COMPENDIUM OF

SLM

SUSTAINABLE LAND MANAGEMENT PRACTICES

CENTRE OF EXCELLENCE ON SUSTAINABLE LAND MANAGEMENT
INDIAN COUNCIL OF FORESTRY RESEARCH AND EDUCATION
DEHRADUN, INDIA

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मंत्री
पर्यावरण, वन एवं जलवायु परिवर्तन
और
श्रम एवं रोज़गार
भारत सरकार

सत्यमेव जयते

MINISTER
ENVIRONMENT, FOREST AND CLIMATE CHANGE
AND
LABOUR AND EMPLOYMENT
GOVERNMENT OF INDIA

भूपेन्द्र यादव
BHUPENDER YADAV

आज़ादी का अमृत महोत्सव

MESSAGE

Land resources facilitate various physical, social, economic, and infrastructure activities. For example, the land is used for agriculture, watershed management, afforestation, mining, transportation, and development. It is, therefore, important to protect and maintain land resources to ensure the sustained provision of vital services by terrestrial ecosystems. However, human activities such as extensive agriculture, overgrazing, and deforestation can degrade the land by reducing its productivity and quality. Additionally, various natural factors, such as earthquakes, heavy rainfall, landslides, cloud bursts, and volcanic eruptions, contribute to land degradation. Land degradation affects people, ecosystems, and climate across the world. The impact of climate change aggravates the ongoing land degradation processes and introduces new degradation patterns. Land degradation and climate change adversely affect the livelihoods of societies dependent on natural resources—the decline in soil quality and agricultural productivity due to land degradation cause significant harm to rural communities.

Land degradation can be avoided, reduced, or reversed through Sustainable Land Management practices that yield multiple co-benefits, including climate change adaptation and mitigation. Merely restoring land is also insufficient; stewardship is essential for continuous and ongoing conservation while addressing community needs. An ideal restoration scenario involves a repaired ecosystem, community governance of land, and establishing mutually beneficial relationships between people and resources for sustainable livelihoods. This strategy empowers local communities, encourages them to take ownership of the protection of their land, and engages them in decision-making, planning, and implementation. Sustainable Land Management is the comprehensive approach comprising technologies combined with social, economic, and political enabling conditions.

The Government of India has extended its support for the Bonn Challenge pledge at Paris COP 2015 to restore deforested and degraded land, becoming one of the first Asian countries to join the global commitment, and has targeted to restore 26 million hectares of degraded lands to achieve Land Degradation Neutrality (LDN) by 2030. Indian Council of Forestry Research and Education, Dehradun, has set up a Centre of Excellence on Sustainable Land Management (CoE-SLM) under its umbrella for the creation of a national-level database on degraded lands, develop state-of-the-art scientific approaches and facilitate induction of cutting-edge technologies for restoration of degraded land in the country.

CoE-SLM has compiled "**Compendium of Sustainable Land Management Practices**" which includes contributions from eminent Researchers and Academicians from various Research and Development organizations. The compendium provides a comprehensive compilation of articles on sustainable land management practices and case studies in agriculture, forestry, and other land use sectors. The proposed interventions and allied conservation measures can act as a roadmap for restoring degraded lands.

I congratulate the CoE-SLM, ICFRE, officials for the remarkable work and especially commend DG, ICFRE, for his leadership in this endeavor. I am confident that the document will be immensely useful for planners and other stakeholders.

Date: 7 .04.2023

(Bhupender Yadav)

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Preface

Land is a finite natural resource that provides the base for the survival of living beings on Earth. Land resources encompass soil, water, and biodiversity which serve as the foundation of the world's socioeconomies. Nearly 44 trillion US $ economic outputs (more than half of the global GDP) are moderately or highly resilient on natural capital. The increasing global population has aggravated food grain demand and exerts huge pressure on land resources. Consequently, the land resources have undergone degradation and suffered loss due to huge anthropogenic pressure in recent decades. Land degradation is the persistent reduction of the capacity of the land to support biodiversity, ecosystem services, and human needs which hampers food production, water storage, biodiversity, and carbon sequestration in the soil–plant system. However, land degradation in arid, semi-arid and dry sub-humid areas is termed as desertification. About 25% area degraded globally has affected 3.2 billion people around the world.

India is the 7th largest country covering 2.4% of the world's geographical area and supporting about 18% each of the human and cattle population of the world. About 228.3 million hectares (i.e. 69.6%) of the total geographical area of the country is estimated as dry lands (arid, semi-arid, and dry sub-humid regions). According to the recent estimates of the Space Applications Centre published in Desertification and Land Degradation Atlas of India, 2021, the current extent of land degradation has been estimated at 97.85 million hectares covering 29.77% of the geographic area of the country.

Restoration of degraded lands need concerted global efforts and has been acknowledged in the 2030 Agenda for Sustainable Development with the adoption of SDG 15, which urges countries to "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably managing forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss". The UN Decade on Ecosystem Restoration (2021-2030) is a rallying call for the protection and revival of ecosystems all around the world, for the benefit of people and nature. The SDG target 15.3 championed by the United Nations Convention to Combat Desertification (UNCCD) states "by 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world."

Achieving land degradation neutrality by preventing land degradation and rehabilitating already degraded land, scaling up sustainable land management, and accelerating restoration initiatives is a pathway to greater resilience and security for all. Restoring the soils of degraded ecosystems has the potential to store up to 3 billion tonnes of carbon annually. To achieve India's ambitious targets of restoring 26 Mha degraded lands and creating an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030, it is essential to realize the current state of institutional and policy arrangements.

Realizing the need for a strong institutional and policy framework the Hon'ble Prime Minister of India while addressing the High-Level Segment of the Fourteenth Session of the Conference of Parties to United Nations Convention to Combat Desertification (UNCCD) made an announcement in 2019 to set up a Centre of Excellence on Sustainable Land Management at Indian Council of Forestry Research and Education (ICFRE) in order to further develop scientific approach and facilitate induction of technology on land degradation issues.

Accordingly, the Centre of Excellence on Sustainable Land Management (CoE-SLM) has been established at ICFRE Dehradun with the aim to facilitate the restoration of degraded lands, achieving land degradation neutrality and promoting South-South cooperation. Capacity building and technical support in setting priorities and LDN target setting, capacity building for developing transformative projects, networking of national and international institutions working on sustainable land and ecosystem management for knowledge sharing and exchange, awareness and technical support for the implementation of sustainable land and ecosystem management programmes/ projects are the key objectives of CoE-SLM.

Preface

CoE-SLM has made an attempt to compile Sustainable Land Management Practices from the domain experts in Agriculture, Forestry, and allied sectors. The compendium consists of thirteen chapters covering soil and water conservation measures, sustainable land management practices, strategies to combat desertification, farming practices in dry lands, mangrove restoration and management, precision farming systems for land restoration and livelihood sustenance of marginalized and smallholder farmers, and sustainable land management practices evolved through indigenous knowledge of the farming communities.

Compilation of this compendium could not have been possible without the valuable contributions made by eminent experts from various organizations. The editors are sincerely grateful to all authors for making valuable contributions and cooperation during various stages of the publication process. We hope that the publication will serve as resource material for the successful implementation of land restoration measures in the country.

Editors

List of Abbreviations

ADWCB	Acidified Dicer Wood Chips Biochar
AFRI	Arid Forest Research Institute
ARSB	Acidified Rice Straw Biochar
BAC	Bacterial and Archeal Communities
BBF	Broad Bed and Furrow
BNF	Biological Nitrogen Fixation
BSC	Bio Solids Co-compost
BT	Box Trenches
BWCD	Brush Wood Check Dam
CAZRI	Central Arid Zone Research Institute
CBT	Conservation Bench Terrace
CCA	Culturable Command Area
CCT	Continuous Contour Trenches
CDA	Chilika Development Authority
CEC	Cation Exchange Capacity
CIL	Coal India Limited
COP	Conference of the Parties
CRIDA	Central Research Institute for Dryland Agriculture
CRZ	Coastal Regulation Zone
CT	Contour Trenches
DAP	Di-amonium Hydrogen Phosphate
DHA	Dehydrogenase
DLD	Desertification and Land Degradation
DLTs	Drainage Line Treatment
EC	Electrical Conductivity
EGS	Ecosystem Goods and Services
EMP	Exchangeable Magnesium Percent
FAO	Food and Agriculture Organization

FGDG	Flue Gas Desulfurization Gypsum
FYM	Farm Yard Manure
GD	Gradoin Ditches
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
GIS	Geographical Information System
GWC	Green Waste Compost
HDPE	High Density Polyethlyene
HLRDC	Haryana Land Reclamation and Development Corporation
ICFRE	Indian Council of Forestry Research and Education
IGNP	Indira Gandhi Nahar Pariyojana
IISWC	Indaian Institute of Soil and Water Conservation
IMD	India Meteorological Department
IMSQI	Integrated Mine Soil Quality Index
IPCC	Intergovernmental Panel on Climate Change
IPZ	Island Protection Zone
IRS-AWiFS	Indian Remote Sensing-Advanced Wide Field Sensor
ISFR	India State of Forest Report
ISRO	Indian Space Research Organization
ITPS	Inter-Governmental Technical Panel on Soils
IWSM	Integrated Watershed Management
JMM	Joint Mangrove Management
LBCD	Loose Boulder Check Dam
LDN	Land Degradation Neutrality
LMU	Land Management Units
LRI	Land Resource Inventory
LULC	Land Use Land Cover
MBC	Microbial Biomass Carbon
MBN	Microbial Biomass Nitrogen
MBP	Microbial Biomass Phosphorus

Abbreviations

MDS	Minimum Data Set
METT	Management Effectiveness Tracking Tool
MG	Marine Gypsum
Mha	Million hectares
MOP	Muriate of Potash
MSSRF	M.S. Swaminathan Research Foundation
MSW	Municipal Solid Waste
Mt	Metric ton
NAAS	National Academy of Agricultural Sciences
NATP	National Agricultural Technology Project
NCL	Northern Coalfields Limited
NDVI	Normalized Difference Vegetation Index
NHM	National Horticultural Mission
NIA	Net Irrigated Area
NPCA	National Plan for Conservation of Aquatic Ecosystems
NPP	Net Primary Productivity
NRAA	National Rainfed Area Authority
NSA	Net Sown Area
OB	Overburden
OCP	Open Cast Project
PAFS	Pineapple Agroforestry Systems
PAME	Protected Area Management Evaluation
PAWC	Plant Available Water Capacity
PCA	Principal Component Analysis
PME	Post Mining Ecosystem
PRA	Participatory Rural Appriasal
RKVY	Rashtriya Krishi Vikas Yojana
R-METT	Ramsar Management Effectiveness Tracking Tool
RMS	Restored Mine Sites
RWH	Rain Water Harvesting

SAC	Space Applications Centre
SAG	Sulfurous Acid Generator
SAGY	Sansad Adarsh Gram Yojana
SALT	Slopping Agricultural Land Technology
SAR	Sodium Adsorption Ratio
SDGs	Sustianable Development Goals
SER	Society for Ecological Restoration
SH	Soil Health
SLM	Sustainable Land Management
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
SQUs	Soil Quality Units
SSP	Single Super Phosphate
STCR	Soil Test Crop Response
SWA	State Wetlands Authorities
SWC	Soil and Water Conservation
TDS	Total Data Set
TGA	Toatal Geographic Area
TN	Total Nitrogen
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UPBSN	Uttar Pradesh Bhumi Sudhar Nigam
USDA	United State Department of Agriculture
VD	V-ditch
VDMC	Village Development and Mangrove Consrvation Council
VGCTR	Vegetally Guarded Conservation Trenches and Ridges
WBC	Wood Chip Biochar
WFPS	Water Filled Pore Space

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CHAPTER NINE

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9.1 Introduction

Degradation and loss of wetlands imperil societal well-being in several ways, such as reduced water, food and climate security and erosion of invaluable cultural heritage. Disruption in the structure, functions and composition of wetlands ecosystems also adversely affects the biological diversity of species dependent on these ecosystems. While removing adverse stressors on the ecological character of wetland ecosystems is the necessary step towards their conservation and wise use, in cases where degradation has already occurred or when addressing the stressors is not feasible, ecological restoration is an appropriate intervention. There has been a renewed interest in the ecological restoration of wetlands in recent times, driven by several factors, including growing water stress and exposure to extreme events such as floods and droughts, however, with limited success and lasting impact. This chapter presents state of the art on wetland restoration and distils challenges. We recommend a pathway for upscaling human investment and political and institutional efforts for securing these vital 'kidneys of landscape'.

9.2 The need for restoring wetland ecosystems

Wetland is a generic term used for aquatic ecosystems located at the interface of land and water and combining attributes of terrestrial and aquatic ecosystems (Keddy, 2010). The Ramsar Convention (a multilateral environmental agreement on wetlands ratified by 172 countries to date, including India which ratified the Convention in 1982) uses a broad definition of wetlands as 'areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six metres' (Ramsar 2016). To ensure connectivity between different habitats, Article 2.1 of the Convention provides that riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands may also be included within the boundary (Ramsar 2016). This broad-ranging definition thus covers a large category of inland aquatic systems (such as ponds, lakes, marshes, swamps and peatlands); coastal and nearshore marine ecosystems (such as coral reefs, mangroves, seagrass beds and estuaries) and human-made wetlands (such as rice–paddies, fish-ponds, and water storage areas as tanks, reservoirs, and dams).

India has a diverse wetland regime ranging from high altitude lakes of the Himalayas, floodplains and marshes of the Gangetic – Brahmaputra alluvial plains, saline flats of Great Indian Desert, tank studded Deccan Peninsula to extensive mangroves and coral reefs areas bordering the country's east and the west coastline (Kumar et al. 2017). As per the National Wetlands Atlas (SAC 2018), India has 15.86 million ha under wetlands, accounting for nearly 4.6 % of its geographical area. In terms of biogeographic zones, the coasts and the Deccan region have the maximum wetlands area, the proportion of natural wetlands being higher in the former and human-made in the latter (Figure 9.1).

Wetlands are critical for functioning of the water cycle (Bullock and Acreman, 2003). As water moves through the surface or underground, it passes through wetlands, which in turn regulate the quantity, quality and reliability of water. Wetlands provide vital water-related ecosystem services at different scales (for example clean water provision, wastewater treatment, groundwater replenishment) and thereby offer significant opportunities to address water management objectives with sustainable, and in several instances, cost-effective solutions (UNEP 2014).

The high altitude wetlands of Himalayas serve as headwaters for the ten largest rivers of Asia, the basins of which support nearly one-fifth of the global population (Trisal and Kumar, 2008). For several cities, wetlands were the primary source of water, and continue to be so, as reflected in the moniker 'city of lakes' given to Bangalore (Nagendra, 2010), Udaipur (Singh et al., 2018), Bhopal (Verma and Negandhi, 2011) and many others. For some, this water store can be highly significant, such as the water storage in Yamuna floodplains has been estimated to be equivalent to three-fourths of Delhi's water supply (Soni et al. 2009). Wetlands have traditionally been the backbone of agriculture practised in the Ganga-Brahmaputra floodplains. The waste treatment capability of wetlands has been effectively used by the City of Kolkata which depends upon the East Kolkata Wetlands to treat nearly 65% of its wastewater, saving nearly Rs. 4,600 million annually in terms of avoided treatment cost (WISA, 2020). Wetlands act as major flood defence systems for cities such as Srinagar (Jammu and Kashmir) and Guwahati (Assam) (Kumar et al., 2017). In the hard rock Deccan Plains and arid regions of the country, there has been an age-old tradition of constructing tanks to store rainwater for use in irrigation and domestic water supply (Bhattacharya, 2015). The value of coastal wetlands as a buffer against tropical storms has been brought out by several researchers (Das and Vincent, 2009; Kathiresan, 2010). Wetlands are also intricately interwoven with the rich cultural and religious tapestry of the country, and several wetlands considered sacred (Singh, 2013).

Not withstanding the high value of ecosystem services that wetlands provide to society, these ecosystems continue to be degraded, polluted, encroached upon and converted for alternate uses. A wetland area trend index constructed by the authors for Indian wetlands based on 237 published data points for 1980 – 2014 using Wetland Extent Trends index method (Dixon et al., 2016) indicates an average decline in natural wetlands area by 41% and a near commensurate increase in area under human-made wetlands by 44% (Kumar et al., 2021). These trends are similar to those reported globally, wherein the natural wetlands have been on a decline, whereas the human-made wetlands are on increasing (Gardner and Finlayson, 2018). These trends are similar to those reported globally, wherein the national wetlands have been on a decline, wherein the human-made wetlands are increasing (Gardner and Finlayson, 2018).

There is a considerable body of research that highlights the increasing vulnerability of landscapes wherein natural wetlands have been degraded or lost (Dewan and Yamaguchi, 2008; Acreman and Holden, 2013; Marois and William, 2015). This is especially true for major urban areas in India, wherein large swathes of wetlands have been converted to give way for housing and other infrastructure (Kumar and Kaul, 2018). A positive relationship between an increase in the built-up area, increasing runoff, loss of wetlands and enhanced flood vulnerability has been observed for several cities, such as Mumbai (Zope et al., 2016), Bangalore (Ramachandra et al., 2019), and Chennai (Gupta and Nair, 2011). Extensive urbanization of floodplains and conversion of wetlands were identified as critical anthropogenic drivers of extensive damage due to 2014 extreme flooding in Kashmir (Romshoo et al., 2018). With the capacity of treating sewage limited to only 31% of total generation (ENVIS, 2019), pollution of wetlands is rampant. Wetlands are also degraded due to fragmentation of hydrological regimes, excessive siltation, encroachment, invasive species, unregulated tourism, and over harvesting of wetland resources (MoEFCC, 2019), although the intensity of drivers of change varies in different biogeographic zones.

9.3 Policy environment

Wetlands conservation was initially led by wildlife values, and several predominantly wetland landscapes such as Keoladeo, Harike, Kaziranga and Manas were declared as wildlife sanctuaries and national parks. Vedanthangal, Keoladeo, Khijadiya and Rangathittu were designated as protected areas under colonial laws and regulations (Kumar, 2019). The work on Indian birds and the passion of stalwarts such as Padma Vibhushan Salim Ali had a major influence on laying the foundation of a network of wetland-protected areas supporting large congregations of waterbirds (Ibid).

Organised efforts for wetlands conservation in India were mainly triggered by India's ratification of the Ramsar Convention in 1982 and the establishment of a separate Ministry of Environment and Forest (presently Ministry of Environment, Forest and Climate Change) in 1985. The Ministry established the National Wetlands Programme in 1986 to provide an overarching national programmatic framework and financial assistance to the state governments for the implementation of site management plans (MoEF, 1992). In 1992, the Ministry constituted a National Committee on Wetlands, Mangroves and Coral Reefs to advise the government on appropriate policies and action programmes for wetlands conservation, research and training

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needs, and collaboration with international agencies. In 2001, the National Lake Conservation Programme was carved out of the former programme to address pollution issues in urban and peri-urban water bodies through interception, diversion and treatment of pollution load. Since March 2013, the two programmes have been merged into the National Programme on Conservation of Aquatic Ecosystems (NPCA). Beyond NPCA, wetlands located within protected areas are funded under the centrally sponsored scheme titled Integrated Development of Wildlife Habitats, whereas mangroves and coral reefs receive funding through a still separate funding stream.

Policy elements related to wetlands conservation and management are articulated in the National Environment Policy of 2006 which makes explicit recognition of wetlands as 'freshwater resources', and emphasizes integration of conservation and wise use of wetlands into river basin management involving all relevant stakeholders (MoEF, 2006). India's National Wildlife Action Plan (2017-2031) identifies conservation of inland aquatic ecosystems as one of the 17 priority areas, and envisages development of a national wetlands mission and a national wetlands biodiversity register (MoEFCC, 2017). Mainstreaming the full range of wetlands ecosystem services into developmental planning is listed as the objective of the national wetlands programme (MoEFCC, 2019).

Likewise, the integration of wetlands in river basin management has been identified as a strategy for the management of river systems (MoWR, 2012). The National Water Policy (2012) recommends adoption of a basin approach for water resources management and identifies conservation of river corridors, water bodies and associated ecosystems as an essential action area (MoWR, 2012). The National Action Plan for Climate Change includes wetland conservation and sustainable management in the National Water Mission and the Green India Mission (MoEF, 2008). The National Disaster Management Plan takes into account several non-structural measures for flood and cyclone risk reduction measures and makes direct reference to wetlands (NDMA, 2019). The national indicator framework for monitoring implementation of Sustainable Development Goals provides a mapping of various sectoral programmes towards assessing the country's progress on sustainable development goals (MoSPI, 2015), and makes several references to integrated management of wetlands and water resources.

Wetlands receive protection from a number of central enacted rules and regulations. Provisions of the Indian Forest Act, 1927, the Forest (Conservation) Act, 1980 and the Indian Wildlife (Protection) Act, 1972 define the regulatory framework for wetlands located within forests and designated protected areas. In 2017, the MoEFCC notified the Wetlands (Conservation and Management) Rules, 2017 under the Environment (Protection) Act, 1986, wherein state wetlands authorities have been constituted as nodal policy-making, programming and regulatory institutions for wetlands in the state. The structure of the Authority includes representation from all sectors, including water resources, thus providing a platform for balancing diverse sectoral interests related to wetlands. Several state governments (notably West Bengal, Odisha, Kerala, Manipur, Assam and Rajasthan) have also enacted their legislation pertaining to wetlands. Further, under the EP Act, coastal wetlands are protected under the Coastal Regulation Zone (CRZ) Notification (2018) and its amendments and the Island Protection Zone (IPZ) Notification 2011. The Environment (Protection) Rules, 1986 under the EP Act, empowers the Central government to prohibit or restrict the location of industries and carrying on of processes and operations in different areas including wetlands. The Indian Fisheries Act, 1897, The Water (Prevention and Control of Pollution) Act, 1974, and The Biological Diversity Act, 2002 provide instruments for regulating various development threats on wetlands. The Coastal Aquaculture Authority Act, 2005 prohibits the conversion of natural coastal wetlands such as mangroves, salt pans, estuaries and lagoons for aquaculture. Further, under the Biological Diversity Act, 2002, the Central Government can issue directives to State Governments to take immediate ameliorative measures to conserve any area rich in biological diversity, biological resources and their habitats especially when the area is being threatened by overuse, abuse or neglect. The said Act also gives State Governments the powers to notify areas of biodiversity importance as biodiversity heritage sites.

India ratified the Ramsar Convention in 1982. The 75th year of independence was commemorated by designating 75 wetlands to the List of Wetlands of International Importance covering an area of 1.33 million ha (Figure 9.1).

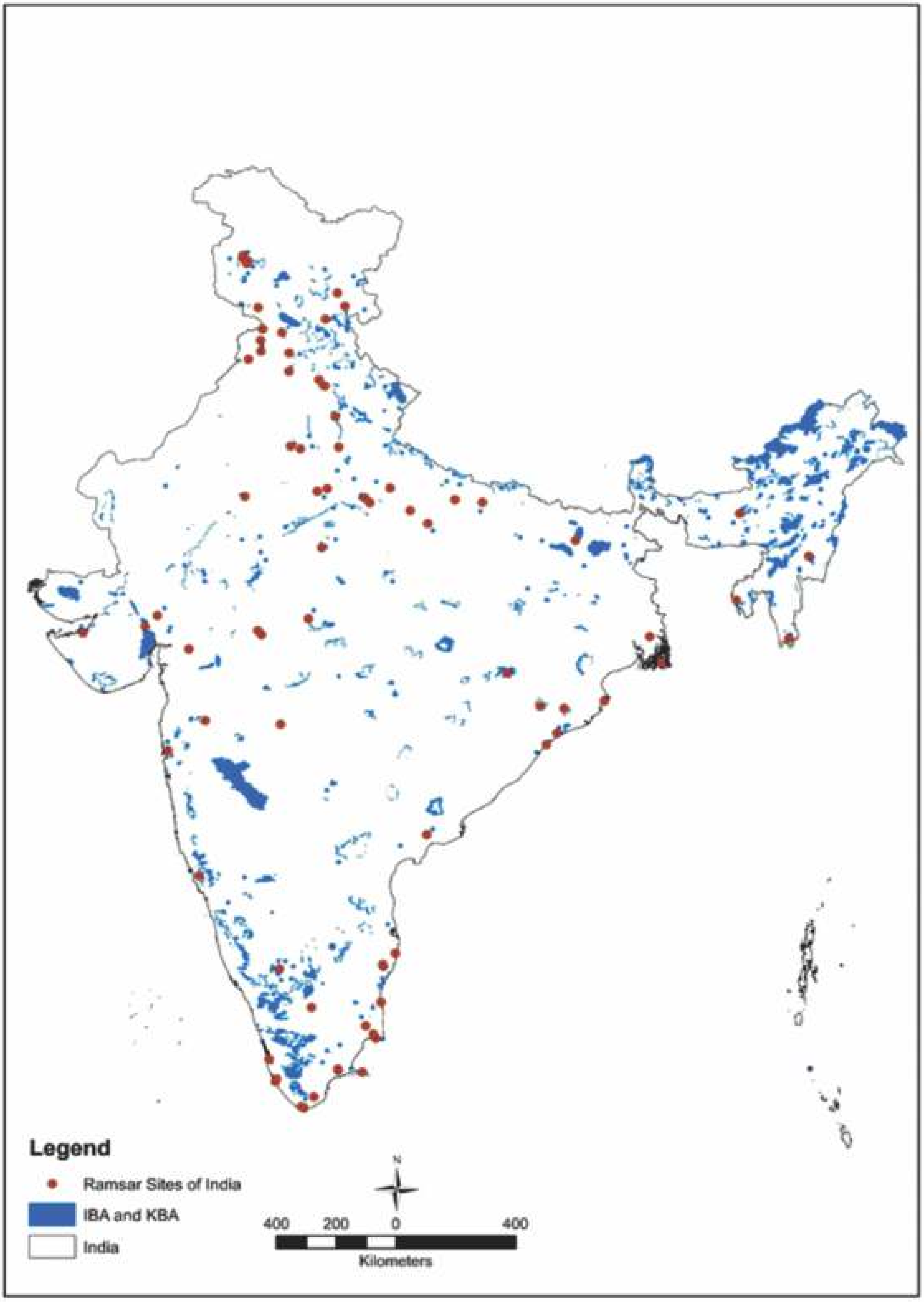

Figure 9.1: Location of seventy-five Ramsar sites and wetlands coinciding with important bird and biodiversity areas (IBAs) and key biodiversity areas (KBAs)

Ecological restoration of wetlands has received increasing support from international policy processes as well. The Ramsar Convention has called for restoration through several resolutions, notable being Resolution in CoP 10 on 'A Framework for processes of detecting, reporting and responding to change in ecological character', which resulted in the development of Ramsar Principles and Guidelines on Wetlands Restoration.

The United Nations General Assembly declared 2021-2030 as the United Nations Decade for Ecological Restoration, responding to the critical need to halt, prevent and reverse ecosystem degradation, and to effectively restore degraded terrestrial, freshwater and marine ecosystems across the globe.

The United Nations Biodiversity Conference, held in December 2022 in Montreal, Canada, ended with adopting the landmark Kunming-Montreal Global Biodiversity Framework (CBD, 2022). The Framework consists of four overarching global goals to protect nature, including: halting human-induced extinction of threatened species and reducing the rate of extinction of all species tenfold by 2050; sustainable use and management of biodiversity to ensure that nature's contributions to people are valued, maintained and enhanced; fair sharing of the benefits from the utilisation of genetic resources, and digital sequence information on genetic resources; and that adequate means of implementing the framework is accessible to all Parties. Target 2 (on the effective restoration of at least 30 percent of degraded ecosystems by 2030) and Target 3 (on the effective conservation and management of 30 percent of areas of particular importance for biodiversity and ecosystem functions and services) make a specific mention of 'inland waters', the term for wetlands in the Convention on Biological Diversity Processes.

The Sharm-el Sheikh Implementation Plan that resulted from the UNFCCC CoP 27 called for the protection, conservation and restoration of water and water-related ecosystems as a part of the adaptation actions (UNFCCC 2022).

9.4 Wetland restoration efforts and lessons learnt

The Society for Ecological Restoration (SER) defines ecosystem restoration as 'the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed'. The purpose is to move a degraded ecosystem to a trajectory of recovery that allows adaptation to local and global changes, as well as persistence and evolution of its component species. The SER Standards use the term restoration for the activity undertaken and recovery for the outcome sought or achieved. It is stressed that for an activity to be considered ecological restoration, it must result in a net gain for biodiversity, ecosystem health and integrity, and human well-being, including sustainable production of goods and services (Gann et al., 2019).

Restoration includes a spectrum of actions, including: (1) reduction of negative environmental and societal impacts, such as pollution and unsustainable resource use and management; (2) removal of contaminants, pollutants and other threats, often known as remediation; (3) rehabilitation of ecosystem functions and services in highly modified areas; and (4) ecological restoration, which aims to remove degradation and assists in recovering an ecosystem to the trajectory it would be on if degradation had not occurred, accounting for environmental change (FAO, 2021). The literature distinguishes between rehabilitation (wherein the primary objective is to improve ecosystem functions and ecosystem services in transformed ecosystems) and ecological restoration (wherein the aim is to put ecosystems on a path towards a state of high integrity, with natural state as a reference, taking into account climate change and natural ecological dynamics when setting objectives).

Public funds investments into wetlands, especially those of the central sector schemes administered by the MoEFCC, is on the basis of integrated management plans. These plans intend to address the drivers of adverse degradation, as well as maintain and enhance biodiversity and ecosystem services values. However, in several cases, these funds have also been directed at ecological restoration and rehabilitation. We discuss a few of such initiatives in this section and distil lessons learnt.

Restoring natural wetlands : Chilika, a brackishwater coastal lagoon situated in Odisha, and the base of livelihood security to more than 0.2 million fishers is an assemblage of shallow to very shallow marine, brackish and freshwater ecosystems and a hotspot of biodiversity. The wetland went through a phase of reduced connectivity to the sea during 1950 – 2000 owing to increasing sediment loads from degrading catchments. There was a rapid decline in fisheries, with annual average landing dropping from 8600 kg to 1702 kg between 1985/86 and 1998/99 (Mohapatra et al., 2007). The rapid decline in ecosystem condition and the associated livelihoods of dependent communities prompted the Odisha state government to constitute the Chilika Development Authority (CDA) as a formal institution mandated to undertake conservation and management of the wetland. CDA, working with the state and national governments, a range of scientific organizations, as well as civil society organizations, mobilized the necessary evidence for ecological restoration. Measures put in place since 2000 included opening of a new mouth and dredging of a channel within the northern sector of the lagoon to ensure that riverine sediments are flushed out. These interventions were complemented by a basin scale participatory watershed management programme to contain silt loading from the catchments and enhance resources for community livelihoods (Kumar et al., 2020).

The response of the hydrological intervention and basin management has been rapid and sustained. After initial trophic bursts, the annual fish landing stabilized at nearly 13,000 MT (Raman and Das, 2019). Annual CDA censuses of Irrawaddy dolphins within Chilika reported an increase from 89 to 151 individuals between 2003 and 2022, as well as increases in habitat use, improvements in breeding and dispersal, and declines in mortality rates (CDA monitoring records, unpublished). Seagrass meadows expanded from 20 km^2 in 2000 to 172 km^2 by 2022, along with a significant decline in freshwater invasive species (CDA monitoring records, unpublished).

Located on the river Yamuna front, the Yamuna Biodiversity Park is an ambitious restoration project of the Delhi Development Authority and the University of Delhi. Since 2005, restoration of 157 ha barren and highly sodic floodplains has involved reintroduction of native plant species, landscaping, and creation of wetland habitats. Majority of the waste dumps and solid wastes accumulated on the floodplain have been removed. Agriculture on the floodplain has been regulated to prohibit the use of agrochemicals, and has been restricted to areas beyond 100 m on either side of the river channel. The higher elevation areas of the floodplain are being developed for improving the water quality of the wastewater which will be allowed to pass post treatment in the STPs (or in situ treatment on storm water drains) (Babu et al., 2013).

Restoring urban wetlands : Projects on urban wetlands restoration have centered on addressing pollution, reestablishing water regimes, and enhancing amenity values. Restoration of Bhoj Wetland in Madhya Pradesh, implemented during 1995-2005 with financial assistance from the Japan Bank of International Cooperation, is a noteworthy example. The Ramsar Site is a complex of two wetlands, the Upper Lake created in 11th century and the Lower Lake, created in the 18th century, and constitute the major source of water supply to Bhopal City. Rapid urbanization with insufficient waste management subjected the wetland to various environmental stresses, of which deterioration of water quality, reduction in water spread area and siltation were the most significant. Restoration was targeted at water quality improvement and enhancement of storage capacity. Desilting, deweeding, afforestation of catchments, creation of waste diversion and treatment infrastructure, curbing grazing and encroachment, and communication and outreach were implemented over a decade, leading to considerable improvement in lake ecosystem health (Verma et al., 2001, Pani, 2008).

The Hauz Khas, a historic waterbody in south Delhi, went dry by the sixties as the catchment flows were diverted and the water table depleted. Its restoration has involved diversion of treated wastewater, introduction of carp fingerlings, wetlands mediated treatment of inflows, and installation of aerators. The restoration has stabilized the water regimes, increased sighting of waterbirds, increase in groundwater levels and creation of a recreational avenue for the citizens (Bhatnagar, 2008; Roy 2016).

Communities living in and around have historically played an important role in conservation of urban wetlands. The case of restoration of Kaikondrahalli lake in south-east Bangalore is an example of collective action by concerned citizen groups. Till 2000, this urban wetland brimmed with freshwater and was a habitat for several species. By 2003, Kaikondrahalli lake went into prolonged drying as the inflowing channels were blocked and the solid waste dumped rampantly. Rejuvenation, implemented during 2009-11 involved concerned citizens group working with Bruhat Bangalore Mahanagara Palike (BBMP) to ensure catchment inflows into the wetland, realigning shoreline landuse to maintain waterspread area, diverting and treating waste from upstream sources, enhancing water storage capacity, managing grazing, and educating citizens on the diverse wetland values. As a result of the efforts, the lake regained much of its lost waterspread, with frequent sightings of diverse species (Nagendra, 2016).

Several urban wetland restoration projects in recent times have tended to bypass the mre complicated catchment restoration efforts, and instead leveraged availability of treated wastewater to restore water regimes.

Mangroves restoration : Mangrove restoration in India is an impressive turnaround story. As per biennial assessments published by the Forest Survey of India, the extent of mangroves in the country has increased from 4,046 sq km in 1987 to 4,975 sq km in 2019. The Global Mangrove Alliance, which maintains consistent global datasets on mangrove cover, has estimated that worldwide, since 1996, there has been a net global loss of mangroves cover by 3.4%, with the losses having occurred globally at rates twice the gains (Bunting et al., 2022). India is one of the few countries with positive trends in mangrove cover. Restoration efforts particularly picked pace after the Kalinga Super Cyclone (1999) and Indian Ocean Tsunami (2004), wherein mangroves sheltered hamlets located behind these swamps, absorbing the storm surges to a large extent. This success is attributed to immense efforts in mangrove plantations based on localised models, community engagement in their protection and upkeep and strengthening coastal zone regulation architecture. States like Maharashtra have established a separate Mangrove Cell to ensure a consistent focus on the conservation and management of these ecosystems (DasGupta and Shaw, 2013).

The MS Swaminathan Research Foundation is credited with the popularisation of the fish-bone model of mangrove restoration, which allows for the creation of hydrological conditions for the regeneration of mangroves. What started as an experiment in a small patch in Pichavaram, has now been successfully applied in Bhitarkanika (Odisha), and Krishna Delta (Andhra Pradesh). The integrated mangrove fisheries farming system, again from the stable of MSSRF, specifically addresses livelihood elements in the restoration of abandoned aquaculture farms in Tamil Nadu, Andhra Pradesh and other parts of the Indian coastline (Shah and Ramesh, 2022).

Restoring ponds : Historically ponds have played an important role in water security and livelihoods, however, with the advent of irrigation and water supply systems, and predominance of groundwater use, the relevance of these small wetlands has declined resulting in their degradation and rampant conversion for alternate land use. In 2005, the Ministry of Jal Shakti launched a Repair, Renovation, and Restoration (RRR) scheme (later merged with Prime Minister Krishi Sinchayee Yojana-2015) aimed at harnessing the irrigation potential of these aquatic ecosystems. Pond restoration has received increasing support in recent times, with the major interventions being restoration of hydroperiod, water depth and silt control. There are several grass root organizations and motivated individuals who spearhead restoration of ponds, as their revival directly contributes to local water security and livelihoods (Yadava and Goyal, 2022).

A deeper reading into the restoration initiatives provides several insights into the factors that underpin a successful wetland restoration and regeneration effort. Following are some of the major lessons learned.

Selection of appropriate restoration goals and pathways is critical. Clear and achievable restoration goals are critical to successful restoration. In Chilika, restoration targeted reestablishment of salinity regime, and used reestablishment of hydrological connectivity between the estuary and the Bay of Bengal as a pathway. Similarly, in the case of restoration of Yamuna floodplains, the project specifically targeted reestablishment of native vegetation. Similarly, in the case of Bhoj Wetlands restoration, clear targets in terms of water quality and water levels were established, and catchment level management was adopted as a restoration pathway. These clear targets and pathways allowed clear definition of restoration projects. In case of Loktak Lake, though the restoration project has identified viable restoration outcomes in terms of desired hydrological regimes and extent of vegetation, the pathway of restoration involving reoperation of Ithai Barrage is highly contested, and not implemented thus far. In several urban wetlands, the restoration outcomes in terms of desired water quality standards require heavy investment in grey water treatment infrastructure. The outcomes are seldom achieved because of inefficiencies in infrastructure functioning, and poor addressal of catchment land use interactions.

Monitoring. Monitoring plays a crucial role in determining the success of ecological restoration and rehabilitation, as well as enabling replication and upscaling. In cases of Chilika and Yamuna Biodiversity Park, elaborate arrangements are in place to record changes in ecological and hydrological indicators. The monitoring data also instills confidence in decision-makers on the efficacy of their decisions regarding wetlands restoration and rehabilitation.

Management plays an important role in sustaining the benefits of restoration and rehabilitation. While restoration and rehabilitation efforts can bring the wetland to a desired condition, maintaining the condition requires putting in place arrangements for managing these ecosystems for maintenance of their ecological character. In case of Chilika, proactive basin-scale management has ensured that the restoration outcomes have been sustained over time, and the lagoon maintains a salinity gradient conducive for fish landings and habitats for dolphins and other species of high conservation values. Similarly, in Pichavaram, the Forest Department works with communities for maintaining the fish bone channels which provide the desired salinity regime for mangrove regeneration. In contrast, the dissolution of Lake Conservation Authority constituted as a part of Lake Bhopal Conservation and Management Project led to considerable dissipation of the gains made under the rehabilitation project, as water quality declined, water levels rendered unstable and pressures from intensifying catchment land use increased.

Standardization helps, but restoration and rehabilitation must take into account landscape and socioeconomic context. There is a tendency to standardize restoration and rehabilitation methods, which allows for replication and upscaling of best practices. However, it is important that restoration and rehabilitation measures take into account landscape and socioeconomic factors. A case in point is that of mangrove restoration. The National Decadal Wetland Change Atlas published by Space Application Center in February 2022 reports that between 2006/7 and 2017/18, the natural coastal wetlands declined from 3.69 million ha to 3.62 million ha. The intertidal mudflats have decreased by a whooping 116,897 ha and salt marshes by 5,647 ha. Mangrove plantation over inter-tidal mudflats is a prominent reason for this loss.

Institutions matter for restoration success. Successful ecological restoration and rehabilitation efforts were led by dedicated agencies (such as Chilika Development Authority, the Delhi Development Authority working with the Center for Management of Degraded Ecosystems of the University of Delhi) which ensured systematic implementation of the restoration plan, bringing on board partners and networks, and periodically evaluating success.

9.5 Scaling up wetland restoration – future priorities

It is apparent that efforts placed on restoring and rehabilitating Indian wetlands has not matched up with the rapid pace of degradation of these ecosystems. There is an urgent need to scale up efforts in this direction. Following are some priorities that need consideration:

Ecological restoration planning. Investment is needed in developing robust, sustainable and equitable wetland restoration and rehabilitation plans. A national system for prioritising wetlands in need of restoration may serve as a basis. Restoration may be guided by reference models - which describe the approximate condition the wetland would be had the degradation not occurred. Such reference models should also factor in the impacts of climate change. Restoration projects should have clear targets (informed by reference ecosystems), goals (medium to long term desired ecological and social condition), objectives (interim outcomes towards condition of recovery) and indicators (specific and quantifiable measures of attributes). The design of restoration plans must reflect the expectations and interests of stakeholders.

Capacity development. The lack of formal and systematic training and skill development opportunities to support wetlands restoration needs to be adequately addressed through targeted training programmes, learning networks, field support and building practitioner-researcher collaborations.

Strengthening wetlands governance. Successful wetlands restoration requires governance arrangements that can ensure stakeholder engagement, incorporation of diverse worldviews and values, political ownership and continuity of action. The Wetlands (Conservation and Management) Rules, 2017 have mandated State Wetlands Authorities (SWA) as the nodal policy-making and regulating bodies. The SWA can play an important role in ensuring that there is appropriate policy and programmatic support for wetlands restoration within the state. Several states have also constituted District level wetland authorities, which provide a platform for district level monitoring and coordination of actions with government line departments. What is pertinent is that site level restoration is made the responsibility of a single department, which should ensure coordination with other line departments and agencies, experts and civil society organizations in implementing.

Building supportive knowledge systems. Effective restoration planning and implementation requires supportive knowledge systems that can assist in making evidenced based choices. Restoration interventions should be guided by best available knowledge, including traditional and indigenous ecological knowledge. Innovation and learning can be fostered by building practitioner-researchers collaborations. Effort should also be made to share practical and as well as scientific knowledge to support efficient implementation of restoration plans.

A major focus of science has been to unpack 'what wetlands are' in terms of unravelling the complexities of ecosystem structure functioning. This science has provided a robust basis of conservation. However, for wetlands to be effectively mainstreamed into sector plans and programmes, the pertinent questions are – 'what can wetlands do to meet development outcomes such as flood buffering, water security' and so on. This would require a science and knowledge system to demonstrate wetland functioning within a landscape. For most parts, this is an interdisciplinary endeavour, which requires wetland ecologists to work with hydrologists, social scientists, geographers, landscape planners and others.

Monitoring and evaluation. It is pertinent that restoration success is evaluated through a systematic monitoring and evaluation system that ascertains effectiveness of investment and application of human, financial and political capital. Monitoring can be directed at specific hypotheses (such as reestablishing hydrological conditions is sufficient for regeneration of native species). Engaging stakeholders in collection and analysis of data can help build stakeholder capability, as well as provide an environment of collaborative decision making. Finally, monitoring and evaluation provides the basis of adaptive management, by continually updating knowledge and adjusting restoration practices as an outcome. Each wetland restoration project must have an inbuilt component of monitoring and evaluation.

Emphasizing the significance of evaluating the management effectiveness of Ramsar Sites and other wetlands, especially in places where mechanisms are not already in place, the Contracting Parties to the Ramsar Convention at their 12th Conference of Parties in 2015 adopted a revised version of the Management Effectiveness Tracking Tool (METT), called the Ramsar Management Effectiveness Tracking Tool (R-METT), based on the Protected Area Management Evaluation (PAME) tool for effective management over time. This encourages wetland management authorities to evaluate the effectiveness of wetland management in collaboration with relevant stakeholders as appropriate.

Sector mainstreaming. Several sectors, such as water resources development, urban development, rural development to name a few, are including wetlands restoration within their plans and programmes. Unfortunately, the restoration practices adopted by the sectors seldom take a holistic view of wetlands as an ecosystem, and rather focus on a few elements (such as water regimes, or amenity values). Given the complexity of wetlands ecosystems, the outcomes of sectoral approaches are short lived and often counter-productive. It is therefore essential that all sectors are guided by a common national standard of wetlands restoration and rehabilitation.

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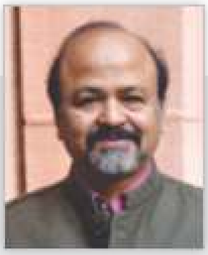

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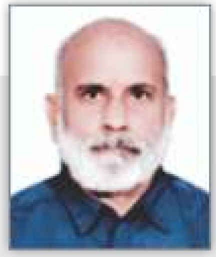

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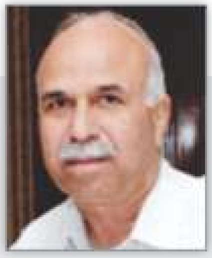

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