be implemented alone or in an integrated manner with other solutions to societal challenges;
2. The NbS are applied at a landscape scale; and
3. NbS are an integral part of the overall design of policies, and measures or actions, to address a specific challenge.

However, they also recognised that several concepts of other frameworks such as adaptive management/governance, effectiveness, uncertainty, multi-stakeholder participation, and temporal scale are not captured in the NbS principles. IUCN drafted global NbS standards and put on for global consultation in September, 2019 (https://www.iucn.org/news/ecosystem-management/201908/17th-september-have-your-say-iucn-global-standard-nature-based-solutions). The public consultation has now closed and IUCN plans to release these standards in it next World Conservation Congress (WCC) being held in Marseille, France in June, 2020.

14.2.1 NbS Typology

Eggermont et al. (2015) proposed a typology for the NbS, based on the nature and extent of interventions, and recognised three types as:

Type 1. None or minimal intervention in ecosystems. This type maintains/improves delivery of ecosystem services of preserved ecosystems. It incorporates areas where people live and work in a sustainable way including nature conservation and national parks.

Type 2. Partial interventions in ecosystems. This type develops sustainable and multi-functional ecosystems and landscapes that improve delivery of selected ecosystem services. It is strongly connected to benefitting from natural systems agriculture and conserving the agro-ecology.

Type 3. Inclusive intervention in ecosystems. This type manages ecosystems in intrusive ways and includes full restoration of degraded or polluted areas using grey infrastructures.

14.2.2 NbS and Water Resources Management

Haase (2015) observed that NbS can help to tackle three water-related problems: flood risk, water scarcity and water quality, for example through using or mimicking the natural processes of infiltration, evapotranspiration and phytoremediation. Recently, the UN World Water Assessment Programme has also lent its support to the nature-based solutions by stating that the '*NbS are inspired and supported by nature and use, or mimic, natural processes to contribute to the improved management of water. The defining feature of an NbS is, therefore, not whether an ecosystem used is "natural" but whether natural processes are being proactively managed to achieve a water-related objective*' (WWAP/UN Water 2018).

The World Water Development Report (WWAP/UN Water 2018) has discussed three areas of application of NbS in relation to water: (a) management of water availability, (b) management of water quality and (c) management of water-related risks. Natural ecosystems offer solutions for water storage along with other attendant ecosystem services (such as groundwater recharge). An important function of natural watersheds is to regulate the fate of precipitation by influencing its partitioning. Delayed and gradual runoff ensures prolonged availability downstream and prevents water-related hazards (flood and drought). The most significant of all functions of natural ecosystems is the maintenance/improvement or regulation of water quality in which the biota—from microbes to algae, plants and fish play a major role. Another important aspect related to NbS is the use of organisms in the assessment and monitoring of water quality. The Report also states that the 'NbS can involve conserving or rehabilitating natural ecosystems and/or the enhancement or creation of natural processes in modified or artificial ecosystems. They can be applied at micro-or macro-scales'.

14.2.3 Advantages of Nature-Based Approach

With particular respect to water resources management, NbS offer several advantages that include (see Liquete et al. 2016, WWAP-UN Water 2018):

- Costs of implementation and maintenance are comparable or much lower than any engineering solution that involves elaborate construction and demands energy.
- Improved water quality can be assured at all times.
- There is better flexibility and adaptability to changing environmental pressures.
- These are more effective in tackling non-point sources of pollution.

Liquete et al. (2016) also concluded that green infrastructure performs equal or even better than the grey infrastructure alternative for water purification and flood protection, it has a similar cost, and it provides additional benefits (like wildlife support and recreation).

14.3 Degradation of Freshwater Ecosystems in India

Most of the freshwater ecosystems in India—rivers, streams, natural and man-made lakes and wetlands—are in different states of degradation. Deterioration of water quality due to organic pollution from disposal of domestic wastewater and other solid wastes is the most serious and widespread problem. Water quality deterioration is manifested in two forms: depletion of dissolved oxygen and enrichment with nutrients, high organic matter content (dissolved or particulate) in the wastewater causes turbidity and coloration of water, and its high biochemical oxygen demand (BOD) rapidly depletes the dissolved oxygen. Further chemical processes in the absence of oxygen result in the release and accumulation of harmful substances. Nutrients which enter the water bodies along with the runoff from the catchments, including urbanised catchments, cause eutrophication that leads to unsightly and often toxic algal growth, with consequent impacts on aquatic biota (Ryding and Rast 1989; Hutzinger et al. 2015).

Both mineral and organic matter are carried with the runoff from catchments where erosion occurs due to a variety of anthropogenic activities, making siltation a serious problem in all reservoirs and lakes. Himalayan rivers are known for their sediment load which contributed to the development of fertile floodplains and productive deltas but are now getting rapidly accumulated behind the dams, thereby affecting the reservoirs adversely. Whereas in rural areas, agriculture and overgrazing in the close vicinity of water bodies are important factors contributing to siltation, in the urban areas storm runoff carries with it all silt and solid wastes to the water bodies.

River ecosystems in India are degraded largely by the discharge of untreated or partly treated domestic sewage, industrial effluents and storm water from urban areas. However, they are getting increasingly impacted by the reduction in the extent of their floodplains (by embankments and urban encroachments) and agrochemical-based intensive cultivation on the remaining floodplains. The rivers are further degraded due to flow diversion and abstraction upstream that significantly lowers or eliminates their waste-assimilation capacity (Gopal and Vass 2013).

Invasive aquatic weeds, particularly exotic species such as water hyacinth, are among other drivers of rapid degradation, especially in lakes and reservoirs. They accelerate siltation as well as degradation of water quality. Amongst the other factors adversely affecting the freshwater ecosystems, mention must also be made of in-lake/in-stream activities such as washing, idol immersion, and disposal of religious offerings. Further, there is widespread shoreline modification through removal of natural vegetation, and disposal of solid wastes, usually followed by concretisation in name of lake beautification, river front development and recreational facilities, particularly in urban areas.

14.3.1 Impacts of Degradation

The degradation of aquatic bodies, especially lakes and wetlands, has both direct and indirect consequences for humans. The reduction or loss of various functions of lake ecosystems directly affects humans. For example, the reduction in area and depth by siltation affects the amount of water stored and the groundwater recharge. Recent flood events (September 2019) in and around Hyderabad were found to be the direct consequence of loss of natural water bodies in the drainage basin. Loss of riparian vegetation both along the river banks and lake shores not only causes loss of biodiversity but results in accelerated erosion and siltation, as well as unchecked entry of pollutants from the surrounding areas into the water body. Degradation of water quality affects drinking water supplies, human health and recreational use. The loss of fisheries and other biota due to eutrophication or toxic pollution have both direct and indirect social, cultural and economic impacts. Another impact of lake degradation is the decline in tourism which provides sustenance to numerous people (Gopal et al. 2010).

14.3.2 Restoration of Freshwater Ecosystems

During the middle of the past century, great concern for the rapid degradation of water quality, exemplified by the development of toxic algal blooms (eutrophication) emerged from a view point of recreational use of large lakes. In developing countries, the water quality concerns centred largely around domestic use of water. It is only during the past three decades that the multiple benefits or ecosystem services of the freshwater ecosystems are being realised along with the need for their restoration/rehabilitation. Initially, most of the efforts aimed at restoration of water bodies focussed largely upon engineering-oriented solutions that did not consider the water bodies as 'ecosystems'. More holistic, ecosystem-based approaches to restoration of degraded freshwater ecosystems however, emerged towards the end of the last century.

14.4 Indian Experiences

Long before the concept of NbS was formulated and promoted, its elements were well recognised and practised in India as also in many other countries (MOEF 2008). These elements of NbS also found support and acceptance in good measure by the policy makers. Recognising the threats that anthropogenic and non-anthropogenic drivers and pressures pose on aquatic ecosystems, the Govt. of India through the Ministry of Environment & Forests had been implementing 'Conservation Programs for Wetlands & Lakes', located in urban and semi-urban settings, since late 1980s and early 2000, respectively. The guidelines for implementation of the conservation projects for the lakes specifically provided the overarching policy framework with a clear emphasis on the non-engineering interventions and green infrastructure (NbS) for their restoration and addressing degradation due to pollution (Gopal et al. 2010). After the merger of the conservation plans for wetlands and lakes into the National Plan for Conservation of Aquatic Ecosystems (NPCA), the new Plan further reiterated the objective of halting and reversing the continued degradation of lakes and wetlands in the country through integrated management involving NbS as part of planning and implementation of the conservation projects. However, since the management of lakes & wetlands is based on diagnostic evaluation of not only the ecological and socioeconomic but also hydrological features, a mix of NbS with certain engineering solutions found place in the guidelines for NPCA to address the root causes of the degradation in order to maintain a network of healthy water bodies that can contribute through their diverse ecosystem services as well as sustain varieties of wetland dependent species (MOEFCC 2019).

Some of the initiatives are described briefly here. Two distinct areas of interventions can be recognised where nature-based solutions were recommended and implemented, at different scales, in case of all freshwater ecosystems—the rivers, lakes and wetlands.

14.4.1 Catchment Treatment

First of these areas relate to the catchments where anthropogenic activities cause depletion of vegetal cover with consequential soil erosion and high runoff. This results in hydrological changes, inflow of sediments and nutrients leading to rapid siltation and water quality degradation. Intensive agrochemical-based agriculture in the catchments also contributes to the same problems. Therefore, catchment treatment required extensive revegetation with minimal engineering support. Catchment treatment, focusing on revegetation around the lakes and wetlands has been undertaken extensively. Important examples of revegetating the catchment areas are those of Dal lake in Srinagar (Jammu & Kashmir), Loktak lake in Manipur, Lake Harike in Punjab, Lake Chilika in Odisha, and Upper Lake in Bhopal (Madhya Pradesh). During the past couple of years, extensive plantation exercise has been undertaken along a wide belt of floodplain on both sides of the river Ganga and River Narmada. Whereas in case of river Narmada, the State Government undertook plantation with the support of local communities (http://www.namamidevinarmade.mp.gov.in/horticulture.pdf), in the case of River Ganga, the National Mission for Clean Ganga formally supports this work through funds allocated to the forest departments of all riparian states (https://nmcg.nic.in/NamamiGanga.aspx#).

An action plan for 'Forestry Interventions in Ganga' were drawn out by the Forest Research Institute (FRI), Dehradun after a detailed study, which envisaged afforestation in 134,106 hectares along Ganga river in its riparian states. The project was approved for the period 2016–2021, at an estimated cost of Rs. 22,930.73 million and a MoU was signed with a Japanese firm in 2017. The plantation work was kick-started at Sambhal and Varanasi and is continuing.

14.4.2 Water Quality Improvement

Second area is that of improving water quality of rivers and lakes through two kinds of interventions: (a) prevention of inflow of pollutants by treating the wastewaters in a natural manner before they are released into the river or the lake, and (b) by in-lake treatment following NbS (see WWAP 2018).

14.4.3 Treatment of Inflowing Wastewaters

The conventional wastewater treatment by engineering-dominated methods involves huge civil construction and intensive use of energy for sewerage network and sewage/effluent treatment plants. Yet, a significant proportion of the wastewater effluents enter the freshwater systems through drains including storm water drains without treatment. One of the best-known nature-based solution to control, reduce and/or eliminate a wide range of pollutants from both the soil and water, and that is efficient, cost-effective, energy saving and resource-generating, is offered by bioremediation. Bioremediation is the process where pollutants are degraded or transformed to other less toxic forms under controlled conditions by the use of living organisms ranging from bacteria and fungi to plants (Dubchak and Bondar 2019). Prasad (2012) also considered bioremediation as 'interventions of biodiversity for mitigation (and wherever possible, complete elimination) of the noxious effects caused by environmental pollutants in a given site' and included phytoremediation and rhizo-remediation (often called as root zone treatment) within the term bioremediation. However, many people confine the use of the term bioremediation to only the use of microorganisms (Abatenh et al. 2017). Similarly, the term 'constructed wetlands' is used where aquatic and wetland plants are employed singly or in different combinations for the treatment of wastewaters from different sources (Vymazal 2008; Sundaravadivel and Vigneswaran 2001; Ghosh and Gopal 2010). In case of phytoremediation and constructed wetlands also, the microbes and the roots play a major role in the pollutant removal or degradation processes (see Shukla et al. 2011).

Whereas numerous studies have been undertaken in India on microbial bioremediation (Dafale et al. 2010; Kharayat 2012; Sharma and Malaviya 2016; Rana et al. 2017) and phytoremediation (including constructed wetlands) under laboratory and experimental conditions (see Prasad 2012; Juwarkar et al. 1995; Ghosh and Gopal 2010), there are relatively fewer examples of field scale applications with variable success. Microbial bioremediation has been attempted on some wastewater drains by dosing microbial consortia. Jain et al. (2013) used a microbial consortium developed by MSI Biotech, India, together with some co-enzymes at eight locations in the Khjarana drain in Indore (Madhya Pradesh). Data recorded seasonally over a 1-year period showed reductions in odour (more than 98%), BOD (75–80%) and COD (70%) as compared to that under natural conditions. Similar bioremediation has been implemented in drains in Kanpur (U.P.), Budha Nala, Ludhiana (Punjab), Morigate Nala, Allahabad (U.P.), City Drain, Farukhabad (U.P.) and Bakarganj Nala, Patna (Bihar) by the Central Pollution Control Board through different Implementing Agencies and with the funding from the Ministry of Environment & Forests, Govt of India, in 2012.

Constructed wetlands have been used on the field scale to treat domestic sewage and wastewater in drains before allowing the treated effluents to be discharged into streams or lakes (Billore et al. 1999, 2001). A large Phragmites-based constructed wetland was designed and implemented in Jaipur at Mansagar lake for meeting its water requirement. The wetland improved the quality of treated sewage effluents before their release into the lake. The National Lake Conservation Plan's guidelines specifically required the implementation of constructed wetland in lake restoration projects (Gopal et al. 2010).

Shristi Eco-Research Institute (SERI), Pune, developed a 'Green Bridge technology' which combines the components of both microbial bioremediation and phytoremediation, and involves filtration, biodegradation and biosorption mechanisms by microbes and plants. The technology patented by Dr. Sandeep Joshi, uses

Ecofert—the active microbial consortia, with biomats, sand, gravels and plants. The system is designed specifically depending upon the conditions and flow of the wastewater. It has been used satisfactorily for in-situ treatment in case of River Aharand Udaisagar lake in Udaipur (Kodarkar and Joshi n.d.; https://www.cseindia.org/green-bridge-technology-3788).

14.4.4 In-Situ Water Quality Improvement

Both bioremediation and phytoremediation have been implemented for in-situ improvement of water quality in the lakes. Microbial bioremediation was used for the first time in India in Lakes Ooty and Kodaikanal in Tamil Nadu, and lakes of Thane in Maharashtra (Box 14.1). Later, bioremediation was followed also in Lake Rankala of Kolhapur (Maharashtra). In the first phase of restoration of the Hauz Khas lake in Delhi also, in-situ bioremediation was initiated by INTACH to improve the quality treated effluent from a sewage treatment plant. However, its discontinuance created the problem of algal blooms in the lake (Bhatnagar 2018).

Box 14.1 NbS Experience at Thane, Maharashtra

Thane city is the first of the 18 Urban Centres on the periphery of Greater Mumbai. Topographically, Thane is separated from the mainland by the Ulhas estuary and the Thane creek, and is connected through reclaimed land with the island city of Mumbai. The city, surrounded by hills, has about 30 lakes within city limits. Most of the lakes were suffering from degradation of water quality to different extent.

Thane Municipal Corporation, responsible for addressing the environmental concerns, aims to conserve natural resources, protect the environment and improve standards of living on the concepts of Sustainable Development. In the year 2002, the Municipal Corporation initiated the Lakes Restoration Project under the National Lake Conservation Plan of the Ministry of Environment & Forests, to revive ten lakes in the first phase. In-situ bioremediation technology, using a consortium of microorganisms, was implemented for the first time in India. It also accompanied by the use of wetland vegetation around the lake periphery as well as the construction of filters and grease traps around the lakes (EMC 2010).

Around the same time, pollution levels along the creek were minimised by constructing lined soak pits, using bio-sanitiser enzymes, and planting about 0.1 million trees along the creek (EMC 2010).

Constructed wetlands in the form of small floating islands have been an age-old global practice for managing water bodies for various purposes (Van Duzer 2004). In India also, floating wetlands were traditionally constructed in Lake Loktak (Manipur), Dal lake (J&K), and Khajiar and Rewalsar lakes of Himachal Pradesh (Gopal et al. 2003). Although conflicting views have been expressed about them (Gopal et al. 2003), the floating masses of wetland plants have been demonstrated to help improve the water quality and have now been introduced in many lakes. In Hauz Khas lake (Delhi) itself, after the emergence of the problem of algal blooms, floating islands with wetland plants were introduced with encouraging results (https://www.indiawaterportal.org/articles/islands-float-delhi-lake).

In the Dal lake (Srinagar) while the age-old floating islands, which in fact got stranded and settled down reducing the lake area, were to be removed, new constructed floating wetlands were introduced as a part of the lake restoration program (Box 14.2). Recently, an NGO, Dhruvansh, introduced about 250 m^2 of floating islands in Lake Neknampur in Hyderabad (https://www.thebetterindia.com/129968/india-floating-island-hyderabad-lake/).

Box 14.2 NbS Experience in Dal Lake, Srinagar (J&K)

Under the component of Restoration and Development Works for Dal Lake Restoration Project in Srinagar (India), besides the activities like dredging of blocked channels, dredging and de-weeding within the lake, reed bed creation including creation of constructed wetlands was implemented effectively. The restoration of springs, shore line development, development of jetties and Ghats were other restoration activities undertaken.

Works on constructed wetlands were undertaken, mainly for further improvement in quality of treated effluents from the Sewage Treatment Plants and also to address the agricultural runoff from the lake catchment. Different plants species used for biological treatment in these wetlands were local species.

Another phytoremediation measure adopted in some places include the naturalisation of lake shore line with wetland plants in place of stone pitching or concrete lining, as implemented in Dal lake. Similar recommendations were made by a National Green Tribunal appointed expert committee for restoring the floodplain areas of River Yamuna in Delhi but the plan is yet to be implemented.

Among nature-based solutions, is also included the biological control of invasive aquatic weeds such as water hyacinth, *Salvinia molesta* and the alligator weed. Host-specific insects were introduced with good success against water hyacinth in Lake Manipur and lake Harike (Punjab). Since the insects had to be bred and introduced frequently, the control measures were discontinued.

Another oft-quoted and widely acclaimed example of NbS in India since late 1990s, are the East Kolkata Wetlands (EKW) which receive the untreated domestic sewage and storm water of the Kolkata metropolis. These are a series of natural and human-made freshwater ponds along an old estuary and have been turned into sewage-fed fisheries and vegetable fields on municipal solid wastes. The EKW is projected to have enormous waste-assimilation function and to support numerous livelihoods besides significant biodiversity. EKW were designated as Ramsar site in 2002. They are also projected to be a flood regulating structure for the metropolis but it is not readily realised that the original freshwater wetland system have turned into sewage lagoons and that out of the total sewage inflows, 'more than 95% is siphoned off from the wetland to reduce water logging within the Kolkata city. Drastic reduction of freshwater flows and gradual dominance of marine flows has induced rapid siltation within the system' (Kumar 2010). The system today suffers from several problems that raise a question mark on its being a NbS (for details see Kumar 2010).

Constructed wetlands, Dal Lake (Picture Courtesy: Dr. Rooprekha Dalwani)

Shore line naturalisation—in place of stone pitching/concrete lining.

Shore line development/plantation, Dal Lake (Picture Courtesy: Dr. Rooprekha Dalwani)

14.4.5 Sustainability of Conservation Measures Using NbS

The Nature-based Solutions need to be designed scientifically for achieving the desired results and require long-term monitoring and follow-up for providing standardised guidelines for implementing NbS. In this respect, the IUCN's planned release of Global NbS standards will go a long way to help streamline the use of the NbS. The sustainability of conservation measures using NbS is highly dependent on operation and maintenance resources to be provided by the local Government, having ownership of the responsible water management body or bodies (especially in case of the lakes and wetlands). One way of achieving this is by vesting the local bodies with specific statutory powers for generating resources through various means like, penalising the polluters, introducing sewage tax and collecting charges through the use of public facilities in the lake precinct etc., for making conservation efforts successful.

14.5 Conclusions

In its efforts to mitigate the problems of water pollution and to restore the freshwater ecosystems, India has already recognised the importance of interventions mimicking the natural ecosystem processes instead of grey infrastructure-based engineering interventions. Revegetation of catchments of water bodies, plantation along the margins of water bodies to check erosion and pollution, use of constructed wetlands for treatment of wastewaters entering the water bodies and even within the water bodies have been practised in recent years in many parts of the country at various scales. The restoration of these ecosystems for their biodiversity and ecosystem services has yet to go a long way and the NbS offer a viable, cost-effective and socially useful approach that needs to be adopted as a matter of policy (Dhyani et al. 2018; Dhyani and Thummarukudy 2016). However, adding a word of caution: the ecosystem structure and function if restored and/or managed can help, within certain limitations, solve the human-made problems only to a limited extent and at a certain rate. Some of the NbS also require to be standardised for their design parameters for effective implementation which is expected to be addressed to some extent by Global NbS standards of the IUCN. The nature and magnitude of the degradation of Indian freshwater ecosystems is more often so different and large as compared to some of the other countries that the NbS may have to be assisted or supported by some measure of engineering interventions.

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