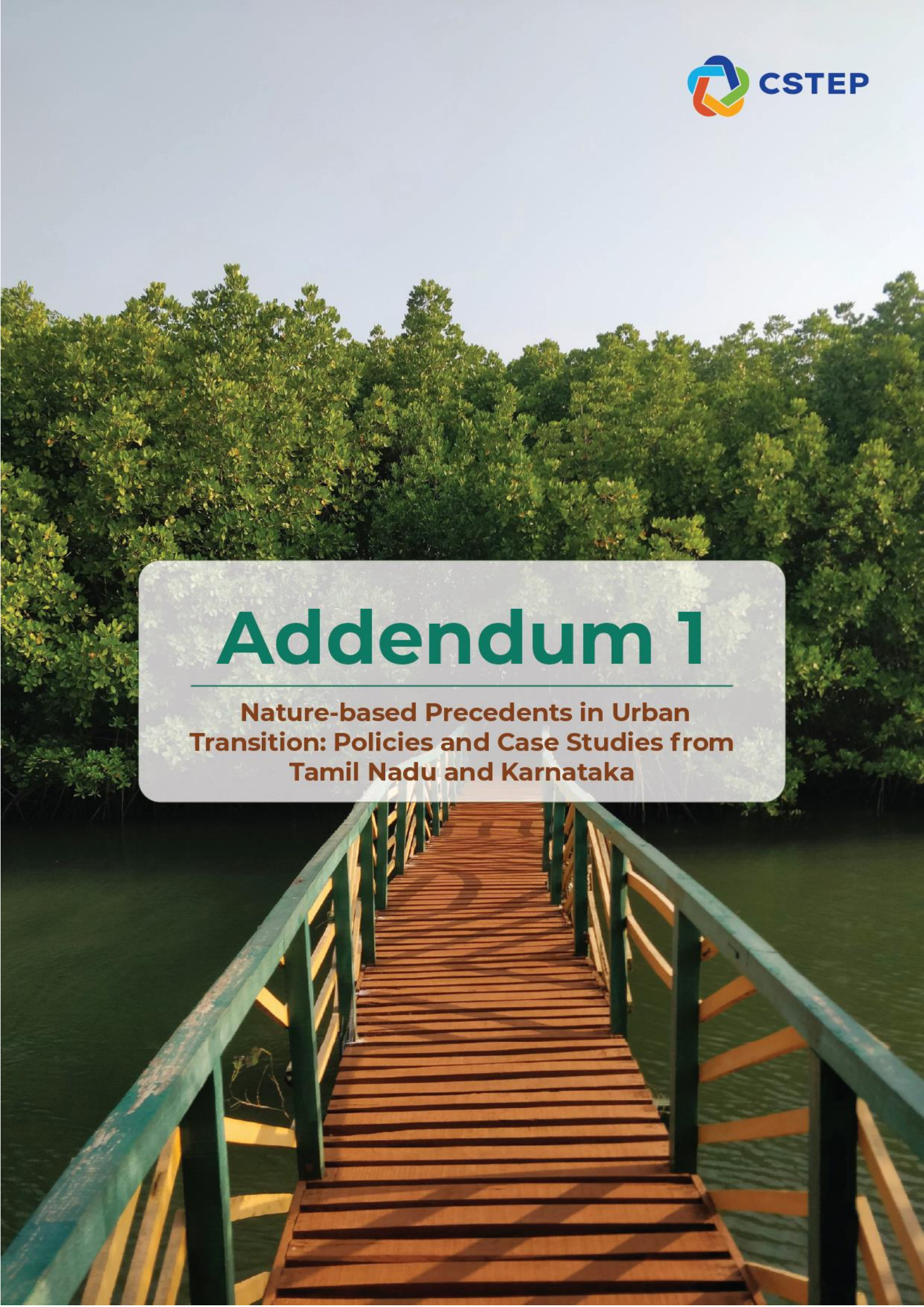

Addendum 1

Nature-based Precedents in Urban Transition: Policies and Case Studies from Tamil Nadu and Karnataka

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Nature-based Precedents in Urban Transition: Policies and Case Studies from Tamil Nadu and Karnataka

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April 2025

Edited and Designed by CSTEP

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1. Setting the Context

NbS in the cities of Chennai and Mangaluru are deeply embedded not only within the ecological systems shaped by its geography but also within the legislative, judicial, and executive boundaries of their states, Tamil Nadu and Karnataka, respectively. While the national policy landscape has been covered in CSTEP's compendium on 'Nature-Based Solutions for Climate Adaptation in Coastal Urban Areas' (2024), this section offers a closer examination of the states' initiatives, legislations, and policies to integrate nature with their urbanising regions.

1.1. Tamil Nadu

1.1.1. NbS legislations and policies

Tamil Nadu's environmental and conservation efforts are highlighted through a comprehensive suite of policies, acts, and initiatives dedicated to preserving the state's natural heritage and fostering sustainable development (Table 1). Significant emphasis is placed on bolstering resilience and readiness to mitigate and adapt to the impacts of climate change. By focusing on these critical areas, the policies establish a strong foundation for sustainable development and environmental stewardship, demonstrating the state's efforts to address the challenges presented by climate change.

Table 1. Legislations and policies promoting NbS implementation in Tamil Nadu

#	Name	Enabling agency	Provision	Relevance
1	Forest (Conservation) Act, 1980	Tamil Nadu Forest Department	Establishes the framework for forest conservation, management, and regulation	Provides foundational legal support for forest conservation
2	Tamil Nadu Coastal Restoration Mission, 2024	Government of Tamil Nadu, supported by the World Bank	A 5-year mission aimed at protecting and enhancing the resilience of coastal ecosystems Includes initiatives for biodiversity, livelihoods, and pollution abatement	Protects Tamil Nadu's long coastline, improves coastal biodiversity, protects livelihoods, and ensures sustainable utilisation of coastal resources
3	Tamil Nadu Protection of Tanks and Eviction of Encroachment Act (2007)	Commissionerate of Land Administration and Department of Revenue and Disaster Management	Focuses on protecting water bodies from encroachment, ensuring the conservation and management of tanks and ponds	Ensures conservation and management of tanks and ponds
4	Tamil Nadu Marine Fishing Regulation (Amendment) Act (2016)	Department of Animal Husbandry, Dairying and Fisheries	Amends existing laws to better regulate fishing practices, aiming to protect marine life and ensure sustainable fishing	Protects marine life and ensures sustainable fishing practices

#	Name	Enabling agency	Provision	Relevance
5	Tamil Nadu Ecotourism Policy (2017)	Tamil Nadu Department of Environment and Forests (State Ecotourism Board)	Promotes low-impact trips to natural areas that enhance visitor experiences and provide local livelihood opportunities	Enhances visitor experiences and provides livelihood opportunities to local communities.
6	Tamil Nadu Biological Diversity Rules (2017)	Tamil Nadu Department of Environment and Forests	Establishes guidelines for conserving biodiversity and its sustainable use as well as equitable benefit sharing from genetic resources	Conserves biological diversity and sustainable use of its components
7	Tamil Nadu Integrated Coastal Zone Management Plan (2018)	Ministry of Environment, Forests and Climate Change	Comprehensive approach to manage shorelines, conserve biodiversity, control coastal pollution, enhance fisheries, improve livelihoods, develop ecotourism, and manage disaster risks.	Supports ecosystem preservation, sustainable resource use, and integrated environmental resilience
8	Green Tamil Nadu Mission (2021-2022)	Office of the Green Tamil Nadu Mission	Aimed at increasing the state's forest and tree cover from 23.8% to 33% by 2030-2031 to enhance biodiversity and ecological balance.	Enhances biodiversity and ecological balance
9	Palmyrah Development Mission (2022-23)	Department Agriculture and Farmers Welfare	Dedicated to promoting the state tree, Palmyrah, by distributing seed nuts, setting up processing units, and supplying climbing equipment	Promotes value addition and provides equipment for value addition and tree climbing
10	Blue Flag Beach Certification Programme (2021)	Ministry of Environment, Forests and Climate Change	Launched to enhance beach cleanliness, safety, and sustainability, while conserving coastal ecosystems	Enhances coastal ecosystem health and promotes sustainable beach management practice
11	Tamil Nadu Wetlands Mission (2022)	Tamil Nadu Department of Environment Climate Change and Forests	Aims to protect and restore wetlands, map 100 sites over five years, enhancing ecological balance and supporting livelihoods	Restores ecological balance and focuses on livelihood options through the protection of wetlands

1.1.2. Chennai Metropolitan Area

Chennai, situated on the highly exposed southeast coast of India, in the state of Tamil Nadu, faces unique challenges spurred by rapid urban expansion and its geographical positioning. From 1997 to 2017, the city's built-up area expanded to cover about 88% of the total surface area (Murali & Madhiyazhagan, 2018). This unchecked growth has significantly altered the natural landscape, particularly impacting the city's water bodies. Over half of Chennai's 19 major water bodies have been encroached upon, drastically reducing their water retention capacity and limiting the city's ability to mitigate the impacts of extreme weather events (Sivakumar & Perumal, 2023). Industrial sectors along the coast are particularly vulnerable, facing heightened risks of asset damage and income loss due to prolonged inundation. The urban poor, residing in substandard housing within flood-prone zones such as canals and riverbeds, are disproportionately affected owing to their limited access to essential services and affordable housing (Joerin et al., 2014). The 2015 floods, which submerged over a third of the city, underscored the severe consequences of such vulnerabilities, causing significant loss of life and damage to livelihoods, particularly among vulnerable populations alongside water bodies. Despite recent lessons on building flood resilience, Chennai lags behind in urban infrastructure development and resilience planning. Its sewerage system and stormwater drainage fall significantly below the recommended standards set by the Ministry of Urban Affairs, Government of India (Govindarajulu, 2020). With climate change expected to increase rainfall intensity by 11%–16% by 2050, identifying and addressing flood risks in vulnerable hotspots become crucial for municipal planners aiming to enhance flood mitigation and adapt to future climate scenarios (ADB, 2021).

1.2. Karnataka

1.2.1. NbS legislation and policies

Karnataka's approach to environmental conservation and sustainable development through NbS focuses on protecting existing natural resources while fostering socio-economic growth. Over the years, a series of progressive policies and programmes have been implemented, each addressing different aspects of environmental sustainability and community well-being (Table 2).

Table 2 Legislations and policies promoting NbS implementation in Karnataka

#	Name	Enabling Agency	Provision	Relevance
1	Karnataka Forest Act, 1963	Karnataka Forest Department	Designates reserved forests, district forests, village forests, protected forests, and other lands under the control of the Forest Department.	Bolsters forest conservation efforts
2	Karnataka Biological Diversity Rules, 2005	State Biodiversity Board	Establishes guidelines for biodiversity preservation, emphasising sustainable use and conservation	Preserves the state's biodiversity

#	Name	Enabling Agency	Provision	Relevance
3	Karnataka Sustainable Forest Management and Biodiversity Conservation (KSFMBC), 2005	Karnataka Forest Department	Aims to rehabilitate forests, uplift local communities, and promote ecological restoration	Enhances livelihoods and environmental health
4	Daivivana/Devara kadu Scheme, 2011-12	Karnataka Forest Department	Cultivates forests near temples, creating spaces like Rashivana, Nakshatravana, and Navagrhavana	Conserves local biodiversity
5	Sustainable Coastal Protection and Management Investment Programme (SCIPM), 2012	Karnataka Public Works, Ports and Inland Water Transport Department	Safeguards the coastline from erosion and boosts income of coastal communities	Shifts to sustainable and eco-friendly coastal protection methods
6	Karnataka Urban Development and Coastal Environment Management Plan (KUDCEMP-EAP), 2015	Urban Development Department, Government of Karnataka	Enhances urban development in coastal regions, improving quality of life for the urban poor	Integrates services in water, sanitation, waste management, and infrastructure
7	Karnataka State Tree Cover Enhancement Policy, 2016	Karnataka Forest Department	Sets a target to increase tree cover to 33% of the state	Contributes to green infrastructure and ecological balance
8	Karnataka Tourism Policy 2020–26	Karnataka State Tourism Development Corporation Limited	Advocates for eco-tourism, encouraging conservation awareness and sustainability	Promotes the natural and cultural heritage of the region
9	Karnataka Coastal Regulation Zone Notification, 2019	Ministry of Environment, Forest and Climate Change, Government of India	Aims to develop 92 beaches as major tourist spots under the Coastal Zone Management Plan (CZMP)	Elevates the state's profile in global tourism and fosters socio-economic growth through sustainable practices
10	Sahasra Sarovara Scheme, 2024	Ministry of Rural Development	Aims to rejuvenate 1,000 lakes with an investment of INR 75 crore, focusing on water source conservation	Demonstrates commitment to environmental stewardship and sustainable development

1.2.2. Mangaluru

Situated along India's southwestern coast, Mangaluru has seen a rapid population growth, from 0.49 million in 1971 to over 1.5 million today, with projections of 2.2 million by 2030 (Census of India). Once a maritime hub, the city has evolved into a centre for trade, commerce, and information technology. Its geographic footprint expanded from 135 sq km to 280 sq km by 2011, with built-up areas increasing by 18% between 1997 and 2017, now covering 85% of the city's surface (Dhanaraj & Angadi, 2022; Dhanaraj & Jain, 2023).

This rapid urbanisation has brought challenges, including encroachment on flood-prone zones, reducing green cover, open spaces, and water bodies. Mangaluru's sewerage and stormwater systems fall below national standards, and affordable housing shortages push the urban poor into high-risk areas such as riverbanks (MoHUA, 2020). At an elevation of just 22 m, the city is vulnerable to floods and landslides, incurring financial losses of INR 51.37 crore in 2018 and INR 35.24 crore in 2019 (GoK, 2019).

Key documents including the Dakshina Kannada District Disaster Management Plan (2019) and the Mangaluru Master Plan (2018) highlight the need for resilience planning. Agriculture and water bodies make up a significant portion of the local planning area, while urban growth follows north–south patterns along the coastline (Deeksha et al., 2023). Mangaluru experiences significant rainfall from June to October, peaking in August. Extreme rainfall variations have led to inundation and flooding, particularly in waterlogged areas such as Kottara Chowki, Balmatta, Kankanady, Hampankatta, and Bejai (Nagaraj et al., 2023). The city aligns with national wetland recovery programmes emphasising buffer and no-development zones for biodiversity and environmental protection (MOSPI, 2022). Aligned with the national focus on wetland recovery, Mangaluru’s efforts for resilience planning and urban infrastructure development are critical for managing future climate impacts and enhancing the city’s liveability and sustainability.

2. Case Studies

2.1. Tamil Nadu

Tamil Nadu is leading the way in climate action, with a strong focus on NbS to address coastal resilience and environmental sustainability. Key initiatives include the Rehabilitation of Coastal Habitats Study, which promotes eco-friendly approaches to adapt coastal ecosystems to climate change, and the Green Space Development Initiative, which offsets event-related carbon emissions through native tree planting (GoT, 2024). The following section explores successful NbS case studies, showcasing their impact on coastal sustainability and resilience.

2.1.1. Integrated Mangroves Fisheries Farming System (IMFFS): Sustainable coastal livelihoods and ecosystem restoration

The Integrated Mangroves Fisheries Farming System (IMFFS) was developed to restore the livelihoods of coastal communities impacted by the collapse of the shrimp aquaculture industry in the 1990s, leaving large areas of saline land abandoned (Mangroves for the Future, 2019; The Hindu Bureau, 2021). This NbS integrates mangroves with aquaculture using natural tidal flows to maintain water quality and provide food for shrimp, crabs, and fish, creating a sustainable and low-energy farming system that enhances both ecological resilience and economic opportunities.

Box 1. Case Study of Integrated Mangrove Fishery Farming System, Cuddalore

Location	Vellar-Pichavaram-Coleroon estuarine, Cuddalore District
Enforcement Agencies	International Union for Conservation of Nature (IUCN), M S Swaminathan Research Foundation (MSSRF), and Mangroves for the Future (MFF) initiative with Tamil Nadu Fisheries and Forest Departments
Timeline	2007 onwards
Objective	To develop and demonstrate a community-based brackish water farming system that integrates mangroves and aquaculture for sustainable livelihood security and ecological conservation in coastal areas
Ecosystem type	Mangroves, tidal water systems, and marsh grasses
Climate change impacts addressed	• Addresses sea-level rise and salinization of coastal lands due to climate change by transforming degraded lands into productive aquaculture systems • Enhancing carbon sequestration through mangroves and reducing the need for synthetic feeds and energy, thus lowering the carbon footprint
Socio-economic outcomes	• Improved income stability for coastal families, with earnings between USD 224 and 676 within 4 months of setting up the IMFFS ponds • Increased financial security, reduction in debt, better access to food, improved housing, and children's education opportunities

Project cost	USD 0.03 million by National Bank for Agriculture and Rural Development (NABARD)
Monitoring and evaluation	IUCN and MSSRF monitor biodiversity enhancement, income generation, and community well-being. Growth of mangroves, fish and crab production, income generated by families, and overall community resilience are documented by the local communities.
Trade-offs/Limitations	• Initial setup requires technical support and land donation • Replication at scale faces challenges in terms of governance, resource allocation, and initial investment

2.1.2. Artificial Coral Reefs, Tamil Nadu: Marine biodiversity enhancement

Tamil Nadu is making significant strides in reviving marine ecosystems and supporting coastal communities through the deployment of artificial reefs (TNIE, 2024). These reefs, constructed from materials such as concrete and steel, serve as a habitat for marine life, helping restore biodiversity and enhance fish stocks. Some studies demonstrate increased fish catch (50%–150%), reduced search and hazard time for fishermen, diversified catch (R et al., 2010), reduced reliance on alternative income sources such as liquor brewing, and enhanced community solidarity through collective participation in reef installation (Kasim et al., 2015; Ramesh et al., 2020). Coastal areas including the Gulf of Mannar and Rameswaram are key beneficiaries of these efforts, where artificial reefs are being strategically placed to support sustainable fishing practices and protect fragile coastal ecosystems (UNDP, 2024).

Box 2. Case Study of Artificial Coral Reefs along the Tamil Nadu Coast

Location	30 sites in the Gulf of Mannar, Rameswaram, Chennai, Kancheepuram, Tiruvallur, and Chengalpattu
Enforcement Agencies	Government of Tamil Nadu, Department of Fisheries, United Nations Development Programme (UNDP), Global Environment Facility (GEF), The Energy and Resource Institute (TERI), Central Marine Fisheries Research Institute (CMFRI), and Participatory Learning Action Network and Training (PLANT) Trust
Timeline	2006 onwards
Objective	To revive fishing grounds, reduce coastal erosion, and create habitats for marine life to regenerate
Ecosystem type	Marine ecosystems: coral reefs, seagrass beds, mangroves, and shorelines
Climate change impacts addressed	• Coastal erosion, habitat loss, declining fish stocks, and damage to natural coral reefs due to climate change and overfishing • Artificial reefs act as breakwaters, reducing wave energy and protecting coastlines from erosion
Socio-economic outcomes	• Increased fish yields, reduced fuel consumption for fishing trips, and improved livelihoods • Creation of eco-tourism opportunities (e.g. scuba diving and snorkelling), contributing to additional income streams for coastal communities
Project cost	USD 0.04 million for the Rameswaram project, USD 2.14 million for the Gaja Rehabilitation project, and USD 1.2 million for the oil spill damage

Monitoring and evaluation	Reefs support marine life within months, with full maturity in 2 years. Regular assessments are conducted to monitor biodiversity growth and socio-economic impacts on fishing communities.
Trade-offs/Limitations	Consistent monitoring required to prevent damage from trawler boats, and the time taken for artificial reefs to fully mature and stabilise

2.1.3. Mangrove Restoration, Palk Bay: Enhancing fisheries through community-led mangrove conservation.

The Mangrove Restoration for Sustainable Fishery project in Palk Bay, Tamil Nadu, is a community-driven initiative aimed at restoring degraded mangrove ecosystems to support local fisheries and enhance coastal resilience (Lovelock et al., 2022; SER, 2010; Thampi et al., 2023). It addresses the environmental and livelihood challenges faced by fishing communities in the aftermath of the 2004 tsunami and from decades of mangrove degradation.

Box 3. Case Study of Mangrove Restoration, Palk Bay

Location	Keezhathottam and Velivayal villages, Palk Bay, Tamil Nadu
Enforcement Agency	OMCAR Foundation (Organization for Marine Conservation, Awareness, and Research) and DEEPWAVE (Germany), Government of Tamil Nadu
Timeline	2005-2010
Objective	To restore mangroves through community-based ecological restoration utilising scientific knowledge alongside socio-economic development
Ecosystem type	Coastal/Marine ecosystems
Climate change impacts addressed	• Coastal erosion • Habitat degradation • Biodiversity loss • Protection against future storm surges and extreme weather events
Socio-economic outcomes	• Increased awareness among local communities and employment opportunities through the recruitment of local villagers for restoration activities such as seed collection, plantation, canal cleaning, and nursery maintenance • Empowerment through women's self-help groups and skill development initiatives
Monitoring and evaluation	Regular assessments of seedling survival rates and growth. Continuous monitoring of plant height, leaf count, and health was performed to assess the ecological outcomes.
Trade-offs/Limitations	Exposure to cattle grazing, resulting in stunted growth in some areas. Algal blooms caused by heavy monsoon flooding impeded seedling survival.

2.1.4. Island Reef Restoration, Tamil Nadu: Efforts to rebuild coral reef ecosystems to support marine biodiversity and local livelihoods

The Island Reef Restoration initiative under the Tamil Nadu Coastal Restoration Mission aims to rehabilitate sinking coral reef islands in the Gulf of Mannar (Kumar, 2024). Using innovative artificial reef modules, the efforts have successfully revived Vaan Island and are now focused on restoring Kariyachalli Island, enhancing biodiversity, and supporting the livelihoods of local fishing communities.

Box 4. Case Study of Island Reef Restoration, Tamil Nadu

Location	Gulf of Mannar, Vaan Island, and Kariyachalli Island located between Rameswaram and Thoothukudi, Tamil Nadu
Enforcement Agency	Government of Tamil Nadu, Wildlife Warden, Gulf of Mannar Marine National Park; Suganthi Devadason Marine Research Institute (SDMRI); Indian Institute of Technology Madras (IIT-M)
Timeline	Vaan Island Restoration: 2015–2019 Kariyachalli Island Restoration Start: 2024–2025
Objective	To restore and protect the sinking islands in the Gulf of Mannar using artificial reef modules, enhance biodiversity, stabilise the islands, and support coastal communities reliant on fisheries
Ecosystem type	Coastal/Marine ecosystems: Coral reef islands, mangrove ecosystems
Climate change impacts addressed	• Coastal erosion • Habitat degradation • Biodiversity loss
Socio-economic outcomes	• Increased awareness among local communities and employment opportunities through the recruitment of local villagers for restoration activities such as seed collection, plantation, canal cleaning, and nursery maintenance. • Empowerment through women's self-help groups and skill development initiatives.
Project cost	USD 6 million
Monitoring and evaluation	• Continuous monitoring of the artificial reef modules to assess their impact on biodiversity, fish production, and coastal stabilisation. Scuba divers and bathymetric studies are used to track changes in sedimentation and underwater ecology. • Observations include coral recruitment and changes in fish populations.
Trade-offs/Limitations	• The long-term sustainability of artificial reef modules is still under assessment, particularly as sedimentation continues to change the bathymetry around the islands. • Fishing restrictions due to the island being part of the Marine Park may limit local access to resources but protect long-term ecosystem health.

The case studies from Tamil Nadu showcase how NbS, such as mangrove restoration and artificial reefs, effectively address both environmental degradation and socio-

economic challenges. These insights are valuable for expanding NbS to other vulnerable regions, including urban areas like Chennai, where such solutions can tackle issues such as flooding, heatwaves, and coastal erosion. The following urban case studies will examine ongoing efforts in Chennai to enhance resilience and improve quality of life in rapidly growing cities.

2.2. Chennai

Chennai is increasingly incorporating NbS into its urban planning to address critical environmental challenges such as flooding and water management. The city's stormwater drainage system has been widely criticised for poor execution and its failure to tackle root issues such as reduced natural water absorption caused by extensive concretisation (Ganesh, 2022; Satish & Satish, 2021). These systems focus on draining excess water rather than recharging groundwater, resulting in frequent waterlogging and the loss of valuable rainwater to the sea. In the following case studies, we explore how Chennai is leveraging NbS to overcome these challenges.

2.2.1. City of 1000 tanks

The City of 1,000 Tanks project represents a comprehensive effort to transform Chennai's urban water management system through innovative, decentralised NbS. By reviving and repurposing traditional water systems including temple tanks, the project integrates sustainable strategies to enhance Chennai's climate resilience (Chakrapani, 2023; Ooze Architects, 2023).

Box 5. Case Study of the City of 1000 tanks, Mylapore, Chennai

Location	T Nagar and Mylapore areas, Chennai
Enforcement Agency	Greater Chennai Corporation (GCC), Ooze Architects & Urbanists, Madras Terrace Architectural Works, Care Earth Trust, Biomatrix Water, IIT Madras, IRCDUC (Information and Resource Centre for the Deprived Urban Communities), Uravugal Social Welfare Trust, Goethe-Institut/Max Mueller Bhavan, Paperman Foundation, IHE Delft Institute for Water Education
Timeline	2018 onwards
Objective	Develop a 'Water Balance Model' for Chennai, which involves collecting rainwater, treating wastewater and runoff pollution using decentralised NbS, and recharging the underground aquifers
Ecosystem type	Urban blue-green infrastructure including traditional temple tanks
Climate change impacts addressed	• Drought prevention by increasing groundwater reserves • Flood mitigation by creating a flood-proof system through interconnected tanks • Saline intrusion prevention by recharging the aquifers to prevent sea level rise impacts
Socio-economic outcomes	• Improved water supply capabilities for the city • Reduced sewage pollution and improved water quality • Enhanced resilience to climate-induced water challenges
Monitoring and evaluation	• Sensors track water quality, flow rates, and groundwater recharge with real-time data collection.

	• Groundwater levels and water quality are regularly monitored, along with biodiversity and ecosystem health. • Feedback from local communities and public health improvements, such as reduced waterborne diseases, are tracked.
Trade-offs/Limitations	• High initial investment required for infrastructure development. • Ongoing maintenance and management of the systems are crucial for long-term success. • Scaling the project to cover the entire city may present logistical and financial challenges.

2.2.2. Eco-Restoration of Adyar Creek

The Eco-Restoration of Adyar Creek project is a pioneering initiative in Chennai for its role in reintroducing nature-based education and community engagement into urban spaces (Baraasu, 2024; Chennai River Restoration Trust, 2019a). By transforming a previously neglected and polluted area into an eco-park, the project creates opportunities for both ecological research and public involvement, fostering a deeper connection between the city's residents and their natural surroundings.

Box 6. Case Study of Eco-Restoration of Adyar Creek, Chennai

Location	Adyar Creek and Estuary, Chennai
Enforcement Agency	Chennai Rivers Restoration Trust (CRRT) and Tamil Nadu Urban Infrastructure Financial Services Ltd (TNUIFSL)
Timeline	2008 onwards
Objective	To restore the degraded Adyar Creek and Estuary ecosystem, improve water quality, enhance biodiversity, and create an eco-park for public awareness and environmental education
Ecosystem type	Estuarine ecosystem, including tidal wetlands, mangroves, and mudflats
Climate change impacts addressed	• Improved flood management by increasing water retention and carrying capacity • Tidal exchange enhancement to prevent flooding and support biodiversity • Shoreline stabilisation to combat erosion
Socio-economic outcomes	• Enhanced public awareness and education on environmental issues • Increased biodiversity, leading to better ecosystem services • Creation of eco-tourism opportunities and improved recreational spaces
Monitoring and evaluation	• Continuous monitoring of water quality, biodiversity, and tidal exchange • Regular surveys of flora and fauna to assess restoration progress • Public engagement and education on environmental conservation
Trade-offs/Limitations	• High initial costs for clean-up and restoration

	• Ongoing maintenance required to prevent pollution and manage tidal exchange • Potential challenges in keeping the estuary open to tidal flow due to sandbar formation

2.2.3. Integrated Cooum River Eco-Restoration Plan

The Cooum River Eco-Restoration Project is a comprehensive initiative aimed at reviving one of Chennai's most degraded urban rivers. Historically, the Cooum River was a lifeline for the city, supporting both agriculture and transportation (Chennai River Restoration Trust, 2019b). Through this restoration effort, the project aims to reconnect local communities with the river, transforming it from an open sewer to a thriving ecological corridor.

Box 7. Case Study of the Integrated Cooum River Eco-Restoration Plan, Chennai

Location	Cooum River, from Paruthipattu to the mouth of the Bay of Bengal, Chennai
Enforcement Agency	Chennai Rivers Restoration Trust (CRRT), in collaboration with various departments such as Public Works Department (PWD), Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB), and Tamil Nadu Slum Clearance Board (TNSCB)
Timeline	2014 onwards
Objective	To restore the Cooum River by reducing pollution, improving water quality, maintaining ecological flows, and enhancing its flood-carrying capacity while developing the riverfront and exploring future uses
Ecosystem type	Urban riverine ecosystem with surrounding wetlands, floodplains, and mangroves
Climate change impacts addressed	• Flood mitigation by improving the river's flood-carrying capacity • Restoration of tidal exchange at the river mouth to prevent flooding and ecological degradation • Enhancement of ecological flows to maintain seasonal water availability
Socio-economic outcomes	• Improved sanitation infrastructure and waste management along the river • Resettlement and rehabilitation of informal settlements along the riverbank • Development of recreational spaces, cycle tracks, parks, and walkways for community use
Project cost	USD 230.78 million for resettlement
Monitoring and evaluation	Continuous monitoring of water quality, biodiversity, and solid waste management along the river; feedback on social impacts from resettled communities
Trade-offs/Limitations	• High resettlement costs and challenges in relocating slum dwellers • Ongoing maintenance and management of solid waste removal and sewage infrastructure • Potential ecological disruption if interventions are not carefully managed

2.2.4. Chennai Urban Farming Initiative

The Chennai Urban Farming Initiative (CUFI) is a pioneering effort to transform unused urban spaces and rooftops into thriving vegetable gardens, addressing the twin challenges of food insecurity and urban heat (Mohan, 2022; Resilient Cities Network, 2022). By empowering local communities, especially women and youth, CUFI promotes sustainable food production, greening the city, and building resilience against climate change impacts.

Box 8. Case Study of the Chennai Urban Farming Initiative

Location	Various locations in Chennai
Enforcement Agency	Chennai Resilience Centre, Greater Chennai Corporation, Tamil Nadu Department of Horticulture and Plantation Crops, Tamil Nadu Corporation for Development of Women, Tamil Nadu Skills Development Corporation, and Care Earth Trust
Timeline	2020 onwards
Objective	To create a sustainable urban farming system across Chennai, improving food security, generating livelihoods, and promoting climate resilience through rooftop and community vegetable gardens
Ecosystem type	Urban green spaces, including rooftop gardens and mobile vegetable gardens
Climate change impacts addressed	• Reducing urban heat through green rooftop gardens • Mitigating water runoff and improving rainwater harvesting • Promoting food security in the face of climate change-related disasters
Socio-economic outcomes	• Improved access to fresh, nutritious food for low-income communities • Creation of green livelihood opportunities, particularly for women and youth • Enhanced community resilience and self-reliance through urban farming
Monitoring and evaluation	Regular monitoring through surveys, focus group discussions, and temperature sensors to assess food production, heat mitigation, and the social impact on vulnerable communities
Trade-offs/Limitations	• Initial resistance from some communities regarding garden maintenance • Dependence on external funding and grants for scalability • Ongoing challenges in motivating long-term engagement from participants and ensuring project sustainability

2.2.5. Integrated Urban Flood Management for the Chennai–Kosasthalaiyar Basin Project

The Integrated Urban Flood Management project in the Chennai-Kosasthalaiyar Basin combines traditional infrastructure with NbS to address flood risks intensified by urbanisation and climate change (ADB, 2021). By upgrading stormwater systems, enhancing water bodies, and involving local communities, the project aims to boost

flood resilience and create a more sustainable, climate-adaptive Chennai (Jameson & Baud, 2016; Nithila Devi et al., 2020).

Box 9. Case Study of the Integrated Urban Flood Management for the Chennai–Kosasthalaiyar Basin Project

Location	Chennai-Kosasthalaiyar River Basin, Chennai
Enforcement Agency	Greater Chennai Corporation (GCC), Public Works Department (PWD), funded by Asian Development Bank (ADB), Municipal Administration and Water Supply Department, Government of Tamil Nadu
Timeline	2022 onwards
Objective	• To enhance flood resilience in Chennai through infrastructure improvements, community engagement, and sustainable urban planning practices • Building 588 km of new stormwater drains and rehabilitating 175 km of existing drains • Enhancing 11 km of water channels to improve capacity in areas like Ambattur, Kadappakkam, and Korattur • Upgrading an existing station and constructing a new one to manage excess rainwater • Reducing flood risk in Kolathur and Thiru. Vi. Ka Nagar, and improving the Madhavaram tank's surplus canal for better flood routing • Enhancing flood preparedness through community training and sustainable operation measures for long-term drainage management
Ecosystem type	Urban, Coastal
Climate change impacts addressed	• Urban flooding caused by storm surges and heavy rainfall • Increased flood preparedness and resilience to climate-related disasters
Socio-economic outcomes	• Reduced flood risks and improved quality of life • Better public health through improved water, sanitation, and hygiene (WASH) facilities • Economic stability by safeguarding infrastructure from flood disruptions
Project cost	USD 32.70 million
Monitoring and evaluation	• Continuous assessment of stormwater drainage efficiency • Regular checks on the performance of pumping stations and flood mitigation systems • Ongoing community training programmes to ensure preparedness
Trade-offs/Limitations	• Potential displacement of urban communities and disruption during construction • High initial investment and long-term maintenance of new infrastructure • Challenges in integrating natural and engineered flood solutions

2.2.6. Eyes on the Canal Project, Chennai: Community engagement in canal restoration

The ‘Eyes on the Canal’ project aims to restore the Buckingham Canal in Chennai by integrating green infrastructure and engaging the community (GIZ, 2019). By involving local residents in sustainable practices, the project enhances biodiversity, supports climate resilience, and promotes a more inclusive and vibrant urban environment.

Box 10. Case Study of the Eyes on the Canal Project, Chennai

Location	Buckingham Canal, Adyar, Chennai
Enforcement Agency	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Urban Design Collective, Greater Chennai Corporation (GCC), Tamil Nadu Biodiversity Conservation and Greening Project, Chennai River Restoration Trust, Inland Waterways Authority of India, Water Resources Department
Timeline	2018–2019
Objective	To make Buckingham Canal a liveable and vibrant space for residents by integrating participatory planning to create a sustainable urban environment capable of handling climate-related challenges
Ecosystem type	Urban, Riverine ecosystem
Climate change impacts addressed	Improved flood resilience by increasing the canal's capacity to manage monsoonal waters and storm surges
Socio-economic outcomes	• Encouraging local involvement in urban environmental management, fostering a sense of ownership and stewardship
Monitoring and evaluation	Tracked through stakeholder engagement and environmental improvements
Trade-offs/Limitations	• Pollution and encroachment along the canal reduce its capacity, complicating restoration efforts • Revitalisation risks increasing property values, potentially displacing lower-income residents • Previous governmental restoration efforts faced challenges due to long-standing pollution and structural issues

2.2.7. Pallikaranai Marshland Restoration, Chennai: Wetland conservation for biodiversity and water management

The Pallikaranai Marshland Restoration project is a pivotal environmental initiative aimed at revitalising one of Chennai’s most crucial natural ecosystems. This restoration effort seeks to reverse decades of environmental degradation, bringing back biodiversity, improving the wetland's role as a flood buffer, and mitigating the effects of climate change (Jayaprakash, 2019; Sivapriyan, 2024; Surya, 2016).

Box 11. Case Study of Pallikaranai Marshland Restoration, Chennai

Location	Pallikaranai Marshland, Chennai
Enforcement Agency	Tamil Nadu Forest Department, Conservation of Pallikaranai Marshland Authority, supported by NGOs like Nature Trust and Care Earth.
Timeline	2003 onwards
Objective	To restore and conserve the wetlands by addressing environmental degradation, improving biodiversity, and preventing further encroachment and pollution
Ecosystem type	Freshwater marsh ecosystem
Climate change impacts addressed	• Acts as a natural flood buffer, reducing the risk of urban flooding in Chennai • Plays a significant role in carbon sequestration, helping mitigate climate change • Supports biodiversity by providing habitat to local and migratory species
Socio-economic outcomes	• Increased awareness and involvement of local communities through bird-watching and eco-tourism • Boosts local environmental education efforts • Helps mitigate urban flood risks, reducing potential economic losses from climate-related disasters
Project Cost	USD 3 million
Monitoring and evaluation	• Regular monitoring by the Tamil Nadu Forest Department and NGOs to prevent further encroachment and pollution • Success indicators include increased sightings of migratory birds and restoration of biodiversity in the marsh
Trade-offs/Limitations	• Urbanisation pressures, including encroachments and pollution from the nearby Perungudi dump yard, pose ongoing challenges. • The restoration may lead to increased land values, which could drive further encroachment and displacement of nearby communities. • The marshland is also a source of methane emissions due to the decades-old landfill, complicating its role in carbon sequestration.

Chennai's diverse projects highlight the potential of integrating green infrastructure into urban planning to enhance climate resilience. From water management initiatives to ecological restoration efforts, the projects demonstrate how NbS can mitigate urban flooding, improve water security, and restore biodiversity. Central to their success is community engagement, which fosters public ownership and long-term sustainability. However, to scale up these efforts to mainstream NbS for climate adaptation, significant financial, logistical, and maintenance issues will have to be resolved.

2.3. Karnataka

2.3.1. Coastal Karnataka Mangrove Restoration

Mangrove restoration in Karnataka has been a community-led effort to protect coastal ecosystems from climate impacts such as flooding and erosion. In Karwar, especially, sacred groves are preserved by locals who associate them with deities, showcasing the value of integrating traditional conservation practices and involving local communities in sustainable ecosystem management (Yadav, 2021; Youdon, 2020).

Box 12. Case Study of Coastal Karnataka Mangrove Restoration

Location	Karwar and Honnavar, Uttara Kannada district
Enforcement agency	Karnataka Forest Department, National Centre for Sustainable Coastal Management (NCSCM), Karnataka State Coastal Zone Management Authority (KSCZMA), Society for Coastal Management and Research (SCMR), and Dakshina Kannada Environment Conservation Trust (DKECT)
Timeline	1990 onwards
Objective	To restore and conserve mangrove forests; protect coastal communities from climate impacts; and promote sustainable livelihoods through afforestation, conservation, and local engagement
Ecosystem type	Mangrove ecosystems
Climate change impacts addressed	• Coastal erosion prevention • Flood protection, particularly from storm surges and cyclones • Carbon sequestration
Socio-economic outcomes	• Enhanced livelihoods through sustainable fishing and mangrove-based employment opportunities • Protection of coastal communities from extreme weather events • Increased access to medicinal plants for traditional Ayurvedic treatments • Boost in eco-tourism and conservation awareness
Monitoring and evaluation	• Continuous monitoring of both mature and regenerating mangrove areas, with close collaboration between local communities and government agencies
Trade-offs/Limitations	• Potential for land conflicts due to rising land values • Challenges in maintaining long-term community involvement • Ongoing threats from industrial pollution and development pressures

2.3.2. Karnataka Coastal Resilience Programme

Karnataka's coastal regions are implementing a project to address coastal erosion by integrating infrastructure development with fishery-cum-tourism initiatives. This approach aims to strengthen local economies, create sustainable jobs, and promote long-term resilience. In collaboration with local governments and non-governmental organisations (NGOs), the project will also focus on maintaining clean beaches,

reducing pollution, and ensuring sustainable coastal management for climate adaptation (Kulkarni, 2023).

Box 13. Case Study of the Karnataka Coastal Resilience Programme

Location	Bhatkal, Tadadi, Gangolli, and Padubidri, Coastal Karnataka
Enforcement Agency	Karnataka Maritime Board (KMB), funded by Asian Development Bank (ADB)
Timeline	2024 onwards
Objective	To mitigate and adapt to the impacts of climate change on Karnataka's beaches, shorelines, and marine habitats through nature-based solutions, infrastructure development, and capacity building
Ecosystem type	Coastal ecosystem
Climate change impacts addressed	Mitigation of coastal erosion and flooding
Socio-economic outcomes	• Boost local economies and ensure long-term employment opportunities • Build local expertise and institutional capacity to manage nature-based solutions • Construction of fishery-cum-tourism berths to diversify income sources • Collaboration with local governments and NGOs to maintain clean beaches and reduce pollution
Project cost	USD 130 million

2.3.3. Udupi Wetland Conservation Initiative

The Anekere Wetland in Karnataka's Udupi district has emerged as a vital ecological hotspot, especially for avifauna. Originally a man-made pond, it has evolved into an important habitat for both resident and migratory birds. However, environmental degradation has posed significant threats to its biodiversity. Efforts are now focused on restoring the wetland's ecological balance, with local communities, NGOs, and government agencies playing a crucial role in protecting this rich habitat.

Box 14. Case Study of the Udupi Wetland Conservation Initiative

Location	Anekere Wetland, Karkala, Udupi District
Enforcement Agency	Karnataka Forest Department
Timeline	2004 onwards
Objective	To study and enhance the avifaunal diversity and restore the ecological features of the Anekere wetland
Ecosystem type	Man-made freshwater wetland
Climate change impacts addressed	• Mitigation of habitat loss • Flood control through water retention • Biodiversity conservation

Socio-economic outcomes	• Promotes eco-tourism and bird-watching activities • Enhances local water sources by recharging nearby wells • Supports biodiversity conservation efforts by sustaining resident and migratory bird species
Monitoring and evaluation	Continuous monitoring of bird populations, siltation levels, and weed infestation impact, with the need for government and public involvement to restore the wetland's original ecology
Trade-offs/Limitations	• The pond is heavily infested with invasive weed species • Siltation and pollution threaten bird habitats • Restoration requires long-term commitment and collaboration between government, NGOs, and local communities to maintain ecological balance

The case studies presented highlight the importance of integrating NbS and sustainable development into coastal management strategies in Karnataka. With the approval of the Coastal Zone Management Plan (CZMP) and its alignment with tourism and environmental policies, the state is poised to balance ecological integrity with economic growth. These insights provide a valuable foundation for extending NbS to other at-risk regions, including urban areas like Mangaluru. The following case studies highlight efforts in lake conservation, sea erosion control, and urban resilience enhancement to improve living conditions in this rapidly expanding coastal city.

2.4. Mangaluru

Mangaluru is increasingly adopting NbS in its urban planning to tackle environmental challenges such as flooding and water management. Traditional infrastructure has been insufficient, leading to frequent waterlogging and loss of rainwater due to inadequate stormwater drainage and reduced natural absorption from urbanisation. The case studies given below explore how Mangaluru is utilising NbS to enhance resilience, biodiversity, and sustainable water management.

2.4.1. Tannirbhavi Coastal Bioshield Project

The Tannirbhavi Coastal Bioshield Project is a pioneering initiative designed to protect Mangaluru' s vulnerable coastline from erosion and other climate-related threats by creating natural barriers, such as mangroves and other vegetation (TOI, 2023).

Box 15. Case Study of Tannirbhavi Coastal Bioshield Project

Location	Tannirbhavi, Mangaluru
Enforcement agency	Government of Karnataka
Timeline	2023 onwards
Objective	To prevent coastal erosion through eco-restoration and the creation of a bio-shield using various types of vegetation
Ecosystem type	Coastal ecosystem, including sandy beaches and adjacent vegetative zones
Climate change impacts addressed	• Coastal erosion • Loss of biodiversity and water quality

Socio-economic outcomes	• Impact on local communities due to changing coastal landscapes • Increased recreational opportunities • Protection of local infrastructure and properties from erosion
Monitoring and evaluation	Ongoing monitoring of vegetation growth and effectiveness in preventing erosion
Trade-offs/Limitations	• Initial costs and maintenance of the bio-shield • Potential displacement of local flora and fauna during the initial planting phase • Long-term commitment required for monitoring and maintenance

2.4.2. Mangalore Refinery and Petrochemicals Ltd Green Belt Initiative

The Kudumbur rivulet and mangrove forest rejuvenation project in Mangaluru is a significant environmental initiative aimed at restoring vital ecosystems within the Baikampady Industrial Area. The project seeks to combat industrial pollution and environmental degradation, transforming the area into a green belt (Sastry, 2022).

Box 16. Case Study of Mangalore Refinery and Petrochemicals Ltd

Location	Kudumbur rivulet and Mangrove Forests, Baikampady Industrial Area
Enforcement Agency	Forest Department of Karnataka with funding from Mangalore Refinery and Petrochemicals Ltd. (MRPL), Karnataka State Pollution Control Board (KSPCB), and Karnataka Industrial Area Development Board (KIADB) for monitoring
Timeline	2022 onwards
Objective	To rejuvenate and restore the Kudumbur rivulet and mangrove forests by preventing the flow of industrial effluents, domestic sewage, and solid waste into the rivulet and preserve the area as a green belt
Ecosystem type	Mangrove forests and tidal ecosystem within an industrial area, with backwater connections to the Phalguni (Gurupura) river
Climate change impacts addressed	• Enhances the ability to mitigate coastal flooding and combat coastal erosion • Preserves biodiversity, allowing the region to withstand climate-related changes by supporting a diverse range of flora and fauna
Socio-economic outcomes	• The restoration will improve water quality, revive biodiversity, and support sustainable environmental management. • Establishing a green belt can enhance air quality and contribute to the well-being of local communities living near the industrial zone.
Project cost	USD 2 million
Monitoring and evaluation	• Regular monitoring for the prevention of waste flow and solid waste dumping

	• Clear blockages in the creeks to restore the natural tidal cycle from time to time
Trade-offs/Limitations	Clearing blockages and ensuring long-term water flow will require continuous maintenance and cooperation from local authorities and industrial stakeholders.

2.4.3. INTERACT-Bio project

The INTERACT-Bio project is an international initiative aimed at enhancing urban sustainability by integrating NbS into the planning and management of fast-growing cities. Focusing on cities in the Global South, including Mangaluru, the project promotes the restoration of ecosystems, improves urban planning strategies, and provides tools for managing biodiversity through collaborations with local governments, communities, and stakeholders (ICLEI, 2018).

Box 17. Case Study of INTERACT-Bio, Mangaluru

Location	Mangaluru
Enforcement Agency	Ministry of Environment, Forest and Climate Change (MoEFCC), State Biodiversity Board, City Corporations - Mangaluru, the National Biodiversity Authority, ICLEI South Asia, German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU) through the International Climate Initiative (IKI)
Timeline	2017–2020
Objective	To improve the utilisation and management of NbS within fast-growing cities focusing on integrating biodiversity and ecosystem services into spatial planning, land-use management, local economic development, and infrastructure design to promote sustainable urban development and climate resilience
Ecosystem type	Urban green spaces, coastal zones, and mangrove ecosystems
Climate change impacts addressed	• Moderation of extreme weather events (flooding and coastal erosion) • Enhancement of urban resilience to climate change through NbS • Improvement of water quality and management • Preservation of biodiversity and reduction of the urban heat island effect
Socio-economic outcomes	• Increased local capacity for managing natural resources and implementing NbS • Generation of new or enhanced economic opportunities, such as eco-tourism and urban agriculture • Support for biodiversity conservation efforts that contribute to sustainable livelihoods for local communities
Monitoring and evaluation	• Stakeholder engagement, capacity building, and technical workshops to identify critical ecosystems and track the effectiveness of NbS interventions • Monitoring includes the development of natural asset maps and the assessment of biodiversity and ecosystem services in participating cities

Trade-offs/Limitations	• Integrating NbS into urban planning can face challenges due to urban expansion and existing infrastructural limitations. • Long-term success relies on cross-sectoral cooperation and ensuring continuous funding for sustainable urban development. • The balance between development and conservation is a key concern, especially in rapidly urbanising areas.

2.4.4. Kavoor Lake rejuvenation project

The Kavoor Lake rejuvenation project in Mangaluru is a significant initiative aimed at restoring the ecological health of this vital urban waterbody. Over the years, rapid urbanisation has led to pollution, siltation, and degradation of the lake, threatening its biodiversity and reducing its capacity to manage stormwater. This project focuses on restoring the lake's natural ecosystem while promoting sustainable urban development. (Berger, 2019).

Box 18. Case Study of Kavoor Lake, Mangaluru

Location	Kavoor Lake, North Mangaluru
Enforcement Agency	Mangaluru Smart City Limited (MSCL) - Government of Karnataka (GoK), with consultancy provided by Louis Berger.
Timeline	2019 onwards
Objective	• Rejuvenation of Kavoor Lake to increase water catchment capacity through rainwater harvesting • Creation of recreational spaces to foster community interaction • Promotion of socio-cultural engagement through lakefront development • Raise awareness of water conservation and environmental protection
Ecosystem type	Urban freshwater lake ecosystem
Climate change impacts addressed	• Water management through rainwater harvesting and better catchment • Improvement in the lake's ability to manage runoff and flooding, aiding urban climate resilience
Socio-economic outcomes	• Creation of a social interaction space for local communities, including walking and cycling tracks, plazas, and public facilities • Property value increase around the lake due to enhanced aesthetics and recreational amenities • Improved microclimate through lake restoration, enhancing local living conditions • Potential for increased tourism and local commerce due to new public spaces and amenities
Project Cost	USD 0.24 million
Monitoring and evaluation	Continuous water quality monitoring, maintenance of public facilities, and community engagement for sustained upkeep
Trade-offs/Limitations	• Eutrophication and siltation may degrade the water quality and limit capacity of the lake unless properly managed.

- Challenges include anthropogenic stress from surrounding residential areas and lack of continuous government commitment to lake upkeep prior to the Smart City Mission intervention.

In conclusion, Mangaluru's ongoing integration of NbS into urban planning demonstrates a proactive approach to addressing environmental challenges such as flooding, coastal erosion, and water management. By adopting NbS, Mangaluru is not only improving its environmental sustainability but also providing economic opportunities and enhancing the quality of life for its residents.

3. Role of Stakeholders

3.1. Chennai, Tamil Nadu

In Tamil Nadu, and particularly Chennai, a diverse network of stakeholders plays a pivotal role in advancing NbS for climate adaptation, environmental conservation, and sustainable urban development. These stakeholders can be categorised into government agencies, non-governmental organisations, private entities, and international agencies (Figure 1). Their collective efforts address pressing challenges such as urban flooding, biodiversity loss, water management, and coastal resilience.

Government agencies in Tamil Nadu, such as the Tamil Nadu Forest Department, PWD, and GCC, are playing a vital role in advancing large-scale NbS projects such as the Pallikaranai Marshland Restoration and Cooum River Eco-Restoration. These initiatives demonstrate a strong commitment to biodiversity conservation and water management, setting a solid foundation for climate resilience. NGOs, including the M S Swaminathan Research Foundation and Care Earth Trust, are crucial in ensuring community engagement and balancing ecological restoration with livelihood improvements. Their grassroots efforts, especially in projects like the Integrated Mangrove Fisheries Farming System (IMFFS), highlight the importance of local participation in achieving sustainable outcomes. Private entities and international agencies contribute significantly by providing innovative design and funding. Their collaboration with local stakeholders helps bridge the gap between global expertise and local implementation, driving forward the integration of NbS into urban and coastal resilience strategies.

In conclusion, the stakeholder landscape for NbS in Tamil Nadu is robust and diverse yet fragmented in execution. For NbS to be mainstreamed as a sustainable approach to climate adaptation in Chennai and beyond, there needs to be a shift from isolated projects to more systemic, integrated models that prioritise local community ownership, long-term governance, and equity. Additionally, the involvement of private and international entities must be balanced with a commitment to ecological justice, ensuring that the economic, social, and environmental benefits are shared equitably among all stakeholders.

Figure 1: Overview of NbS Stakeholders in Tamil Nadu and Chennai

Government Agencies	Non-governmental Organisations	Private Entities	International Agencies
Tamil Nadu Forest Department	M.S. Swaminathan Research Foundation (MSSRF)	Ooze Architects & Urbanists	Mangroves for the Future (MFF) Initiative
Department of Fisheries and Fishermen Welfare	The Energy and Resources Institute (TERI)	Madras Terrace Architectural Works	Global Environment Facility (GEF)
Department of Horticulture	Central Marine Fisheries Research Institute (CMFRI)	Biomatrix Water	DEEPWAVE (Germany)
Public Works Department	PLANT Trust	IHE Delft Institute for Water Education	GIZ
Water Resources Department	OMCAR Foundation (Organization for Marine Conservation, Awareness, and Research)	Paperman Foundation	National Bank for Agriculture and Rural Development (NABARD)
Inland Waterways Authority of India	Suganthi Devadason Marine Research Institute (SDMRI)	Urban Design Collective	
Tamil Nadu Slum Clearance Board (TNSCB)	Indian Institute of Technology Madras (IIT-M)		
Tamil Nadu Coastal Restoration Mission	Chennai Resilience Centre		
Tamil Nadu Corporation for Development of Women	Care Earth Trust		
Tamil Nadu Skills Development Corporation	Uravugal Social Welfare Trust		
Wildlife Warden, Gulf of Mannar Marine National Park	Conservation of Pallikaranai Marshland Authority		
Greater Chennai Corporation (GCC)			
Chennai Rivers Restoration Trust (CRRT)			
Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB)			

3.2. Mangaluru, Karnataka

In Mangaluru, the integration of NbS into urban planning is being driven by a wide array of stakeholders, each contributing to climate resilience and environmental conservation (Figure 2). Government agencies such as the Forest Department of Karnataka and Mangaluru Smart City Limited (MSCL) have led key initiatives like the Tannirbhavi Coastal Bioshield Project and Kavoor Lake Rejuvenation. These projects highlight the city's commitment to addressing issues such as coastal erosion and flooding through ecological approaches. However, there remains a need for more community involvement in planning and decision-making, as many of these efforts have predominantly been top-down.

The Mangaluru Urban Development Authority, alongside organisations like Dakshin Foundation and INTACH Mangaluru, plays crucial roles in shaping urban landscapes that prioritise NbS. These organisations work towards strengthening the city's capacity to integrate environmental resilience into its planning processes. NGOs such as ICLEI South Asia, through projects like INTERACT-Bio, emphasise the importance of aligning NbS with local needs and ensuring that biodiversity and ecosystem services are central to urban development.

Private sector involvement, especially from Mangalore Refinery and Petrochemicals Ltd (MRPL) and international bodies like the German Federal Ministry for the Environment, has been instrumental in providing financial and technical resources for projects such as the Kudumbur Rivulet and Mangrove Forest Green Belt Initiative. While these contributions are invaluable, there is a risk that external agendas could overshadow local cultural and ecological contexts. Real estate developers and citizen action groups, although not as prominent, have a growing role in ensuring that NbS are implemented on a broader scale.

In conclusion, while significant progress has been made in advancing NbS in Mangaluru, the city must address challenges such as fostering deeper community engagement, strengthening policy frameworks, and ensuring sustainable funding. A more inclusive approach, where local voices are central to the process, will be key to creating resilient and equitable urban environments. By balancing development with ecological stewardship, Mangaluru can ensure that its NbS efforts provide lasting benefits for both people and nature.

Figure 2: Overview of NbS Stakeholders in Karnataka and Mangaluru

Government Agencies	Non-governmental Organisations	Private Entities	International Agencies
Karnataka Forest Department	ICLEI South Asia	Louis Berger	German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU)
Karnataka State Pollution Control Board (KSPCB)	Local Environmental Groups	Manipal Group	Asian Development Bank (ADB)
Karnataka Industrial Area Development Board (KIADB)	Dakshin Foundation		World Wildlife Fund
Ports and Inland Water Transport Department	PLANT Trust		
Mangaluru Smart City Limited (MSCL)	INTACH, Mangaluru chapter		
Mangaluru Urban Development Authority	NIT - K		
State Ecotourism Board	St. Aloysious College		
Mangalore Refinery and Petrochemicals Ltd. (MRPL)			
Mangaluru City Corporation (MCC)			
State Biodiversity Board, Karnataka			

4. Challenges

In Chennai and Mangaluru, the widespread adoption of NbS faces several significant challenges indicative of the pressures of development and climate impacts that hinder their integration into urban development and ecological conservation efforts, similar to other cities in India.

4.1. Ad-hoc planning measures

While the Chennai Metropolitan Development Authority (CMDA) is recognised as one of India's most proactive urban development bodies, efforts to integrate NbS have been fragmented (Babbar, 2024). Various third parties have implemented NbS in isolation, lacking a systemic approach that takes into account the overall biodiversity and climate evidence. A more concerted effort from CMDA is needed to foster comprehensive NbS strategies across the city.

4.2. Land availability and land-use encroachments

Significant land allocations for NbS projects continue to battle with the challenge of urban encroachment (J, 2024). There is a critical need for effective policies that are strictly enforced to preserve these lands for ecological use. Additionally, real estate developers should be educated about the benefits of NbS, not only for environmental sustainability but also for enhancing their property values. They should also be encouraged to collaborate with CMDA for developing an NbS-informed urban framework.

4.3. Limited community awareness and engagement

Current NbS initiatives often lean towards reactive or restorative measures, such as clean up drives around Lake Sembakkam or mangrove restoration by the OMCAR Foundation (Ooze Architects, 2023). There's a profound need to shift towards transformative adaptation through NbS, requiring robust community education and active participation in both implementation and maintenance of these projects (Scolobig et al., 2023).

4.4. Lack of coordinated NbS urban frameworks and policy-enabling mechanisms

The successful integration of NbS into urban planning requires a coordinated approach across various sectors including water management, urban forestry, and public works (TNC, 2018). However, the current institutional setup makes NbS adoption daunting, reflecting a significant gap in robust policy mechanisms that could incentivise NbS adoption, similar to subsidies provided for renewable energy projects.

4.5. Lack of NbS funding

Funding for NbS in Chennai predominantly comes from international aid or financial institutions focused on disaster resilience or restoration. In Mangaluru, it comes from government grants and private sector contributions, which are often insufficient to meet the growing demands for sustainable urban development. There is an urgent need for consistent and reliable funding sources (Bureau, 2024). Establishing stable

funding streams through diversified channels, including public–private partnerships, community-based financing, and corporate social responsibility initiatives, is crucial for the sustainability and expansion of NbS initiatives. Encouraging local businesses and industries to invest in NbS can also provide additional financial support, ensuring long-term viability and broader implementation of these essential environmental projects.

By addressing these gaps, cities such as Chennai and Mangaluru can enhance their resilience to environmental challenges and improve the overall quality of urban life.

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