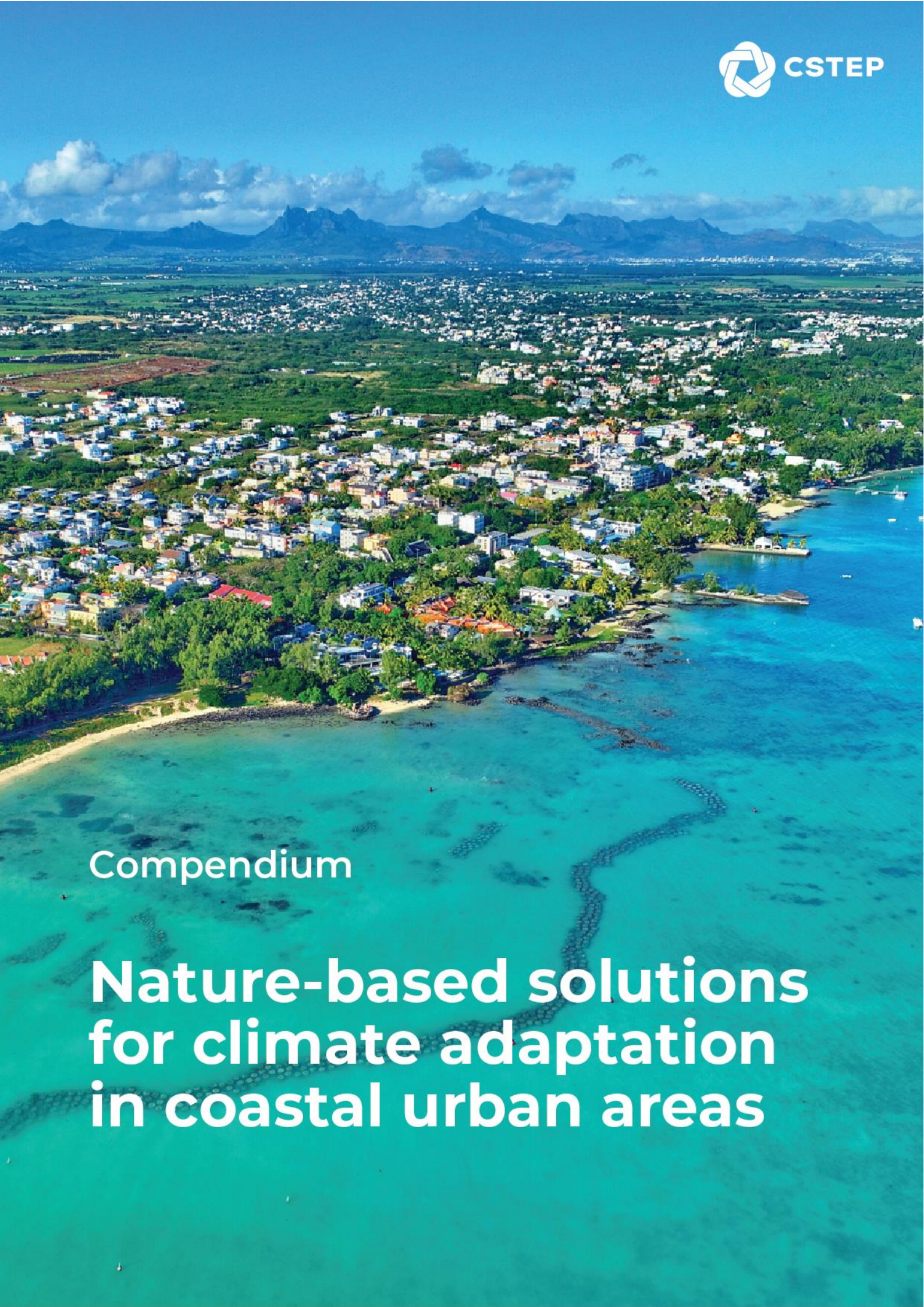

CSTEP

Compendium

Nature-based solutions for climate adaptation in coastal urban areas

Cover image: An artificial reef installed at Mon Choisy Beach, Mauritius, to combat coastal erosion, providing a habitat for marine life.

Credit: Reuben Pillay, 2021 / Climate Visuals Countdown

Compendium

Nature-Based Solutions for Climate Adaptation in Coastal Urban Areas

Lakshmi Menon
Vidhatri Thakkar
Tanushree Garg
Abhishri Gupta
Anushiya J
Indu K Murthy

Center for Study of Science, Technology and Policy
October 2024

Edited and Designed by CSTEP

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Suggested citation: CSTEP. 2024. *Compendium: Nature-based solutions for climate adaptation in coastal urban areas*. (CSTEP-CP-2024-01).

October 2024

Editor: Shayantani Chatterjee
Designer: Bhawna Welturkar

Bengaluru
No. 18, 10th Cross, Mayura Street
Papanna Layout, Nagashettyhalli
RMV Stage 2, Bengaluru 560094
Karnataka (India)

Noida
1st Floor, Tower-A
Smartworks Corporate Park
Sector 125, Noida 201303
Uttar Pradesh (India)

Tel.: +91 (80) 6690 2500
Email: cpe@cstep.in

Foreword

In the face of escalating biodiversity loss and climate change, the urgency for sustainable solutions is undeniable. This compendium is a crucial resource that addresses these challenges through nature-based solutions (NbS). As an environmental strategist and advocate for sustainable development, I am privileged to introduce this vital document.

This compendium synthesises effective NbS practices and methodologies, serving as both a historical record and a blueprint for future actions. Its broad scope—from theoretical frameworks to practical applications—highlights the ability of NbS to tackle environmental, social, and economic issues effectively.

Being significant as a research tool, the compendium lays a robust foundation for scholars, practitioners, and policymakers, fostering adaptable strategies that respect diverse local conditions. It also facilitates practical implementation, translating complex ecological data into actionable insights for stakeholders at all levels.

Moving forward, the strategies within this compendium will be essential in shaping sustainable futures, informing policy, guiding research, and inspiring community actions in line with environmental stewardship.

Let this compendium guide us towards a more sustainable interaction with our planet, reminding us that every nature-based step is a stride towards a sustainable future.

Dr Indu K Murthy

Head, Climate, Environment and Sustainability

Executive Summary

Coastal urban ecosystems are under siege from climate change, rapid urbanisation, and environmental degradation. These escalating pressures threaten the sustainability, resilience, and well-being of communities in these regions. Despite the transformative potential of nature-based solutions (NbS) to combat these issues, their integration into urban planning and policy frameworks remains lacking owing to a persistent knowledge gap and ambiguity surrounding NbS concepts.

This compendium aims to bridge this information deficit by providing a thorough overview of NbS and its relevance to coastal urban ecosystems. It highlights the alignment of NbS with Sustainable Development Goals and diverse policy frameworks, serving as an essential guide for policymakers, practitioners, and stakeholders. Through detailed explanations, practical case studies, and in-depth policy analysis, this document illuminates the path towards wider NbS uptake and implementation in urbanising coastal landscape in India.

Starting with a comprehensive background and clear definitions of NbS, this compendium will aid in facilitating subsequent discussions and case studies. A non-exhaustive review of the policy landscape, covering international commitments, national policies, constitutional provisions, and relevant legislation, underscores the robust legal and policy frameworks supporting NbS. The exploration of funding mechanisms identifies innovative strategies to bridge financial gaps in NbS projects, ensuring the effective allocation of resources.

The compendium features several case studies showcasing practical NbS applications across various scales and regions under four categories, namely, national government initiatives, sub-national efforts, community-driven projects, and issue-specific interventions. Each case study offers invaluable insights into the successes and challenges of implementing NbS, highlighting the importance of collaborative efforts among key stakeholders such as international organisations, non-governmental organisations, research institutions, and government bodies.

To help understand the planning, evaluation, and implementation processes of NbS projects, the compendium provides a roundup of successful NbS frameworks. It offers guidelines and standards for assessing the benefits and performance of NbS projects, ensuring their effectiveness and scalability.

In conclusion, the compendium serves as a primer for a larger body of upcoming work on NbS, emphasising their increasing relevance in promoting sustainable development, enhancing urban resilience, and addressing climate change. It calls for integrated planning, robust policy support, and innovative funding mechanisms to mainstream NbS in urban environments among stakeholders and advance the role of NbS in creating resilient and sustainable coastal urban ecosystems.

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Abbreviations

ADB	Asian Development Bank
BGI	Blue–Green Infrastructure
C-Cube	Climate Centre for Cities
CDIA	Cities Development Initiative for Asia
CEC	Central Empowered Committee
CGWA	Central Ground Water Authority
CPCB	Central Pollution Control Board
CSR	Corporate Social Responsibility
DEFRA	Department of Environment, Food and Rural Affairs
DHS	Department of Human Settlements
DRR	Disaster Risk Reduction
EFA	Economic and Financial Analysis
EGREE	East Godavari River Estuarine Ecosystem
EKW	East Kolkata Wetlands
FSI	Forest Survey of India
GEF	Global Environment Facility
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
ICLEI	International Council for Local Environmental Initiatives
ICZM	Integrated Coastal Zone Management
IFC	International Finance Corporation
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
MISHTI	Mangrove Initiative for Shoreline Habitats and Tangible Incomes
MoEFCC	Ministry of Environment, Forest and Climate Change
NABARD	National Bank for Agriculture and Rural Development
NBA	National Biodiversity Authority
NbS	Nature-Based Solutions
NCSCM	National Centre for Sustainable Coastal Management
NDC	Nationally Determined Contribution
NICFI	Norway's International Climate and Forest Initiative
NIUA	National Institute of Urban Affairs
RECONECT	Regenerating ECOsystems with Nature-based solutions for hydro-meteorological risk rEduCTion
SDG	Sustainable Development Goals
SEI	Stockholm Environment Institute
SMART	Specific, Measurable, Achievable, Relevant, and Time-Bound
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
UNEP	United Nations Environment Programme
UNHCR	United Nations High Commissioner for Refugees
USAID	United States Agency for International Development
WCMC	World Conservation Monitoring Centre
WRI	World Resources Institute
WWF	World Wildlife Fund

1. Background

The world is facing unprecedented and complex environmental and climate challenges. Global warming, driven by human activities, is leading to more frequent and severe weather events such as heatwaves, droughts, storms, and floods. The Indian Meteorological Department states that the duration of heatwaves in India has increased by about 2.5 days between 1961 and 2021. Climate models show that heatwaves might become about 12 times more frequent by the 2040s owing to climate change (Pandey & Sengupta, 2023).

From 1970 to 2016, the populations of mammals, birds, fish, reptiles, and amphibians dropped by an average of 68%, indicating a rapid decline in biodiversity. There are various reasons for this degradation, with land-use changes being the predominant cause, particularly the conversion of natural habitats such as forests, grasslands, and mangroves into agricultural lands (World Wildlife Fund, 2022). These challenges are compounded by the need to sustain a growing population, manage finite natural resources, and reduce inequality and poverty. Given the interconnectedness of these issues, solutions that can simultaneously tackle multiple problems are crucial. Hence, the need for innovative solutions like nature-based solutions (NbS) is more critical than ever. They offer a holistic approach to the pressing environmental and climate challenges of our time, and their rising prominence reflects a growing recognition of the need to harness the power of nature in our quest for a sustainable future.

1.1. Definitions and terminologies

NbS are defined by the International Union for Conservation of Nature as 'actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously benefiting people and nature' (Cohen-Shacham et al., 2016).

They address societal challenges through the protection, sustainable management, and restoration of both natural and modified ecosystems, benefiting both biodiversity and human well-being. They stem from the concept that healthy ecosystems offer multiple benefits to address major challenges including climate change, disaster risk reduction (DRR), food and water security, biodiversity loss, and human health, all of which are critical to sustainable economic development.

Some of the common examples of NbS are (a) the restoration of mangrove forests to protect coastlines from storm surges and erosion and the development of urban green spaces, such as parks and green roofs, (b) for mitigating urban heat island effects, improving air quality, and (c) enhancing urban biodiversity. Rewilding agricultural landscapes to enhance ecosystem services including pollination, water purification, and carbon sequestration also exemplifies NbS in action.

Several global organisations have variations of the same NbS definition to highlight the primary impact of NbS in alignment with their organisational agenda. For instance, the uses the term nature-based infrastructure to underline nature-based projects as vehicles for investment that address multiple 'societal challenges such as climate change, human health, food and water security, and disaster risk reduction

effectively and adaptively, simultaneously providing human well-being and biodiversity benefits' (World Bank, 2022b).

The Nature Conservancy (2017) uses the term natural climate solutions to address NbS that are tailored - "to protect, better manage and restore nature to reduce greenhouse gas (GHG) emissions and store carbon" (Griscom et al., 2017).

Examples include practices that improve forest management to help forest owners increase the carbon stored in trees, reduce fertiliser use resulting in lower GHG emissions, and restore coastal wetlands sequestering carbon in submerged soil.

Another commonly used term that addresses a wider scope of NbS is ecosystem-based adaptation (EbA).

Coined by the Convention on Biological Diversity, EbA is defined as 'the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change' (Convention on Biological Diversity, 2016).

Examples include protecting coastal habitats such as mangroves to provide natural flood defences, reforestation to halt desertification and recharge groundwater supplies during drought, and provision of natural drainage by water bodies such as rivers and lakes to reduce flooding. More recently, EbA was integrated into the Intergovernmental Panel on Climate Change documents to underline the 'use of ecosystem management activities to increase resilience and reduce the vulnerability of people and ecosystems to climate change'.

Other terminologies that are widely used interchangeably with NbS include Building with Nature, Working with Nature, Engineering with Nature, and Working with Natural Processes (Burgess-Gamble, et al., 2018; Ecoshape, 2024; The World Association for Waterborne Transport Infrastructure, 2021). A critical subset of NbS directed towards risk mitigation is ecosystem-based DRR (Eco-DRR). The International Union for Conservation of Nature (IUCN) defines Eco-DRR as 'the sustainable management, conservation and restoration of ecosystems to reduce disaster risk, with the aim to achieve sustainable and resilient development' (IUCN, 2020a).

For the current study, terms such as nature-based coastal adaptation (NbCA) and integrated coastal zone management (ICZM) are relevant. Rahman et al. (2019) first defined NbCA as -

Any coastal adaptation approach that uses ecologically available adaptation options, leverages socio-politically available opportunities, allowing for natural adjustment to coastal climate change impacts while considering societal demand for diverse ecosystem services and minimizing engineered construction as a supporting component.

Common examples of NbCA include managed realignment of existing coastal defence lines to create natural foreshore tidal marsh habitat, greening shorelines through planting, restoring saltmarshes, and relocating houses and infrastructures.

Similarly, the concept of ICZM originated at the 1992 Rio Earth Summit and was outlined as an integrated coastal management and planning approach that encompassed both geographical and political boundaries, with the goal of achieving sustainability (United Nations, 2020).

Residents of Ghoramara Island, West Bengal, reinforce a soil embankment to prevent further coastal erosion that is rapidly submerging their land.

Credit: Debsuddha Banerjee, 2017 / Climate Visuals Countdown

2. Why NbS?

2.1 NbS in the context of Sustainable Development Goals (SDGs)

Adopted in September 2015, SDGs encompass social and economic issues that are directly addressed by NbS. Eradicating poverty (SDG 1), Ensuring food security (SDG 2), Fostering health (SDG 3), Providing clean water and sanitation (SDG 6), Creating jobs (SDG 8), Making cities sustainable (SDG 11), Promoting responsible resource consumption (SDG 12), Taking climate action (SDG 13), Conserving aquatic life (SDG 14), and Protecting terrestrial ecosystems (SDG 15) are targeted through the co-benefits offered by NbS (Figure 1). These solutions boost economic development in coastal regions by improving fisheries, tourism, agriculture, water quality, and resilience to natural disasters, enhancing urban biodiversity

Figure 1. Sustainable Development Goals

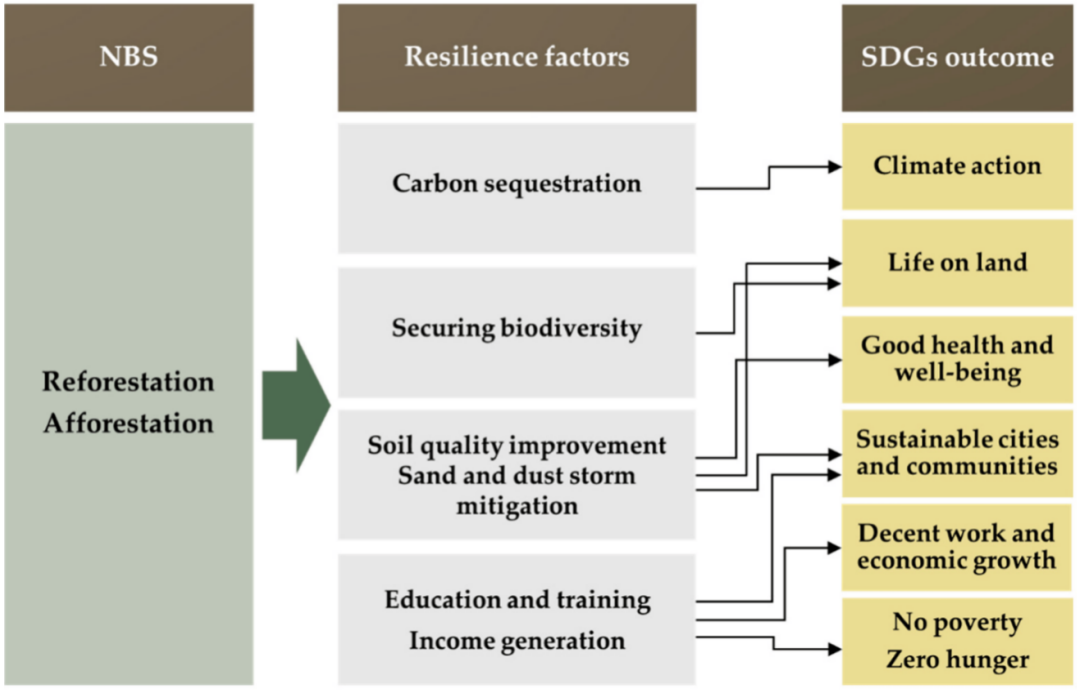
Source: United Nations

In one of the earliest and most comprehensive definitions of NbS and social interlinkages, Cohen-Shacham et al. (2016) explored the role of NbS in water and food security, health, and DRR. They depicted that NbS enhance integrated water management (SDG 6), Adapt food systems (SDG 2), and Improve environmental quality (SDGs 3, 11, 13). Similarly, Dhyani et al. (2021) explored the relevance of NbS in South Asia. By promoting land use that serves multiple functions and reversing land degradation, NbS contribute to multiple SDGs at lower costs (Figure 2). Customising NbS based on local needs and integrating them with engineering solutions can enhance DRR and address both climate-induced and anthropogenic environmental issues. Exceptional progress has been made in South Korea in this regard. This has been discussed by Kim et al. (2021) in terms of fortifying ecosystem and community resilience focussed on terrestrial life (SDG 15), climate action (SDG 13), and sustainable urban communities (SDG 11).

By incorporating NbS into national and international plans, countries can demonstrate how such solutions can lead to substantial changes and a green economic recovery..

Through research and policy integration, NbS can be instrumental in forging a sustainable and equitable future.

Figure 2. Direct contributions of NbS to achieving specific SDGs



Source: Kim et al., 2021

2.2 NbS in the context of coastal urban ecosystems

Climate change poses severe challenges to India's coastal regions, primarily affecting

- Fisheries and agriculture, which are critical to the livelihoods and food security of millions.
- Increased GHG emissions have warmed sea surface temperatures, disrupting marine ecosystems and aquaculture, with species that are particularly vulnerable to temperature fluctuations. Zacharia et al. (2016) noted that this has forced fishermen in the Bay of Bengal to fish in deeper waters and has reduced tuna catches in the Indian Ocean due to altered wind patterns.
- Additionally, rising temperatures have increased the energy requirements for fishing near Mumbai. This includes the increased energy demand for operational purposes and for cooling needs to maintain optimal conditions for catch.
- Similarly, Kerala's fishing communities face threats from erratic monsoon patterns, with anticipated ecosystem service losses on India's east coast possibly reaching USD 17 billion by 2050. Mohanty et al. (2017) explained that NbS policies such as green fishing protocols and the ecosystem approach to aquaculture offer promising avenues for reducing energy demands for fishing.

- Agricultural activities in coastal zones are equally compromised owing to climate change, experiencing seawater intrusion, increased salinity, cyclones, and altered rainfall patterns. These changes have affected crop phenology and yields, especially in irrigated paddy and maize, and increased the risk of pest invasions, notably in Kerala's cashew nut production (George et al., 2019; Kumar, 2011).
- Moreover, the temporal trends in oceanic and marine activities, coupled with increased competition for natural resources and interactions with other sectors, are emerging as significant factors that pose prospective challenges for coastal agriculture (Singh, 2022). Food security is deeply interconnected with climate change and sea-level rise, especially in low-lying coastal regions and small islands, because of the impacts of saltwater intrusion and soil salinisation (Eswar et al., 2021).
- Sea-level rise is a looming threat, and projections indicate potential devastation in major Indian coastal cities by 2030, risking economic stability and infrastructure and displacing populations (Rasmussen, 2021). Urban areas, such as Mumbai, could face significant impacts on the economy and public health (Pednekar & Siva Raju, 2020), while sea-level rise might submerge Tamil Nadu's coastal hamlets, affecting thousands (Khan et al., 2012). In this context,

NbS emerge as vital approaches for coastal adaptation, offering cost-effective and sustainable means to mitigate climate change impacts, including sea-level rise, erosion, and extreme weather.

NbS leverage natural ecosystems such as mangroves and coral reefs to protect coastlines from storm surges and floods, enhancing coastal resilience. Beyond their protective function, NbS contribute to biodiversity conservation and carbon sequestration and support local economies through eco-tourism and fisheries, underpinning the socio-economic fabric of coastal communities. Thus, implementing NbS can significantly bolster the resilience of coastal ecosystems and populations against the adverse effects of climate change.

Urban growth along coastlines significantly impacts coastal ecosystems through (a) habitat loss, (b) pollution, and (c) increased demand for resources. Expanding urban areas often lead to the destruction of vital coastal habitats such as mangroves, wetlands, and coral reefs, which play important roles in supporting marine biodiversity, protecting shorelines from erosion, and absorbing carbon dioxide. Increased urban stormwater runoff can lead to water pollution, affecting water quality and marine life. Furthermore, the construction of infrastructure including seawalls and breakwaters can alter natural coastal processes, leading to issues such as coastal erosion and habitat degradation.

NbS offer a sustainable approach to mitigate the adverse effects of urban growth on coastal ecosystems by integrating natural elements into urban planning and development.

Implementing NbS requires integrated urban planning and management, along with coastal ecosystem protection. This approach promotes the coexistence of human and natural systems, ensuring the long-term health and resilience of coastal environments in the face of urbanisation and climate change.

Local communities are essential to the implementation of NbS in coastal areas, especially for the management and restoration of ecosystems such as mangroves. Their unique traditional knowledge and deep connection to these ecosystems play a pivotal role in realising the full spectrum of benefits from NbS, including biodiversity conservation, climate change mitigation, and livelihood support.

In India, the involvement of coastal communities has been instrumental in the success of mangrove restoration projects. For instance, in the Sundarbans, local efforts have not only enhanced fish stocks and protected against natural disasters but also supported various livelihoods (Hossain et al., 2023).

Communities situated far from primary markets inherently possess limited livelihood opportunities, thereby increasing their reliance on mangrove ecosystems. Additionally, owing to their geographical proximity to the coasts, these communities are particularly vulnerable to inundation during cyclonic events (Ranjan, 2019). As established by Anneboina and Kumar (2017), the significant interconnectedness of mangroves and fisheries in India can present an additional incentive for coastal livelihoods (Anneboina & Kumar, 2017). The organisational and governance structures set up by communities, as seen in the Godavari Mangroves of Andhra Pradesh, facilitate effective management of such projects (Ramasubramanian et al., 2022). Despite facing issues such as interdepartmental challenges, governance roadblocks, and funding constraints, Indian coastal communities have made strides in conservation efforts, partly because of programmes like Mangroves for the Future (MFF), which aim to overcome these barriers by providing support and promoting integrated coastal management (Aung & MacDonnell, 2016).

The role of community-led efforts—supported by private sector involvement and the administrative oversight of local authorities, in alignment with sustainability goals such as National Action Plan on Climate Change—is paramount (Ministry of Environment and Forests, 2008)..

These efforts are further amplified by partnerships with international non-governmental organisations (NGOs), enhancing the scalability and visibility of NbS projects.

Compared with traditional grey infrastructure, NbS offer a cost-effective and multifaceted approach to coastal defence, providing long-term benefits for coastal adaptation in India.

With lower initial and maintenance costs, NbS including mangrove restoration serve multiple functions, including storm surge protection, biodiversity enhancement, and carbon sequestration, delivering greater economic and social value (Le Coent et al., 2021). NbS adapt to changing climate conditions, ensuring continued protection and ecosystem services that support the livelihoods of coastal communities. Additionally,

NbS contribute to disaster risk reduction, safeguarding against the increasing threats of cyclones and floods. By enhancing sustainable livelihoods and preserving cultural identities, NbS ensure the resilience and well-being of coastal communities, aligning with India's broader climate goals and sustainable development objectives.

2.2.1 Challenges in implementing coastal NbS

Implementation of NbS in India's coastal regions faces several challenges. Inadequate funding limits the initiation and sustainability of projects. Weak institutional capacity hampers effective planning and management, and a lack of public awareness and participation undermines community resilience efforts. Knowledge gaps about NbS applications and their effectiveness, combined with an insufficient understanding of their costs and benefits, can impede the accurate assessment and appreciation of their value (Dhyani et al., 2021; Santhanam & Kundu, 2022).

Additionally, the scarcity of policy and economic instruments restricts the adoption and integration of NbS into broader coastal management strategies (Timboe & Pharr, 2021).

Diversity in stakeholder values and perceptions presents an opportunity for nuanced learning and adaptation of NbS across different contexts and geographies. Leveraging this diversity can inform and enhance NbS initiatives, turning challenges into tailored strategies for building climate resilience in India's coastal areas.

A coordinated approach among governments, communities, and stakeholders is essential to harness the full potential of NbS, transforming diverse perspectives into unified action for sustainable impact.

2.2.2 Benefits of integrating NbS in coastal city planning

Incorporating NbS into the urban planning of Indian coastal cities offers a strategic pathway to tackle challenges such as climate change, rapid urbanisation, and the degradation of aging infrastructure (United Nations Environment Programme, 2023). For example, by incorporating green infrastructure such as green roofs and living walls, NbS can protect built infrastructure from weather damage, extending their lifespans. Mangroves are natural barriers that prevent erosion and flooding and thus enhance the resilience of coastal and riverside structures.

Rain gardens and permeable pavements can more effectively manage stormwater, preventing flood damages (Khodadad et al., 2023).

By applying NbS, Indian cities can enhance their urban landscapes, making them more resilient and liveable.

Key strategies for this integration include embedding NbS in land-use planning; establishing supportive policies; fostering partnerships across public, private, and community sectors; and engaging local populations in the planning process (Dhyani et al., 2021). Additionally, education and research, dedicated funding, and interdisciplinary collaboration are crucial for the successful adoption of NbS.

The aesthetic appeal of NbS can transform urban spaces into attractive and engaging environments, which is particularly important in densely populated areas such as Mumbai and Chennai. Furthermore, creating green urban commons through NbS can significantly enhance liveability and social cohesion, addressing the scarcity of public spaces in rapidly expanding cities (Kabisch et al., 2022). Trust in local governance and the NbS process is vital, requiring transparency and community involvement. Moreover, this co-creation of NbS involving local governance and communities, taking advantage of the diverse cultural and ecological landscape of Indian coastal cities, ensures that solutions are tailored to local needs. Collaborative governance, involving various stakeholders, helps address complex urban challenges, while an inclusive narrative for NbS aligns them with broader urban agendas such as climate resilience and biodiversity conservation (Kiss et al., 2022). Moreover, designing NbS for adaptability and replicability is essential to apply the learnings across different contexts.

3. Why this Compendium on NbS?

It is evident from the literature that NbS offer holistic solutions to address multiple challenges and could be transformative if integrated into urban planning. However, there remains a gap in knowledge and ambiguity surrounding NbS. To address this gap and bridge the information deficit, the Center for Study of Science, Technology and Policy (CSTEP) has put together this compendium to provide an overview of NbS and its relevance to coastal urban ecosystems and present a framework to aid decision-making.

This compendium is designed as an essential reading material that demystifies NbS for a wide audience. It documents relevant terms, schemes, policies, organisations, methodologies, typologies, funding mechanisms, and case studies. It serves as a reference for policymakers, urban planners, and researchers and aims to facilitate the application of NbS, particularly in coastal contexts. This resource, especially in the Indian context, is aimed to serve as a reference document for field experts on the current state of knowledge and best practices in NbS.

A key section of the compendium delves into the financial landscape of NbS for coastal adaptation—vital for tapping into and optimising funding sources. Crafted as a non-exhaustive guide, this compendium aims to empower readers to explore and apply NbS, steering towards the resilience of communities in the urban coastal landscape in India and the Global South.

The compendium is structured in the following manner. Section 4 discusses the policies at the international and national levels to guide NbS implementation. Funding mechanisms of various NbS projects have been described in Section 5, and selected case studies are delineated in Section 6. Institutions and organisations promoting NbS and important frameworks and applications are described in Sections 7 and 8, respectively.

4. Policy Landscape

4.1. International commitments

International commitments are powerful mechanisms to guide and bolster global consensus for climate action. They provide a robust framework and a shared vision that can guide cities in the Global South, like those in India, to effectively implement NbS for coastal adaptation. By aligning local action with these global agreements, developing nations can progress towards sustainable development, climate resilience, and enhanced ecosystem and community well-being, setting a pathway for sustainable coexistence between humans and nature. International frameworks discussed here underscore the urgent need for sustainable, resilient, and inclusive approaches such as NbS to combat climate change, enhance disaster risk reduction, promote biodiversity conservation, and achieve socio-economic development goals.

Apart from the Sustainable Development Goals, coastal and marine NbS have been recognised in the Intended Nationally Determined Contributions during the Paris Agreement in 2015, along with the commitments made in the Sendai Framework for Disaster Risk Reduction and the post-2020 Global Biodiversity Framework. The inclusion of NbS vocabulary in these international commitments underscores the global acknowledgment of the critical role of NbS in addressing climate change and DRR. Overall, 97 countries have incorporated coastal and marine NbS in their Nationally Determined Contributions, with 61 countries focussing on both mitigation and adaptation and acknowledging the socio-economic benefits for coastal communities (Lecerf et al., 2021).

The 30 × 30 post-2020 Global Biodiversity Framework under the Convention of Biological Diversity is a global commitment to conserve 30% of the Earth's lands and oceans by the year 2030. It further highlights the importance of NbS in preserving biodiversity, sequestering carbon, and enhancing ecosystem and community resilience against climate impacts.

4.2. National policies and frameworks

India's national policies and frameworks adhere to international obligations and enhance the national capacity to address environmental challenges through innovative, sustainable, and locally adapted solutions. This strategic alignment enables the country to advance its development goals while contributing to global efforts to mitigate climate change, conserve biodiversity, and reduce disaster risks. The nation's commitment to environmental preservation and sustainable development is deeply rooted in its legal and policy framework, which encompasses various measures aimed at the conservation, protection, sustainable use, access, and benefit-sharing of its natural resources. India's approach to NbS involves integrating these solutions across various sectors and levels of governance, from national to local. This includes constitutional provisions, legislation, and national policies related to water management, agriculture, urban development, and coastal zone management (*Nature-Based Solutions for Urban Climate Resilience in South Asia*, 2022).

Effective coordination between different governmental levels and sectors ensures that India's policies are comprehensive and aligned with international commitments.

4.2.1. Constitutional Provisions

The Constitution of India has evolved to include provisions for environmental protection that align with NbS motives. It provides a robust framework for implementing NbS, promoting greater public participation, environmental awareness, and preservation of ecological integrity crucial for the well-being of all citizens. Major constitutional provisions and their relevance for NbS are explained in Table 1.

Table 1. Constitutional provisions and their relevance for NbS

Constitutional provision	Provision	NbS relevance
Fundamental Right: Article 14 (Right to Equality)	Grants equality before the law or equal protection of the laws within the territory of India.	Links a healthy ecosystem maintained through NbS to resilience against climate impacts, emphasising adaptation co-benefits for vulnerable communities Expands to encompass protections against climate change, underscoring environmental health as a core element of the right to life
Fundamental Right: Article 21 (Right to Life)	Expansively interpreted to include the right to a healthy environment, extended to include protection against the adverse effects of climate change	
Fundamental Right: Article 19(1)(g) (Freedom to Practice Profession, Occupation, Trade, or Business)	Grants the right to pursue any profession or business, conditioned by environmental considerations	Provides a legal basis for NbS in business and industry, prioritising ecological health in economic activities
Article 47 (Duty of the State to Enhance the Nutrition Levels and Living Standards and Promote Public Health)	Marks the duty of the State to raise the nutrition level and living standards of its people, improve public health, and prohibit the consumption of substances that are injurious to health.	Connects the enhancement of ecosystem services through NbS with improved nutrition and living standards, including access to green spaces
Article 48 (Organisation of Agriculture and Animal Husbandry)	Notes the duty of the State to protect and improve the environment, safeguard forests and wildlife, and promote modern and scientific practices for agriculture and animal husbandry	Aligns with NbS such as agroforestry and sustainable land use for ecological conservation, supporting better air, water, and soil quality
Fundamental Duty: Article 51A (g) (Duty of Every Citizen to Protect the Environment)	Highlights the duty of every citizen to protect the environment, including forests, lakes, rivers, and wildlife, and be compassionate towards living creatures	Emphasises citizen involvement in natural resource protection and supports NbS for ecological balance

Constitutional provision	Provision	NbS relevance
Article 246 (Subject-matter of laws made by the Parliament and by the State Legislatures)	Delineates the jurisdiction for legislation between the Union and State Governments, addressing different environmental issues at appropriate levels.	Enables effective local and state-level management of environmental issues, supporting national standards for pollution control and wildlife conservation, beneficial for NbS
Article 253 (Legislation for giving effect to international agreements)	Empowers the Parliament to legislate on environmental protection to fulfil international commitments	Facilitates India's compliance with international environmental treaties and strengthens the legal framework for NbS globally
Panchayati Raj Act, 1992	Empowers local bodies i.e., Panchayats for water management, irrigation, watershed development, and sanitation.	Decentralisation aids NbS by enabling localised management of ecosystems, water resources, and community-led conservation efforts
74th Constitutional Amendment Act, 1992	Marks a significant shift towards decentralisation and greater local governance, emphasising urban local bodies as self-governing entities promoting participatory governance	Provides a foundation for local bodies to integrate ecological strategies into urban planning and encourages community-led NbS initiatives, with local governments including Panchayats playing a vital role in soil, water, and forestry management (Legasis, 2022)

4.2.2. Legislation

The linkage between India's legislative framework for environmental protection and the NbS encompasses conservation, restoration, and sustainable use of ecosystems to address challenges such as climate change, water security, water pollution, and disaster risk management (Figure 3). Some environmental laws and their relevance for NbS are described in Table 2.

Figure 3. Legislation and enforcement agencies

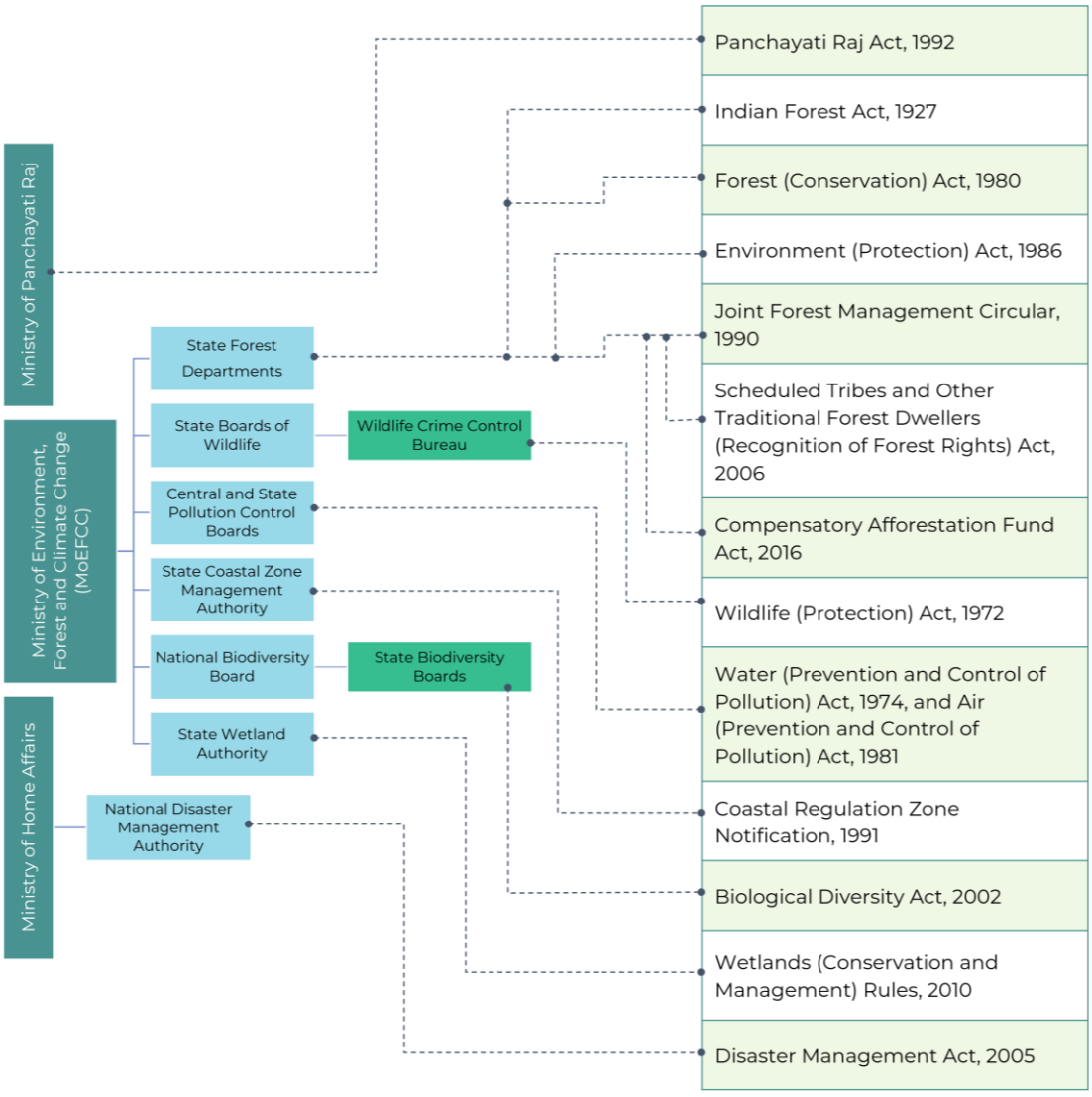


Table 2. Legislative frameworks and their relevance for NbS

Legislative framework	Enforcement agency	Provision	NbS relevance
Indian Forest Act, 1927	Ministry of Environment, Forest and Climate Change (MoEFCC), through State Forest Departments	Governs forests, forest produce transit, and duties on timber and other forest products within various forest categories, excluding those under government control	Supports a balanced ecological cycle, aids in climate regulation and biodiversity support and sustains forest-based livelihoods
Wildlife (Protection) Act, 1972	MoEFCC, through State Boards for Wildlife, and Wildlife Crime Control Bureau	Protection of wildlife and their habitats with amendments to provide better protection mechanisms and include conservation reserves and community reserves within its purview	Aims to ensure biodiversity and ecological balance for sustaining ecosystem services complementarily provided by NbS
Water (Prevention and Control of Pollution) Act, 1974, and Air (Prevention and Control of Pollution) Act, 1981	MoEFCC, through Central Pollution Control Board and respective State Pollution Control Boards	Earliest legislation that laid the foundation for India's fight against environmental pollution, establishing the framework for controlling air and water pollution	Implicitly support NbS by aiming to maintain the natural purifying role of wetlands and forests in filtering air and water pollutants
Forest (Conservation) Act, 1980	MoEFCC, through State Forest Departments	Restricts de-reservation of forests and use of forest land for non-forest purposes without the explicit approval of the Central Government	Aims to strengthen NbS by enhancing ecosystem resilience and promote the sustainable use of natural resources
Environment (Protection) Act, 1986	MoEFCC, through State Forest Departments	Empowers the Central Government to prevent environmental pollution and address specific environmental challenges	Enhances environmental protection and management capabilities, supporting diverse NbS applications across regions
Joint Forest Management Circular, 1990	MoEFCC, through State Forest Departments	Mandates forest preservation and regeneration through community co-management	Enhances biodiversity and improves socio-economic conditions of communities, maintaining ecosystem services through NbS

Legislative framework	Enforcement agency	Provision	NbS relevance
Coastal Regulation Zone Notification, 1991	MoEFCC, through State Coastal Zone Management Authority	Protects beaches from unplanned development and identifies sensitive areas for conservation. Mandates states to prepare Coastal Zone Management Plans by classifying four different Coastal Regulatory Zones.	Promotes NbS by maintaining coastal and marine ecosystems, vital for biodiversity conservation and climate adaptation
Biological Diversity Act, 2002	MoEFCC, through National Biodiversity Authority with state biodiversity boards	Focusses on the conservation of biodiversity, sustainable use of its components, and equitable resource benefits	Critical for achieving the Convention on Biological Diversity goals, focussing on NbS for ecological conservation and sustainable resource use
Disaster Management Act, 2005	Ministry of Home Affairs through National Disaster Management Authority	Establishes comprehensive disaster management mechanisms at various administrative levels	Incorporates ecosystem-based solutions for disaster risk mitigation, enhancing community resilience through NbS
Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006	MoEFCC, through Ministry of Tribal Affairs	Grants forest-dwelling communities rights over inhabited forest lands and promotes community forest resource management	Advances community-driven environmental governance to legally 'protect, regenerate, conserve, or manage' their forest resources, effectively incorporating NbS into statutory law
Wetlands (Conservation and Management) Rules, 2010	MoEFCC, through the respective state wetland authorities	Aims for wetland conservation and management to prevent degradation	Highlights the role of wetlands as NbS for water purification, flood control, and climate resilience, urging nationwide conservation
Compensatory Afforestation Fund Act, 2016	MoEFCC, through State Forest Departments	Enables compensatory afforestation and forest conservation compliance	Supports forest conservation efforts through a specific institutional framework, aligned with the Forest (Conservation) Act, 1980

4.2.3. Policy Landscape

The policy landscape encompasses a range of policies across forestry, agriculture, water management, and urban planning, designed to bridge the gap between sustainable development and climate action. Although not explicitly labelled as NbS, these crucial mechanisms are essential for enhancing ecosystem resilience, conserving biodiversity, and contributing to climate adaptation and DRR (Figure 4). Key policies and their implications for NbS are summarised in Table 3.

Figure 4: Policy Landscape and Enabling Agencies

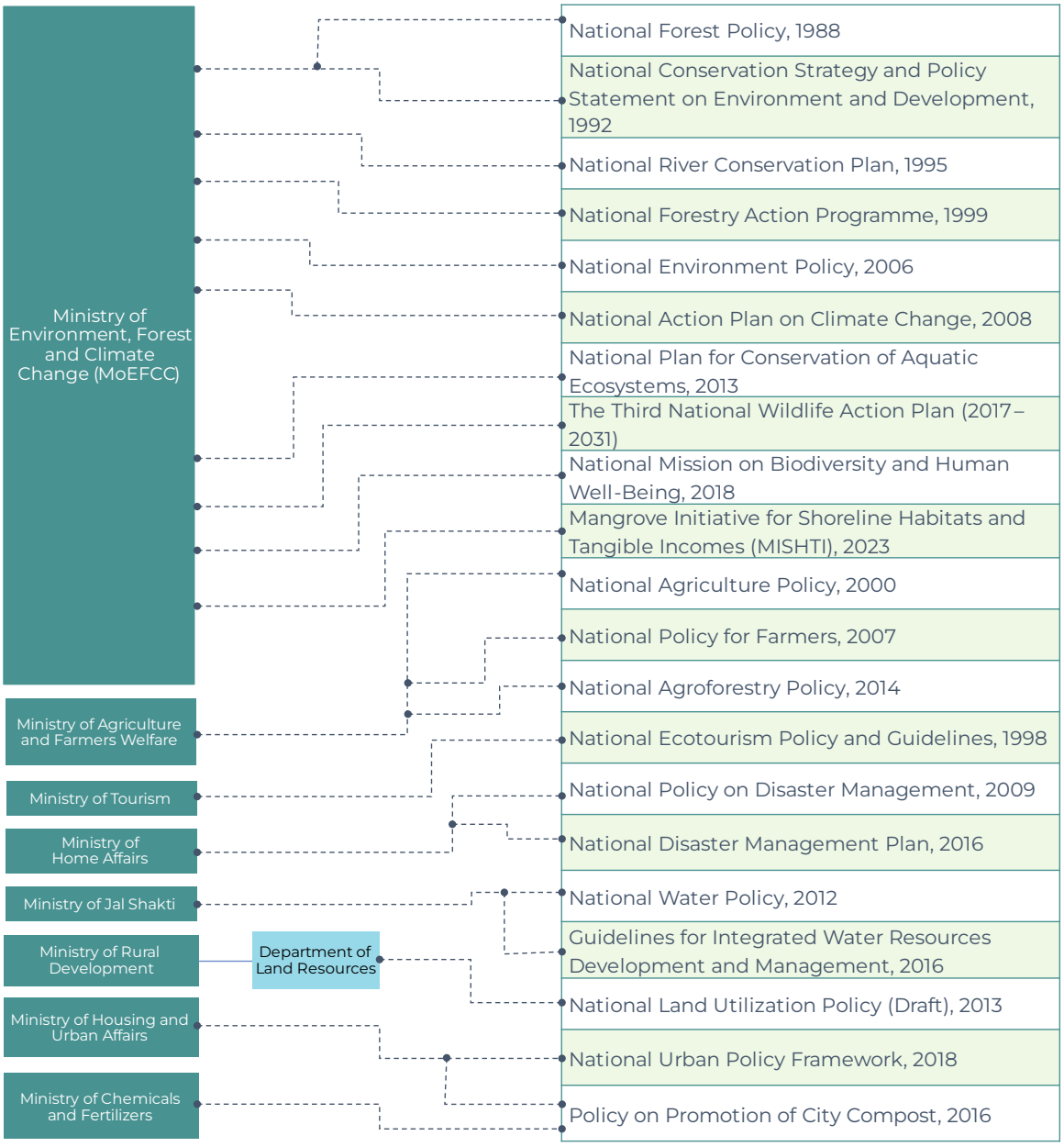


Table 3. Major policies and their relevance for NbS

Policy	Enabling agency	Provision	NbS relevance
National Forest Policy, 1988	Ministry of Environment, Forest and Climate Change (MoEFCC)	Advocates an ecology-centric approach to protect, conserve, and develop forests, with the 2018 modifications suggesting improvements in partnerships for afforestation, forest fire prevention, and timber industries	Increases forest cover, encourages community management of forests, and integrates climate considerations into forestry practices
National Conservation Strategy and Policy Statement on Environment and Development, 1992	MoEFCC	Aligns India's policies with environmental perspectives to address current challenges and set future priorities	Guides the inclusion of environmental considerations in national development policies to support NbS
National River Conservation Plan, 1995	MoEFCC	Outlines strategies for preventing pollution in over 33 rivers	Focusses on river conservation to maintain water quality and ecosystem health
National Ecotourism Policy and Guidelines, 1998	Ministry of Tourism	Focusses on preserving natural resources and regulating ecotourism based on seven principles from a community development and ecological conservation perspective	Promotes sustainable tourism that conserves natural resources and supports communities, aligning with NbS principles
National Forestry Action Programme, 1999	MoEFCC	Details actions for sustainable forest development over 20 years, targeting forest and tree cover as per the National Forest Policy	Supports sustainable forest management and development initiatives
National Agriculture Policy, 2000	Ministry of Agriculture and Farmers Welfare	Promotes equitable growth and sustainability in agriculture, emphasising bio-resource conservation and sustainable resource usage, including soil conservation through NbS	Encourages sustainable agricultural practices and conservation of natural resources

Policy	Enabling agency	Provision	NbS relevance
National Policy for Farmers, 2007	Ministry of Agriculture and Farmers Welfare	Supports farmers' productivity and quality of life improvements, emphasising natural resource protection	Aims to enhance agricultural productivity while ensuring environmental sustainability
National Environment Policy, 2006	MoEFCC	Outlines India's strategy to address challenges of environmental conservation, guide regulatory reforms, and mainstream environmental considerations into all developmental activities	Facilitates environmental safeguarding across development sectors
National Action Plan on Climate Change, 2008	MoEFCC	Outlines eight national missions focussing on aspects such as sustainable development, energy efficiency, water conservation, and strategic knowledge for climate change	Addresses climate change concerns and promotes sustainable development, central to NbS strategies
National Policy on Disaster Management, 2009	Ministry of Home Affairs	Takes a proactive approach to disaster risk reduction and management	Enhances the capacity for disaster preparedness and response across multiple levels of governance
National Water Policy, 2012	Ministry of Jal Shakti	Advocates integrated water resource management based on hydrological units, integrating quality, quantity, and ecological factors, and declares water as a community resource. The Draft National Water Framework Bill (2016) encapsulates principles of water protection, conservation, regulation, and management.	Promotes sustainable water management practices and legal frameworks for water resource conservation
National Plan for Conservation of Aquatic Ecosystems, 2013	MoEFCC	Focusses on the restoration and conservation of water bodies and wetlands	Aims to preserve aquatic ecosystems, enhancing biodiversity and water quality

Policy	Enabling agency	Provision	NbS relevance
National Land Utilization Policy (Draft)	Department of Land Resources; Ministry of Agriculture	Aims at sustainable development with an emphasis on preserving lands with important environmental functions	Seeks to balance land-use development with the conservation of ecologically important areas
National Agroforestry Policy, 2014	Ministry of Agriculture	Addresses climate change mitigation and sustainability in agriculture through agroforestry practices	Integrates trees and shrubs into agricultural landscapes to enhance productivity, sustainability, and climate resilience
National Disaster Management Plan, 2016	Ministry of Home Affairs	Addresses disaster management across various levels based on the Sendai Framework for Disaster Risk Reduction	Enhances the coordination and management of water resources to ensure sustainability and efficiency
Guidelines for Integrated Water Resources Development and Management, 2016	Ministry of Jal Shakti	Implements integrated management principles at the river-basin level in line with the National Water Policy	Enhances the coordination of water resources to ensure sustainability and efficiency
Policy on Promotion of City Compost, 2016	Ministry of Housing and Urban Affairs; Minister of Chemicals and Fertilizers	Encourages organic waste composting to manage waste and reduce greenhouse gas emissions	Supports waste reduction and sustainable practices in urban waste management
The Third National Wildlife Action Plan (2017–2031)	MoEFCC	Focusses on wildlife conservation with considerations for climate change impacts, including adaptation and mitigation strategies	Enhances wildlife conservation efforts with a focus on climate resilience and adaptation

Policy	Enabling agency	Provision	NbS relevance
National Mission on Biodiversity and Human Well-Being, 2018	MoEFCC	Aims to address biodiversity loss and environmental degradation through scientific research and public participation for protecting natural heritage sites	Promotes the conservation of biodiversity and the engagement of communities in environmental stewardship
National Urban Policy Framework, 2018	Ministry of Housing and Urban Affairs	A unified strategy for India's urban planning built on 10 principles related to key urban functions, focussing on environmental sustainability to achieve sustainable urbanisation. It urges all government levels to integrate sustainability efforts to proactively mitigate negative impacts on crucial natural systems, supporting communities, economy, and infrastructure.	Guides sustainable urban development with a strong focus on environmental sustainability and NbS integration
Mangrove Initiative for Shoreline Habitats and Tangible Incomes (MISHTI), 2023	MoEFCC	Launched at the Mangrove Alliance for Climate during the 27th Conference of Parties under the United Nations Framework Convention on Climate Change, MISHTI strives to improve shoreline habitats while offering real economic benefits through the restoration of ecosystems.	Focusses on the restoration and economic valourisation of mangrove ecosystems, enhancing coastal resilience and community livelihoods

5. Funding Mechanisms

Globally, the annual funding for NbS amounts to USD 200 billion, which is only a third of the amount required each year until 2030 (USD 542 billion) to achieve targets related to climate change, biodiversity, and land degradation. Further, 82% of this amount is government-funded, underscoring the substantial investment opportunities offered by NbS owing to their cost-effectiveness and wide-ranging benefits to the commons (UNEP, 2023).

In India, the FY2023–2024 Union Budget emphasised expanding NbS to enhance natural ecosystems and local livelihoods, with initiatives such as the Amrit Dharohar scheme and the Mangrove Initiative for Shoreline Habitats and Tangible Incomes focussing on wetland use, biodiversity enhancement, and shoreline protection.

However, challenges such as inadequate funding, limited institutional capacity, and poor public engagement continue to impede progress. There is also a significant gap in stakeholder understanding of the risks and benefits of NbS projects, deterring investment owing to outcome uncertainties.

Financing for NbS in India primarily comes from government grants and loans, with substantial contributions from public sector institutions such as the National Bank for Agriculture and Rural Development (NABARD). NABARD collaborates with international development finance institutions such as the World Bank, United States Agency for International Development (USAID), Kreditanstalt für Wiederaufbau (KfW), Japan International Cooperation Agency, and Global Environment Facility (GEF) to provide targeted financial support for forestry, water management, and soil conservation projects that directly contribute to climate adaptation.

The private sector contributes through Corporate Social Responsibility (CSR) funds, primarily supporting forestry and water-related NbS projects, with non-CSR funds occasionally directed towards broader environmental initiatives through green bonds or concessional loans.

During the coronavirus disease pandemic, the Indian government's fiscal stimulus significantly boosted investments in rural job creation under the Mahatma Gandhi National Rural Employment Guarantee Act. These investments aimed to enhance long-term climate resilience through afforestation and land, soil, and water management while ensuring income generation during the global crisis.

5.1. Bridging financial gaps

Gaps in funding NbS fundamentally stem from a lack of understanding about NbS. Often, their roles in several existing initiatives remain underappreciated because of inadequate accounting of their ecosystem services. The absence of market mechanisms, limited private-sector financing opportunities, and the lack of cost–benefit analysis for nature-based infrastructure have resulted in grey infrastructure projects based on short-term profit being favoured over NbS.

Although 94% of NbS funding in India comes from government sources, mirroring global trends, this reveals a fragmented financial landscape that underlies the funding

structure. Moreover, the provision of technical assistance to organisations engaged in NbS lacks an executive committee under the Ministry of Environment, Forest and Climate Change (MoEFCC) to review and distribute grants, which hinders the exploration of new NbS strategies and models. This gap detracts from attracting private investments (currently a meagre 3.6%) and aligning NbS measures with national initiatives.

To address these financing gaps, it is crucial to establish coordinated funding procedures, explore public funding sources, and promote financial instruments such as India's Sovereign Green Bond Framework (Dorst et al., 2021; Yadav et al., 2024). Including diverse sectors and private equity in this framework can foster a more inclusive approach and help mobilise additional resources necessary for implementing large-scale nature-based climate adaptation projects.

A dedicated monitoring body is needed to manage and track fund disbursement and application (*What Are Nature-Based Solutions and Why They Matter for India*, 2023). This would ensure transparency and accountability in fund management calls for state-specific reporting and issue-resolution mechanisms.

Public–private partnership models and financial risk minimisation strategies can incentivise private sector involvement in NbS, thus broadening the funding base beyond government sources. Last but not least, developing clear legal frameworks and a comprehensive list of funding instruments can provide clarity and support for both public and private entities involved in NbS.

6. Case Studies

The applicability of NbS for adaptation is underscored by the no one-size-fits-all approach. Examining real-world case studies is essential for learning their adaptation objectives, design context, implementation, and generation of co-benefits. The case study compilation looks at the effectiveness of various NbS approaches, offering valuable lessons and inspiration for research, decision-making, and implementation. The following sections have been sampled from global NbS initiatives that wrestle with complexities of development, population density, and climate vulnerability representative of developing nations, particularly along the tropics. They have been categorised broadly on the basis of implementation agencies for large-scale impact and specific targeted interventions. A summary of the case studies in this compendium is given in Table 4. Summary of case studies (n = 30), and the locations are highlighted in Figure 5. The timeline of implementation of the studied NbS projects is shown in Figure 6.

Figure 5. Distribution of case studies in India and Bangladesh

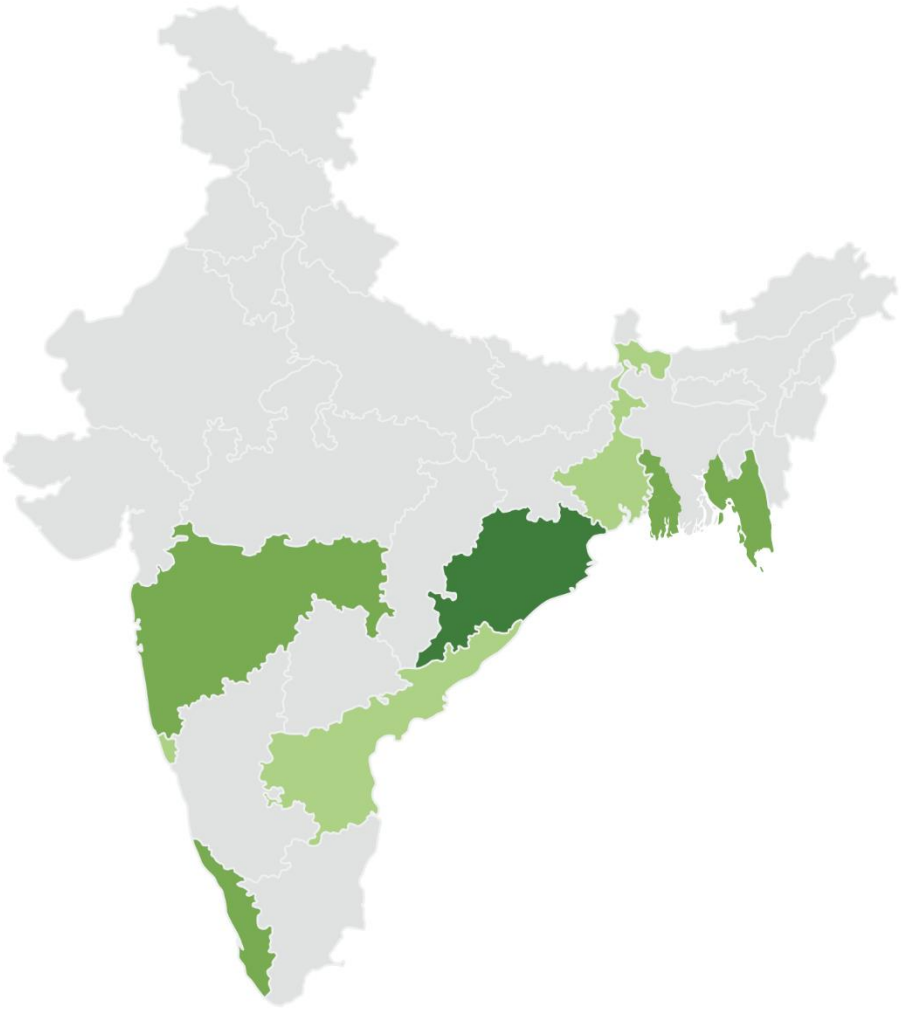


Figure 6. Timeline of implementation of NbS projects

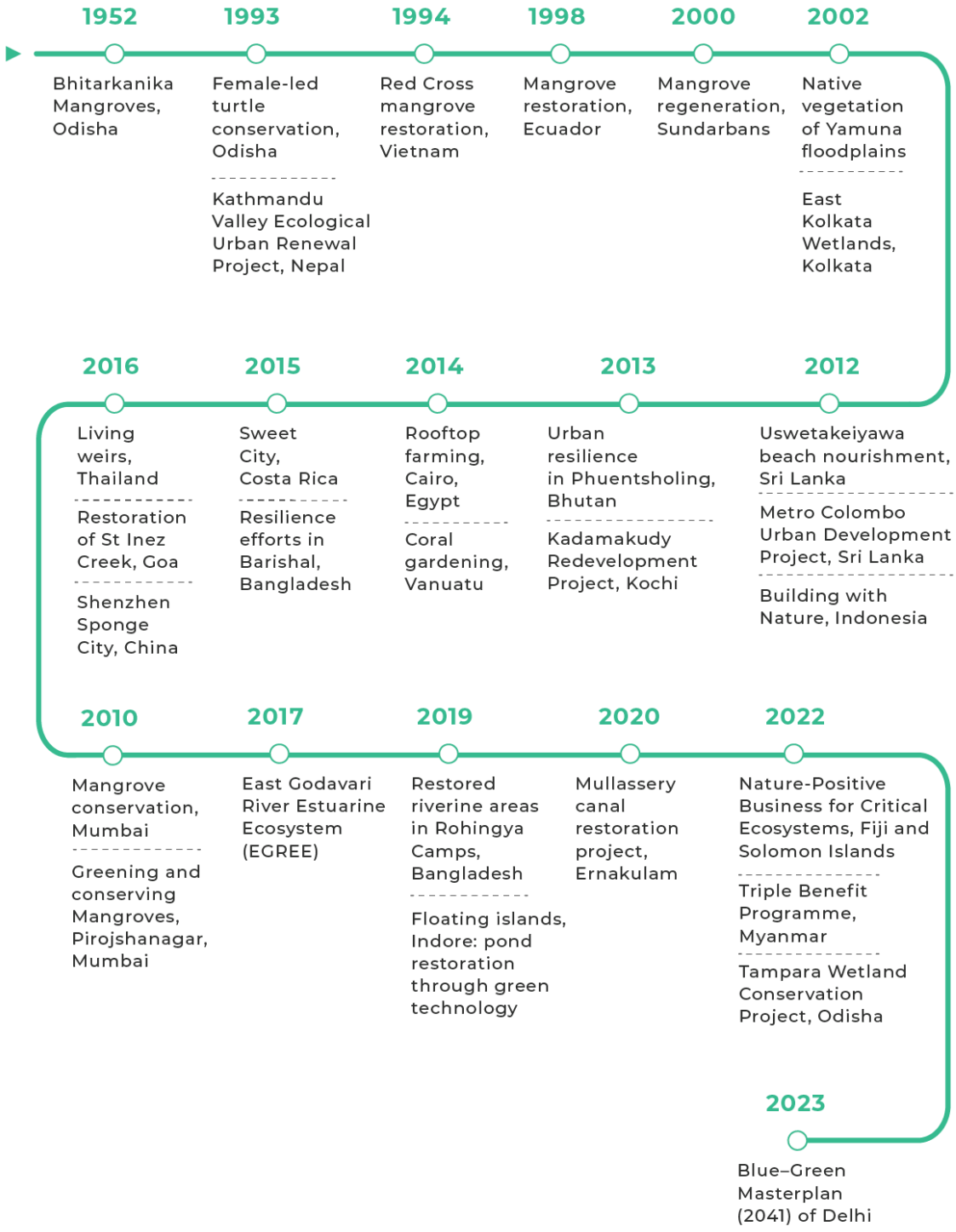


Table 4. Summary of case studies (n = 30)

Type	Case studies	Year	Location	Objective	Ecosystem type	Agency	Cost (in USD)
NbS	Uswetakeiyawa beach nourishment, Sri Lanka: Shoreline restoration and erosion control (Ongoing)	2012	Uswetakeiyawa, Western Province, Sri Lanka	Beach Nourishment; Tourism; Coastal Erosion	Coastal	Coast Conservation Department of Sri Lanka	300 million
NbS	East Godavari River Estuarine Ecosystem (EGREE): Policy-driven ecosystem management (Ongoing)	2017	East Godavari District, Andhra Pradesh, India	Biodiversity Conservation; Mangrove Restoration; Socio-economic Engagement	Estuarine; Mangroves	Government of India; Wildlife Institute of India; EGREE Foundation; Global Environment Facility, United Nations Development Programme	0.94 million
Hybrid	Urban resilience in Phuentsholing, Bhutan: Integrating NbS in urban planning for DRR (Ongoing)	2013	Phuentsholing, Chukha District, Bhutan	Urban Resilience; Disaster Mitigation; Community Development	Urban; Riverine	Royal Government of Bhutan, Department of Human Settlements, Phuentsholing Thromde (municipality), Global Environment Facility, and Asian Development Bank (ADB)	63 million
NbS	Living weirs, Thailand: Enhancing water quality and biodiversity in urban waterways (Ongoing)	2016	Khlong-La River, Songkhla Province; Khlong Wang Heep River, Nakhon Si Thammarat Province, Thailand	Water Management; Community Resilience; Biodiversity Enhancement	Urban; Riverine	Office of the National Water Resources - Kingdom of Thailand, and GIZ GmbH; United Nations Environment Programme-World Conservation Monitoring Centre	-
NbS	Native vegetation of Yamuna floodplains: Policy-supported ecological restoration (Completed in 2010)	2002	New Delhi, National Capital Territory of Delhi, India	Biodiversity Conservation; Ecosystem Restoration; Community Engagement	Urban; Wetlands	Government of National Capital Territory of Delhi; Government of Uttar Pradesh and its agencies; Delhi Development Authority; Centre for Environmental Management of Degraded Ecosystems of the University of Delhi	57 million
Hybrid	Restoration of St Inez Creek, Goa: Urban waterway revitalisation (Ongoing)	2016	Panaji, Goa, India	Urban Revitalization; Community Engagement; Ecological Restoration	Urban; Wetlands	Corporation of City of Panaji; Imagine Panaji Smart City Development Limited Taleigao Village Panchayat; Greater Panaji Planning and Development Authority; Asian Development Bank (ADB),	25 million
Grey	Mullassery Canal restoration project, Ernakulam: Local-led waterway revitalisation (Ongoing)	2020	Kochi, Kerala, India	Community Participation; Urban Resilience; Waterway Revitalisation	Urban; Coastal	Kochi Municipal Corporation, Cochin Smart Mission Limited and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) via Non-National Infrastructure Pipeline Real Estate Joint Venture	8.26 million

Type	Case studies	Year	Location	Objective	Ecosystem type	Agency	Cost (in USD)
Hybrid	Metro Colombo Urban Development Project, Sri Lanka: Urban flood resilience and water management (Ongoing)	2012	Sri Jayawardenapura Kotte, Colombo, Sri Lanka	Flood Resilience; Wetland Conservation; Urban Development	Urban, wetlands, coastal, riverine	Sri Lanka Land Development Corporation, Colombo Municipal Council. Funded by World Bank, International Bank for Reconstruction and Development	321 million
NbS	Sweet City, Costa Rica: Urban green space development for community well-being (Completed in 2020)	2015	Curridabat, San José, Costa Rica	Urban Green Space Biodiversity Restoration Citizen Participation	Urban, wetlands	Municipality of Curridabat, civil society organisations, private firms, not-for-profit organisations, and city residents/resident associations	45 million
Hybrid	Blue–Green Masterplan (2041) of Delhi: Integrating green and blue spaces into urban planning (Ongoing)	2023	New Delhi, National Capital Region, India	Integrated Urban Planning; Green-Blue Infrastructure; Environmental Rejuvenation	Urban, Floodplains	Delhi Development Authority	-
NbS	Female-led turtle conservation, Odisha: Community-driven marine conservation initiatives (Ongoing)	1993	Ganjam, Odisha, India	Community-Driven Marine Conservation, Female Empowerment, Turtle Habitat Protection	Coastal	Samudram Women's Federation, Odisha Marine Resource Conservation Consortium, Odisha Traditional Fish Workers' Union, United Artists Association, Greenpeace, World Wildlife Fund (India), Odisha University of Agriculture and Technology, Central Institute of Fisheries Education, Ford Foundation, International Council of Agricultural Research, Coastal Marine Fisheries Research Institute (Government of India), Berhampur University funded by Equator Initiative (United Nations Development Programme), Conservation International.	-
NbS	Mangrove regeneration, Sundarbans: Community efforts in mangrove conservation (Ongoing)	2000	Gosaba, West Bengal, India; Karamjal, Khulna, Bangladesh	Mangrove Conservation; Community Resilience; Ecotourism Sustainability	Mangroves	Caritas India, Gram Panchayats, community-based organisations; non-governmental organisations	-
Hybrid	Rooftop farming, Cairo, Egypt: Urban agriculture driven by community participation (Completed in 2017)	2014	Ezbet-al Nasr, Cairo, Egypt	Urban Agriculture, Community Empowerment, Climate Adaptation	Urban, Building Rooftops	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ); Shaduf	-
NbS	Coral gardening, Vanuatu: Community-	2014	Pele, Shefa Province, Vanuatu	Coral Reef Restoration; Community-Based	Coral reefs, Marine	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ); Vanuatu's	-

Type	Case studies	Year	Location	Objective	Ecosystem type	Agency	Cost (in USD)
	based coral reef restoration (Completed in 2017)			Adaptation; Marine Biodiversity		Nguna-Pele Marine and Land Protected Area Network	
NbS	Building with Nature, Indonesia: Community-centric coastal protection (Ongoing)	2012	Demak, Central Java Province, Indonesia	Coastal Resilience; Mangrove Rehabilitation; Community-Centric Protection	Mangrove; Coastal	Government of Indonesia, Wetlands International, Ecoshape, World Bank, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Germany)	400 million
NbS	Restored riverine areas in Rohingya Camps, Bangladesh: Rehabilitation of water systems and natural areas within refugee settlements (Ongoing)	2019	Ukhiya, Chittagong, Bangladesh	Refugee Camp Rehabilitation, Riparian Ecosystem Restoration, Water System Improvement	Coastal, Highland Riparian	Center for Natural Resource Studies and United Nations High Commissioner for Refugees	0.44 million
NbS	Mangrove restoration, Ecuador: Ecosystem recovery project aimed at restoring vital mangrove habitats for biodiversity and coastal protection (Ongoing)	1998	Esmeraldas, Manabí, Guayas, El Oro, Ecuador	Mangrove Conservation; Coastal Protection; Sustainable Use Agreements	Mangroves	Conservation International Ecuador, Coastal Fisheries Initiative in Latin America	25 million
NbS	Nature-Positive Business for Climate Critical Ecosystems, Fiji and Solomon Islands: Business-led initiatives promoting conservation and restoration in biodiversity-rich areas (Ongoing)	2022	Macuata and Ba Province; Western Province, Fiji, Solomon Islands	Business-Led Conservation; Habitat Restoration; Community Resilience	Mangroves, Coral reefs	World Wildlife Fund Pacific, Matanataki Pte Ltd, Strongim Bisnis; Locally Managed Marine Area Network, Western Province Fisheries	0.67 million
Hybrid	East Kolkata Wetlands, Kolkata: Ecosystem services and livelihoods through wetland conservation (Ongoing)	2002	Kolkata, West Bengal, India	Wetland Conservation; Natural Sewage Treatment; Sustainable Livelihoods	Urban, Wetlands	East Kolkata Wetlands Management Authority, East Kolkata Wetlands Development Society, National Wetlands Authority, Kolkata Municipal Corporation	0.24 million
NbS	Bhitarkanika Mangroves, Odisha: Mangrove ecosystem conservation for biodiversity and coastal protection (Completed in 2002)	1952	Bhitarkanika Conservation Area, Odisha, India	Mangrove Conservation; Biodiversity Protection; Coastal Resilience	Mangroves	Rajnagar Wildlife Division - State Forest Department, State Pollution Control Board, Department of Water Resources of Odisha, United Nations Development Programme, Food and Agriculture Organization	-

Type	Case studies	Year	Location	Objective	Ecosystem type	Agency	Cost (in USD)
Hybrid	Kadamakudy Redevelopment Project, Kochi: Habitat restoration and sustainable development (Ongoing)	2013	Kadamakudy, Kerala, India	Habitat Restoration; Sustainable Urban Development; Mangrove Conservation	Urban, Wetlands, Mangroves	Cochin University of Science and Technology, Department of Town and Country Planning, International Council for Local Environmental Initiatives [South Asia], Deutsche Gesellschaft für Internationale Zusammenarbeit, Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection, Germany	-
NbS	Mangrove conservation, Mumbai: Initiative focussed on preserving mangrove ecosystems to enhance urban biodiversity and flood resilience (Ongoing)	2010	Vasai Creek, Thane Creek, Manori and Malad, Mahim-Bandra, Versova, Sewree, and Mumbra-Diva, Maharashtra, India	Urban Biodiversity; Flood Resilience; Mangrove Protection	Mangroves	Soonabai Pirojsha Godrej Foundation; Various government bodies, local non-governmental organisations (NGOs)	-
NbS	Greening and conserving Mangroves, Pirojshanagar, Mumbai (Ongoing)	2010	Vikhroli-Mumbai, Maharashtra, India	Mangrove Conservation, Climate Resilience, Community Engagement	Mangroves, Urban, Coastal	Godrej and Boyce Manufacturing Company Limited	62 million
Hybrid	Floating islands, Indore: pond restoration through green technology (Ongoing)	2019	Indore, Madhya Pradesh, India	Pond Restoration, Green Technology, Water Quality Improvement	Urban, Ponds	Clean-Water (Sustainable Water Technologies Private Limited), Police Training College	-
Hybrid	Red Cross mangrove restoration, Vietnam: Mangrove reforestation for storm protection (Completed in 2010)	1994	Thai Binh, Thai Binh Province, Vietnam	Mangrove Reforestation, Coastal Protection, Community Benefits	Mangroves, Coastal	Vietnam Red Cross, Danish Red Cross, Japanese Red Cross Societies	8 million
NbS	Triple Benefit Programme, Myanmar: Multi-faceted approach targeting DRR, climate change adaptation, and sustainable livelihoods (Ongoing)	2022	Kachin and Shan States, Mandalay, Magway, Ayeyarwady Divisions, Myanmar	Community Forestry; Benefit-sharing Mechanisms; Sustainable Livelihoods	Tropical Rainforests	Danish International Development Agency (Strategic Partnership), World Wildlife Fund (Kenya, Uganda, Madagascar and Myanmar)	10 million
Hybrid	Kathmandu Valley Ecological Urban Renewal Project, Nepal: Urban renewal integrating green spaces for enhanced resilience against	1993	Kathmandu, Central Hill Zone, Nepal	Risk-sensitive Land Use; Blue-Green Infrastructure; Urban Renewal	Urban, Mountain, Riverine	The Kathmandu Urban Development Project, High-Powered Committee for Integrated Development of the Bagmati Civilization; funded by ADB, World Bank and Deutsche Gesellschaft für Internationale Zusammenarbeit	12 million

Type	Case studies	Year	Location	Objective	Ecosystem type	Agency	Cost (in USD)
	natural disasters (Ongoing)						
Hybrid	Resilience efforts in Barishal, Bangladesh: Community and ecosystem resilience to flooding (Ongoing)	2015	Kutubdia, Barishal, Bangladesh	Climate Migration; Natural Drainage Restoration; Salinity Intrusion	Urban, Riverine, Coastal	Barishal District Administration, Barishal City Corporation, 'Barisal-Problem and Prospects' Facebook civic engagement group and funding from Kreditanstalt für Wiederaufbau (KfW) Development Bank	40 million
NbS	Tampara Wetland Conservation Project, Odisha: Protection and restoration of a Ramsar site to maintain its ecological integrity and water quality (Ongoing)	2022	Chatrapur, Odisha, India	Wetland Conservation; Salinisation Risks; Peri-urban Wetlands	Peri-urban; Freshwater Wetlands	Pallishree Limited, Chilika Development, Panchayats in Chatrapur Block, Ganjam District funded by Government of India	4 million
Hybrid	Shenzhen Sponge City, China: National programme for urban water retention and flood control (Ongoing)	2016	Shenzhen, China	Urban Water Retention; Stormwater Management; Urban Liveability	Urban, Riverine	Public–private partnership with Shenzhen Government	206 million

Women line up to plant mangrove saplings along the banks of the Matla River, Sundarbans, India, as a critical defence against coastal storm surges and tiger habitat incursions.

Credit: Avijit Ghosh, 2022 / Climate Visuals

6.1. National government initiatives

These projects encompass nature-based initiatives that have received substantial backing and collaboration from national governments, aiming for broad-scale impact and holistic integration within country-level frameworks for sustainable development. They represent the top-down thrust for large-scale NbS either in response to existing climate risks or undertaken proactively to tackle anticipated environmental challenges. The involvement of national governments in these cases has been able to draw substantial funding and facilitate administrative support at an ecosystem scale.

6.1.1. Uswetakeiyawa beach nourishment, Sri Lanka: Shoreline restoration and erosion control

Beach nourishment is a soft engineering solution for shoreline stabilisation in areas that are affected by a reduction of sand owing to either natural or man-made reasons (Ratnayake et al., 2018). Beach nourishment initiative in Sri Lanka began in the mid-1980s with the aim to preserve its picturesque beaches, crucial for both natural heritage and a thriving tourism industry (Food and Agricultural Organisation, 2006). Initiated by the Government of Sri Lanka, the Uswetakeiyawa project is one of the earliest interventions of artificial beach nourishment. as part of a long-term coastal management strategy (Box 1). Along with other sites on the west coast, it seeks to address the underlying causes of erosion, as part of the Coastal Zone Management Plan (Coast Conservation and Coastal Resources Management Department, 2023) to ensure the sustainability of local fisheries and maintain ecological balance.

Box 1. Case study of Uswetakeiyawa, Sri Lanka

Location	Uswetakeiyawa, Western Province, Sri Lanka
Enforcement Agency	Coast Conservation Department of Sri Lanka (Ratnayake et al., 2018)
Timeline	2012 onwards
Objective	Artificial nourishment of the beach to combat coastal erosion (areas affected because of sediment supply issues, including Uswetakeiyawa beach, Negombo Lagoon, and Kelani River), potential tourist hub development, and conducting pilot projects for future beach nourishment programmes
Ecosystem type	Coastal
Climate change impacts addressed	Mitigation of coastal erosion and preservation of the beach ecosystem in the face of changing environmental conditions
Socio-economic outcomes	Potential economic benefits from tourism and addressing coastal erosion issues to maintain recreational and economic activities along the coast
Project cost	USD 300 million

Monitoring and evaluation	• Continuous monitoring of beach profiles and sand grain size data over a 1-year period • Satellite image analysis covering the period from 2010 to 2015 • Assessment of the performance of breakwaters and beach nourishment strategies
Trade-offs/Limitations	Potential impacts on longshore sediment transport, variations in beach profiles, and potential downstream effects on neighbouring coastal areas due to the presence of breakwaters

6.1.2. East Godavari River Estuarine Ecosystem (EGREE): Policy-driven ecosystem management

EGREE is the second-largest mangrove area in India (Shankar, 2022) and cited as an Important Bird Area and settling site for the olive ridley sea turtle (Box 2). The landscape is characterised by mangroves, tidal flats, and sand dunes under the constant threat from activities including aquaculture expansion and habitat loss due to submersion, urban development, and Casuarina plantations (Bagaria et al., 2021). Since 2011, the Government of India has initiated biodiversity conservation projects in the region (Wildlife Institute of India, 2017) along with other resilience-focussed initiatives including effective knowledge management to disseminate vital information about biodiversity, ecological changes, and anthropogenic impacts in the region.

Box 2. Case study of East Godavari River Estuarine Ecosystem, Andhra Pradesh, India

Location	East Godavari District, Andhra Pradesh, India
Enforcement agencies	Government of India, Wildlife Institute of India, EGREE Foundation funded by Global Environment Facility, United Nations Development Programme
Timeline	2017 onwards
Objective	Identifying research gaps, studying payment for ecosystem services, examining climate change impacts, and conducting workshops on biodiversity conservation in coastal/marine contexts
Ecosystem type	Estuarine, mangroves
Climate change impacts addressed	Restoration of mangrove habitats and biodiversity conservation
Socio-economic outcomes	Engages communities for park management, relying on local labour, eco-tourism services, and awareness efforts, considering them stakeholders. However, conflicts arise because of the unauthorised extraction of mollusc species and timber collection within the sanctuary, despite permitting fishing activities.
Project cost	USD 0.94 million (GEF, 2012)
Monitoring and evaluation	Estimation of the flora and fauna in the EGREE region, monitoring land-use and shoreline changes, and detection of change in the area covered by mangrove aquaculture ponds

Trade-offs/Limitations	Competing land use and rampant land cover change. Surveys revealed the challenge that most people who partly or entirely depend on fuelwood are not willing to stop its use owing to easy availability and low costs of mangrove species.

6.1.3. Urban resilience in Phuentsholing, Bhutan: Integrating NbS in urban planning for DRR

Phuentsholing is a town located in southern Bhutan (Box 3). It is situated on the Himalayan foothills and remains highly vulnerable to annual flash floods, earthquakes, and landslides because of its geographical and climatic conditions (Mukherjee et al., 2022). Susceptibility to these risks, compounded by rapid urbanisation and limited land for development, has highlighted the need for nature-based interventions to enhance urban resilience in the region (Asian Development Bank, 2023).

Box 3. Case study of Phuentsholing, Bhutan

Location	Phuentsholing, Chukha District, Bhutan
Enforcement agencies	Royal Government of Bhutan, Department of Human Settlements (DHS), Phuentsholing Thromde (municipality), Global Environment Facility, and Asian Development Bank (ADB)
Timeline	2013 onwards
Objective	Enhance resilience to climate change impacts and natural disasters, mitigate flood and erosion risks, develop smart urban infrastructures, and promote community vitality and safety (Gupta & De, 2024; Mehta et al., 2023).
Ecosystem type	Urban; riverine
Climate change impacts addressed	Addresses vulnerabilities to flash floods, earthquakes (due to tectonic plate boundaries), landslides, windstorms, and pollution from industrial areas. The risk of mosquito-borne diseases is also noted.
Socio-economic outcomes	Initiatives aim at making Phuentsholing a highly liveable town with enhanced safety, recreational parks, sports facilities, and improved urban infrastructure to support residents and commercial activities
Project cost	USD 63 million (ADB, 2018)
Monitoring and evaluation	The success of projects is evaluated through the Annual Performance Agreement and compliance reports prepared by the DHS. Land-use planning and development activities are periodically reviewed for adherence to environmental and urban development standards.
Trade-offs/Limitations	Limited land for urban development creates continuous pressure owing to rapid urbanisation. The balance between development and environmental conservation presents ongoing challenges.

6.1.4. Living weirs, Thailand: Enhancing water quality and biodiversity in urban waterways

Thailand has been witnessing severe droughts over the past decades. The evolving situation has spurred water management projects and the promotion of research and innovation for local community solutions (Hicks & Mills, 2022). Strategies such as constructing living weirs (low dams built across watercourses using natural materials by community groups) and restoring floodplains are being reimagined to reduce community and ecosystem vulnerabilities, offering benefits in both urban and rural areas (Box 4).

Box 4. Case study of Songkhla and Nakhon Si Thammarat Provinces, Thailand

Location	Khlong-La River, Songkhla Province and Khlong Wang Heep River, Nakhon Si Thammarat Province, Thailand
Enforcement agencies	Office of the National Water Resources - Kingdom of Thailand, GIZ GmbH, with technical support from the United Nations Environment Programme-World Conservation Monitoring Centre (UNEP-WCMC)
Timeline	2016 onwards
Objective	Utilise living weirs made from local materials such as bamboo, sand, coconut coir, and manure as flood buffers, reduce ambient temperatures, mitigate the urban heat island effect, improve groundwater recharge, enhance biodiversity, and foster unity among stakeholders (Srichaiwong et al., 2020).
Ecosystem type	Urban, Riverine
Climate change impacts addressed	Mitigate urban heat island effect, reduce flooding and biodiversity loss, and enhance groundwater recharge
Socio-economic outcomes	Increased crop yields from improved groundwater recharge; enhanced fish habitats leading to better fishing opportunities; and stronger community bonds, income diversity, and food security through collective action (Cowan, 2023).
Monitoring and evaluation	UNEP-WCMC, GIZ, along with local NGOs, and university-backed researchers
Trade-offs/Limitations	The project faced challenges because of a lack of scientific planning, leading to the construction of weirs in inappropriate locations or at incorrect times, which sometimes resulted in damage or destruction of incomplete structures.

A woman cycles home from work along a path regularly flooded by rising sea levels in Demak, Indonesia.

Credit: Dhana Kencana, 2020 / Climate Visuals

6.2. Sub-national initiatives

The following case studies receive backing from state-level or local jurisdictions and are anchored within policy frameworks that emphasise regional climate and nature goals, aligning with the specific geographical needs. They are designed to act as a conduit, linking national strategies with local execution and prioritising areas most susceptible to environmental risks. Each project not only tackles specific environmental challenges but also evaluates the impacts of NbS on local communities, aiming to enhance their adaptive capacities. These projects acquire substantial funding from national or international partners and provide essential administrative support at an ecosystem scale.

6.2.1. Native vegetation of Yamuna floodplains: Policy-supported ecological restoration

The 22-km urban section of the Yamuna River in New Delhi has experienced considerable environmental degradation. The National Green Tribunal (MoEFCC) reviewed the Yamuna River Front Development Plan and proposed several enhancements. Some of the most relevant recommendations included establishing a conservation zone under the Environmental Protection Act, creating the Yamuna Biodiversity Park, and developing wetlands and greenways to improve water quality and aesthetics (Box 5).

Box 5. Case study of New Delhi, India

Location	New Delhi, National Capital Territory of Delhi, India
Enforcement Agency	Government of National Capital Territory of Delhi and Government of Uttar Pradesh and its agencies; Delhi Development Authority with the Centre for Environmental Management of Degraded Ecosystems of the University of Delhi (Bhadu & Punia, 2023; Kumar et al., 2019)
Timeline	2002–2010
Objective	• Conservation of keystone and threatened species and preservation of biodiversity in potential urban development areas • Creation of field gene banks for endangered land areas and genetic resources and promotion of environmental education and awareness • Establishment of native communities along the Yamuna River basin in Delhi • Development of wetlands supporting diverse aquatic life in the Yamuna River
Ecosystem type	Urban, Wetlands

Climate change impacts addressed	The ecological diversity within the wetland habitat sustains rich flora and fauna. The high primary productivity contributed by abundant phytoplankton and zooplankton and submerged, floating, and emergent aquatic vegetation attracts a wide range of birds and other benthic fauna and fishes.
Socio-economic outcomes	The biodiversity park inhabits local communities who help in the maintenance of the park, thereby providing livelihood.
Project cost	USD 57.5 million (GoNCTD, 2008)
Monitoring and evaluation	Land and Revenue Department of Uttar Pradesh and Ministry of Water Resources, Government of India
Trade-offs/Limitations	• Collaboration among various stakeholders along with securing timely funding for the extensive restoration • Managing the technical and legal aspects while minimising unintended environmental impacts • Continuous and long-term monitoring of the large-scale site

6.2.2. Restoration of St Inez Creek, Goa: Urban waterway revitalisation

Originating from the paddy fields in Taleigao, St Inez Creek is a 4-km-long channel meandering through downtown Panaji before it drains into the Mandovi River (Ramanathan et al., 2021). The creek holds significant ecological and social value, serving as a vital habitat for diverse wildlife and a focal point for community recreation. However, because of ad-hoc development and encroachment over time, it suffers from neglect and pollution, warranting a holistic rejuvenation approach that combines civil engineering with NbS to restore the creek and foster community engagement (Box 6).

Box 6. Case study of Panaji, Goa, India

Location	Panaji, Goa, India
Enforcement agencies	Corporation of City of Panaji; Imagine Panaji Smart City Development Limited Taleigao Village Panchayat; Greater Panaji Planning and Development Authority; Asian Development Bank (ADB), (Gajjar, 2020)
Timeline	2016 onwards
Objective	Establish citizen-led restoration programmes along the creek, align with national urban development initiatives, enhance waterbody health, and boost climate resilience through natural resource utilisation
Ecosystem type	Urban, Wetlands

Climate change impacts addressed	By remodelling the creek mouth to maintain tidal inflow, water quality can be improved and adverse ecological disturbances and flooding can be prevented.
Socio-economic outcomes	It helped reduce waterborne diseases, increase biodiversity for aquaculture, and enhance opportunities for livelihoods and community engagement. However, temporary disruptions and livelihood impacts might have occurred during construction.
Project cost	USD 25 million
Monitoring and evaluation	Online/Offline surveys to estimate the impact
Trade-offs/Limitations	• Apathy or disinterest among residents • Integration with the City Development Plan encounters hurdles in coordinating actions across various agencies • Focus on 'replacement' rather than 'rehabilitation' of assets, driven by financial constraints

6.2.3. Mullasery Canal restoration project, Ernakulam: Local-led waterway revitalisation

The Mullassery Canal, located in Kochi, Kerala, is a tidal waterway spanning approximately 1 km from the backwaters to the city centre. The Mullassery canal restoration project originated from an urban design competition under the EnteKochi multi-stakeholder initiative, highlighting the importance of blue–green infrastructure (Box 7). Identifying the canal as pivotal for integrated civic development, the project aimed to tackle urban challenges through a participatory approach.

Box 7. Case study of Ernakulam, Kerala, India

Location	Kochi, Kerala, India
Enforcement agencies	Kochi Municipal Corporation, Cochin Smart Mission Limited and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) via Non-National Infrastructure Pipeline Real Estate Joint Venture (Menon & Sharma, 2022)
Timeline	2020 onwards
Objective	• Revitalisation of neighbouring communities through an open design competition and urban laboratory process • Development of participatory surveys for urban planning and redevelopment projects
Ecosystem type	Urban, Coastal
Climate change impacts addressed	Flood mitigation and identification and resolution of issues such as solid waste disposal and weed growth affecting water flow in Mullassery canal

Socio-economic outcomes	Increased social resilience through community participation. Proposal for the creation of more public spaces along the waterfront to restore lost connectivity with the city's water bodies.
Project cost	USD 8.3 million (The Hindu Bureau, 2024)
Monitoring and evaluation	Ongoing urban laboratory process involving participatory surveys
Trade-offs/Limitations	The project, initially planned for 3 months in 2022, faced administrative delays, resulting in only half of the work being completed by April 2024 (The Hindu Bureau, 2024)

6.2.4. Metro Colombo Urban Development Project, Sri Lanka: Urban food resilience and water management

The Beddagana Wetlands in Colombo, declared a Wildlife Sanctuary in 1985, have been experiencing rapid degradation, resulting in reduced water storage and increased flood risks (World Bank, 2016). As part of the Metro Colombo Urban Development Project, a Wetland Park has been developed to enhance flood resilience (Box 8).

Box 8. Case study of Colombo, Sri Lanka

Location	Sri Jayawardenapura Kotte, Colombo, Sri Lanka
Enforcement agencies	Sri Lanka Land Development Corporation, Colombo Municipal Council (Hewawasam & Matsui, 2020). Funded by World Bank, International Bank for Reconstruction and Development
Timeline	2012 onwards
Objective	Increase urban resilience and reduce flood impacts through the development of wetlands, improvement of the natural flood reduction network, and enhancement of green and blue infrastructure
Ecosystem type	Urban, wetlands, coastal, riverine
Climate change impacts addressed	The initiatives address the impacts of flash floods, particularly during the Southwest monsoon; river flooding; and other hydro-meteorological hazards exacerbated by climate change.
Socio-economic outcomes	The enhancement of green cover and the conservation of wetlands are aimed at reducing disaster risks, improving recreational spaces and potentially generating income through tourism and recreation.
Project cost	USD 321 million (MCUDP, 2020)
Monitoring and evaluation	Urban Development Authority, Colombo

Trade-offs/Limitations	Potential trade-offs include balancing urban development with environmental conservation, managing public access to natural areas without degrading them, and ensuring long-term sustainability and maintenance of the infrastructure.

6.2.5. Sweet City, Costa Rica: Urban green space development for community well-being

Curridabat is Costa Rica's largest urban agglomeration and has about 77,000 inhabitants. It grapples with social and ecological challenges, such as reduced drainage capacity and fragmented urban vegetation cover, stemming from unplanned densification and informal settlements. In response, the Sweet City programme was launched in 2015, addressing these challenges comprehensively and achieving notable success in public policy implementation (Box 9).

Box 9. Case study of Curridabat, Costa Rica

Location	Curridabat, San José, Costa Rica
Enforcement Agency	Municipality of Curridabat, civil society organisations, private firms, not-for-profit organisations, and city residents/resident associations
Timeline	2015–2020
Objective	• Restore biodiversity and build a resilient city by recovering public and private urban spaces in disuse to create green spaces for recreation and improve the health and well-being of residents. • Extend citizenship to pollinators, trees and native plants, and other flora and fauna that coexist within the urban space (Greenfield, 2020) • Enhance wetlands to boost biodiversity and mitigate flood risk • Promote soil health through biodiverse vegetation and organic farming for climate change mitigation • Enhance water management through sustainable drainage, construction of riverfront parks, and springwater recovery for climate change mitigation
Ecosystem type	Urban, wetlands
Climate change impacts addressed	Reduction of urban heat islands, increase in green spaces, and encouragement of pollinator biodiversity
Socio-economic outcomes	Green space improvements have led to the uptake of organic farming practices, motivating citizen participation.
Project cost	USD 45 million

Monitoring and evaluation	Monitoring/evaluation reports and availability of a web-based monitoring tool
Trade-offs/Limitations	• Complexity of land fragmentation, which stems from political boundaries, uncoordinated development, and transportation limitations • Insufficient data on groundwater usage and soil quality hinder development of targeted solutions

6.2.6. Blue-Green Masterplan (2041) of Delhi: Integrating green and blue spaces into urban planning

Delhi boasts of abundant natural and man-made green and blue assets, including the Aravalli Ridge, the Yamuna River, forests, parks, and lakes, which form an interconnected network crucial for the city's infrastructure (Delhi Development Authority, 2021). The city's masterplan outlines a strategy to enhance this green–blue infrastructure by increasing the area of natural assets and incorporating planned green spaces into new development projects (Box 10).

Box 10. Case study of Delhi, National Capital Territory, India

Location	New Delhi, National Capital Region, India
Enforcement agencies	Delhi Development Authority (Singh, 2022)
Timeline	2023 onwards
Objective	• Develop an integrated approach to environmental strategies within the broader urban context, aligning with transport, heritage, and industries to address overall environmental challenges • Recognise and address existing gaps in environmental strategies, particularly focussing on the rejuvenation of Yamuna floodplains through greenways and public waterfronts • Implement a comprehensive framework that treats green and blue assets as essential infrastructure, emphasising pollution control • Protect and enhance natural assets with public interfaces, create new city-level green–blue assets, and promote greening of plots/buildings with the introduction of the Green–Blue Factor
Ecosystem type	Urban, Floodplains
Climate change impacts addressed	Mitigation: Pollution control and carbon sequestration Adaptation: Urban flood management, groundwater retrenchment, and reduction in urban heat island effect
Socio-economic outcomes	Community well-being, potential increase in economic opportunities, and improved quality of life

A man tends to his rooftop garden in Kolkata, India, demonstrating a second-degree solution to capturing rooftop runoff to prevent urban flooding while promoting local produce.

Credit: Sudip Maiti, 2018 / Climate Visuals Countdown

6.3. Community-driven initiatives

The projects showcased below demonstrate the critical role of local communities in the planning, management, and implementation of NbS, emphasising the power of grassroots engagement and local knowledge. Spanning both urban and coastal regions globally, these community-led initiatives tackle environmental challenges through diverse efforts, including endangered species conservation, mangrove regeneration, and construction of community gardens. These strategies not only promote biodiversity and social cohesion but also illustrate the effectiveness of bottom-up approaches in urban environmental governance.

6.3.1. Female-led turtle conservation, Odisha: Community-driven marine conservation initiatives

Odisha, nestled along India's eastern coastline, grapples with environmental challenges amidst its natural wealth, including the critical olive ridley turtle nesting sites (Box 11). Samudram Women's Federation works in the state uniting several women's self-help groups across 50 villages (United Nations Development Programme, 2012). They aim to empower marginalised women while conserving Odisha's biodiversity, notably the endangered turtle habitats.

Box 11. Case study of Odisha, India

Location	Ganjam, Odisha, India
Enforcement agencies	The Samudram Women's Federation supported by the Odisha Marine Resource Conservation Consortium, Odisha Traditional Fish Workers' Union, United Artists Association supported by Greenpeace and World Wildlife Fund (India), Odisha University of Agriculture and Technology, Central Institute of Fisheries Education, Ford Foundation, International Council of Agricultural Research, Coastal Marine Fisheries Research Institute (Government of India), and Berhampur University funded by Equator Initiative (United Nations Development Programme) and Conservation International.
Timeline	1993 onwards
Objective	Monitoring turtle population size, protecting and reintroducing young turtles, restoring habitats, advocating against extractive industry practices, constructing artificial reefs for coastal protection, promoting seaweed cultivation for climate change awareness and income generation, and empowering female members through sustainable fishing practices and economic opportunities (Sharma & Pandey, 2020).
Ecosystem type	Coastal

Climate change impacts addressed	• Seaweed cultivation positively impacts climate change mitigation, potentially enhancing carbon sequestration • Reported income increases and female empowerment strengthen community resilience • Positive ecological effects include increased turtle populations and artificial reefs discouraging destructive fishing
Socio-economic outcomes	Doubling their annual income, from USD 458 in 2004 to USD 967 in 2009, largely because of agar-agar sales
Monitoring and evaluation	Partakes in turtle population monitoring efforts tracking both adults and eggs
Trade-offs/Limitations	Impediments in seeking legal recognition of the artificial reef zone as a biodiversity heritage site

6.3.2. Mangrove regeneration, Sunderbans: Community efforts mangrove conservation

The Sundarbans, home to Asia's largest mangrove forests and a unique tiger population, face significant ecological threats amidst its invaluable biodiversity. Rising salinity, tidal velocity, commercial exploitation, and human encroachment pose formidable challenges to the sustainability of mangroves in this critical region (Hazra et al., 2021). In this context, the Sundarbans Biosphere Reserve addresses the pressing need for mangrove conservation and community resilience in the Sundarbans (Box 12).

Box 12. Case study of Sundarbans Biosphere Reserve, India and Bangladesh

Location	Gosaba, West Bengal, India; Karamjal, Khulna, Bangladesh (Ranjan, 2019)
Enforcement agencies	Caritas India, Gram Panchayats, community-based organisations; non-governmental organisations
Timeline	2000 onwards
Objective	Mitigate disaster risk, highlight the importance of conservation and mangrove management involving local communities, and address policy issues for effective mangrove conservation
Ecosystem type	Mangroves
Climate change impacts addressed	Counteract rising salinity, tidal velocity, commercial exploitation, and human encroachment
Socio-economic outcomes	Community-based mangrove regeneration is expected to increase workdays, enhance local biodiversity, promote unity and cooperation within the community, and boost ecotourism in the Sundarbans.

Monitoring and evaluation	• Studying tidal velocities and salinities and addressing potential plantation site issues prior to regeneration efforts • Advocating for multi-species plantation and scientific selection of species based on environmental conditions
Trade-offs/Limitations	Need for natural recovery before plantation, the importance of long-term protection and maintenance of new plantations, and a ban on harmful practices such as shrimp farming expansion at the expense of mangroves

6.3.3. Rooftop farming, Cairo, Egypt: Urban agriculture driven by community participation

Since the 1950s, the Greater Cairo Metropolitan Region (Box 13) has witnessed an unparalleled surge in informal urbanisation across fertile agricultural areas, resulting in a fragmented terrain and accompanied by substantial socio-economic repercussions (Youssef et al., 2020). As socio-economic conditions in Cairo's informal settlements worsen with increasing climate vulnerabilities, adaptation measures needed to be linked to income generation. To address this issue, the rooftop farming project was initiated in 2014 to encourage community members to grow their own food and reduce dependency on the market (Prinz, 2017).

Box 13. Case study of Cairo, Egypt

Location	Ezbet-al Nasr, Cairo, Egypt
Enforcement agencies	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in collaboration with Shaduf, a local social enterprise (Kamel & El Bilali, 2022)
Timeline	2014–2017
Objective	Regulate micro-climate in densely populated areas, reduce the urban heat island effect, increase green cover, promote sustainable urban farming practices, and empower residents through capacity building and knowledge sharing
Ecosystem type	Urban, Building Rooftops
Climate change impacts addressed	Adapting to heatwaves and urban heat island effect, improving living conditions, and reducing air quality issues
Socio-economic outcomes	Reduced vulnerability to food price fluctuations, development of economic benefits from increased agricultural production and knowledge exchange for local communities

Monitoring and evaluation	The impacts suggest some level of monitoring and evaluation, focussing on climate adaptation, food security, income generation, social cohesion, and increased awareness of nature-based solutions.
Trade-offs/Limitations	Technical and managerial challenges were acknowledged and the necessity for continuous improvement in policy and practice was highlighted to better manage urban water and agricultural systems.

6.3.4. Coral gardening, Vanuatu: Community-based coral reef restoration

Vanuatu is an archipelagic nation nestled in the Southwest Pacific Islands. It is frequently affected by intensified climate-induced hazards, such as tropical cyclones and storm surges, and suffers from slow-onset events including ocean acidification, which pose direct threats to Vanuatu's life-sustaining coral reefs (Waiwai et al., 2023). To address this challenge, the coastal communities have taken up this coral gardening initiative to propagate healthy corals (Box 14).

Box 14. Case study of Shefa Province, Vanuatu

Location	Pele, Shefa Province, Vanuatu
Enforcement agencies	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) with Vanuatu's Nguna-Pele Marine and Land Protected Area Network (Komugabe-Dixson et al., 2019)
Timeline	2014–2017
Objective	Implement climate change adaptation measures for coral reefs through coral gardening, contributing to the restoration of damaged coral reefs, enhancing eco-tourism revenue, and supporting community-based climate adaptation
Ecosystem type	Coral reefs, Marine
Climate change impacts addressed	Addressed ocean acidification, increased ocean temperatures, sea-level rise, and extreme weather events such as hurricanes and tropical cyclones
Socio-economic outcomes	• Plantation of over 3000 coral fragments, stabilising eroding coastlines and improving local food security through increased abundance of coral-associated fish • Generation of sustainable income flows for seven island villages, with funds reinvested in local adaptation and environmental management projects • Empowerment of village women and girls in marine climate adaptation activities

Monitoring and evaluation	Coral fragments were monitored for growth and resilience, particularly against Cyclone Pam. Education programmes engaged over 500 youths in comprehensive coastal management.
Trade-offs/Limitations	Reliance on eco-tourism for project funding, which can be susceptible to fluctuations in tourism, and the challenges of scaling up coral gardening efforts to address widespread reef damage

6.3.5. Building with Nature, Indonesia: Community-centric coastal protection

Having one of the longest coastlines in the world, Indonesia is extremely vulnerable to rising sea levels and sinking land and has lost about 78% of its natural barrier, mangroves (Oliver, 2020). 'Building with Nature' is a holistic concept that integrates nature's services into water and marine engineering, avoiding traditional infrastructure such as sea walls and levees (Box 15), prioritising adaptability and environmental benefits such as carbon storage and biodiversity (Tonneijck & van der Goot, 2022).

Box 15. Case study of Demak, Central Java Province, Indonesia

Location	Demak, Central Java Province, Indonesia
Enforcement agencies	Public–private partnership with the Government of Indonesia, Wetlands International, and Ecoshape, (Wilms et al., 2017) funded by the World Bank, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Germany) as part of the International Climate Initiative
Timeline	2012 onwards
Objective	Increase resilience of 20 km of coastline with mangrove rehabilitation
Ecosystem type	Mangrove; Coastal
Climate change impacts addressed	Natural mangrove regeneration through semi-permeable brushwood structures, which mimic the roots of mangroves. This slowed the scouring currents and trapped sediment, thereby addressing coastal erosion. Aquaculture ponds donated by the villagers were re-engineered to connect with the ocean.
Socio-economic outcomes	• Improving aquaculture livelihoods through sustainable practices and mangrove conservation. • Coastal field schools trained farmers, resulting in increased yields and improved resilience. • Associated mangrove aquaculture further enhanced productivity and provided alternative livelihoods.
Finance	USD 400 million (World Bank, 2022a)
Monitoring and evaluation	Project monitoring and evaluation occur post-monsoon, informing design updates for coastal safety and socio-economic measures (mangrove count, sediment bed level, and water level).

6.3.6. Restored riverine areas in Rohingya Camps, Bangladesh: Rehabilitation of water systems and natural areas with refugee settlements

With a population of 978,003 individuals, Rohingya camps in Bangladesh are one of the largest refugee camps in the world (UNHCR, 2024). Majority of the refugees inhabit provisional camps atop hills in Cox's Bazar, lacking sufficient water and sanitation amenities. This has led to frequent outbreaks of diseases such as cholera, typhoid, and diarrhoea (Akhter et al., 2020). To combat this, the Center for Natural Resource Studies in Bangladesh, in partnership with the United Nations High Commissioner for Refugees, devised a comprehensive technical blueprint employing NbS to rehabilitate deteriorated riparian ecosystems (Box 16).

Box 16. Case study of Chittagong, Bangladesh

Location	Ukhiya, Chittagong, Bangladesh
Enforcement agencies	Center for Natural Resource Studies and United Nations High Commissioner for Refugees (Jalal et al., 2023)
Timeline	2019 onwards
Objective	• Develop the socio-ecological resilience of the Madhur Chhara watershed with support from environmental specialists and hydrologists • Meet local challenges within the Sustainable Development Goals framework through equal prioritisation of ecosystem preservation and human well-being
Ecosystem type	Coastal, Highland Riparian
Climate change impacts addressed	Micro-climate regulation, carbon sink, reduced flooding and landslides, reduced drought effects, crop diversity / farming systems. Stable riverbanks mitigate erosion, enhance soil fertility, and reduce landslides.
Socio-economic outcomes	Improved water availability and reduced waterborne diseases. Green cover in denuded lands, plant-based food diverse systems, livelihood enhancement, reduced extreme events such as floods and droughts, conservation of agriculture practices, and a 123% increase in wildlife.
Project cost	USD 0.44 million
Monitoring and evaluation	Tracking research progress, assessing the effectiveness of payment for ecosystem services, national workshops on coastal/marine biodiversity conservation
Trade-offs/Limitations	Need for extensive financial resources and ensuring consistent stakeholder engagement for effective restoration efforts in refugee camps

Residents walk past the ruins of buildings along the eroded coastline at Bommiarpalayam, Puducherry. India's eastern coast, shaped by monsoons, faces high longshore drift, making it highly dynamic and vulnerable to coastal erosion.

Credit: Pattabi Raman / Climate Visuals

6.4. Issue-specific interventions

The following section comprises case studies that address specific environmental issues through targeted interventions such as ecosystem restoration, biodiversity conservation, and DRR. Many of these projects are supported by international organisations to mobilise ground-level action.

6.4.1. Conservation

These initiatives are primarily aimed at conserving or restoring ecosystems, with a strong focus on biodiversity, habitat protection, and ecological health. Along the coasts, there is a significant impetus for mangrove conservation through community restoration efforts. Multiple stakeholders, including government agencies, NGOs, and local communities, are key to the enforcement of such projects to enable long-term ecosystem resilience.

6.4.1.1. Mangrove restoration, Ecuador: Ecosystem recovery project aimed at mangrove habitats for coastal protection

Historical mangrove degradation in Ecuador has been mainly linked to the expansion of shrimp aquaculture. The Custody and Sustainable Use of Mangrove Agreements (Acuerdos de Uso Sustentable y Custodia del Manglar) was established in 1999, acknowledging the rights and customary practices of communities residing in or reliant upon mangrove ecosystems for sustenance (López-Rodríguez, 2021). In recent years, mangrove restoration efforts in Ecuador, particularly in Esmeraldas and El Oro provinces, have led to noticeable land recovery (Box 17). This progress is attributed to conservation initiatives and sustainable-use agreements implemented in key ecological reserves (Morocho et al., 2022).

Box 17. Case study of Ecuador

Location	Esmeraldas, Manabí, Guayas, El Oro, Ecuador
Enforcement agencies	Conservation International Ecuador, Coastal Fisheries Initiative in Latin America
Timeline	1998 onwards
Objective	Protect and sustainably manage mangrove ecosystems despite the challenges posed by deforestation and the expansion of shrimp farming
Ecosystem type	Mangroves
Climate change impacts addressed	Land recovery from coastal erosion and carbon sequestration
Socio-economic outcomes	• Empower local communities through custody agreements covering an extensive area • Ensure sustainable extraction of mangrove resources • Ensure that over 40% of mangroves are conserved (Morocho et al., 2022; Rodríguez, 2018).

Project cost	USD 25 million (IUCN & CI Ecuador, 2016)
Monitoring and evaluation	Utilises remote sensing and Geographic Information System tools to evaluate changes in mangrove cover over a 20-year period, identifying areas of loss and recovery and evaluating the effectiveness of conservation efforts
Trade-offs/ Limitations	Despite recovery efforts, mangrove loss remains constant with continued threats from shrimp farming expansion, agriculture, and construction.

6.4.1.2. Nature-Positive Business for Climate Critical Ecosystems, Fiji and Solomon Islands: Business-led initiatives promoting conservation and restoration in biodiversity-rich areas

Situated in the South Pacific Ocean, the Solomon Islands and Fiji are biodiverse regions known for their volcanic landscapes and rich cultural heritage (WWF, 2021a, 2021b). They are critical conservation hotspots and host the Southern Hemisphere's third-longest barrier reef, the Great Sea Reef, and the richest birdlife in Western Polynesia (Box 18). World Wildlife Fund's efforts in these regions demonstrate a business-led approach to preserving and restoring vital habitats, in addition to building community resilience against ecological degradation (WWF, 2024).

Box 18. Case study of Fiji and Solomon Islands

Location	Macuata and Ba Province, Fiji; Western Province, Solomon Islands
Implementation / Funding authority	World Wildlife Fund Pacific, Matanataki Pte Ltd, Strongim Bisnis. and local stakeholders for implementation in Fiji; Locally Managed Marine Area Network and Western Province Fisheries in Solomon Islands
Timeline	2022 onwards
Objective	• Restore and manage mangroves through soil restoration, sustainable resource use for enhanced livelihoods and food security, integration of mangrove and fisheries farming management, and implementation of culture-based solutions, including establishing indigenous and community-protected areas • Creation of nature-positive business models in Fiji and sea grapes in Solomon Islands are the focus (Châles, 2023; Seidl et al., 2024).
Ecosystem type	Mangroves, Coral reefs
Climate change impacts addressed	Protection of coastal edge, sea level rise impacts on the coastal communities, and reduction in ocean acidification by reef restoration
Socio-economic outcomes	Livelihood diversification as well as skill enhancement through mangrove plantation trainings.
Project cost	USD 0.68 million

6.4.1.3. East Kolkata Wetlands, Kolkata: Ecosystem services and livelihoods through wetland conservation

The East Kolkata Wetlands (EKW), covering 12,500 hectares, feature a network of water bodies that are part of the Gangetic Delta draining into the Bay of Bengal (Box 19). The area processes 900 million litres of sewage daily from Kolkata, which lends organic matter for fish, vegetable, and rice cultivation. This natural treatment system saves the city nearly INR 4,680 million annually in sewage treatment costs and helps reduce GHG emissions (EKWMA & WISA, 2021). However, EKW faces severe threats from urbanisation and industrial pollution, which compromise its capacity to maintain these functions.

Box 19. Case study of Kolkata, West Bengal, India

Location	Kolkata, West Bengal, India
Enforcement agencies	Managed by a network of local communities and supported by East Kolkata Wetlands Management Authority and East Kolkata Wetlands Development Society (Mundoli et al., 2023; Roy-Basu et al., 2020); National Wetlands Authority and Kolkata Municipal Corporation
Timeline	2002 onwards
Objective	• Implementing nature-based solutions for wastewater management • Sewage water treatment for a healthy circular economy • Providing sustenance and livelihood to 150,000 people through pisciculture and agriculture
Ecosystem type	Urban, Wetlands
Climate change impacts addressed	• Reduce Kolkata's carbon footprint by approximately 3500 tonnes of CO2 annually, equivalent to 60% of the city's emissions. • Function as a sponge, recharging groundwater, storing water for agro-economic activities, and contributing to soil quality improvement and erosion control
Socio-economic outcomes	• Employment opportunities in pisciculture and agriculture • Supporting livelihood of the local community
Project cost	USD 0.24 million
Monitoring and evaluation	Consistent surveillance of waterbird numbers is performed using established protocols from the Asian Waterbird Census at key gathering locations. The West Bengal Pollution Control Board conducts monthly assessments to monitor the quality of water. Current wetland monitoring focusses on land-use changes via remote sensing and assessment of water quality parameters and fish production.
Trade-offs/Limitations	Key knowledge gaps include understanding climate vulnerability, mitigating risks, assessing heavy metal impacts on food production, and studying the effects of soil and plastic waste on the wetland environment.

6.4.1.4. *Bhitarkanika Mangroves, Odisha: Mangrove ecosystem conservation for biodiversity coastal protection*

Spanning 65,000 hectares along the Odisha coast, the Bhitarkanika Mangroves lie between the Brahmani and Baitarani Rivers nurtured by over two decades of conservation efforts. Recognised as both a vital wildlife sanctuary and an important coastal wetland, Bhitarkanika is home to the world's largest known sea turtle nesting beach and the highest density of saltwater crocodiles in India (Box 20). However, intense human activity is degrading the mangroves. Around 300 villages, primarily engaged in paddy farming, border the area (Pandav et al., 2002). Recent constructions such as embankments and aquaculture farms have increased salinity altering the landscape and reducing its suitability for traditional uses. Moreover, a rise in the number of in-migrants from regions near West Bengal has led to deforestation and strained local resources, disrupting the ecological balance.

Box 20. Case study of Bhitarkanika Conservation Area, Rajnagar, Odisha, India

Location	Bhitarkanika Conservation Area, Odisha, India
Enforcement agencies	Rajnagar Wildlife Division - State Forest Department, State Pollution Control Board, Department of Water Resources of Odisha, United Nations Development Programme, Food and Agriculture Organization
Timeline	1952–2002
Objective	Preservation of mangrove ecosystems, wildlife conservation, and sustainable resource management
Ecosystem type	Mangroves
Climate change impacts addressed	Mitigation of devastating cyclones and tidal surges and conservation of biodiversity by setting up waterbird habitats and breeding grounds for brackish water and estuarine fish fauna (Barik et al., 2016)
Socio-economic outcomes	Traditional sustainable harvesting of food, medicines, tannins, fuel wood, construction materials, honey, and fish, balancing ecosystem conservation with human needs
Monitoring and evaluation	Regular assessments of wildlife populations, habitat health, and the impact of conservation measures as part of the Ramsar Convention
Trade-offs/Limitations	Potential threats from population pressures and encroachment and the need for balancing conservation with local livelihoods

6.4.1.5. *Kadamakurdy Redevelopment Project, Kochi: Habitat restoration and sustainable development*

The Kochi Municipal Corporation conducted a spatial analysis of the mangrove areas under its jurisdiction, with a sharp decrease of 14% in coverage from 2013 to 2017. However, 2.5 km^2 of new mangrove areas were established during this period (K M et

al., 2020). The loss of mangrove vegetation poses a severe threat, underscoring the need for targeted conservation efforts to preserve the ecological and economic benefits provided by mangroves in urbanising regions (Box 21).

Box 21. Case study of Kadamakudy, Kochi, Kerala, India

Location	Kadamakudy, Kerala, India
Enforcement agencies	Cochin University of Science and Technology, Department of Town and Country Planning, International Council for Local Environmental Initiatives [South Asia], Deutsche Gesellschaft für Internationale Zusammenarbeit, Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection, Germany
Timeline	2013 onwards
Objective	Protection and restoration of wetlands for paddy and shrimp cultivation Redevelopment of blue–green infrastructure (BGI) in urban planning and development Development of a scientifically informed and participatory local biodiversity strategy and action plan (Sánchez & Govindarajulu, 2023)
Ecosystem type	Urban, Wetlands, Mangroves
Climate change impacts addressed	Flood mitigation through BGI redevelopment
Socio-economic outcomes	• Protection of wetlands for agriculture • Development of a 'sponge city' to absorb and mitigate floods • Integration of climate change perspectives with Sustainable Development Goals • Preservation of traditional Pokkali cultivation

6.4.1.6. Mangrove conservation, Mumbai: Initiatives to enhance urban biodiversity and flood resilience

Mumbai, originally comprising several islands in 1670, retains only about 60% of its mangrove cover compared with a decade ago, primarily because of urban expansion and pollution from industrial zones and sewage discharge (Karelia, 2021). The city is home to 15 of the 35 mangrove species found in India, especially those resilient to pollution and salinity (Sarkar, 2017). To maintain these critical habitats and biodiversity, community participation and enforcement of legal protections are crucial in the rapidly expanding metropolis (Box 22).

Box 22. Case study of Mumbai Coast, Maharashtra, India

Location	Vasai Creek, Thane Creek, Manori and Malad, Mahim-Bandra, Versova, Sewree, and Mumbra-Diva, Maharashtra, India

Enforcement agencies	Various government bodies, local non-governmental organisations (NGOs), and community initiatives under Soonabai Pirojsha Godrej Foundation (Azeez et al., 2022; Shyam, 2016)
Timeline	2010 onwards
Objective	Conserve and restore the mangrove ecosystems in Mumbai, highlighting their ecological and socio-economic importance, addressing challenges posed by urbanisation, and enhancing government and community efforts to protect these vital coastal buffers
Ecosystem type	Mangroves
Climate change impacts addressed	Protection against coastal erosion, storm surges, and tsunamis, contribution to soil/sediment accretion, and serving as a natural barrier safeguarding the coastline and supporting biodiversity
Socio-economic outcomes	Supporting livelihoods through fisheries and other marine resources, potential for medicinal and research purposes, and offering opportunities for eco-tourism and education about coastal ecosystems
Monitoring and evaluation	Monitoring and evaluation by local communities and NGOs
Trade-offs/Limitations	Challenges include balancing urban development with environmental conservation, overcoming legal and regulatory hurdles, ensuring sufficient funding and resources for conservation projects, and addressing pollution and habitat destruction

6.4.1.7. Greening and Conserving Mangroves, Pirojshanagar, Mumbai

Godrej's Pirojshanagar Mangroves in Vikhroli, Mumbai, cover a 2,000-acre urban forest that exemplifies scientific management for research, conservation, and public awareness (Box 23). These mangroves protect Mumbai's eastern shoreline from erosion, storms, and cyclones while supporting the livelihoods of local fisher folk who rely on the healthy mangrove ecosystem for their sustenance.

Box 23. Case study of Vikhroli, Mumbai, Maharashtra, India

Location	Vikhroli-Mumbai, Maharashtra, India
Implementation / Funding authority	Godrej and Boyce Manufacturing Company Limited
Timeline	2010 onwards
Objective	Focussed on the conservation of this ecologically sensitive area, bringing all areas with mangrove cover under protection

Ecosystem type	Mangroves, Urban, Coastal
Climate change impacts addressed	Conserves the mangroves through a three-pronged approach of research, conservation, and awareness-raising.
Socio-economic outcomes	Increased awareness and engagement among citizens, scientists, and stakeholders, fostering a sense of responsibility towards the preservation of the city's mangroves.
Finance	USD 62 million
Trade-offs/Limitations	• Challenges in planning and implementation arise because of the varying degrees of degradation and slow growth of mangroves, which require at least 20 years to establish. • Stakeholder engagement is crucial for visibility and conservation, demanding expertise in mangrove ecosystems, hydrology, and geology for suitable species selection and site preparation.

6.4.1.8. Floating Islands, Indore: Pond restoration through green technology

Indore, acclaimed as India's cleanest city, is now focussing on restoring its polluted lakes and ponds. The Police Training College spearheads this initiative with the rehabilitation of Nalanda Sarovar, a 10,000 sq ft pond on its grounds (Clean Water, 2019). Deterioration from the presence of algae and decaying organic materials has necessitated this project. This restoration not only rejuvenates a vital urban water body but also serves as a blueprint for sustainable environmental management in Tier-II cities (Box 24).

Box 24. Case study of Nalanda Sarovar campus, Indore, India

Location	Indore, Madhya Pradesh, India
Enforcement agencies	Implemented by Clean-Water (Sustainable Water Technologies Private Limited), Police Training College
Timeline	2019
Objective	Improve the quality of the water in the pond and reverse the eutrophication
Ecosystem type	Urban, Ponds
Climate change impacts addressed	• Decrease in water contamination and the ecological health of aquatic ecosystems. • Addressing pollution to improve the provision of ecosystem services vital to these aquatic environments by installing floating islands.

Socio-economic outcomes	• Hybrid technologies such as floating islands and bio-filters for pond restoration can spur technological innovation and knowledge transfer within the community. • Local organisations and entrepreneurs may develop expertise in water management technologies, leading to new business opportunities and economic growth.
Governance	Water quality testing, nutrient analysis, observation and monitoring, sludge removal, fish population assessment, and installation and monitoring of bio-filters and aeration systems
Finance	Although floating islands and other technologies used for restoration may require minimal maintenance, there is still some level of ongoing upkeep needed to ensure the effectiveness of the interventions.

6.4.2. DRR

These projects specifically address disaster mitigation, resilience, or recovery through NbS, showcasing the role of ecosystems in reducing disaster risk. Mainstreaming ecological integrity and water quality and enhancing local resilience to regional disasters are critical to the sustainability and resilience of coastal settlements. Importantly, they highlight that although DRR is necessary after the occurrence of a disaster, such projects are responsible for building capacity and infrastructure pre-emptively for the community.

6.4.2.1. Red Cross mangrove restoration, Vietnam: Mangrove reforestation for storm protection

Vietnam, with its extensive 3,444-km coastline, is increasing its forest cover to 45% by 2030, focussing on mangrove afforestation in protected areas. The country has been facing various environmental challenges including a 20-cm sea-level rise over the last 50 years and has intensified efforts to enhance coastal forest quality, particularly mangroves, to reduce erosion, flooding, and salinisation (Box 25). In Thai Binh, a province in the Red River Delta, efforts to improve mangrove coverage have been hindered by poor species selection and inappropriate planting (Aouinti, 2022).

Box 25. Case study of Coastal Vietnam

Location	Thai Binh, Thai Binh Province, Vietnam
Implementation / Funding authority	Vietnam Red Cross with support from Danish Red Cross and Japanese Red Cross Societies
Timeline	1994–2010
Objective	Addressing the loss of coastal protection by restoring mangroves to safeguard sea dykes, reduce flooding risk, and protect livelihoods
Ecosystem type	Mangroves, Coastal

Climate change impacts addressed	Mitigation of typhoons, storm surges, sea-level rise, and flooding, in response to Vietnam's vulnerability to extreme weather events
Socio-economic outcomes	Direct benefits to 3,50,000 people and indirect benefits to 2 million Reduction in damages caused by typhoons, leading to economic savings. Increased aquaculture product yields by more than 200%. Reduced flood and sea dyke damage in communities during storms, with avoided damages estimated at USD 68,370 to USD 252,840
Finance	USD 8.9 million
Monitoring and evaluation	Continuous monitoring of mangrove area increase from 1999 to 2013 Longitudinal comparison of damages caused by typhoons before and after the project External evaluation conducted to assess the project's performance, progress, and sustainability
Trade-offs/Limitations	Limited data constraints for before and after comparisons and challenges in the availability of data for impact assessment

6.4.2.2. Triple Benefit Programme, Myanmar: Multi-faceted approach targeting DRR, climate change adaptation, and sustainable livelihoods

In Myanmar, the community forestry programme initiated in 1995 aims to empower local communities through sustainable forest management and various forestry models (Khaine et al., 2019). The Triple Benefit Programme addresses local needs, promotes conservation, explores the generation of cash and non-cash benefits, and assesses current benefit-sharing mechanisms based on existing community forestry experiences and regulations to build ecosystem resilience (Box 26).

Box 26. Case study of Myanmar

Location	Kachin and Shan States, Mandalay, Magway, Ayeyarwady Divisions, Myanmar
Enforcement agencies	Danish International Development Agency (Strategic Partnership), World Wildlife Fund (Kenya, Uganda, Madagascar and Myanmar)
Timeline	2022 onwards
Objective	Enhanced local partners' ability to design and advocate for NbS, according to the IUCN Standard with expert guidance and tools for NbS implementation and community consultations
Ecosystem type	Tropical rainforests

Climate change impacts addressed	Enhanced the community forestry programmes, with benefit sharing mechanisms to prevent deforestation and forest degradation
Socio-economic outcomes	• Livelihood diversification and green job creation while ensuring safeguards for people and nature • Sustainable management schemes and equitable benefit distribution
Finance	USD 10 million

6.4.2.3. Kathmandu Valley Ecological Urban Renewal Project, Nepal: Urban renewal integrating green spaces for enhanced resilience against natural disasters

Kathmandu Valley, home to three million people and encompassing 18 municipalities, has historically practised sustainable living, harmoniously integrating nature preservation, cultural retention, and economic growth (Cities Development Initiative for Asia, 2023). However, rapid urban expansion has led to challenges such as land fragmentation and the degradation of ecological and cultural assets, exacerbating vulnerability to earthquakes and climate-related disasters. Efforts are being taken to leverage NbS with urban planning to build urban resilience (Box 27).

Box 27. Case study of Kathmandu, Nepal

Location	Kathmandu, Central Hill Zone, Nepal
Enforcement agencies	The Kathmandu Urban Development Project, High-Powered Committee for Integrated Development of the Bagmati Civilization; funded by ADB, World Bank and Deutsche Gesellschaft für Internationale Zusammenarbeit
Timeline	1993 onwards
Objective	Improve productivity and the urban environment, ensure the sustainability of investments through environmental improvements, and increase local resource mobilisation. Integrate ecosystem-based approaches for disaster risk reduction and climate change adaptation (Pokhrel, 2019; Poudel et al., 2023, 2023).
Ecosystem type	Urban, Mountain, Riverine
Climate change impacts addressed	The Kathmandu Metropolitan City Risk Sensitive Land Use Plan address risks from earthquakes, floods, landslides, air pollution, and other climate change-related hazards intensified by deforestation, riverine pollution, and loss of agricultural land.
Socio-economic outcomes	Initiatives aim at improving liveability, reducing socio-economic vulnerabilities (especially among the urban poor), and enhancing community well-being through the integration of blue–green infrastructure and other resilience measures

Project cost	USD 12 million
Trade-offs/Limitations	Trade-offs include balancing rapid urban development and environmental conservation and managing limited resources to address the comprehensive needs of a growing population amid escalating climate risks.

6.4.2.4. Resilience efforts in Barishal, Bangladesh: Community and ecosystem resilience to flooding

Kutubdia Island in Bangladesh is rapidly eroding into the sea, exacerbated by climate change, threatening both the land and livelihoods of its residents. Many people have been forced to relocate, while those remaining struggle with the changing landscape. The situation is a stark example of the broader climate migration issues facing Bangladesh, indicating that up to 13.3 million people could be displaced by 2050 owing to environmental changes (Imtiaz, 2021). Resilience efforts in the region highlight the need for early integration of NbS into the urban planning process (Box 28).

Box 28. Case study of Barishal, Bangladesh

Location	Kutubdia, Barishal, Bangladesh
Enforcement agencies	Barishal District Administration, Barishal City Corporation, 'Barisal-Problem and Prospects' Facebook civic engagement group and funding from Kreditanstalt für Wiederaufbau (KfW) Development Bank
Timeline	2015 onwards
Objective	Making Barishal climatically resilient and environmentally sustainable, reducing waterlogging through natural drainage restoration, enhancing naval transportation, and improving public health and well-being (Mukherjee et al., 2022)
Ecosystem type	Urban, Riverine, Coastal
Climate change impacts addressed	Sagardi Canal Development (2015), Climate Change Adaptation for Urban Areas Programme (2016), and Jail canal restoration (2016) address building resilience to cyclones, flooding (waterlogging, riverine/monsoon floods, and storm/tidal surges), salinity intrusion, and riverbank erosion, with a focus on drainage congestion, solid waste management issues, and encroachment of water bodies.
Socio-economic outcomes	Restoration efforts focus on improving disaster resilience, infrastructure, and health outcomes for the community.
Governance	'Barisal-Problem and Prospects' Facebook group for community feedback suggests some level of civic engagement.
Project cost	USD 40 million (KfW, 2018)

Monitoring and evaluation	The condition of the Jail canal was assessed through newspaper article reviews and interviews, indicating some level of monitoring. However, detailed processes for ongoing evaluation of resilience measures are not provided.
Trade-offs/Limitations	The resettlements in canal areas after initial clean-ups indicate challenges in sustaining the benefits of resilience measures. Limitations include a lack of development guidelines, poor local awareness, and the need for continuous community participation.

6.4.2.5. Tampara Wetland Conservation Project, Odisha: Protection and restoration of a Ramsar site to maintain its ecological integrity and water quality

The Tampara freshwater wetland in Chatrapur, Odisha, was declared a Ramsar site in 2022. It is a 300-hectare biome that has experienced significant degradation owing to landscape changes, increased agriculture, and construction (Verma, 2023). These factors have led to reduced wetland area, disrupted hydrological regimes, and heightened salinisation risks. The Tampara Wetland Conservation Project is a 3-year initiative focused on the sustainable management and restoration of the wetland to enhance the resilience of 12,000 households to water-induced disaster risks (Box 29).

Box 29. Case study of Chatrapur, Odisha, India

Location	Chatrapur, Odisha, India
Enforcement agencies	Pallishree Limited, Chilika Development, Panchayats in Chatrapur Block, Ganjam District funded by Government of India
Timeline	2022 onwards
Objective	Upscaling and mainstreaming Eco-DRR approaches into practice and policymaking for building community resilience to water-induced disaster risk covering 12,000 households (about 60,000 people) (Mishra & Mohapatra, 2023; Ojha & Rout, 2022).
Ecosystem type	Peri-urban; Freshwater Wetlands
Climate change impacts addressed	Eco-DRR through wetland basin hydrological restoration to improve resilience against storm surges, coastal erosion
Socio-economic outcomes	Government-supported programmes have enhanced community-based wetlands management, establishing 15 organizations, 11 task force groups, and over 800 women in self-help groups. Sensitizing 18,000 community members on Eco-DRR, these efforts restored nearly 450 hectares of wetlands and promoted sustainable livelihoods among local fishermen.
Finance	USD 4 million (Patnaik, 2016)

Monitoring and evaluation	Integrating Eco-DRR into their Gram Panchayat Development Plan, ensuring scientific assessments of wetlands with landscape assessments, sectoral plan review with community members

6.4.2.6. Shenzen Sponge City, China: National programme for urban water retention and flood control

For many years, China, with its large population, has grappled with enduring water scarcity and destructive floods. In response, the concept of sponge cities—incorporating natural, green infrastructure into urban drainage systems to absorb, store, and cleanse rainwater—was introduced in the early 2010s to alleviate urban pressures from these challenges (Han et al., 2023). Generally, there has been an evolution from 'grey to green' infrastructures (Box 30). Creating a sponge city addresses four critical water challenges in densely populated areas of China: excess water, scarcity, pollution, and turbidity (Rau, 2022).

Box 30. Case study of Shenzhen, People's Republic of China

Location	Shenzhen, China
Implementation / Funding authority	Public–private partnership with Shenzhen Government (Wang et al., 2022)
Timeline	2016 onwards
Objective	Enhance the city's ability to absorb, store, and release rainwater through urban facilities, thereby controlling stormwater runoff, improving the urban water environment, saving water resources, and ensuring no water accumulation during light rains and minimising waterlogging during heavy rains
Ecosystem type	Urban, Riverine
Climate change impacts addressed	Overcoming waterlogging issues due to heavy rains through stormwater management in the context of rapid urbanisation, exacerbated by climate change.
Socio-economic outcomes	Enhancement of urban liveability and promotion of overall resilience and economic stability
Finance	USD 206 million
Trade-offs/Limitations	'Interim Measures' policy faces challenges because of the complexity of the water ecological environment, insufficient monitoring data, and the need for a more systematic and mature sponge city construction standard policy system. Public participation and coordination among various stakeholders are areas for improvement.

The Bajo, a community living on the Arborek Island, Indonesia, since the 1800s, now face threats from climate change and habitat destruction. They plant barriers of mangroves, shrubs, and coral blocks to prevent coastal erosion.

Credit: Alain Schroeder / Climate Visuals

7. Institutions and Organisations Promoting NbS

Exploring the landscape of organisations dedicated to advancing NbS, especially for coastal adaptation involves understanding various stakeholders, ranging from international bodies and NGOs to research institutions and local community groups. These organisations collaborate across various levels, from local to global, to share knowledge, mobilise resources, and implement projects that demonstrate the effectiveness of NbS in enhancing coastal resilience. The landscape is dynamic, with increasing recognition of the importance of integrating ecological and social systems into climate adaptation strategies.

The following sections provide an overview of the key types of organisations involved in this field:

7.1. International and multilateral organisations

United Nations Environment Programme (UNEP)

UNEP puts ecosystem restoration and sustainable management practices at the forefront of their work to protect communities from climate impacts. Its initiatives in the coastal context often focus on mangrove restoration and coral reef protection to enhance biodiversity and natural barriers against sea-level rise and storms.

Intergovernmental Panel on Climate Change (IPCC)

The IPCC provides scientific assessments on climate change, including the effectiveness of NbS in coastal adaptation. It underscores the role of coastal ecosystems in carbon sequestration and their importance in protecting shorelines from erosion and extreme weather events.

United Nations Office for Disaster Risk Reduction (UNDRR)

UNDRR advocates for integrating NbS into DRR strategies, recognising their potential to reduce vulnerability and enhance resilience of coastal areas against tsunamis, storm surges, and coastal erosion.

World Bank

The World Bank invests in NbS for coastal adaptation, offering financial and technical support for projects such as wetland restoration and sustainable fisheries. These projects aim to reduce the risk of flooding and improve livelihoods, contributing to economic and environmental sustainability.

International Finance Corporation (IFC)

As the World Bank's investment arm, IFC supports sustainable development in emerging markets. A key policy of the IFC emphasises biodiversity conservation and sustainable resource management, aiming to protect ecosystems, support livelihoods, and enhance economic prosperity (International Finance Corporation, 2012).

USAID

USAID incorporates NbS into its development programmes to improve coastal resilience by supporting mangrove reforestation and sustainable land management for ensuring the well-being of dependent communities.

World Economic Forum

The World Economic Forum highlights the economic benefits of NbS in coastal adaptation, encouraging public–private partnerships to invest in green infrastructure. This includes funding innovative approaches such as living shorelines, which combine natural habitat restoration with traditional coastal protection methods.

United Nations Development Programme (UNDP)

UNDP, as part of the United Nations' global development network, advocates for change and connecting countries to share knowledge, experience, and resources to help people build a better life. It supports global development projects, including NbS for coastal adaptation, promoting sustainable practices to improve resilience against environmental challenges.

United Nations High Commissioner for Refugees (UNHCR)

Also known as the United Nations Refugee Agency, UNHCR is dedicated to saving lives; protecting rights; and building a better future for refugees, forcibly displaced communities, and stateless people. It also focusses on the integration of NbS in refugee settlements to enhance climate resilience and environmental sustainability amongst other vulnerable areas.

Asian Development Bank (ADB)

ADB is a regional development bank established to facilitate economic development and cooperation among countries in Asia and the Pacific region. It finances projects across the region, including those that incorporate NbS for coastal protection and sustainable development, aiming to mitigate climate change impacts.

Cities Development Initiative for Asia (CDIA)

CDIA is a project preparation facility that provides assistance to Asian cities to bridge the gap between their development plans and the implementation of infrastructure investments, with an emphasis on incorporating NbS for urban and coastal resilience against climate change.

Red Cross

The Red Cross, part of the International Red Cross and Red Crescent Movement, is a humanitarian organisation that provides emergency assistance, disaster relief, and education in various countries. It also engages in mobilising communities for climate adaptation projects, including NbS, to improve disaster preparedness.

Global Environment Facility (GEF)

GEF is a financial mechanism that provides funding to developing countries for projects that benefit the global environment and promote sustainable livelihoods in local communities. It addresses six focal areas, namely biodiversity, climate change, chemicals, international waters, land degradation, and the ozone layer, by supporting projects that mitigate environmental risks and promote sustainable development.

7.2. NGOs and environmental groups

World Resources Institute India (WRI India)

WRI India works on enhancing coastal resilience through NbS by advocating for the restoration of mangroves, wetlands, and other coastal ecosystems. Its initiatives focus

on policy development, stakeholder engagement, and research for effective integration of NbS into urban and rural coastal planning.

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) India

GIZ India supports projects that incorporate NbS for coastal adaptation, emphasising sustainable management of natural resources to protect coastlines from erosion and sea-level rise. It collaborates with local communities and governments to implement projects that blend traditional knowledge with modern conservation techniques.

India Climate Collaborative

The India Climate Collaborative brings together businesses, NGOs, and government entities to fund and implement climate solutions, including NbS for coastal adaptation. Their work often focusses on building resilience in vulnerable coastal communities through ecosystem restoration and sustainable practices.

The Nature Conservancy

The Nature Conservancy implements NbS projects worldwide, including India, with a focus on restoring coral reefs and mangrove forests to reduce the impacts of coastal erosion and storms. Its efforts aim to protect biodiversity while enhancing the natural defence mechanisms of coastlines.

World Wildlife Fund (WWF) India

WWF India is involved in several NbS initiatives aimed at conserving coastal and marine ecosystems. By promoting the protection and restoration of habitats such as mangroves and coral reefs, it contributes to building natural resilience against climate change-induced challenges.

Wetlands International

Wetlands International focusses on the conservation and restoration of wetlands as critical NbS for coastal protection. Its projects in India aim to maintain the functions of these vital ecosystems, including buffering storm surges and providing habitats for biodiversity.

Wildlife Institute of India

The Wildlife Institute of India emphasises the conservation and management of wildlife, offering capacity building and educational training for wildlife research and management. Its initiatives across India focus on preserving natural habitats, which play a crucial role in regulating climate, supporting biodiversity, and providing sustainable resources.

Conservation International

Conservation International operates worldwide, with a strong focus on supporting projects in the Global South. These initiatives prioritise NbS aimed at enhancing coastal resilience, protecting watersheds, and fostering community-based initiatives.

Caterpillar Foundation

The Caterpillar Foundation supports projects that integrate NbS into coastal adaptation strategies, recognising the role of healthy ecosystems in sustaining livelihoods and protecting against climate impacts. Its funding helps scale up successful NbS interventions in vulnerable coastal regions.

Department of Environment, Food and Rural Affairs (DEFRA), Government of the United Kingdom

DEFRA actively supports international initiatives that apply NbS for coastal and marine conservation. Its programmes often fund research and implementation projects that aim to enhance coastal resilience through ecosystem-based approaches.

Norway's International Climate and Forest Initiative (NICFI)

NICFI invests in projects that protect and restore forests as part of broader NbS strategies, including coastal plantations and mangroves. Its support for these ecosystems contributes to global efforts to mitigate climate change and protect vulnerable coastlines.

International Council for Local Environmental Initiatives (ICLEI)

ICLEI focusses on urban sustainable development through NbS, low-carbon solutions, and smart urban infrastructure projects. It facilitates the participation of South Asian local governments in United Nations' conferences and other global forums, strengthening international policies to support local initiatives for the global sustainability agenda.

7.3. Research institutions and academic networks

Stockholm Environment Institute (SEI)

SEI engages in cutting-edge research and policy development to advance NbS for coastal adaptation, focussing on sustainable management of ecosystems such as mangroves and wetlands to protect coastlines from erosion and sea-level rise. Its work emphasises the integration of scientific knowledge with local community practices to enhance the resilience of coastal areas against climate change impacts.

National Institute of Urban Affairs' Climate Centre for Cities (NIUA C-Cube)

NIUA C-Cube plays a pivotal role in promoting NbS in Indian urban coastal cities by advocating for the integration of green infrastructure, such as urban wetlands and mangrove parks, into city planning and development strategies. It focusses on capacity building, policy advocacy, and facilitating partnerships among government bodies, local communities, and private sector stakeholders to implement NbS that enhance urban resilience to climate change.

7.4. Governmental and policy-making bodies

MoEFCC

This ministry is the principal governmental agency responsible for crafting and executing policies and programmes concerning environmental conservation, biodiversity, forest management, and climate change. It oversees various subordinate bodies tasked with specific environmental functions.

Central Empowered Committee (CEC)

The CEC was made a permanent statutory body by the MoEFCC to monitor the implementation of the Supreme Court's orders on environmental issues across India.

Central Ground Water Authority (CGWA)

Falling under the Ministry of Jal Shakti, the CGWA manages and regulates the country's groundwater resources. It establishes guidelines for sustainable groundwater use and issues necessary clearances for groundwater extraction.

Central Pollution Control Board (CPCB)

A statutory body under the MoEFCC, the CPCB serves as the apex authority for pollution control in India. It sets pollution control standards, conducts environmental research, and coordinates National Environmental Monitoring Programmes.

Forest Survey of India (FSI)

As a part of the MoEFCC, the FSI conducts comprehensive surveys and assessments of forest resources in India, monitoring changes in forest cover and contributing to biodiversity conservation.

Indian Council of Forestry Research and Education

This council coordinates forestry research and education in India, fostering sustainable forest management practices.

National Centre for Sustainable Coastal Management (NCSCM)

NCSCM is an Indian government initiative dedicated to the sustainable development of coastal regions. It focusses on implementing NbS such as mangrove restoration to enhance coastal resilience against erosion and storms, ensuring biodiversity conservation and supporting local livelihoods.

National Biodiversity Authority (NBA)

Functioning under the MoEFCC, NBA is dedicated to the conservation of biological diversity, sustainable utilisation of its components, and equitable sharing of benefits derived from biological resources.

8. NbS Frameworks and Application

Recognising the need for a structured approach to harness the full potential of NbS, various frameworks and indicators have been developed by leading organisations and research bodies. These frameworks serve as comprehensive guides for evaluating, designing, and scaling up NbS projects, ensuring they meet the rigorous standards of effectiveness, efficiency, and adaptability. They facilitate the implementation of NbS and the development of conservation measures as well as support policy-making, catering to a diverse audience including governments, businesses, and non-profits. By providing structured methodologies, these tools aim to mainstream NbS as a viable solution for environmental management and sustainable urban planning. Here, we provide a summary of some of these frameworks and the application of certain frameworks in different geographical contexts or for addressing different problems.

8.1. IUCN global standard for NbS

This user-friendly framework developed by the IUCN establishes a standard for verifying, designing, and scaling-up NbS (Figure 7). It guides stakeholders in the on-ground implementation of NbS, expedites policy development, and advances conservation science. Catering to a broad audience including governments, businesses, donors, and non-profits, the standard is versatile and applicable in various settings and scales, from protected areas to urban contexts and for projects of different sizes. Developed based on the feedback from NbS practitioners, it adopts a facilitative approach, avoiding rigid norms to allow for flexibility in achieving outcomes. The standard is structured around 8 criteria and 28 indicators (IUCN, 2020b).

Criterion 1: Identifies societal challenges addressed by NbS, such as climate change adaptation, DRR, and food security

- Prioritise challenges through inclusive consultations
- Document challenges and outcomes for accountability
- Use Specific, Measurable, Achievable, Relevant, and Time-Bound (SMART) targets to assess human well-being impacts

Criterion 2: Guides solution design, considering the geographic, economic, ecological, and societal scales of the issue, and recognises that the target area is part of a larger system

- Design NbS considering economy, society, and ecosystems
- Integrate with other sectors for synergistic solutions
- Include risk management beyond the intervention site

Criteria 3, 4, and 5: Correspond to pillars of sustainable development, focussing on environmental sustainability, social equity, and economic viability

- Set and monitor clear biodiversity conservation targets
- Monitor for unintended impacts, ensuring ecological risk mitigation
- Enhance ecosystem integrity and connectivity
- Assess NbS benefits and costs, specifying impacts on stakeholders

- Conduct cost-effectiveness studies for economic sustainability
- Compare NbS effectiveness against alternatives
- Explore diverse funding options and establish feedback mechanisms
- Promote transparency, equity, and dialogue in grievance resolution
- Value equality in participation across all demographics and indigenous communities
- Perform thorough stakeholder mapping to safeguard interests and rights
- Document and publicise decision-making processes for accountability
- Form joint decision-making bodies for NbS affecting multiple areas

Criterion 6: Addresses the need to balance trade-offs and choices for short- and long-term gains

- Balance trade-offs with safeguards to protect vulnerable groups
- Uphold rights and access to resources for all stakeholders
- Review safeguards to ensure they remain effective and fair

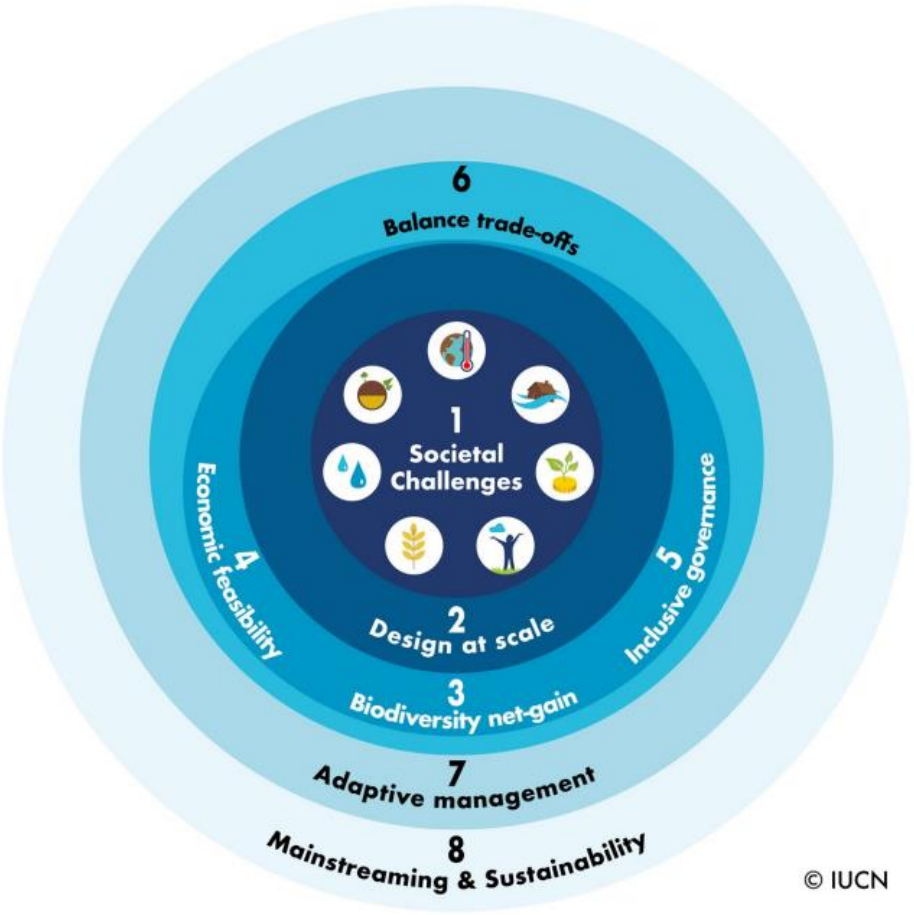
Criterion 7: Highlights the importance of adaptive management for NbS, facilitating continuous learning and adjustment to systemic changes

- Establish NbS strategy for ongoing monitoring and evaluation
- Implement a monitoring plan to adapt strategies based on feedback
- Use iterative learning for continuous improvement

Criterion 8: Stresses the significance of long-term, scaled implementation of NbS and advocates for embedding NbS concepts and actions into policy and regulatory frameworks, aligning with national targets and international commitments to maximise impact

- Embed NbS into policy for alignment with national and international goals
- Share NbS lessons to encourage replication and policy integration
- Align NbS with global targets to ensure sustainability and commitment

Figure 7: Criteria constituting the IUCN Global Standard for NbS



Source: International Union for Conservation of Nature (2020)

8.2. World Bank guideline for project developers

This guideline promotes the adoption of NbS for climate resilience by offering actionable valuation approaches for investments. It underlines that a good assessment values both the risk reduction and additional benefits of NbS, including biodiversity, climate regulation, and ecosystem services. It emphasises a multi-benefit, stakeholder-engaged approach. The guideline suggests engaging stakeholders to identify locally relevant benefits, addressing uncertainties in climate and socio-economic conditions, and integrating benefit and cost assessments into investment projects to ensure economic viability and community engagement. It proposes a tiered approach to research design based on the project phase, data availability, and resource constraints, aiming to select the best method while accommodating different priorities and providing detailed outputs as needed. This structured approach underscores the importance of comprehensively valuing and assessing NbS to support informed decision-making and investment in climate resilience (Figure 8).

Upstream Phase: Before project conception, national or regional economic assessments of NbS raise awareness and identify feasible solutions.

Project Identification and Preparation: NbS investment ideas undergo technical and economic evaluation, often involving biophysical models and economic analysis to attract sustainable financing.

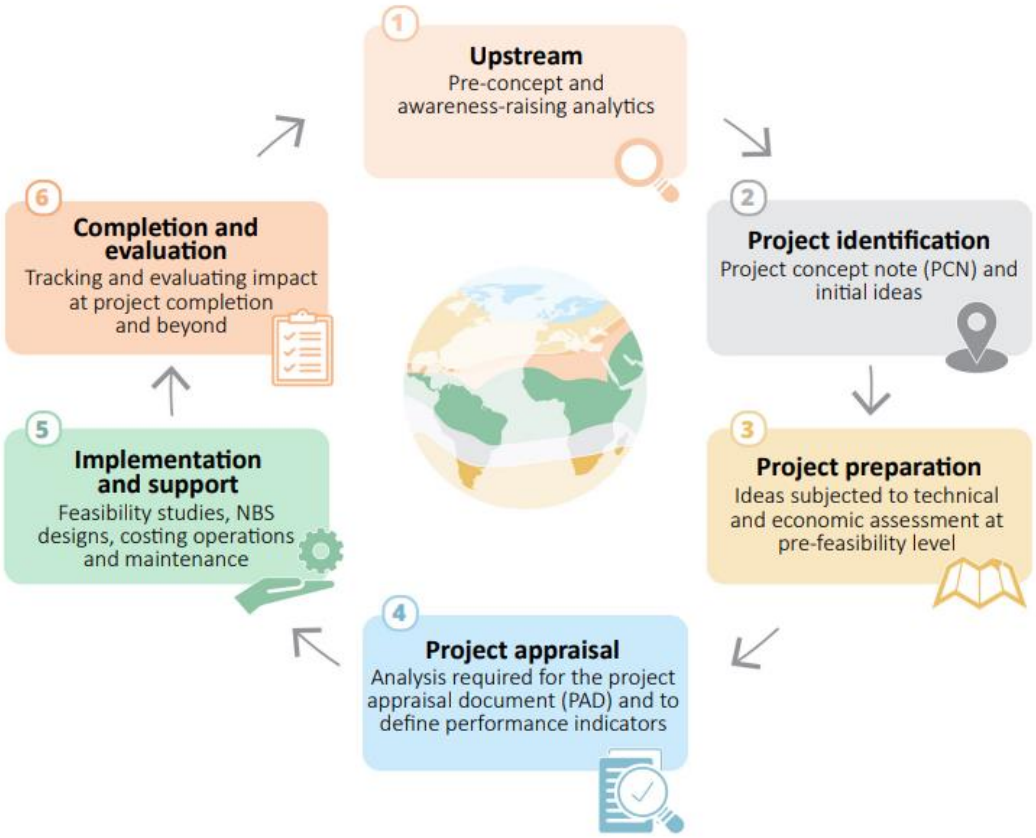
Project Appraisal: Economic and financial analysis (EFA) is conducted using various approaches such as cost–benefit analysis or multicriteria analysis, building on assessments from the identification phase.

Implementation and Support: During implementation, detailed feasibility studies are conducted, including NbS designs, costing, and engagement with local communities.

Resilience Rating System: Projects achieving resilience depend on the analytical approach used for EFA, with probabilistic assessments or robust decision-making yielding higher resilience ratings.

Completion and Evaluation: Well-defined project indicators are crucial for evaluating NbS impact and benefits beyond project completion. The Implementation Completion Report tracks project performance and progress on indicators.

Figure 8: Assessment of NbS benefits and costs at different project cycles



Source: World Bank (2022)

8.3. REGREEN framework

Developed for the European Commission, the document examines strategies aimed at reducing urban land consumption while integrating NbS into planning systems. It also offers guidelines for improved integration into the urban planning documents, for example:

Environmental assessment and knowledge: To address biodiversity and NbS challenges in regional planning, local councils can enhance their understanding through nature surveys and ecological assessments. These evaluations, conducted by ecologists or environmental groups, identify critical ecosystems and areas vulnerable to climate change effects such as urban heat islands and flood risks.

Incorporating ecological corridors into planning documents: In urban areas, green spaces such as parks and gardens act as biodiversity reservoirs and corridors. Planning ecological connectivity at the local level is important because global-scale documents may not suit urban contexts. Ecologists can identify target species to design functional ecological corridors that benefit biodiversity. This helps in land planning by (1) identifying vulnerable areas in ecological networks for conservation prioritisation, (2) locating suitable spots for actions including landscaping to improve connectivity, and (3) assessing the impact of land-cover changes on species.

Improving NbS planning through ecosystem service modelling and mapping: Mapping and modelling tools are essential for urban planners, offering precise land-use mapping and tracking changes over time to achieve objectives such as ecosystem restoration and NbS implementation. It is valuable for incorporating NbS into the planning process, including zoning systems for land protection and restoration, as well as guidelines for biodiverse design and management in planning schemes.

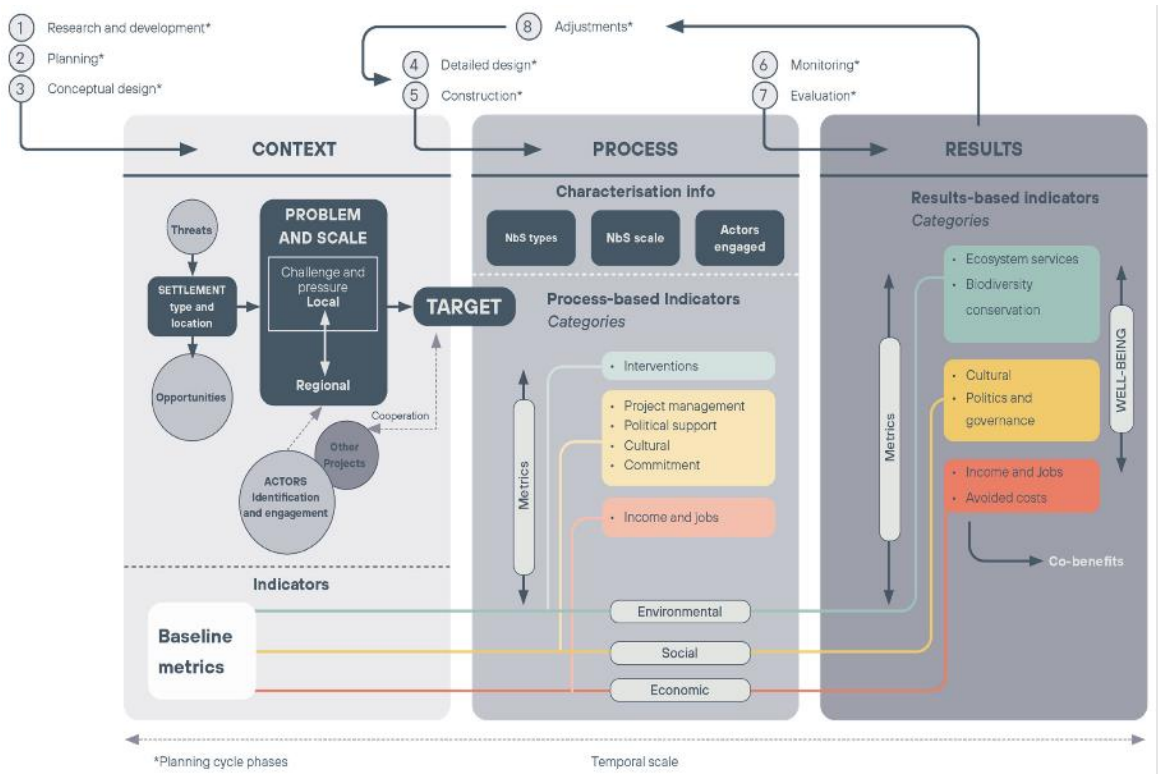
Protecting and restoring ecosystems: Improving the integration of NbS into planning documents involves safeguarding existing ecosystems, which already serve as NbS for conserving biodiversity and adapting to climate change. Urban planning documents can effectively facilitate the widespread implementation of NbS through governmental zoning, private easements, and restrictive covenants.

Increasing awareness and engaging the community: A combination of national and international NbS plans, along with the development of comprehensive policies and growing interest from municipalities and citizens, creates an enabling environment for integrating NbS into urban policies. However, better collaboration among research scientists, urban planners, designers, and other professionals is essential to prioritise NbS in urban planning and design.

8.4. Framework for planning and evaluation of NbS for water in peri-urban areas

A comprehensive framework for planning and evaluating NbS projects was introduced by de Lima et al. (2022), focussing on three stages—context assessment, implementation and adaptation, and evaluation of results (Figure 9). This tool helps assess the sustainability of projects and their contribution to SDGs, offering a valuable resource for enhancing water management and other NbS applications.

Figure 9: Operational framework for planning and evaluating NbS projects



Source: de Lima et al., 2022

Stage 1: Context assessment

- Involves identifying the settlement where the NbS is implemented, defining targets, and linking them with SDGs
- Crucial for understanding peri-urban characteristics and serves as the starting point for any NbS project
- Contextualisation helps propose suitable NbS and establish baseline indicators for future evaluations

Stage 2: NbS implementation process

- Focusses on implementing NbS with process-based indicators evaluating inputs and outputs
- Input indicators assess project interventions and activities, quantifying and qualifying invested resources
- Output indicators describe and quantify short-term results directly produced by NbS interventions
- Process-based indicators cover NbS interventions (environmental dimension), project management, social support, and economic aspects

Stage 3: Evaluation of NbS results

- Evaluates sustainability using results-based indicators, categorised into outcomes and impacts
- Outcome indicators provide medium- to long-term results of implemented activities

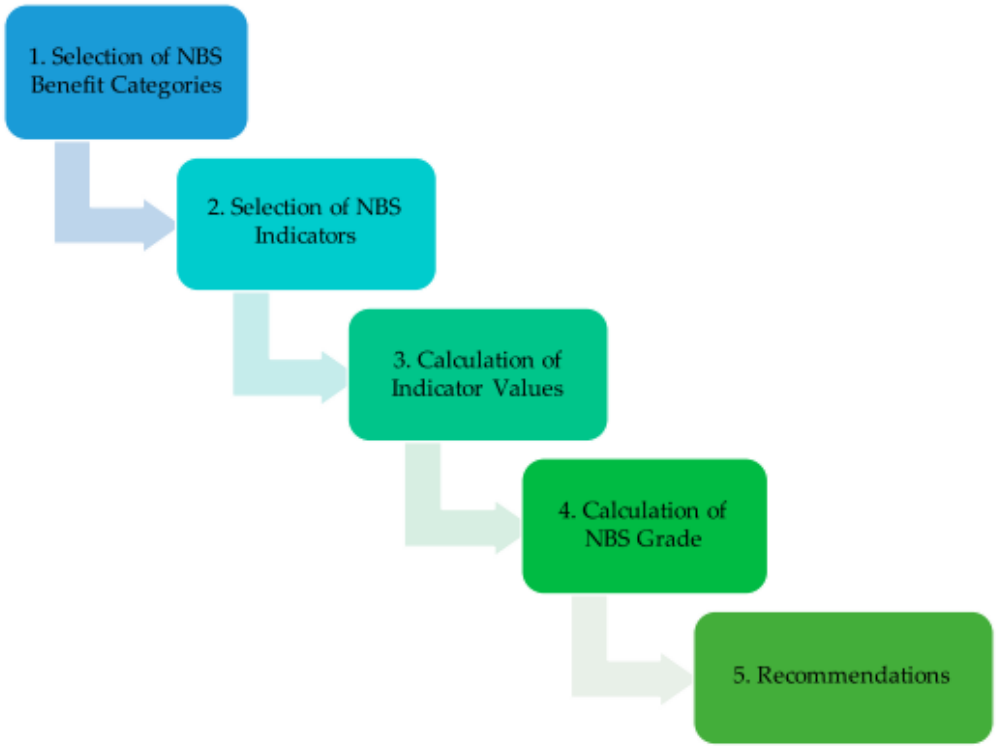
- Impact indicators indicate wider, long-term changes, including co-benefits and unintended results
- Result-based indicators cover biodiversity conservation, cultural and governance aspects, and economic factors such as income, jobs, and avoided costs

8.5. Framework for assessing the benefits of implemented NbS

Watkin et al. (2019) introduced an evaluation framework that qualitatively assesses and quantitatively measures the actual benefits and performance of implemented NbS. The outcomes can guide decision-makers in budgeting, maintenance planning, benefit monitoring, and resource allocation for NbS projects. The framework's efficacy was demonstrated through a case study in Thailand, wherein specific benefits, areas needing improvement, and overall NbS effectiveness were identified, showcasing its potential to optimise NbS implementation and management.

The framework comprises five primary stages (Figure 10).

Figure 10: Five stages of the framework



Source: Watkin et al., 2019

NbS benefit categories: Adapted from Regenerating ECOsystems with NbS for hydro-meteorological risk rEduCTion (RECONECT), benefits are split into water (W), nature (N), and people (P), focussing on hydro-meteorological benefits such as flood control, water reuse, and biodiversity.

Indicator selection: Stakeholders pick indicators for each benefit category to reflect specific benefits.

Indicator value calculation: Values for each indicator are determined using data from interviews, studies, and fieldwork, quantifying the NbS impact.

NbS grade calculation: A grade on a scale of 1–5 is assigned based on average indicator scores, with potential weightage for more critical benefits.

Recommendations: These include enhancing engagement, improving data collection, optimising maintenance, and ensuring ongoing benefit monitoring.

8.6. NbS assessment framework for climate proofing

Calliari et al. (2019) presented a 'dynamic' framework that considers the impact of climate change on NbS effectiveness utilising system analysis and backcasting (Figure 11). This approach supports transformative changes rather than small steps, acknowledging the multifunctional nature of NbS and evaluating both direct and indirect benefits and costs. Aimed for use before implementation, this framework helps in choosing between NbS and traditional methods, aligning with the European Union's environmental challenges. The framework consists of nine steps:

Defining a baseline: Assess current conditions, system boundaries, and interconnections to establish a baseline for NbS discussions

Setting objectives: Detail desired outcomes and specific goals to address the identified issues

Identifying constraints: Consider external influences and practical aspects such as financing strategies to achieve objectives

Proposing actions: Develop a range of potential actions, from traditional to nature-based or hybrid solutions, to meet objectives

Climate resilience: Evaluate options for their long-term viability considering climate change impacts

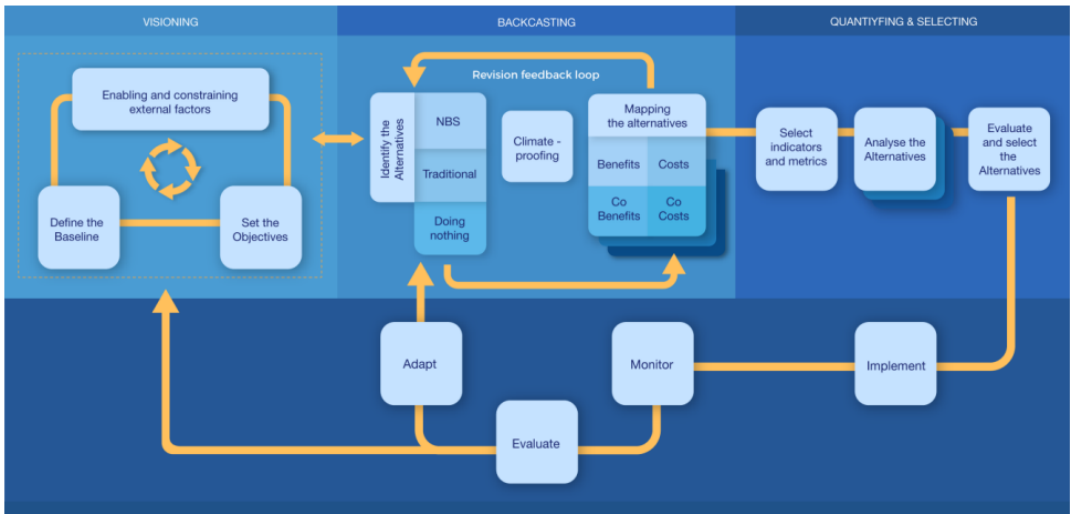
Visualizing impacts: Outline expected benefits and costs of alternatives to aid in selection

Establishing criteria: Choose indicators for quantitatively comparing the impacts of alternatives

Analysis: Utilise scientific models tailored to project needs for analysing alternatives

Evaluation: Apply tools including cost–benefit or multi-criteria analysis to compare alternatives and select the best option

Figure 11: Proposed assessment framework

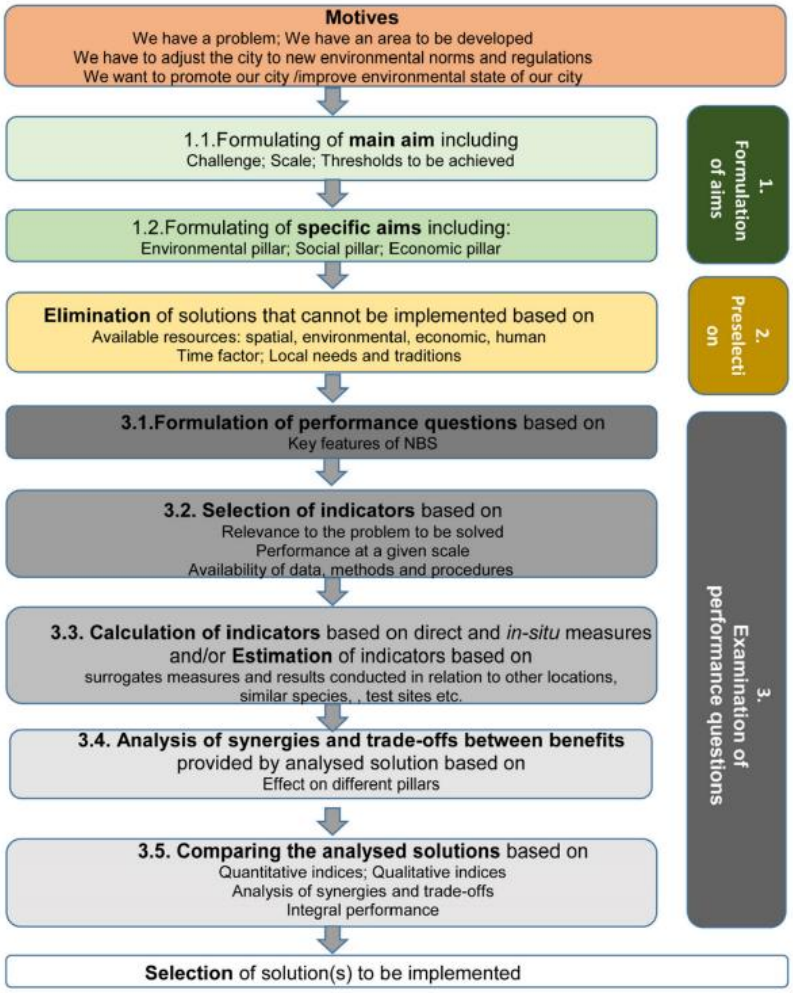


Source: Calliari et al., 2019

8.7. New evaluation framework for NbS projects based on the application of performance questions and indicators approach

Sowińska-Świerkosz and García (2021) introduced a new framework for evaluating NbS projects before implementation, highlighting their effectiveness and efficiency compared with traditional approaches (Figure 12). Aimed at solution selection, the framework is structured around three stages: defining project goals, filtering out unsuitable solutions, and assessing performance questions. With around 130 indicators identified for NbS evaluation, this work enriches the discussion on NbS conceptualisation and practical application, offering multi-perspective standards and guidelines to navigate the complexities of selecting NbS projects and understanding the trade-offs and synergies involved.

Figure 12: Overview of the evaluation framework



Source: Sowińska-Świerkosz and García, 2021

Stage 1: Formulation of aims

The primary aim involves identifying the problem, determining the intervention scale, and setting target thresholds. Specific aims focus on the intervention's impact across the three core pillars of NbS (Environment, Society, and Economy).

Stage 2: Preselection of solutions

Factors influencing solution selection include the area's size and location, environmental conditions, available funding, human resources, time constraints, and local needs/traditions. Feasible solutions are preselected from a range of NbS interventions, which may include purely green approaches, integration with existing infrastructure, or hybrid solutions.

Stage 3: Evaluation of performance

This stage involves crafting performance questions to assess NbS projects, forming the basis for solution selection. One method is economic assessment, combining monetary costs and benefits.

After implementing the framework, a series of potential NbS projects would likely be chosen. If adequate funds and space are available, the optimal approach appears to be employing multiple interventions to address various dimensions concurrently.

8.8. Framework for assessing and implementing the co-benefits of NbS in urban areas

Raymond et al. (2017) formulated a comprehensive framework for evaluating the co-benefits (and costs) of NbS across socio-cultural and socio-economic systems, biodiversity, ecosystems, and climate (Figure 13). The framework consists of seven steps as follows:

Problem identification: Map out the issue across social, economic, ecological, and governance dimensions to determine effective NbS and alternative solutions

Selection and assessment: Choose NbS based on identified problems, ensuring that objectives are flexible yet specific, measurable, achievable, realistic, and time-bound

Designing implementation processes: Ensure that processes are open and transparent, promoting cross-sectoral dialogue and adaptive management in urban ecosystems

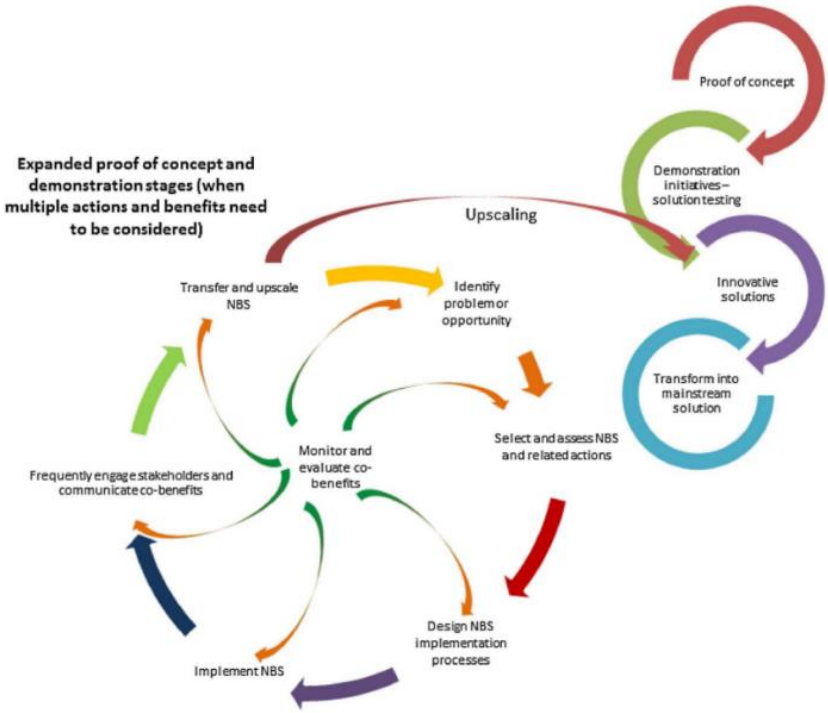
NbS implementation: Implement NbS with multidisciplinary teams, integrating green solutions with grey infrastructure as appropriate and considering all associated costs and benefits

Stakeholder engagement: Continuously communicate co-benefits to stakeholders, using both top-down and bottom-up approaches and fostering collaboration through public–private partnerships and dialogue platforms

Upscaling NbS: Increase confidence in NbS through upscaling, leveraging multi-actor partnerships for evidence-based benefits, addressing implementation challenges, and systematically integrating NbS into governance

Monitoring and evaluation: Continuously monitor the implementation, evaluating co-benefits, stakeholder perception, and responsiveness using targeted indicators for environmental performance, health, participation, and financial viability

Figure 13: Overview of the NbS co-benefits framework



8.9. Pathway for increasing NbS in Nationally Determined Contributions (NDCs)

The UNDP Report assists governments in identifying NbS for cost-effective climate change mitigation and adaptation, offering multiple co-benefits (Figure 14). It supports countries in enhancing the resilience of their NDCs, particularly when faced with challenges such as limited data and resources for NDC implementation.

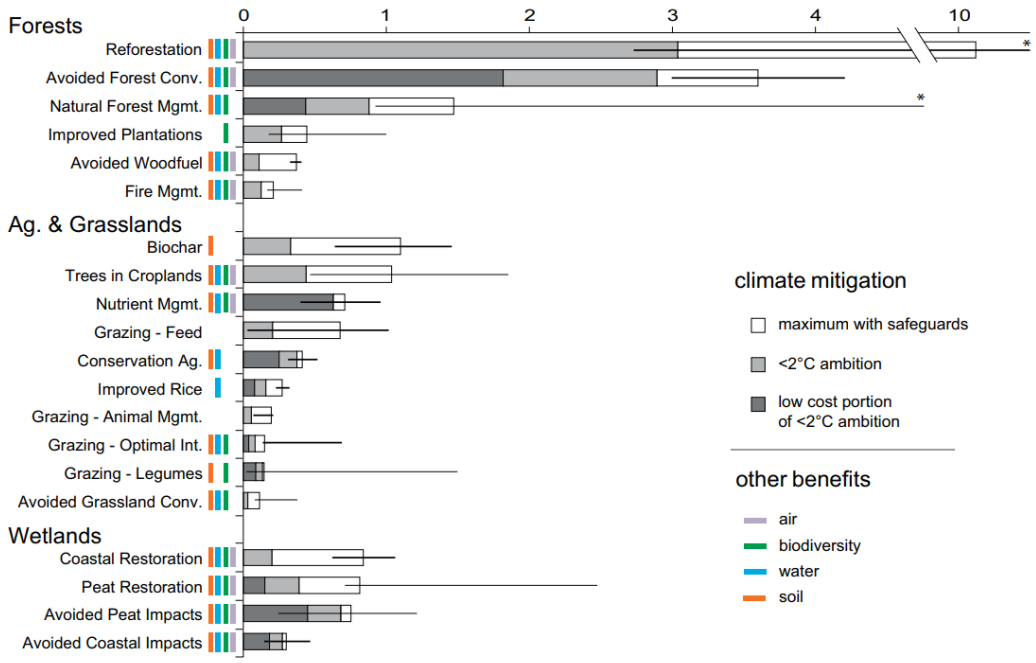
The report outlines seven steps for governments:

- Understanding the national context of GHG accounting
- Reviewing existing nature-based actions within national legal and institutional frameworks, including policies, laws, and regulations
- Assessing nature-based actions in the current NDCs
- Quickly analysing the climate change mitigation and adaptation potential of existing nature-based actions
- Aligning NbS pathways with measurable actions and identifying opportunities to strengthen NDCs using spatial data
- Integrating measurable nature-based actions into the NDCs
- Enhancing or establishing enabling conditions to support NbS integration into the NDCs

This pathway provides guidance for national governments, in both developed and developing countries, along with relevant ministries and sub-national authorities, to align their efforts with national goals. It highlights the need for coordinated action to incorporate NbS into the NDCs and suggests opportunities for collaboration with

companies, NGOs, indigenous peoples, and local communities to improve nature-based actions.

Figure 14: Climate change mitigation potential of 20 natural climate pathways



Source: UNDP, 2019

The frameworks represent a spectrum of scope and applications. For instance, the IUCN Global Standard offers a user-friendly guideline applicable across various settings and scales, from urban areas to protected landscapes, whereas the World Bank Guideline and REGREEN focus more specifically on urban settings and the financial valuation
of NbS.

Each framework presents criteria and indicators with varying degrees of flexibility for designing and evaluating NbS based on their outlined scope. Some adopt continuous monitoring and evaluation, promoting iterative learning and adjustment, whereas others offer a tiered assessment strategy through various project phases, integrating NbS into urban planning. Economic valuation and cost–benefit analyses are also growing domains of interest in NbS, with some frameworks considering economic viability alongside social and environmental considerations.

As we delve into the specifics of these frameworks and their applications in various contexts, it becomes evident that the relevance of NbS in today's world cannot be overstated. The nine frameworks prioritise enhancing ecological, social, and economic sustainability, aiming to improve resilience against climate change and other environmental threats. They underscore the importance of involving diverse stakeholders, including local communities, governments, and private sectors, ensuring that NbS are inclusive and equitable. Additionally, there is a strong emphasis on embedding NbS into existing policy frameworks and aligning them with national and international environmental goals to ensure long-term viability and scalability.

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CENTER FOR STUDY OF SCIENCE, TECHNOLOGY AND POLICY

Bengaluru
No.18, 10th Cross, Mayura Street, Papanna Layout,
Nagashettyhalli (RMV II Stage), Bengaluru-560094
Karnataka, India

Noida
1st Floor, Tower-A, Smartworks Corporate Park, Sector-125,
Noida-201303, Uttar Pradesh, India

www.cstep.in | +91-8066902500 | cpe@cstep.in | @cstep_India