Report #03

Catalogue of Nature-based Solutions Practices in ASEAN Region

March 2025

Disclaimer

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The report is one of several undertaken under the TAF-GTEI to provide insights into the awareness, role and uptake of nature-based solutions across ASEAN. It has not been formally endorsed by the European Union, ASEAN or ASEAN Member States.

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List of Abbreviations

Abbreviations	Definitions
AMS	ASEAN Member States
APAEC	ASEAN Plan of Action for Energy Cooperation
ASEAN	Association of South-East Asian Nations
CB	Capacity Building
CCM&A	Climate Change Mitigation & Adaptation
DRR	Disaster Risk Reduction
EbA	Ecosystem based Approach
EE	Energy Efficiency
EU	European Union
EUD	European Union Delegation
IRENA	The International Renewable Energy Agency
ICZM	Integrated Coastal Zone Management
IWRM	Integrated Water Resources Management
JNKE	Junior Non-key Expert
KE	Key-expert
NbS	Nature-based Solutions
PAM	Protected Areas Management
RE	Renewable Energy
SNKE	Senior Non-key Expert
SLM	Sustainable Land Management
TA	Technical Assistance
TAF-GTEI	Technical Assistance Facility of the Green Team Europe Initiative
TOR	Terms-of-Reference
WWF	World Wildlife Fund

Executive Summary

Nature-Based Solutions (NbS) offer a transformative approach to addressing Southeast Asia's pressing societal and environmental challenges. In a region where rapid urbanisation, biodiversity loss, climate change, and disaster risks threaten sustainable development, NbS provide a resilient, cost-effective, and inclusive pathway for enhancing ecosystem services while strengthening economic and social well-being.

This catalogue presents 70 NbS practices systematically designed to support national and local governments, stakeholders, and communities in implementing nature-inspired strategies that deliver technical, financial, environmental, and social benefits.

A Landscape-Based Framework for NbS Implementation

Building on spatial and geomorphological analyses, this catalogue structures NbS within nine key landscape categories that reflect the ecological, socio-economic, and climate adaptation needs of Southeast Asia. These landscapes – ranging from flood-responsive riverine systems, adaptive coastal ecosystems, and regenerative agriculture to climate-smart cities and wildlife corridors – provide a strategic framework to scale up NbS in synergy with local ecosystems, economies, and communities. This landscape-based approach ensures that NbS applications align with territorial resilience planning, land-use optimisation, and sustainable resource management, reinforcing the long-term viability of climate adaptation strategies.

A Practical and Scalable Approach to NbS

Each of the 70 NbS practices is presented in a structured double-page format, offering technical insights, economic analysis, and real-world applications. The first page provides a conceptual overview, illustrating how the NbS integrates into Southeast Asian landscapes, while the second page delivers detailed technical diagrams, cost assessments, and implementation guidance. This approach enables stakeholders to access replicable and scalable solutions that address key environmental challenges such as flooding, drought, erosion, biodiversity loss, and land degradation, while also providing co-benefits like improved livelihoods, economic opportunities, and enhanced disaster resilience.

Aligning NbS with the the International Union for Conservation of Nature (IUCN) Societal Challenges

The 70 NbS practices align with the IUCN's seven societal challenges, demonstrating their capacity to deliver broad, cross-sectoral benefits:

1. Climate Change Adaptation and Mitigation: Strengthening ecosystem resilience, carbon sequestration, and climate-smart land management.
2. Disaster Risk Reduction: Leveraging natural buffers such as mangroves and wetlands to mitigate floods, storms, and landslides.
3. Water Security: Improving watershed management, reducing urban flooding, and sustaining freshwater resources.
4. Food Security: Enhancing sustainable agricultural practices, soil restoration, and agroforestry.
5. Human Health: Reducing pollution, enhancing air and water quality, and improving public health through green spaces.
6. Economic and Social Development: Creating green jobs, supporting nature-based tourism, and strengthening community-led conservation initiatives.
7. Biodiversity Conservation: Restoring degraded ecosystems, reconnecting fragmented habitats, and safeguarding marine and terrestrial biodiversity.

Strategic Pathways for Scaling Up NbS

To maximise the impact of these 70 NbS practices, this catalogue highlights five strategic recommendations:

1. Scaling up and customisation: Adapt NbS to local socio-economic and environmental conditions to enhance their feasibility and effectiveness.
2. Policy and governance integration: Embed NbS into ASEAN development frameworks, climate strategies, and national policies.
3. Community empowerment: Foster participatory approaches that involve local communities, indigenous knowledge, and stakeholder engagement.
4. Financial and economic viability: Develop financing models, including public-private partnerships, carbon markets, and green investment mechanisms, to support NbS implementation.
5. Cross-border collaboration: Strengthen regional cooperation and knowledge exchange to address transboundary climate and biodiversity challenges.

By providing a comprehensive roadmap for NbS application, this catalogue serves as a practical tool for decision-makers, planners, and investors seeking to implement scalable, cost-effective, and locally adapted nature-based solutions. Through landscape-based planning and ecosystem-sensitive development, Southeast Asia can leverage NbS to build a climate-resilient, ecologically sustainable, and socially inclusive future.

Landscape categories as a Framework for Nature-based Solutions Practices

To address the complex interplay between climate change, ecosystems, and human activity, nine climate-sensitive landscape categories have been identified across ASEAN countries. These landscapes represent key ecological and socio-economic systems where NbS can be planned, implemented, and scaled up to enhance climate resilience, disaster risk reduction, and sustainable development. This approach recognises the spatial coherence of land use and the vital symbiosis between natural ecosystems and human settlements, ensuring that NbS contribute to long-term regional sustainability.

The 70 NbS featured in this catalogue are designed to provide practical, technical, and economic guidance for governments, stakeholders, and local communities on how nature-inspired strategies can be applied effectively. These solutions respond to pressing environmental challenges such as flooding, drought, erosion, biodiversity loss, and land degradation while fostering resilient and adaptive landscapes.

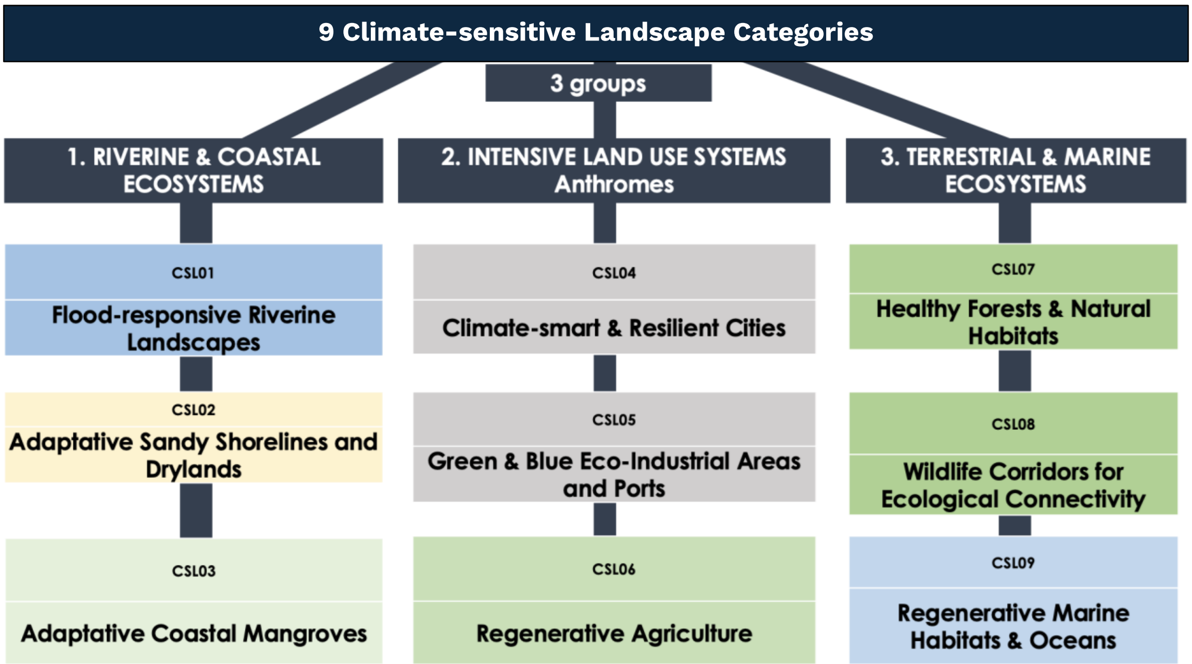
A Landscape-Based Approach to Scaling NbS in Southeast Asia

The selected nine landscape categories are organised into three main groups, reflecting their ecological functions, land use pressures, and climate adaptation needs:

1. **Riverine and Coastal Ecosystems**. These landscapes, including **flood-responsive riverine** systems, **adaptive sandy shorelines**, and **coastal mangroves** require water-sensitive planning and large-scale geomorphological understanding to mitigate flood risks, enhance biodiversity, and sustain water-dependent communities.
2. **Intensive Land Use Systems (Anthromes)**. **Urban, industrial, and agricultural landscapes** face high ecological pressures and demand regenerative and climate-smart approaches to support sustainable urbanisation, eco-industrial development, and resilient food production.
3. **Terrestrial and Marine Ecosystems**. **Natural forests, wildlife corridors, and marine** habitats play a critical role in biodiversity conservation and climate adaptation, requiring landscape-scale restoration and transboundary ecological connectivity.

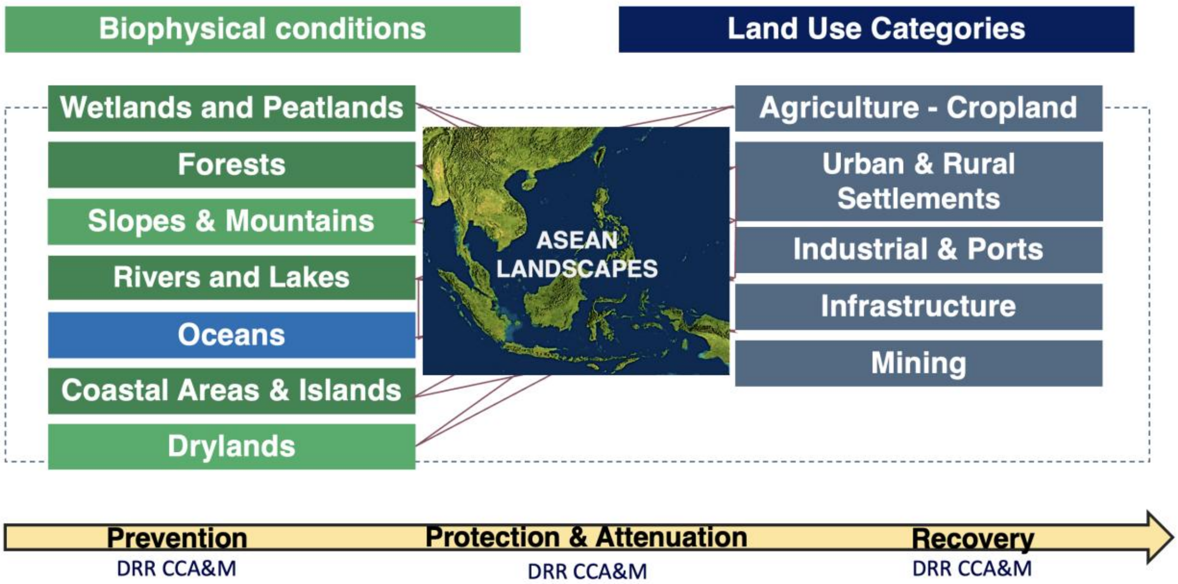
By aligning NbS with these landscapes, Southeast Asia can build climate-resilient regions that balance environmental, economic, and social priorities. This catalogue presents 135 locations, case studies, and project references, demonstrating how NbS can be strategically implemented across ASEAN countries to support territorial resilience in the long term.

Figure 1: Nine Climate-sensitive landscape categories



Nine landscape categories of Southeast Asia illustrate how NbS can be spatially, socially and economically integrated to be scaled up and impact sustainable development and climate resilience at local level.

Figure 2: Biophysical Conditions and Land Use Categories



Biophysical conditions and land use categories are assessed together in the context of Southeast Asia to better understand how prevention (disaster risk prevention measures, climate mitigation), protection and attenuation (disaster risk reduction, climate mitigation, depollution) and recovery from disasters through bioremediation, renaturation and low impact redevelopment can be applied through scaled-up and synergetic NbS.

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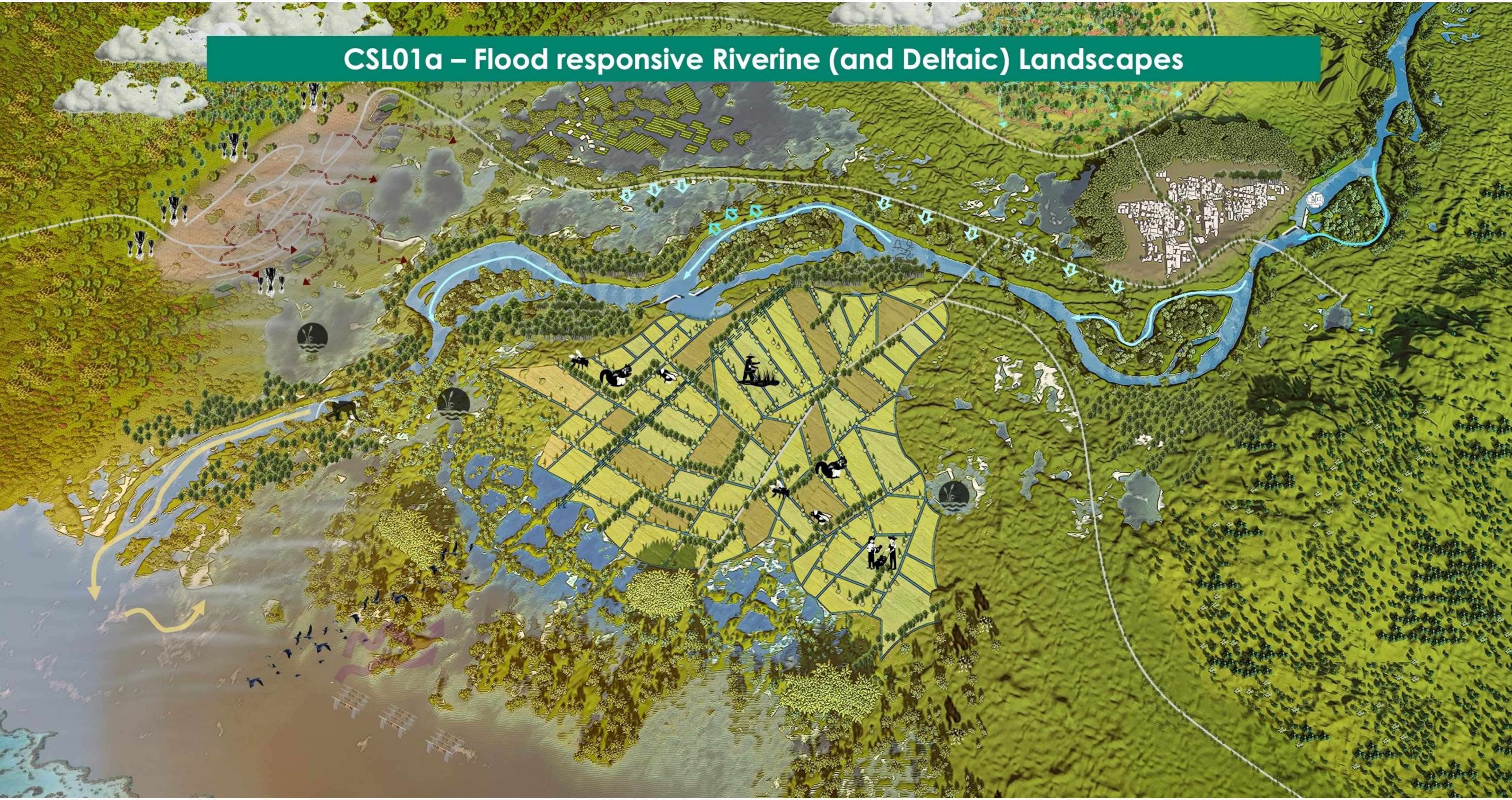
CSL01a – Flood responsive Riverine (and Deltaic) Landscapes



CSL01a – Flood Responsive Riverine and Deltaic Landscapes

Flood-responsive riverine landscapes in Southeast Asia are a vital approach for maintaining ecological balance, supporting agriculture, mitigating the effects of climate change, and fostering resilience in flood-prone communities. The climatic, biophysical, and socio-economic characteristics of ASEAN countries — such as monsoonal rainfall, riverine flooding, saline intrusion in deltas, and high population densities in flood-prone areas require an integrated approach to landscape management along rivers and water bodies.

A holistic analysis of flood frequencies, flow velocities, sediment and nutrient dynamics, and the changing salinity of water bodies that shape both natural ecosystems and human livelihoods promotes a scalable, synergetic approach of NbS in contexts shaped by complexity.

In Southeast Asia's humid riverine areas, restoring riparian forests and wetlands reduces erosion, stabilises riverbanks, and provides natural floodwater storage, protecting downstream communities during monsoon floods. Seasonal floodplains can be managed to retain water, replenishing aquifers while supporting local fisheries and agriculture. In drier riverine zones, check dams and re-vegetation efforts prevent sedimentation and enhance water retention in degraded riverbeds, ensuring water availability during droughts.

In the Mekong Delta — where frequent flooding, saline intrusion, and land subsidence are major concerns — the restoration of **inland natural wetlands** and **constructed wetlands** can mitigate flood impacts while supporting biodiversity and fisheries. Similarly, **river levee setbacks** and reconnecting **oxbow lakes** with rivers can restore natural river dynamics, enhance sediment transport, and improve water quality. These measures reduce the pressure on riverbanks by preventing erosion and creating additional floodplain storage areas.

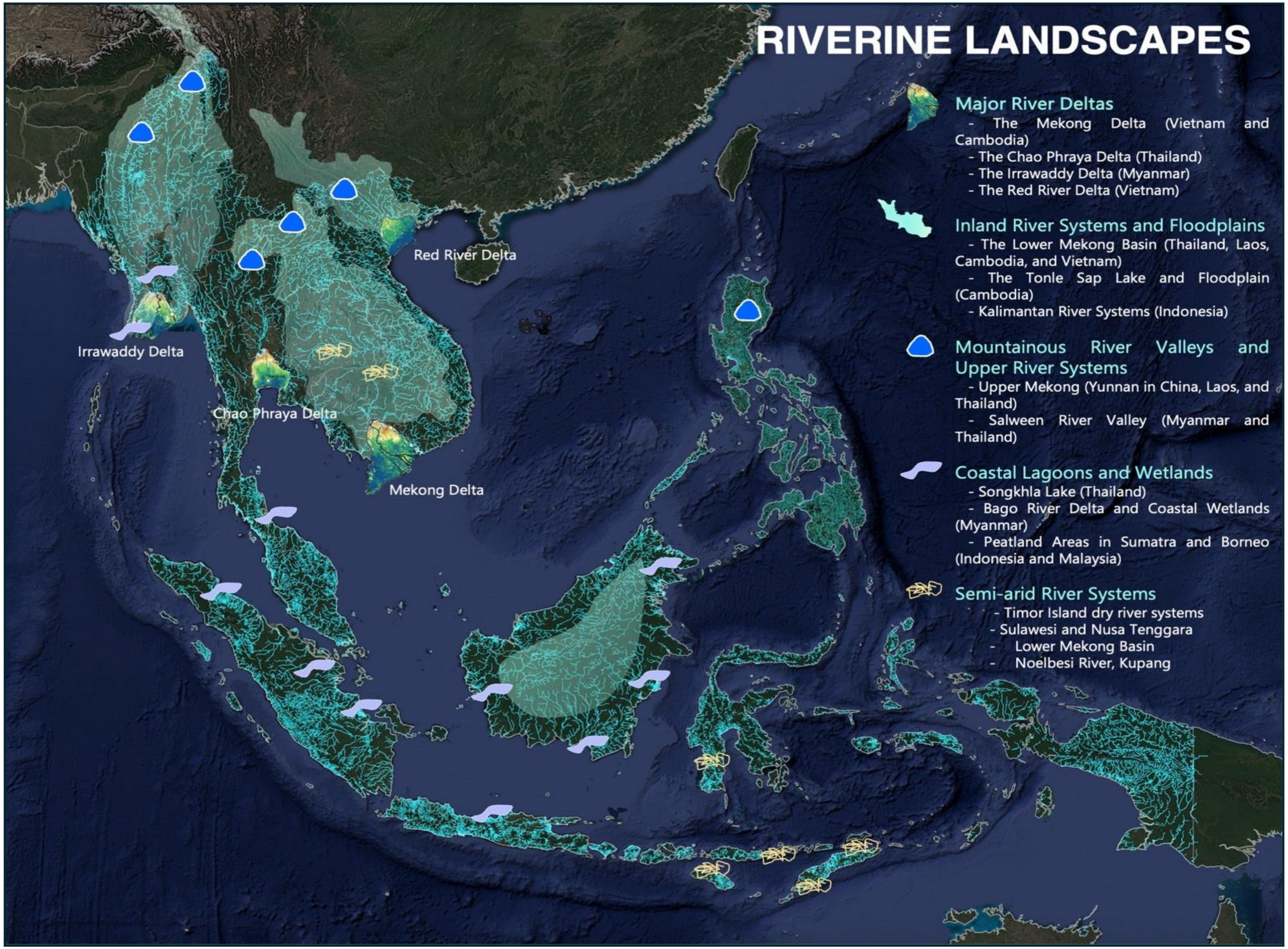
In the context of **flood-based agriculture**, NbS such as floodplain farming techniques, **riparian sylviculture** (forest management along riverbanks), and **small sand dams** on dry rivers promote a more sustainable approach to farming. This regenerative agriculture enhances soil fertility, reduces erosion, and helps communities adapt to shifting flood patterns. The use of **phytofiltration basins**, **water bunds**, and **sediment capture traps** also ensures that excess nutrients and pollutants are filtered out before they reach critical water bodies, preventing downstream contamination.

The implementation of **riparian buffer zones**, **braided brushwood mattresses**, and **log terracing** as water-delay infrastructure further protects vulnerable landscapes from erosion and sediment loss, improving water retention and mitigating the effects of extreme flooding. In regions where waste management is a challenge, solutions like **plastic waste capture biofences** can help reduce pollution while enhancing flood resilience by stabilising riverbanks.

Aquifer recharging spaces and devices, **bioretention ponds**, and **swales** can help manage both floodwater and freshwater resources, ensuring the availability of water during dry periods. By incorporating both freshwater and saltwater flows into the landscape management strategy, we can create adaptive solutions for saline-prone areas and support the livelihoods of communities engaged in both agriculture and aquaculture.

Agroforestry buffer zones along riverbanks reduce runoff, improve soil fertility, and blend sustainable agriculture with flood prevention. These NbS work in synergy to balance water retention, sediment transport, and flood mitigation, fostering regenerative landscapes and sustainable livelihoods.

Across Southeast Asia, riverine and delta landscapes are experiencing shifts in both natural processes and human-driven activities. The integration of these NbS along the Mekong, Chao Phraya, and Red River Deltas exemplifies the potential of using nature's own mechanisms to restore ecological balance while ensuring long-term sustainability.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CSL01b – Flood responsive Dry River Landscapes

CSL01b – Flood Responsive Dry River Landscapes

Dry riverine landscapes, often shaped by seasonal hydrological fluctuations, prolonged droughts, and erratic monsoonal rainfall, require innovative strategies to balance water availability, soil conservation, and agricultural productivity. Many regions, including northeastern Thailand's Mun and Chi River basins, Cambodia's Tonle Sap floodplains during the dry season, Laos' Nam Ngum watershed, and the semi-arid uplands of central Myanmar, experience extreme variability in water flow, necessitating adaptive and integrated water management approaches.

In these fragile ecosystems, NbS play a crucial role in restoring natural hydrology, increasing groundwater recharge, and sustaining agricultural productivity in the face of increasing climate variability. Strategic interventions such as Managed Aquifer Recharge (MAR), small sand dams, and sediment capture traps enhance water retention and slow down runoff, preventing excessive water loss during dry periods.

Restoring Hydrological Balance and Groundwater Recharge

To mitigate water scarcity, NbS focus on capturing and storing seasonal water surpluses for use in drier months. **Managed Aquifer Recharge (MAR)** nature-inspired solutions, such as **bioretention ponds**, swales, and **water bunds**, help regulate infiltration and maintain groundwater levels. In central and northeastern Thailand, **constructed wetlands** and **inland natural wetlands** are being developed to store excess floodwaters during the wet season, replenishing aquifers and supporting irrigation needs during dry spells.

In upland dry riverbeds, interventions such as **gully plugging** and **riverbank stabilisation** help retain moisture and prevent soil degradation. **Small sand dams** – widely implemented in Myanmar's Dry Zone – trap sediments and allow water to percolate slowly into the ground, ensuring reliable water sources for nearby communities even in prolonged dry seasons.

Sustaining Agriculture in Dry Riverine Zones

Agriculture in these regions is often challenged by erratic rainfall and limited soil moisture. By integrating NbS, farmers can enhance productivity while building resilience to climate extremes. **Phytofiltration basins** and **water bunds** reduce evaporation losses while filtering out pollutants, ensuring cleaner and more sustainable irrigation sources. Along riverbanks, **riparian buffer zones** and bed renaturation improve soil fertility, reduce erosion, and create a natural defense against extreme weather events.

In Cambodia's Prek Thnot River Basin, where agricultural communities depend on seasonal floods for soil fertility, **log terracing** as water-delay infrastructure has been introduced to reduce runoff, slow water movement, and retain topsoil, ensuring better yields despite water scarcity. Similarly, **river levee setbacks** and the reconnection of **oxbow lakes** with rivers are being used in the Mekong's upper reaches in Laos to reintroduce natural flood retention areas, allowing water storage while simultaneously enhancing fish stocks and biodiversity.

Protecting Ecosystems and Strengthening Climate Resilience

Dry riverine landscapes are highly vulnerable to desertification, soil depletion, and extreme heat. NbS such as **riparian reforestation** and **sediment capture traps** help restore degraded lands by stabilising riverbanks and replenishing lost topsoil. In Vietnam's Central Highlands, bioretention ponds and **constructed wetlands** have been successfully integrated into agroforestry systems, providing much-needed water storage while enhancing biodiversity.

Further, innovative approaches like reconnecting oxbow lakes with rivers in Myanmar’s Ayeyarwady basin have reintroduced seasonal water retention areas, ensuring that natural ecosystems remain productive and resilient in both wet and dry cycles. These interventions not only support local agriculture but also sustain important habitats for aquatic and terrestrial species, creating a balanced and regenerative landscape.

From Thailand’s dry river basins to Myanmar’s arid floodplains, NbS provide scalable, climate-responsive solutions to mitigate the challenges of water scarcity, land degradation, and agricultural vulnerability. By integrating wetland restoration, aquifer recharge, water-delay infrastructures, and riparian buffer zones, these approaches enable communities to adapt to climate variability while enhancing food security, biodiversity, and ecosystem resilience.


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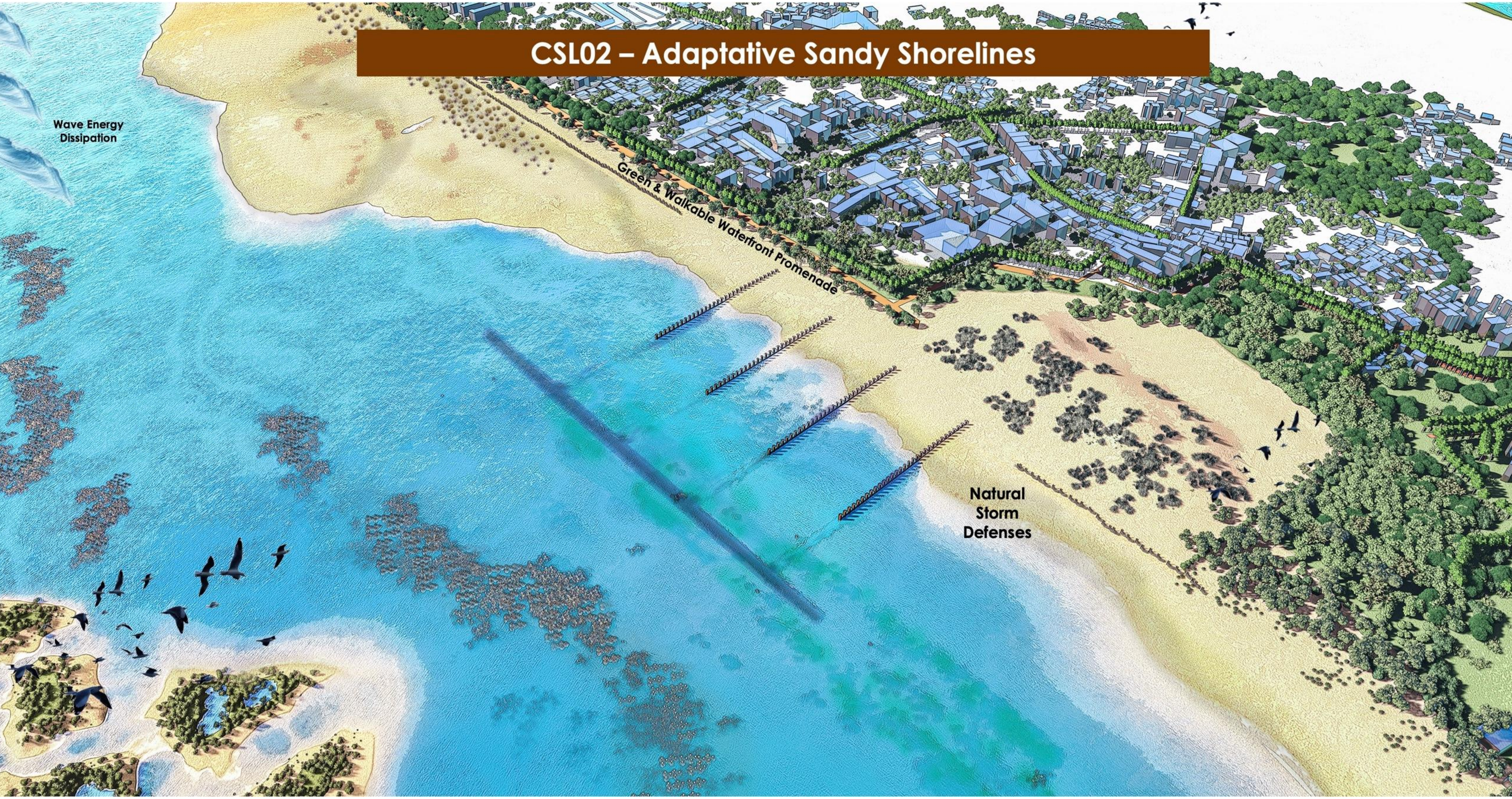

CSL02 – Adaptative Sandy Shorelines
Wave Energy Dissipation
Green & Walkable Waterfront Promenade
Natural Storm Defenses

CSL02 – Adaptative Sandy Shorelines

Sandy shorelines and arid coastal territories and ecosystems, despite their high potential for tourism development, face increasing risks from climate impacts like drought, water scarcity, typhoons, strong winds, and coastal erosion. These areas are also threatened by human-induced pressures, including plastic pollution and loss of biodiversity in coastal and marine habitats.

Adaptative sandy shorelines refer to resilient dry coastlines such as the sandy shorelines of Ilocos Norte (the Philippines) where coastal resilience has been supported by dune restoration and coastal vegetation planting to combat erosion, enhance resilience to typhoons, and support eco-tourism. Similarly, Thailand's Koh Samet Island and its waste management programmes and coral restoration projects address plastic pollution and protect marine biodiversity, fostering sustainable tourism while preserving the natural coastline.

Sandy coastlines face numerous challenges from coastal erosion, storm surges, and rising sea levels, all of which threaten local ecosystems, infrastructure, and livelihoods. A holistic approach to managing these landscapes is essential, integrating multiple NbS that address both the natural dynamics of sandy shores and the socio-economic needs of coastal communities. The approach presented in the NbS catalogue takes into account seasonal monsoons, tropical cyclones, and the delicate balance between marine and terrestrial ecosystems. By focusing on synergies between these NbS, the goal is to enhance coastal resilience, protect biodiversity, and support sustainable coastal livelihoods.

In Southeast Asia, sandy coastlines are protected and enhanced through a combination of natural and engineered solutions.

Coral reef restoration and the establishment of coral **nurseries** help reduce wave energy before it reaches the shore, safeguarding beaches and infrastructure from storm surges and erosion. This is complemented by the restoration of **seagrass meadows**, which stabilise sediments and enhance marine biodiversity.

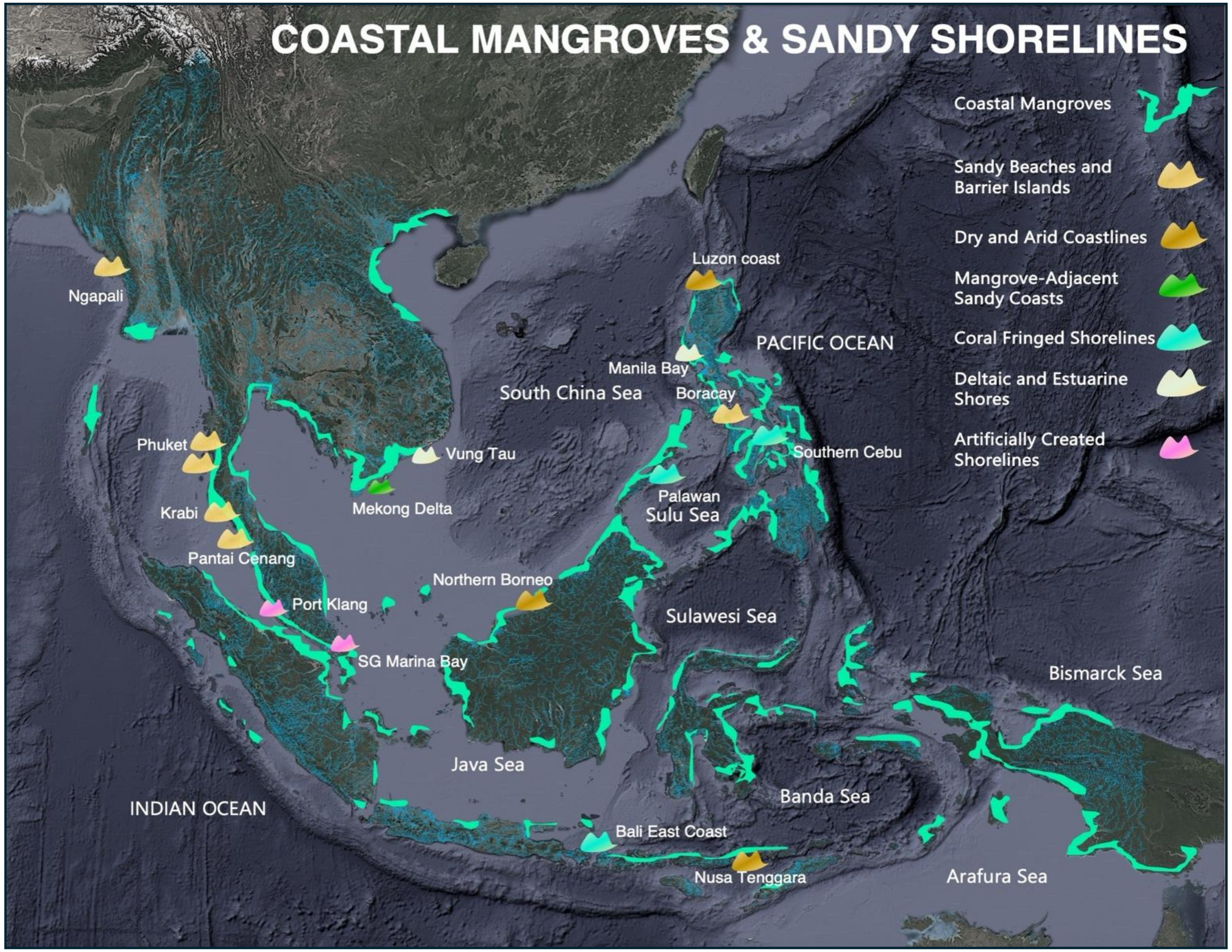
Coastal reforestation, particularly with species like casuarina and pandanus, provides additional windbreaks and stabilises dunes, mitigating the effects of coastal erosion. Windbreaks and shelterbelts, along with sand trapping fences, further protect dune dynamics and improve the resilience of coastal ecosystems.

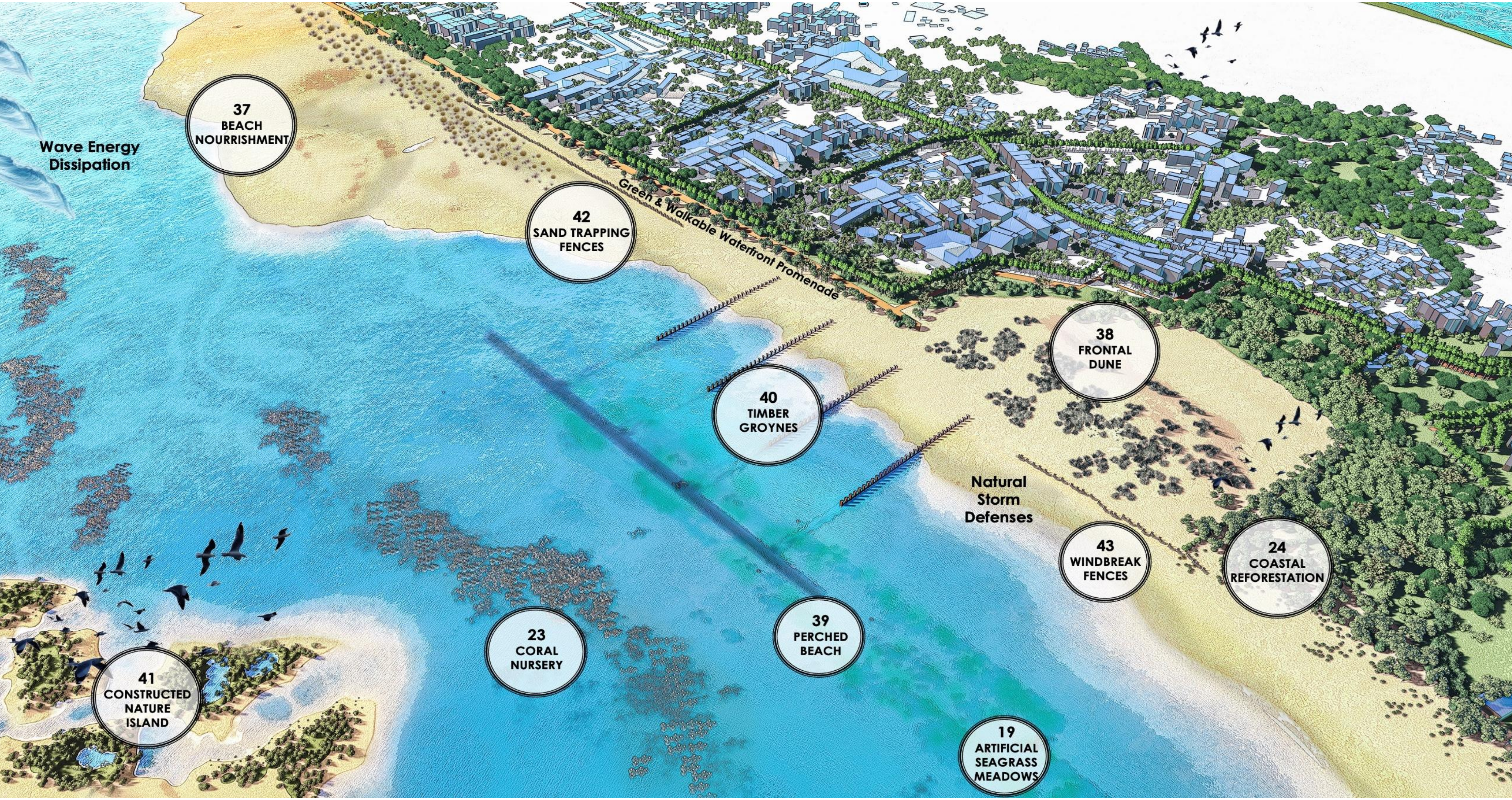
Beach nourishment and **tidal flat nourishment** are key strategies for replenishing eroded beaches and strengthening the shoreline.

Constructed perched beaches and natural **timber groynes** help manage sediment flow and reduce wave energy, preventing further erosion. For more vulnerable areas, **artificial floating reefs** and **nature islands** serve as barriers to mitigate wave energy and support marine life. The integration of sustainable tourism practices ensures that these natural defences are respected and preserved, providing economic opportunities while maintaining the integrity of fragile sandy ecosystems.

These NbS, working in synergy, address not only the immediate needs of coastal protection and erosion control but also contribute to long-term biodiversity conservation and risk management, including the mitigation of tsunami impacts. The collective effort of restoring and protecting sandy coastlines is crucial to maintaining the ecological and economic functions of these coastal zones, enhancing the resilience of Southeast Asia's coastal communities and ecosystems.

Examples from coastal areas such as the beaches of Phu Quoc and the Mekong Delta in Viet Nam, the coastal regions of Palawan and Bohol in the Philippines, and the sandy shores of Bali and Lombok in Indonesia highlight the need for such NbS. These locations are particularly vulnerable to coastal erosion and the impacts of climate change, where the implementation of NbS can strengthen coastal resilience, protect biodiversity, and safeguard local communities from the growing threats of storm surges, rising sea levels, and erosion.





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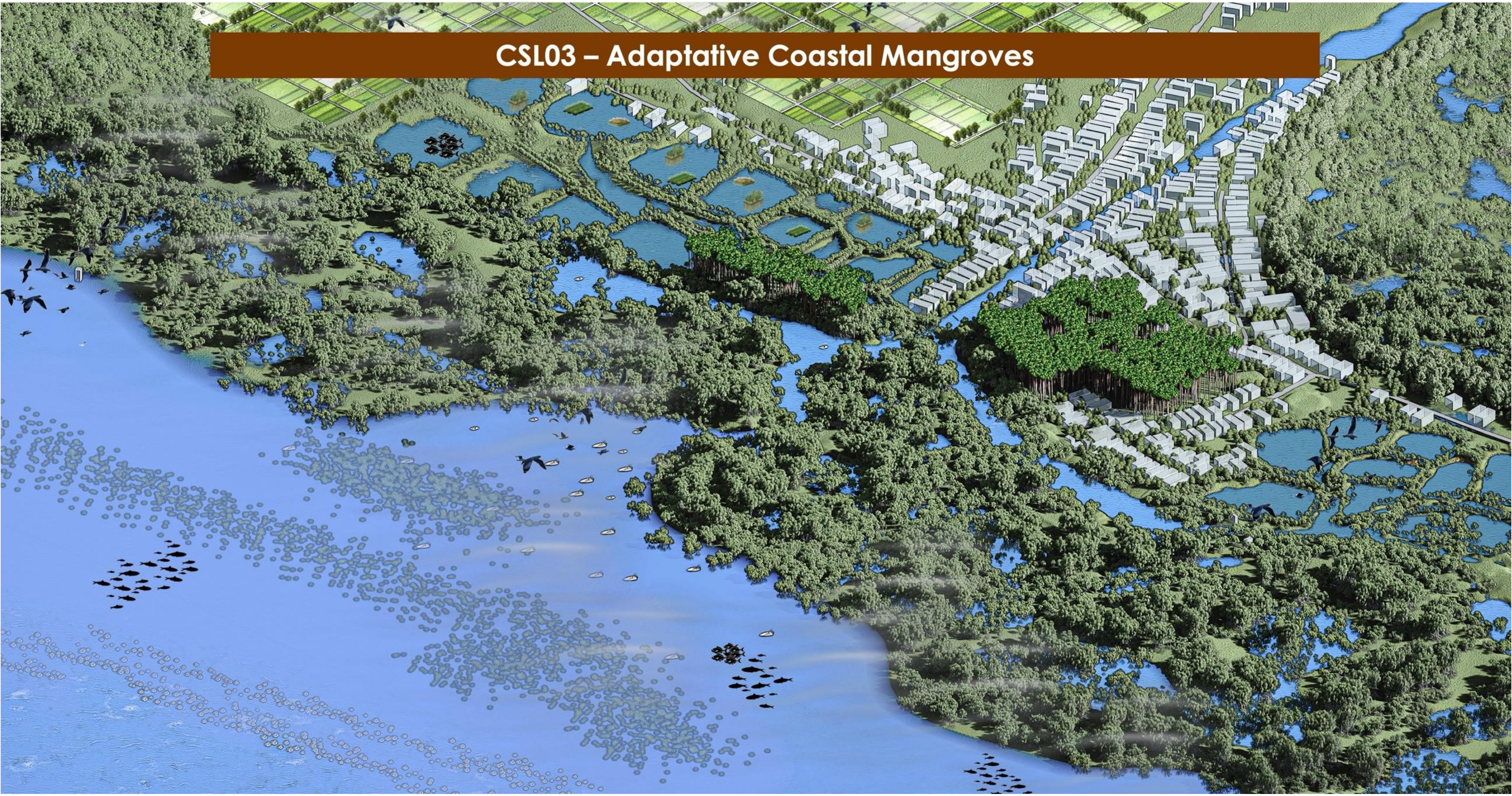
CSL03 – Adaptative Coastal Mangroves



CSL03 – Adaptative Coastal Mangroves

Coastal mangroves in Southeast Asia refer to humid coastal ecosystems characterised by the presence of mangroves, wetlands, and peatlands, which play a vital role in maintaining biodiversity and supporting local communities. These landscapes are increasingly threatened by coastal erosion, tidal waves, plastic pollution, and the loss of marine and coastal biodiversity, exacerbated by climate change and human activities.

Southeast Asia's coastal mangrove forests constitute muddy coastlines where dense mangrove ecosystems provide critical protection against storm surges and support rich biodiversity yet face threats from coastal erosion and plastic pollution. The Peatlands of Central Kalimantan in Indonesia serve as vital carbon sinks and biodiversity hotspots but are increasingly vulnerable to land conversion and fire, necessitating restoration efforts to enhance resilience against climate impacts and preserve these crucial ecosystems.

In Southeast Asia's muddy coastal zones, regenerating coastal mangroves is essential for building climate resilience and safeguarding vulnerable communities from the increasing risks of tidal surges, erosion, and rising sea levels. Mangroves offer critical ecosystem services, such as protecting coastlines from storm surges, stabilising sediments, and enhancing biodiversity.

Landscape-based and scaled-up coastal NbS in synergy have the potential to create layered defences that protect both natural habitats and local economies.

For example, in areas like the Mekong Delta in Viet Nam and the coastal regions of the Philippines, **mangrove restoration** can be complemented by **salt marsh restoration** and **tidal flat nourishment**, which work together to restore and stabilise the coast. The creation of **artificial seagrass meadows** and the use of hybrid structures like **permeable brushwood**, combined with mangrove planting, enhances sediment trapping, accelerates shoreline recovery, and reduces erosion.

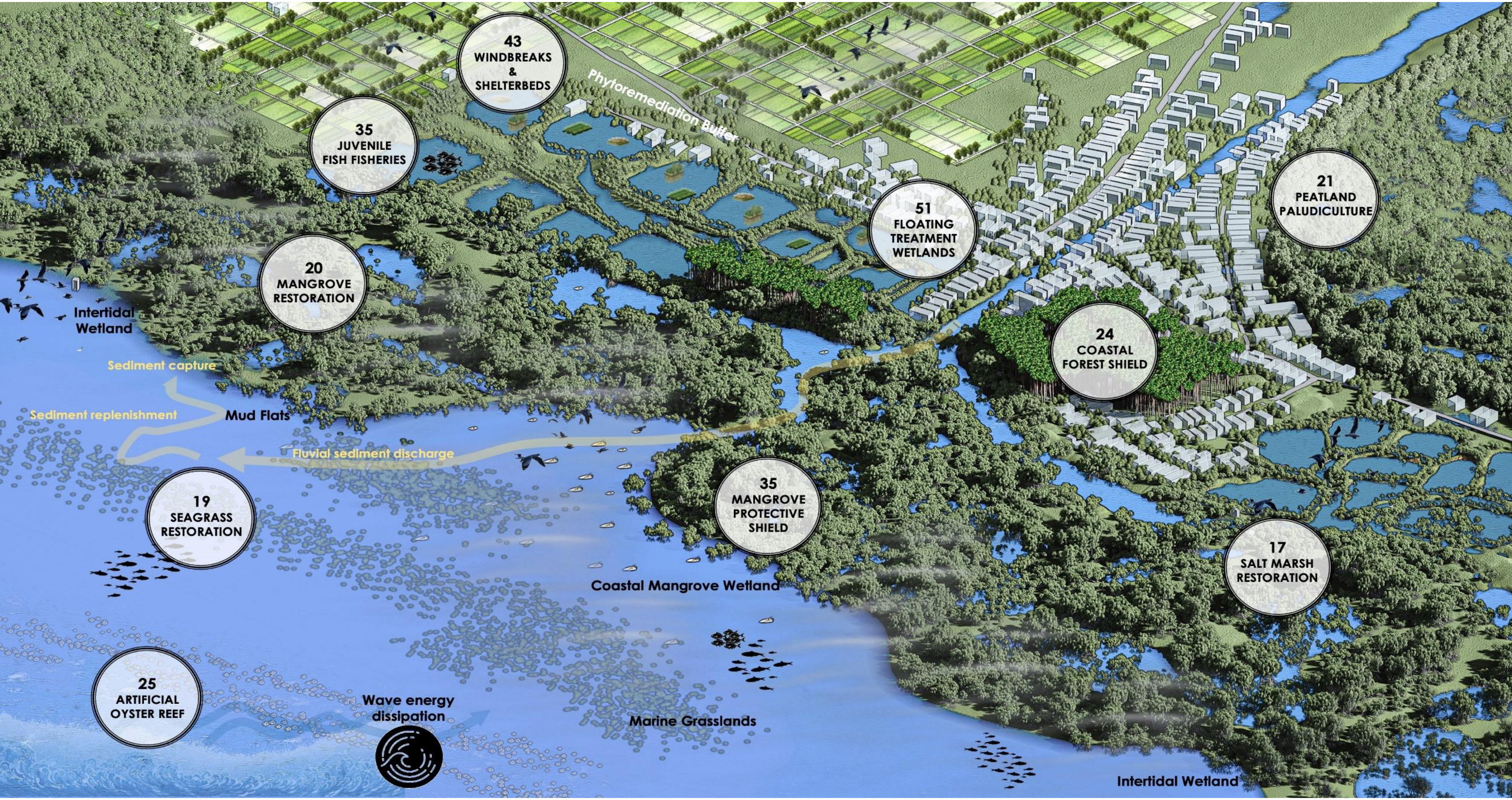
In Indonesia, where mangrove forests are rapidly declining, targeted projects focus on **coastal reforestation** and **sustainable aquaculture practices**, such as community-based shrimp farming integrated with mangrove ecosystems, ensuring economic resilience while protecting the environment.

These NbS strategies, including coastal **mangrove shields**, **paludiculture**, and **planting mats,** foster carbon sequestration, restore ecosystem services, and provide sustainable resources, such as nipa palm and firewood. Collectively, these approaches aim to create a resilient buffer against coastal disasters, supporting both the environment and the livelihoods of coastal communities across Southeast Asia.

While coastal mangrove ecosystems play a critical role in buffering river estuaries from both upstream and marine influences, providing flood protection, sediment stabilisation, and habitat restoration, these dynamic environments are increasingly threatened by coastal erosion, altered sediment flows, and rising sea levels, particularly in the Mekong Delta (Viet Nam), Ayeyarwady Delta (Myanmar), and Mahakam Delta (Indonesia). To enhance their resilience, a combination of flood management, wave attenuation, and integrated sediment management is essential.

Strategic directed **sediment transport**, **placement**, and **capture** can help rebuild eroded mangrove zones while reducing estuarine siltation and maintaining navigable waterways. In areas where river flow has been disrupted by human activities, **managed sediment deposition techniques** – such as restoring **tidal flats**, deploying permeable **sediment traps**, and utilising **artificial oyster reefs** – can redirect sediments to nourish and rebuild mangrove root structures.

This process not only supports mangrove regeneration but also enhances their ability to buffer against storm surges and wave action. Additionally, by combining river levee setbacks, reconnection of oxbow lakes, and controlled sediment flushing from upstream reservoirs, sediment transport can be rebalanced to supply essential nutrients to deltaic mangrove forests, fostering their long-term sustainability and adaptation to climate change.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CSL04 – Climate-smart and Resilient City

CSL04 – Climate-smart and Resilient Cities

The landscape category and concept of 'Climate-smart and Resilient Cities' targets urban agglomerations heading to adapt to climate adaptation through resilient urban planning that incorporates water-sensitive approaches and integrates green and blue infrastructure. These cities focus on effective water management practices, such as rainwater harvesting and flood mitigation, alongside the renaturation of urban spaces to enhance biodiversity and create green areas that alleviate urban heat island effects.

Singapore serves as a prime example of a Climate-smart and Resilient City, implementing innovative water management systems like the Marina Barrage, which integrates green spaces and effective flood control measures while enhancing urban biodiversity. Similarly, the city of Surabaya in Indonesia has adopted a comprehensive green infrastructure plan that includes the development of parks, urban forests, and permeable surfaces to manage stormwater effectively and reduce urban heat, showcasing resilience in the face of climate challenges.

In the face of rapid urbanisation, Southeast Asia's cities are increasingly vulnerable to the effects of climate change, including flooding, heat islands, and water scarcity. To build climate-smart and resilient cities, integrating NbS is key and enable local authorities and communities to address multiple challenges simultaneously. These solutions leverage the natural environment to manage water resources, reduce heat, increase biodiversity, and improve the overall quality of urban life.

One key approach is the integration of green infrastructure, such as **permeable green streets**, **bioretention ponds**, and sponge-city concepts, which enhance stormwater management and reduce the risk of flooding from heavy rainfall and riverine floods.

For example, cities like Jakarta and Bangkok are adequate contexts to implement **urban water buffers** and **terraced green riverfronts** and to manage floodwaters and protect against land subsidence. In these contexts, **aquifer recharging** spaces and **infiltration channels** ensure that water is stored and reused sustainably, addressing both drought risks and water quality issues.

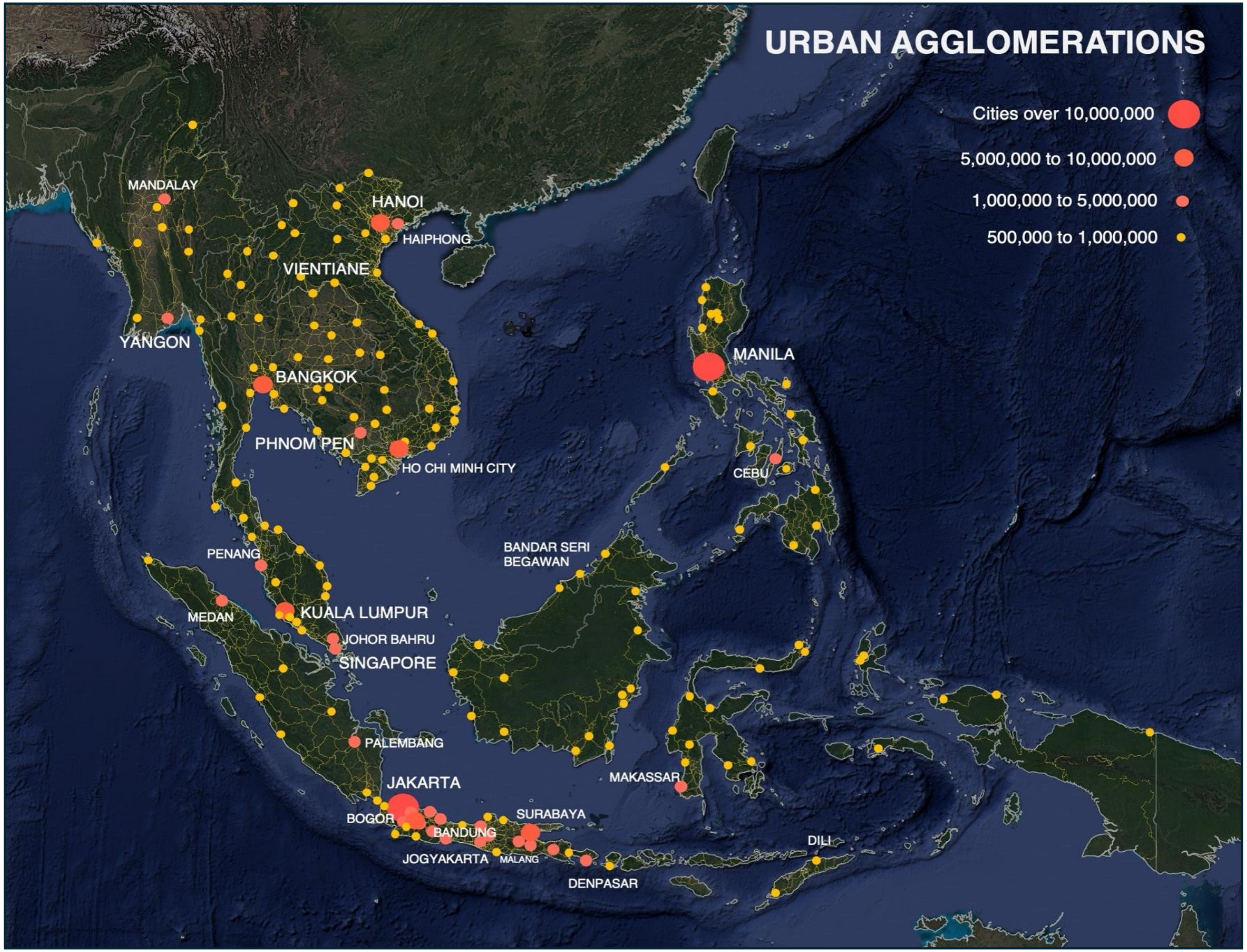
To mitigate urban heat islands, **urban forests**, **green belts**, and **green roofs** are being introduced to provide shade, cooling, and carbon sequestration. In dense areas like Ho Chi Minh City, **vertical gardens** and **green façades** have the potential to transform the built environment, creating liveable, cooler spaces.

Community-driven initiatives such as **urban farming** and **pollinator corridors** are helping to turn neglected urban spaces into hubs of local food security and biodiversity, while **landfill regeneration parks** in cities like Manila could offer opportunities to revitalise degraded lands into productive green spaces.

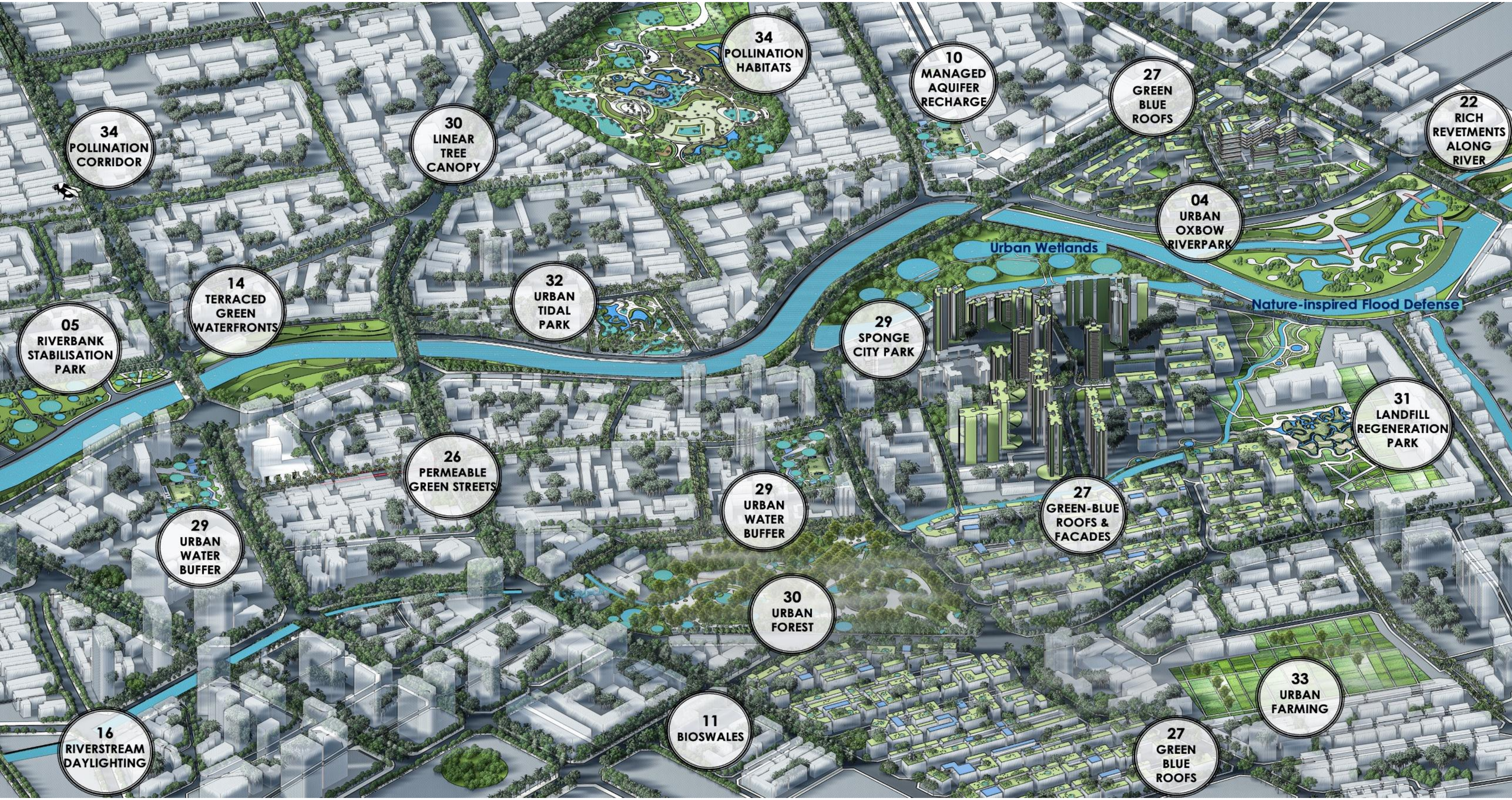
These strategies foster multi-functional urban landscapes that adapt to climate extremes, improve resilience, and create greener and more sustainable urban environments. Through NbS, Southeast Asian cities are transforming into climate-smart, green cities that balance the needs of their growing populations with the imperatives of climate resilience and environmental sustainability.

Climate-smart and resilient cities in Southeast Asia can make use of scaled-up NbS to address urban heat islands, drought episodes, water scarcity, and land subsidence. Green infrastructure, such as **permeable streets, bioretention ponds, and sponge-city designs**, improves stormwater management while MAR solutions in cities like Jakarta and Bangkok help prevent excessive groundwater depletion and subsidence. Constructed wetlands, infiltration channels, and phytofiltration basins ensure water retention and purification, securing water availability during dry seasons.

To mitigate urban heat stress, cities like Ho Chi Minh City and Bangkok can implement more urban forests, green roofs, and vertical gardens, while coastal cities can expand mangrove parks and tidal forests for cooling and flood protection. Urban regeneration efforts, such as landfill conversion into green parks and community-driven urban farming, enhance resilience, improve biodiversity, and create healthier urban environments.



URBAN AGGLOMERATIONS
Cities over 10,000,000
5,000,000 to 10,000,000
1,000,000 to 5,000,000
500,000 to 1,000,000
MANDALAY
HANOI
HAIPHONG
VIENTIANE
YANGON
MANILA
BANGKOK
PHNOM PEN
HO CHI MINH CITY
CEBU
BANDAR SERI
BEGAWAN
PENANG
MEDAN
KUALA LUMPUR
JOHOR BAHRU
SINGAPORE
PALEMBANG
JAKARTA
MAKASSAR
BOGOR
SURABAYA
BANDUNG
DILI
JOGYAKARTA
MALANG
DENPASAR


34 POLLINATION HABITATS
10 MANAGED AQUIFER RECHARGE
27 GREEN BLUE ROOFS
22 RICH REVETMENTS ALONG RIVER
34 POLLINATION CORRIDOR
30 LINEAR TREE CANOPY
04 URBAN OXBOW RIVERPARK
Urban Wetlands
14 TERRACED GREEN WATERFRONTS
32 URBAN TIDAL PARK
Nature-inspired Flood Defense
05 RIVERBANK STABILISATION PARK
29 SPONGE CITY PARK
31 LANDFILL REGENERATION PARK
26 PERMEABLE GREEN STREETS
29 URBAN WATER BUFFER
27 GREEN-BLUE ROOFS & FACADES
29 URBAN WATER BUFFER
30 URBAN FOREST
33 URBAN FARMING
16 RIVERSTREAM DAYLIGHTING
11 BIOSWALES
27 GREEN BLUE ROOFS


CSL05 – Eco-Industrial Areas and Ports

CSL05 – Green & Blue Eco-Industrial Areas and Ports

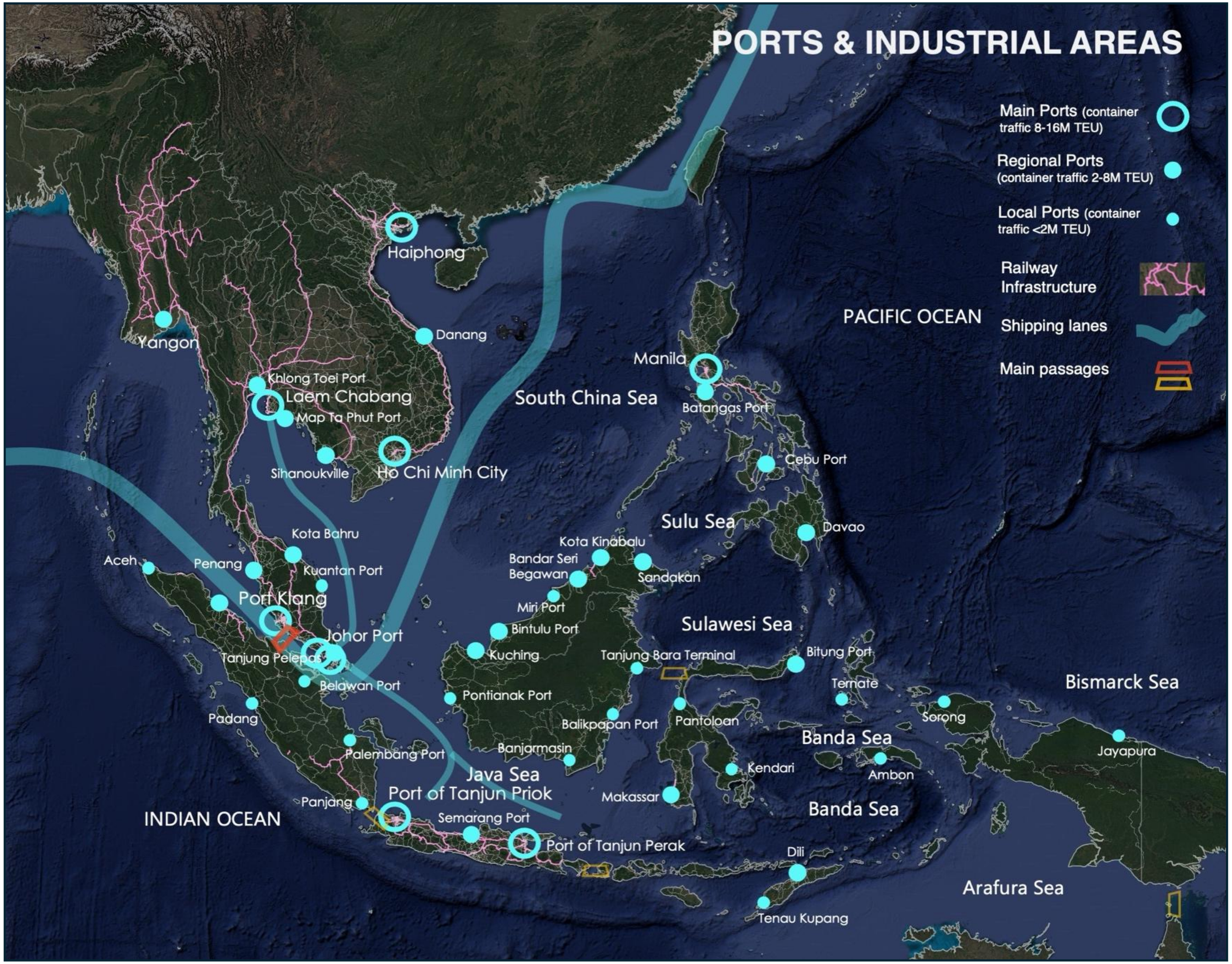
Green & Blue Eco-Industrial Areas and Ports in Southeast Asia encompass coastal and industrial regions designed to minimise environmental impact through the integration of low-impact industries, industrial symbiosis, and circular economy principles. These areas focus on sustainable practices such as efficient wastewater management, resource recovery from post-mining sites, and the utilisation of green infrastructure to enhance ecosystem resilience while promoting economic growth, activities and environmental stewardship. Some industrial areas like Banyan Tree Group's Eco-Industrial Park in Viet Nam are integrating sustainable practices like wastewater recycling, renewable energy usage, and industrial symbiosis among its tenants to minimise environmental impacts and enhance resource efficiency.

Industrial areas and ports in Southeast Asia need a better integration of green and blue infrastructure, as it’s essential for building resilient, sustainable environments that balance economic growth with environmental protection. With the region's rapid industrialisation, effective management of industrial pollution, waste, and climate impacts is critical. By combining NbS that leverage the region’s rich ecosystems, we can transform industrial zones and ports into climate-resilient spaces that support both industrial productivity and ecological health. Eco-industrial parks and ports in Southeast Asia are adopting NbS such as mangrove forest restoration and salt marsh restoration to buffer against storm surges, protect infrastructure, and restore coastal ecosystems.

For example, the **restoration of mangroves** and the establishment of **artificial seagrass** meadows in Viet Nam and Indonesia help stabilise sediments, support biodiversity, and mitigate coastal erosion. In addition, these ecosystems act as carbon sinks, contributing to the reduction of greenhouse gases while enhancing local livelihoods through sustainable fisheries and aquaculture systems. **Constructed wetlands** and bioengineering solutions, including **electro-wetlands** and **gravel wetlands**, play a vital role in treating industrial wastewater, reducing pollutants entering nearby seas, and supporting healthy aquatic environments. Ports and industrial zones such as in Thailand and Malaysia are increasingly adopting **green roofs** and facades to cool the environment, reduce urban heat island effects, and mitigate the impacts of high temperatures on workers and surrounding communities. **Vegetated noise barriers and buffer zones** offer further protection to populations living near industrial areas, reducing noise pollution and improving air quality.

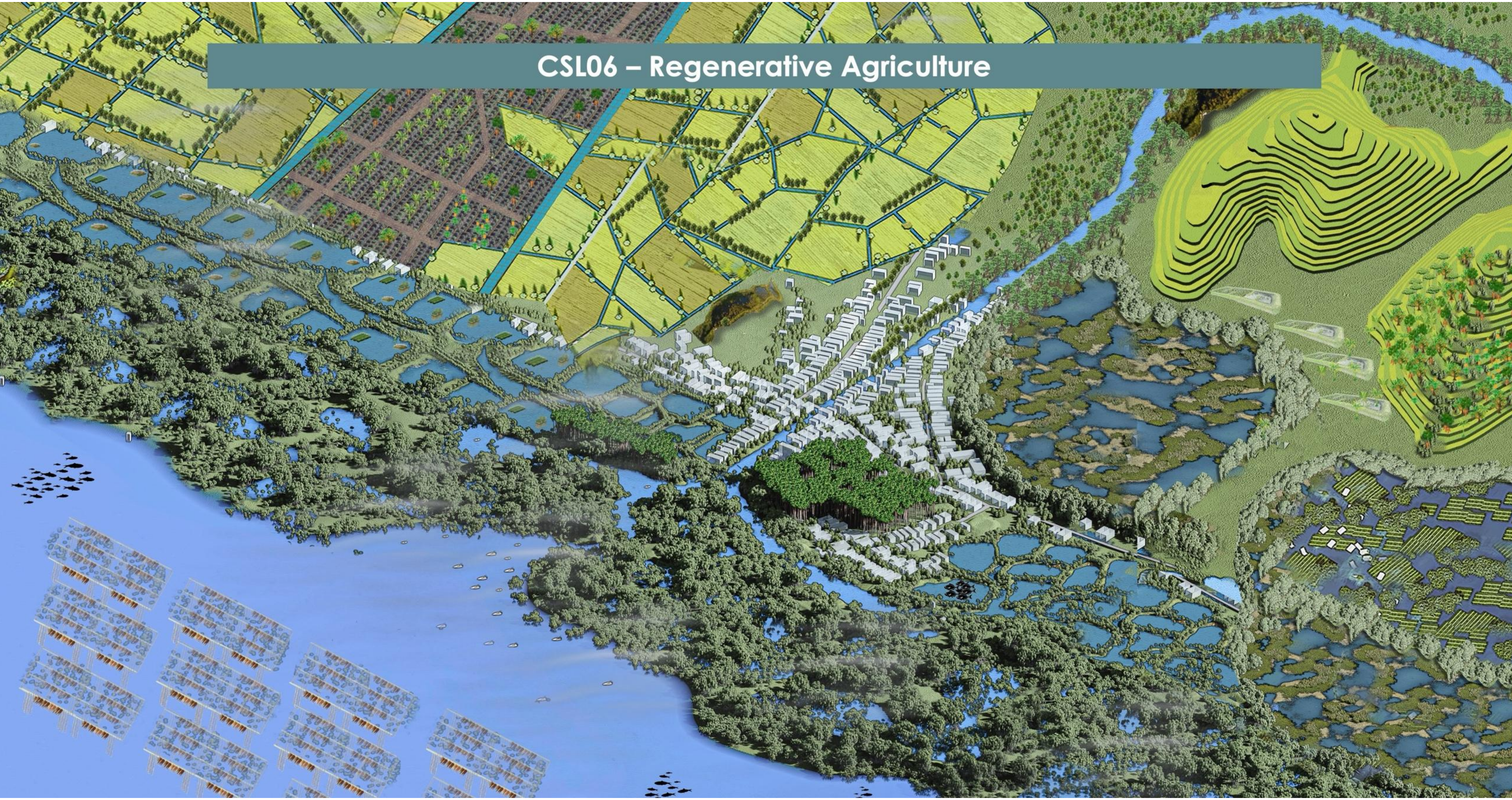
In the mining sector, post-mining recovery strategies such as **bioengineering remediation of contaminated soils** and **landfill regeneration** parks contribute to restoring ecological health and revitalising degraded landscapes. The use of **artificial oyster** reefs and **coral restoration projects** near ports, such as those underway in the Philippines, is enhancing marine biodiversity while improving water quality and creating natural habitats for marine life.

By implementing these NbS in synergy, Southeast Asia’s industrial areas and ports can be transformed into green and blue zones that support economic activities, protect natural ecosystems, and adapt to the impacts of climate change, offering a sustainable model for future development across the region.


PORTS & INDUSTRIAL AREAS
Main Ports (container traffic 8-16M TEU)
Regional Ports (container traffic 2-8M TEU)
Local Ports (container traffic <2M TEU)
Railway Infrastructure
Shipping lanes
Main passages
PACIFIC OCEAN
INDIAN OCEAN
South China Sea
Sulu Sea
Sulawesi Sea
Java Sea
Banda Sea
Banda Sea
Bismarck Sea
Arafura Sea
Haiphong
Yangon
Danang
Manila
Batangas Port
Khlong Toei Port
Laem Chabang
Map Ta Phut Port
Sihanoukville
Ho Chi Minh City
Cebu Port
Davao
Kota Bahru
Kuantan Port
Aceh
Penang
Port Klang
Johor Port
Tanjung Pelepas
Belawan Port
Padang
Palembang Port
Panjang
Port of Tanjun Priok
Semarang Port
Port of Tanjun Perak
Kota Kinabalu
Bandar Seri Begawan
Sandakan
Miri Port
Bintulu Port
Kuching
Pontianak Port
Tanjung Bara Terminal
Balikpapan Port
Banjarmasin
Pantoloan
Makassar
Kendari
Bitung Port
Ternate
Sorong
Ambon
Jayapura
Dili
Tenau Kupang


26 PERMEABLE GREEN STREETS
57 AFFORESTATION PARK
63 ECOLOGICAL AIRFIELD BUFFERS
31 LANDFIL REGENERATION PARK
61 ECO-SENSITIVE RAILWAY
56 SOIL BIO-REMEDIATION
18 TIDAL FLAT NOURRISHMENT
35 MANGROVE PROTECTIVE SHIELD
11 BIO-RETENTION SWALES
27 GREEN BLUE ROOFS
12 PHYTO-REMEDIATION WETLAND
65 ELECTRO-WETLANDS
Habitat Regeneration
60 WILDLIFE OVERPASS
24 COASTAL FOREST SHIELD
69 MARINE SEDIMENTATION BASIN
66 GRAVEL WETLANDS
9 PLASTIC WASTE BIODEFENCE
67 VERTICAL DOCK REEFS
51 FLOATING TREATMENT WETLANDS
62 PHYTO-REMEDIATION FOREST
34 POLLINATION CORRIDOR
22 RICH REVETMENTS
19 SEAGRASS MEADOWS
Fine sediment placing
68 ARTIFICIAL FLOATING REEFS
22 RICH REVETMENTS
Salt marsh nourishment
25 ARTIFICIAL OYSTER REEF
Wave energy dissipation
41 CONSTRUCTED NATURE ISLAND

CSL06 – Regenerative Agriculture



CSL06 – Regenerative Agriculture

Developing regenerative agriculture as a ‘climate-sensitive eco-landscape’ in Southeast Asia covers diverse, climate-smart farming practices, including terrestrial agriculture, forestry, aquaculture, floating farms, and paludiculture (wetland or peatland cultivation), that aim to enhance food security while protecting biodiversity and ecosystem health. This landscape category prioritises sustainable, diversified practices that restore soil health, promote water conservation, and prevent risks like pollution, saltwater intrusion, and land degradation. Implementing NbS within these systems - such as agroforestry, integrated aquaculture, and wetland management - supports resilient agriculture that mitigates climate impacts, counters the negative effects of monocultures, and enhances productivity without compromising environmental integrity.

In Indonesia, rice-fish farming systems in West Java integrate aquaculture with rice paddies, promoting biodiversity, reducing pesticide use, and improving food security by producing both fish and rice. Viet Nam’s Mekong Delta has adopted floating rice cultivation and mangrove-aquaculture integration to manage saltwater intrusion, increase resilience to flooding, and enhance local livelihoods while protecting coastal ecosystems.

Agriculture is central to both the economy and food security in Southeast Asia. Regenerative practices that integrate NbS offer a powerful approach to creating resilient and sustainable farming systems. These landscapes, rich in biodiversity and tradition, face challenges such as soil degradation, water scarcity, shifting rainfall patterns, and the pressures of intensive farming. By leveraging NbS, agricultural systems can regenerate soil health, enhance water management, and mitigate the impacts of climate change, ensuring long-term agricultural productivity and ecosystem restoration.

Agroforestry systems that combine native trees with traditional crops, such as those practiced in Indonesia and the Philippines, improve soil fertility, increase water retention, and support biodiversity. This approach is particularly effective in upland farming, where **terraced farming** and agroforestry work together to reduce erosion and capture rainfall. In the fertile rice paddies of Vietnam and Thailand, techniques like **drainage reduction** and **flood-based agriculture** help optimise water use and prevent runoff, ensuring that water resources are managed efficiently, and that rice production remains stable despite climate variability.

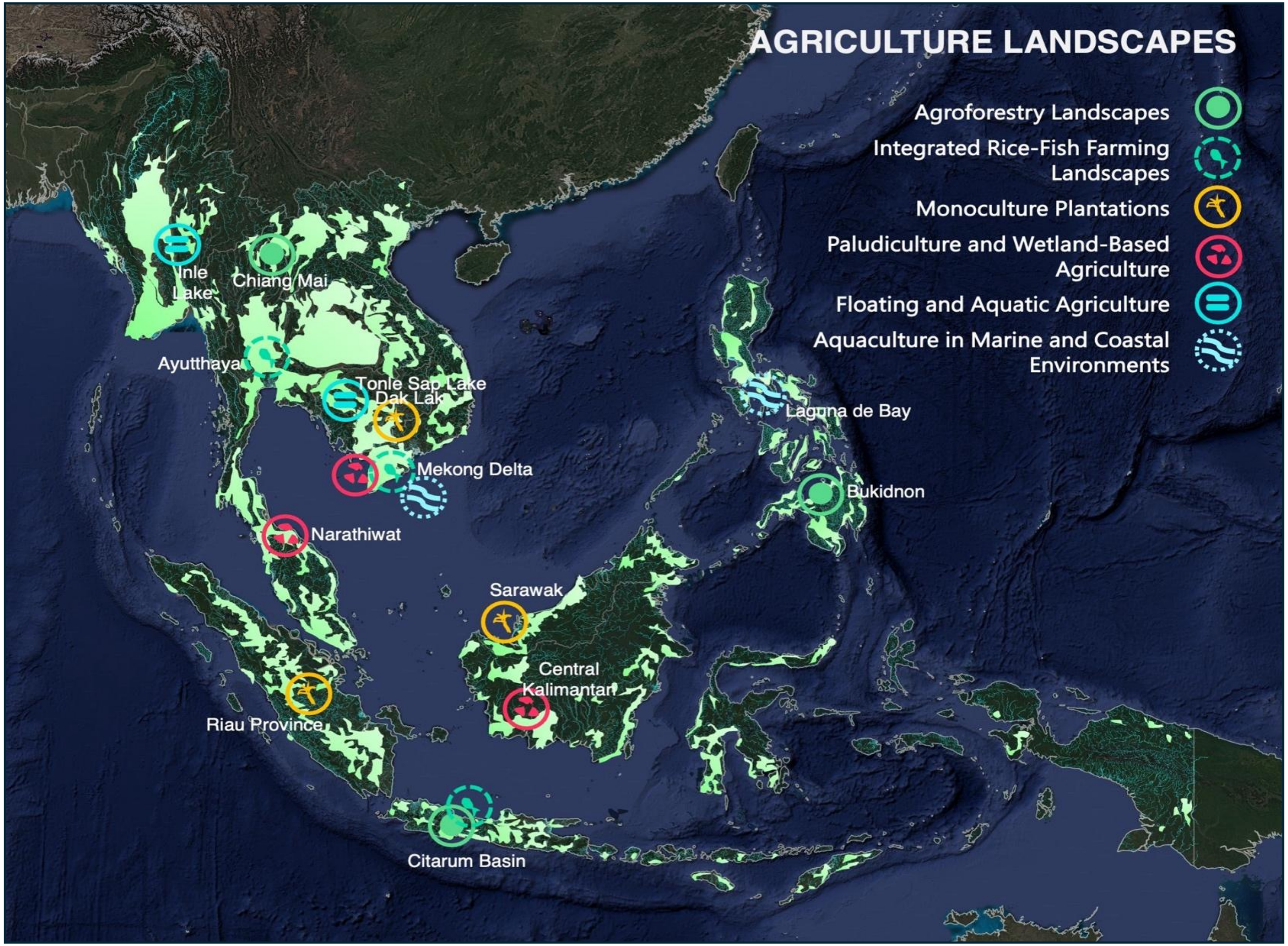
Paludiculture, a practice focused on the restoration of peatlands through sustainable land use, is gaining traction in Indonesia and Malaysia. By restoring peatlands, these areas can sequester significant amounts of carbon, prevent subsidence, and maintain water levels in surrounding areas.

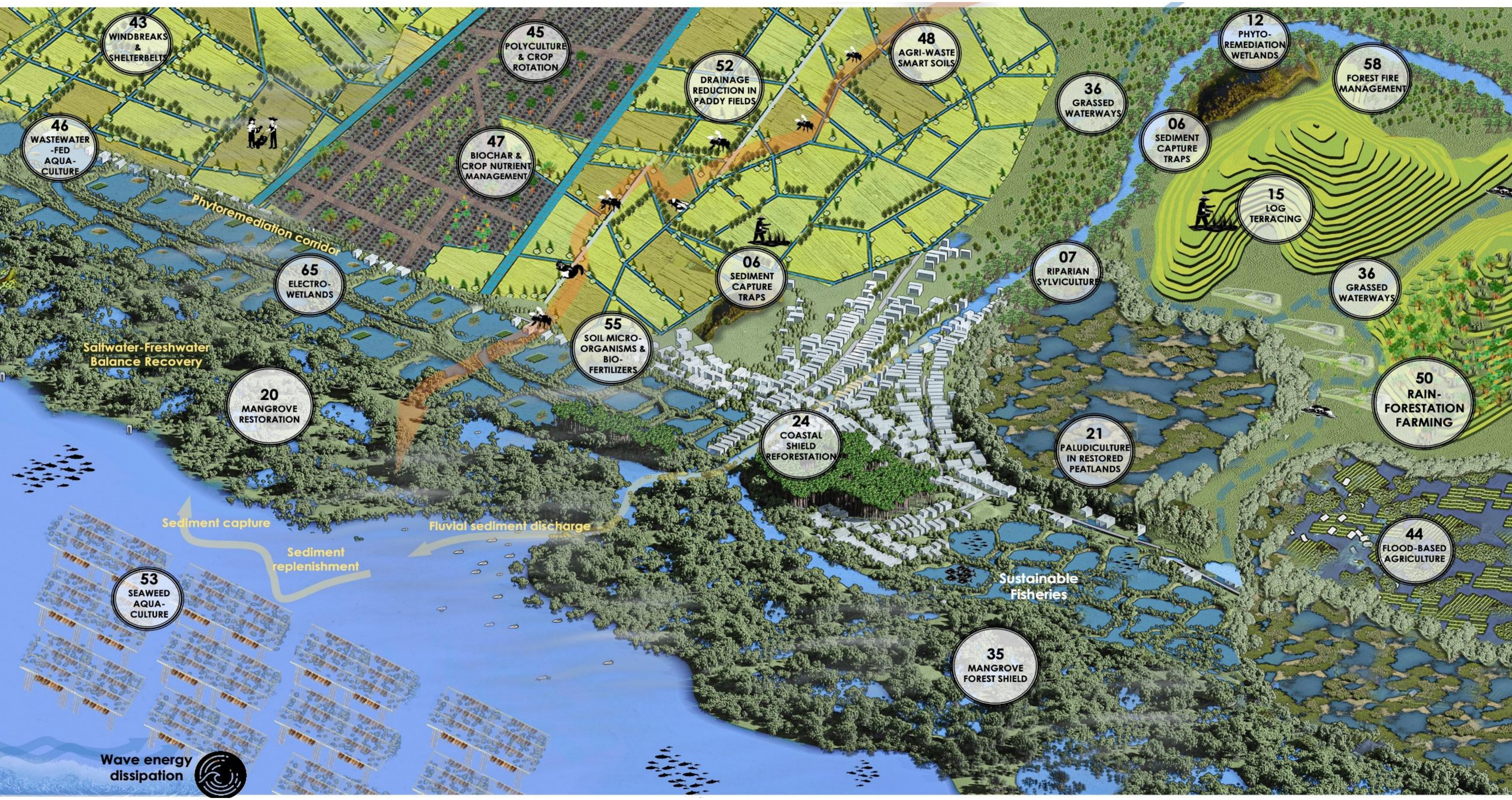
Similarly, **riparian buffer zones**, managed by local communities in places like Cambodia and Laos, help protect watercourses from agricultural pollution and ensure reliable irrigation for crops.

Polyculture and crop rotation, practices long embraced by local farmers, are being enhanced by the integration of organic farming methods that reduce dependency on chemical fertilisers and pesticides. This approach builds resilience to pests and extreme weather events, contributing to both environmental and economic sustainability.

Innovative solutions such as **biochar** for crop nutrient management, **agri-waste smart soils**, and **seaweed aquaculture** are improving nutrient cycles, reducing waste, and supporting alternative income streams for coastal communities.

In areas prone to strong winds and extreme weather, **windbreaks and shelterbelts** offer critical protection to crops and farming communities, while reforestation techniques, including **rainforestation farming** and **riparian sylviculture**, help restore landscapes and strengthen the resilience of rural areas to climate impacts.


AGRICULTURE LANDSCAPES
Agroforestry Landscapes
Integrated Rice-Fish Farming Landscapes
Monoculture Plantations
Paludiculture and Wetland-Based Agriculture
Floating and Aquatic Agriculture
Aquaculture in Marine and Coastal Environments
Inle Lake
Chiang Mai
Ayutthaya
Tonle Sap Lake
Dak Lak
Mekong Delta
Narathiwat
Laguna de Bay
Bukidnon
Sarawak
Central Kalimantan
Riau Province
Citarum Basin


43 WINDBREAKS & SHELTERBELTS
45 POLYCULTURE & CROP ROTATION
52 DRAINAGE REDUCTION IN PADDY FIELDS
48 AGRI-WASTE SMART SOILS
12 PHYTO-REMEDIATION WETLANDS
58 FOREST FIRE MANAGEMENT
36 GRASSED WATERWAYS
06 SEDIMENT CAPTURE TRAPS
46 WASTEWATER -FED AQUA-CULTURE
47 BIOCHAR & CROP NUTRIENT MANAGEMENT
15 LOG TERRACING
Phytoremediation corridor
65 ELECTRO-WETLANDS
06 SEDIMENT CAPTURE TRAPS
07 RIPARIAN SYLVICULTURE
36 GRASSED WATERWAYS
55 SOIL MICRO-ORGANISMS & BIO-FERTILIZERS
Saltwater-Freshwater Balance Recovery
20 MANGROVE RESTORATION
50 RAIN-FORESTATION FARMING
24 COASTAL SHIELD REFORESTATION
21 PALUDICULTURE IN RESTORED PEATLANDS
Sediment capture
Fluvial sediment discharge
Sediment replenishment
44 FLOOD-BASED AGRICULTURE
53 SEAWEED AQUA-CULTURE
Sustainable Fisheries
35 MANGROVE FOREST SHIELD
Wave energy dissipation


CSL07 – Healthy Forests and Natural Habitats

CSL07 – Healthy Forests and Natural Habitats

The diverse forest types in Southeast Asia share common numerous threats such as deforestation, biodiversity loss, landslides, floods, droughts, and forest fires. These threats have prompted numerous reforestation, afforestation, and conservation projects that involve communities and aim to bolster local economies. This climate-sensitive landscape category has a different approach as it covers all forest types in relation with their potential to recover biodiversity, improve agricultural practices, develop innovative solutions to protect forests from urbanisation, industrialisation, mining, infrastructure, and related pollution risks.

Southeast Asia is rich in biodiversity and hosts crucial forest ecosystems. Maintaining healthy forests and natural habitats is essential for climate resilience, sustainable livelihoods, and biodiversity conservation. The region faces significant challenges, including deforestation and land degradation due to agriculture and urbanisation, and the increasing risks posed by climate extremes such as floods, droughts, and fires. To address these, a comprehensive approach using NbS is critical as they are designed to restore and protect forests, mitigate the impacts of human activities, and create landscapes that are resilient to future climate and disaster risks.

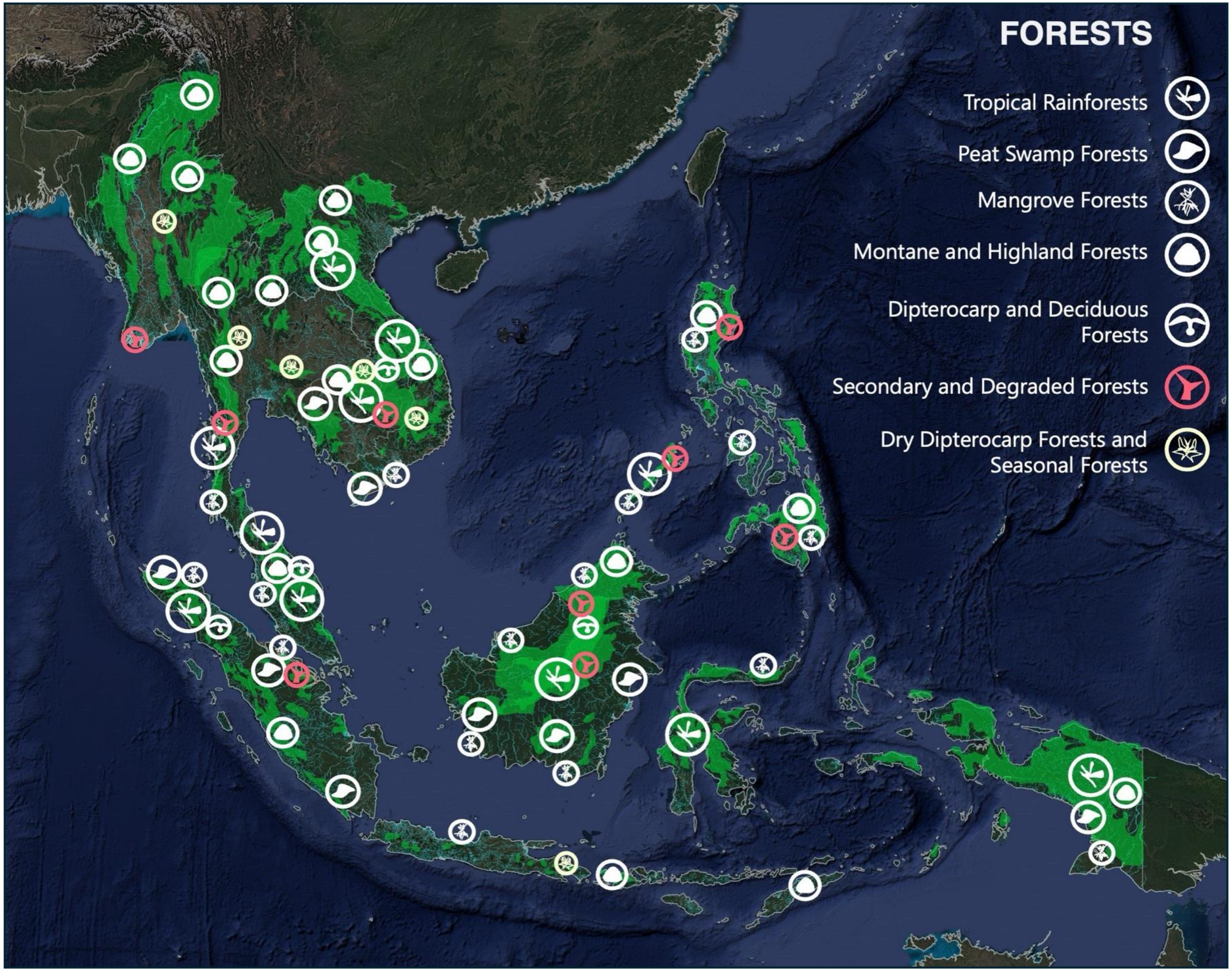
Restoring degraded forests with native species, particularly in the upland areas of the Philippines (the Cordillera Mountains) and Viet Nam (the Annamite Range), helps stabilise soils, reduces landslide risks, and improves water cycles. **Upland reforestation** and **agroforestry**, combined with sustainable practices such as **rainforestation farming** in the Philippines' Sierra Madre mountains, promote biodiversity and enhance carbon sequestration.

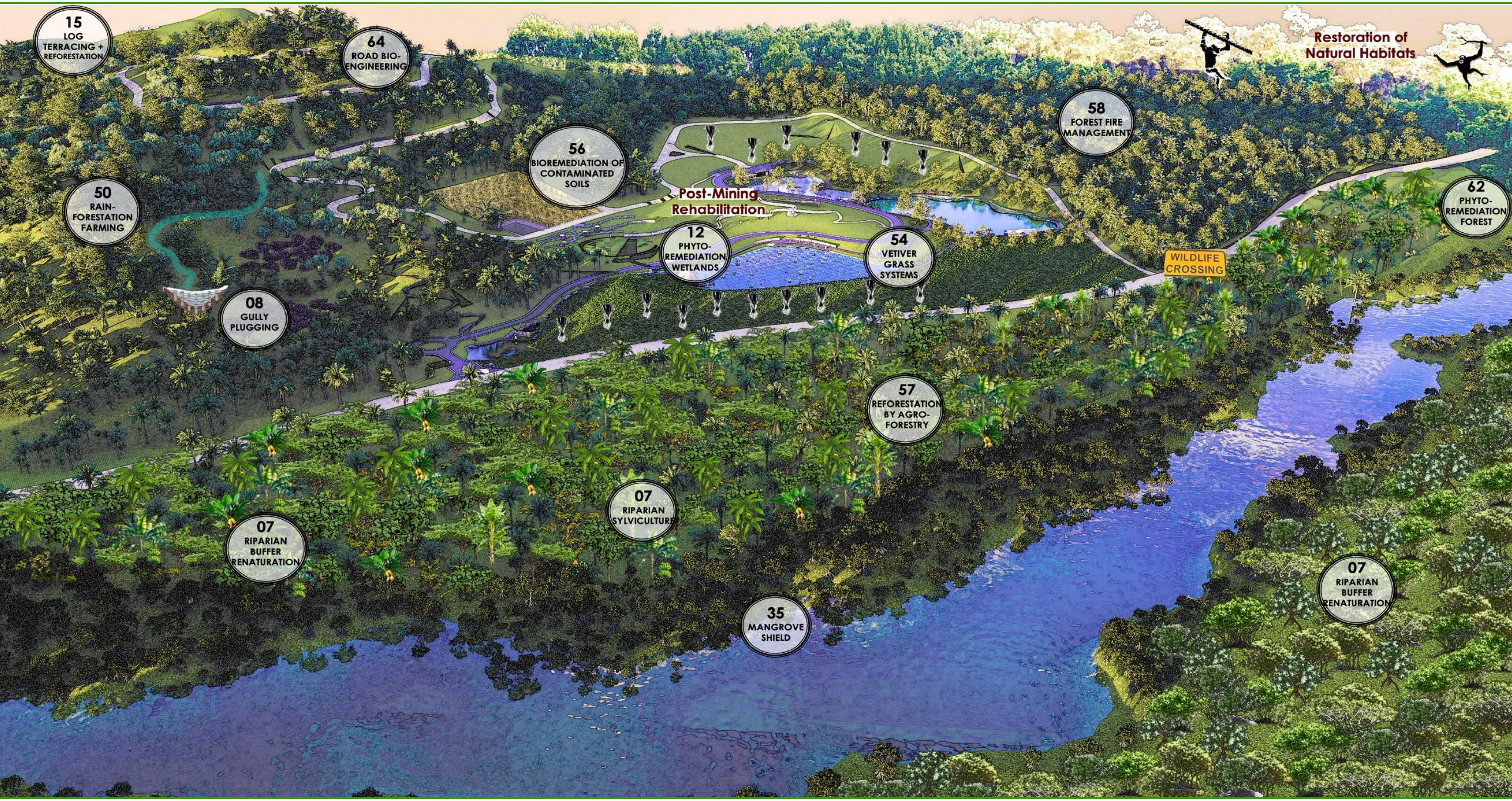
In Indonesia, **peat swamp forest restoration** in areas like Central Kalimantan plays a vital role in reducing carbon emissions, preventing fires, and safeguarding unique ecosystems. Similarly, **riparian forest buffers** along waterways, especially in regions like the Tonle Sap Lake basin in Cambodia and the Mekong Delta in Viet Nam, protect water quality, reduce soil erosion, and mitigate flooding risks while providing critical habitats for wildlife.

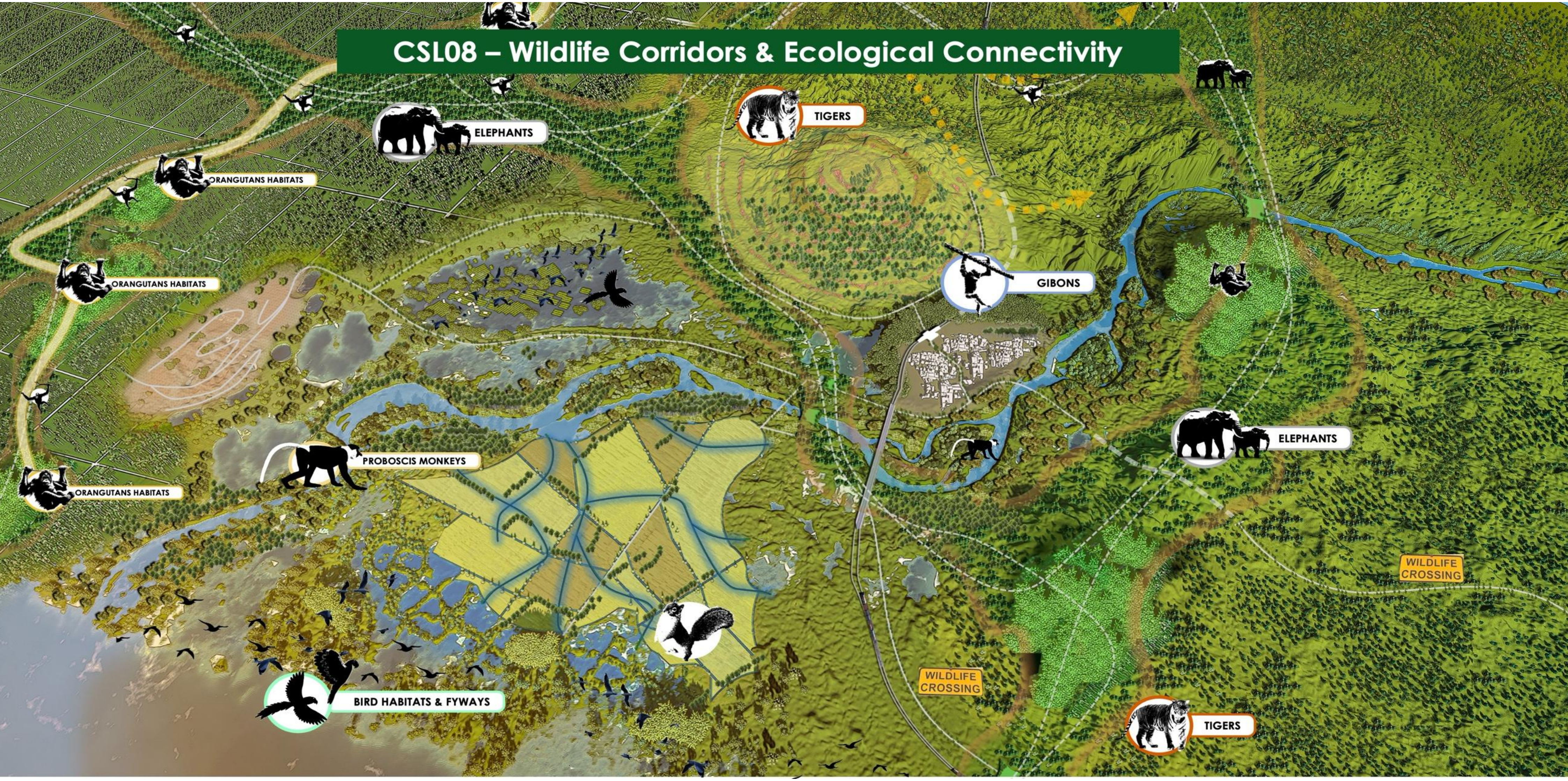
To restore balance in areas affected by mining, urbanisation, and infrastructure development, techniques like **bioengineering remediation of contaminated soils**, **phytoremediation forest corridors**, and **gully plugging** have been identified as essential NbS. These strategies ensure that degraded landscapes, such as those impacted by illegal logging in Malaysia's Taman Negara National Park or urban expansion in Indonesia’s Java island, can recover, support biodiversity, and become functional ecosystems once again. Moreover, community-based initiatives such as community forestry in Thailand's northern forests and assisted natural regeneration in Laos' Xieng Khouang region foster local stewardship and ensure that forests are managed sustainably, benefiting both the environment and local communities.

In coastal areas, **mangrove forest restoration** in places like the Sundarbans in Indonesia, the coastlines of Thailand, and Vietnam's Mekong Delta enhances coastal protection against storm surges and sea-level rise while also providing important ecosystem services such as carbon sequestration and biodiversity support.

This is particularly relevant for countries where mangrove ecosystems are critical to both the environment and the livelihoods of coastal communities. Similarly, the integration of **riparian sylviculture** and **vetiver grass systems** along watercourses in Cambodia's Cardamom Mountains helps protect against erosion and improves water quality, providing further resilience in flood-prone regions.


FORESTS
Tropical Rainforests
Peat Swamp Forests
Mangrove Forests
Montane and Highland Forests
Dipterocarp and Deciduous Forests
Secondary and Degraded Forests
Dry Dipterocarp Forests and Seasonal Forests


15
LOG
TERRACING +
REFORESTATION
64
ROAD BIO-
ENGINEERING
Restoration of
Natural Habitats
58
FOREST FIRE
MANAGEMENT
56
BIOREMEDIATION OF
CONTAMINATED
SOILS
50
RAIN-
FORESTATION
FARMING
Post-Mining
Rehabilitation
62
PHYTO-
REMEDIATION
FOREST
12
PHYTO-
REMEDIATION
WETLANDS
54
VETIVER
GRASS
SYSTEMS
WILDLIFE
CROSSING
08
GULLY
PLUGGING
57
REFORESTATION
BY AGRO-
FORESTRY
07
RIPARIAN
SYLVICULTURE
07
RIPARIAN
BUFFER
RENATURATION
07
RIPARIAN
BUFFER
RENATURATION
35
MANGROVE
SHIELD


CSL08 – Wildlife Corridors & Ecological Connectivity
TIGERS
ELEPHANTS
ORANGUTANS HABITATS
ORANGUTANS HABITATS
GIBONS
ELEPHANTS
PROBOSCIS MONKEYS
ORANGUTANS HABITATS
WILDLIFE CROSSING
WILDLIFE CROSSING
BIRD HABITATS & FYWAYS
TIGERS

CSL08 – Wildlife Corridors for Ecological Connectivity

Wildlife corridors in Southeast Asia are crucial for maintaining biodiversity and supporting the movement of larger species across fragmented habitats. Many corridors face spatial interruptions and biodiversity loss due to monocultures, urbanisation, infrastructure development, and mining. There is a high potential for ecosystem-based approaches and nature-based solutions to contribute to the sustainability of those eco-corridors, as they play roles of linkages for fauna and flora, of buffer zones between conflictual land use systems and between nature and human activity. For this reason, wildlife corridors are identified as climate-sensitive landscapes, and their principles can also be applied to seascapes. There are promising initiatives that aim at restoring connectivity for ecological resilience.

Southeast Asia is shaped by rapidly expanding urbanisation, agriculture, and infrastructure development, and this development model poses a growing threat to biodiversity and the integrity of ecosystems. Maintaining ecological connectivity is vital for the survival of many species. The fragmentation of natural habitats disrupts migratory paths, isolates populations, and intensifies the challenges species face in adapting to climate change. To address these pressing concerns, a strategic nature-based approach to establishing wildlife corridors for ecological connectivity is being developed, incorporating a suite NbS tailored to regional and local climatic, biophysical, and socio-economic characteristics.

Key to this strategy is the restoration and establishment of wildlife mobility linkages across fragmented landscapes, connecting habitats that have been severed by agriculture, infrastructure, and urbanisation.

For instance, in Malaysia's Borneo region, efforts to **restore wildlife corridors** are crucial for the conservation of endangered species like the Bornean orangutan and proboscis monkey, whose survival is threatened by deforestation and habitat fragmentation.

In Thailand, the creation of ecological corridors through **upland reforestation** and **agroforestry** can maintain habitat continuity for species such as tigers, leopards, and elephants, enabling them to migrate freely between protected areas like the Huai Kha Khaeng Wildlife Sanctuary and the Thung Yai Naresuan Wildlife Sanctuary.

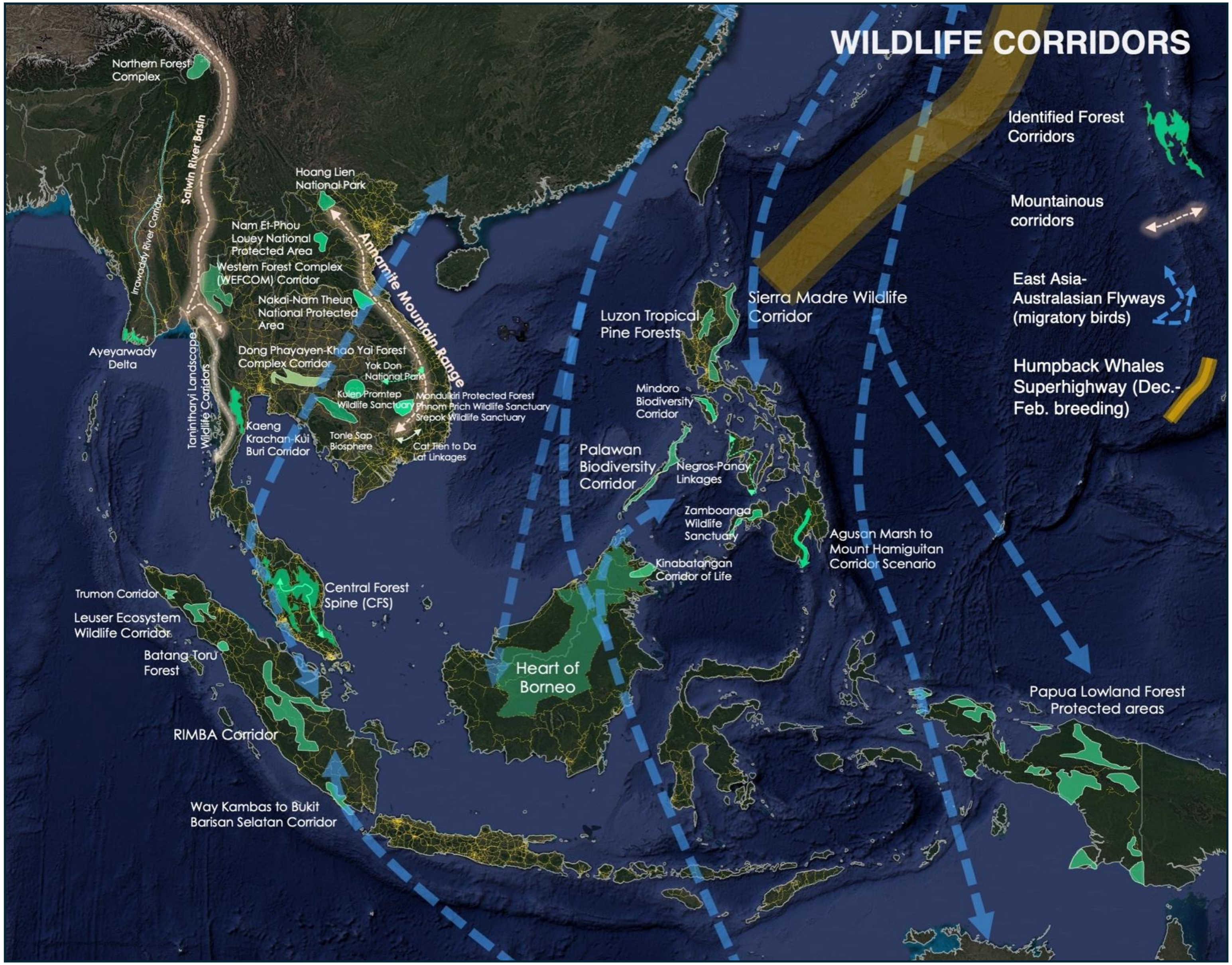
Ecological bridges and underpasses are essential solutions in areas where infrastructure divides wildlife habitats. In Indonesia, where palm oil plantations and logging activities have heavily impacted orangutan populations in Sumatra and Borneo, the installation of wildlife corridors, such as overpasses and tunnels, could facilitate the safe passage of these critically endangered species across human-dominated landscapes.

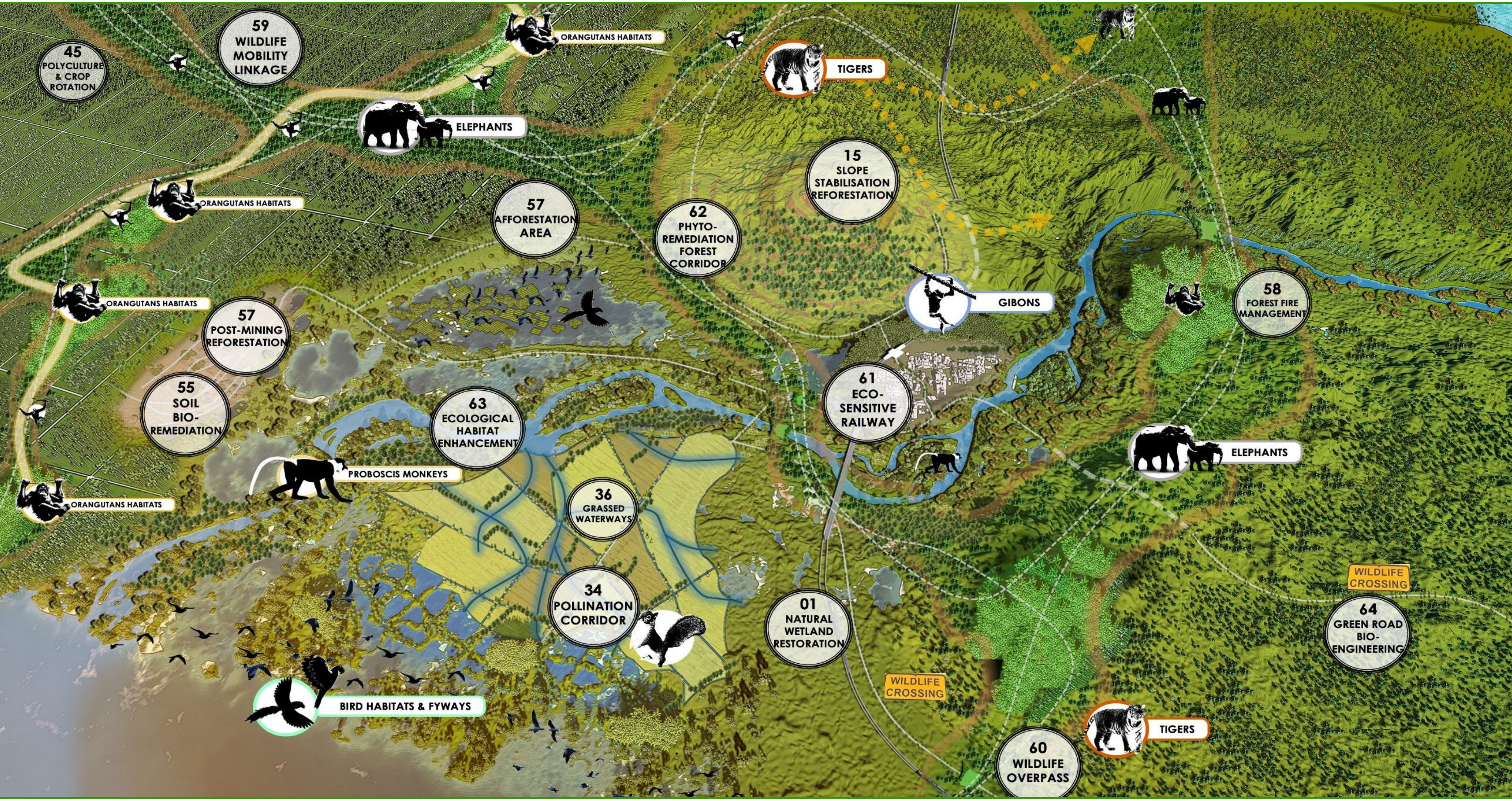
In Viet Nam's Central Highlands, the creation of **wildlife linkages** over roads and railways is improving the movement of animals like sun bears and gibbons, which are increasingly affected by habitat loss and fragmentation.

Community involvement plays a key role in mitigating human-wildlife conflict, which is particularly common in regions like the forests of Cambodia and Laos, where agricultural expansion often encroaches on protected areas. By establishing **community-managed buffer zones** around parks and reserves, such as the Phnom Prich Wildlife Sanctuary in Cambodia, local populations can help reduce conflicts with wildlife, while promoting sustainable livelihoods through eco-tourism and non-timber forest products. This approach helps to balance conservation goals with the needs of rural communities, fostering both ecological and social resilience.

Wetland connectivity is another critical aspect of wildlife corridors in Southeast Asia. The restoration of riparian and wetland habitats, particularly along important migratory routes, is vital for species such as migratory birds and amphibians. The Mekong Delta in Vietnam and Cambodia’s Tonle Sap Lake provide important **flyways** for birds like the globally threatened Sarus crane and waterfowl species. Restoring wetlands and creating **bioretention ponds** in urban and rural areas enhances habitat quality and supports migratory movements, providing safe resting and feeding grounds.

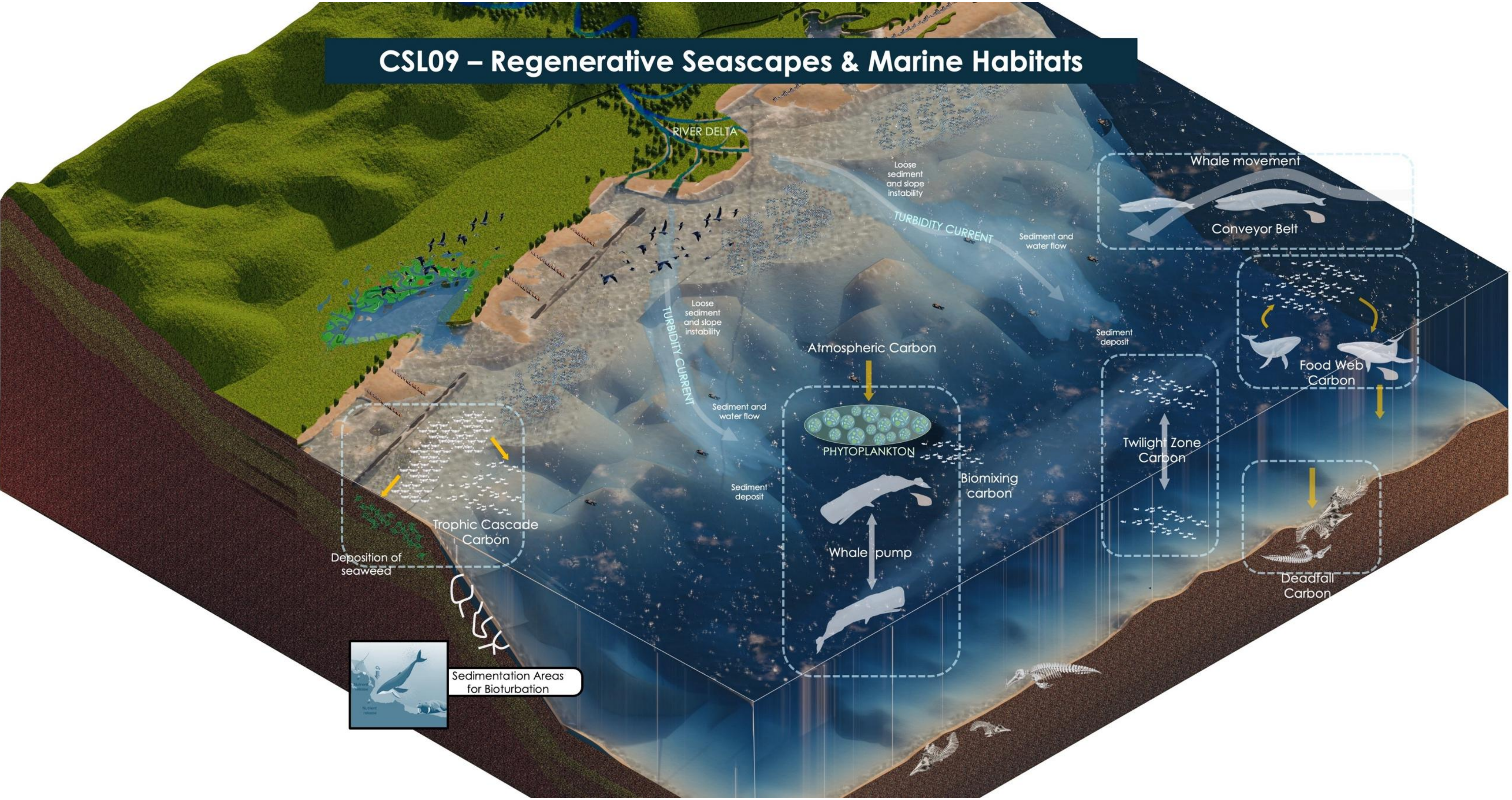
By restoring wildlife corridors, integrating ecological bridges, and creating connectivity between forests, wetlands, and marine ecosystems, Southeast Asia can protect its diverse species, maintain ecosystem services like pollination and seed dispersal, and increase resilience to climate and disaster risks.


WILDLIFE CORRIDORS
Identified Forest Corridors
Mountainous corridors
East Asia-Australasian Flyways (migratory birds)
Humpback Whales Superhighway (Dec.-Feb. breeding)
Northern Forest Complex
Salwin River Basin
Irrowaddy River Corridor
Hoang Lien National Park
Nam Et-Phou Louey National Protected Area
Western Forest Complex (WEFCOM) Corridor
Annamite Mountain Range
Nakai-Nam Theun National Protected Area
Ayeyarwady Delta
Tanintharyi Landscape Wildlife Corridors
Dong Phayayen-Khao Yai Forest Complex Corridor
Yok Don National Park
Kulen Promtep Wildlife Sanctuary
Mondulkiri Protected Forest
Phnom Prich Wildlife Sanctuary
Srepok Wildlife Sanctuary
Kaeng Krachan-Kui Buri Corridor
Tonle Sap Biosphere
Cat Tien to Da Lat Linkages
Luzon Tropical Pine Forests
Sierra Madre Wildlife Corridor
Mindoro Biodiversity Corridor
Palawan Biodiversity Corridor
Negros-Panay Linkages
Zamboanga Wildlife Sanctuary
Agusan Marsh to Mount Hamiguitan Corridor Scenario
Kinabatangan Corridor of Life
Central Forest Spine (CFS)
Trumon Corridor
Leuser Ecosystem Wildlife Corridor
Batang Toru Forest
Heart of Borneo
RIMBA Corridor
Papua Lowland Forest Protected areas
Way Kambas to Bukit Barisan Selatan Corridor



45 POLYCULTURE & CROP ROTATION
59 WILDLIFE MOBILITY LINKAGE
ORANGUTANS HABITATS
ELEPHANTS
ORANGUTANS HABITATS
TIGERS
15 SLOPE STABILISATION REFORESTATION
57 AFFORESTATION AREA
62 PHYTO-REMEDIATION FOREST CORRIDOR
ORANGUTANS HABITATS
57 POST-MINING REFORESTATION
GIBONS
58 FOREST FIRE MANAGEMENT
55 SOIL BIO-REMEDIATION
63 ECOLOGICAL HABITAT ENHANCEMENT
61 ECO-SENSITIVE RAILWAY
ELEPHANTS
PROBOSCIS MONKEYS
ORANGUTANS HABITATS
36 GRASSED WATERWAYS
WILDLIFE CROSSING
34 POLLINATION CORRIDOR
01 NATURAL WETLAND RESTORATION
64 GREEN ROAD BIO-ENGINEERING
WILDLIFE CROSSING
BIRD HABITATS & FYWAYS
TIGERS
60 WILDLIFE OVERPASS

CSL09 – Regenerative Seascapes & Marine Habitats



CSL09 – Regenerative Seascapes and Marine Habitats

Regenerative seascapes and marine habitats refer to coastal and marine ecosystems, including coral reefs, seagrass meadows, kelp forests, and oyster reefs, that not only support biodiversity but also provide essential ecosystem services to coastal communities in Southeast Asia. These habitats help buffer shorelines against storms, enhance fish stocks, sequester carbon, and improve water quality. However, they face significant threats from climate change, overfishing, and pollution. Ecosystem-based approaches (EbA) and NbS, such as coral reef restoration, mangrove planting, and sustainable fisheries management, are critical to regenerating these habitats and restoring ecological balance, while also supporting sustainable livelihoods and food security for coastal populations.

Southeast Asia's marine ecosystems are not only among the most biologically rich in the world but also face significant pressures from climate change, overfishing, coastal development, and pollution. To address these challenges and create a more resilient and regenerative marine environment, a strategic approach involving NbS is essential. These solutions aim to restore and enhance marine habitats, increase biodiversity, support coastal protection, and strengthen the sustainability of local livelihoods, all while contributing to climate adaptation and mitigation efforts.

The regeneration of marine habitats begins with **coral reef restoration**, an urgent priority in the region, where reefs are being damaged by both natural and anthropogenic factors. Coral gardening and the establishment of **coral nurseries** play a critical role in rehabilitating these vital ecosystems. For instance, in the Philippines, coral nurseries and reef restoration programmes along the coast of Palawan and Sulu are rebuilding degraded reefs, improving biodiversity, and reducing wave energy, which in turn protects coastal infrastructure from the impacts of storms and rising sea levels. Similarly, in Indonesia, the use of **artificial reef structures** not only provides habitats for marine species but also reduces the risk of coastal erosion and wave damage, creating a more stable coastline.

Mangrove-seagrass-coral ecosystems are another essential focus for restoration in Southeast Asia, particularly as they provide critical services such as water filtration, carbon sequestration, and habitat for fish stocks. In Malaysia's Sarawak region, efforts to restore degraded mangrove and **seagrass beds** have revived coastal ecosystems, promoting biodiversity, enhancing fisheries, and improving water quality. These systems also act as natural barriers, reducing the impact of storm surges and tsunamis while providing critical nursery grounds for marine life.

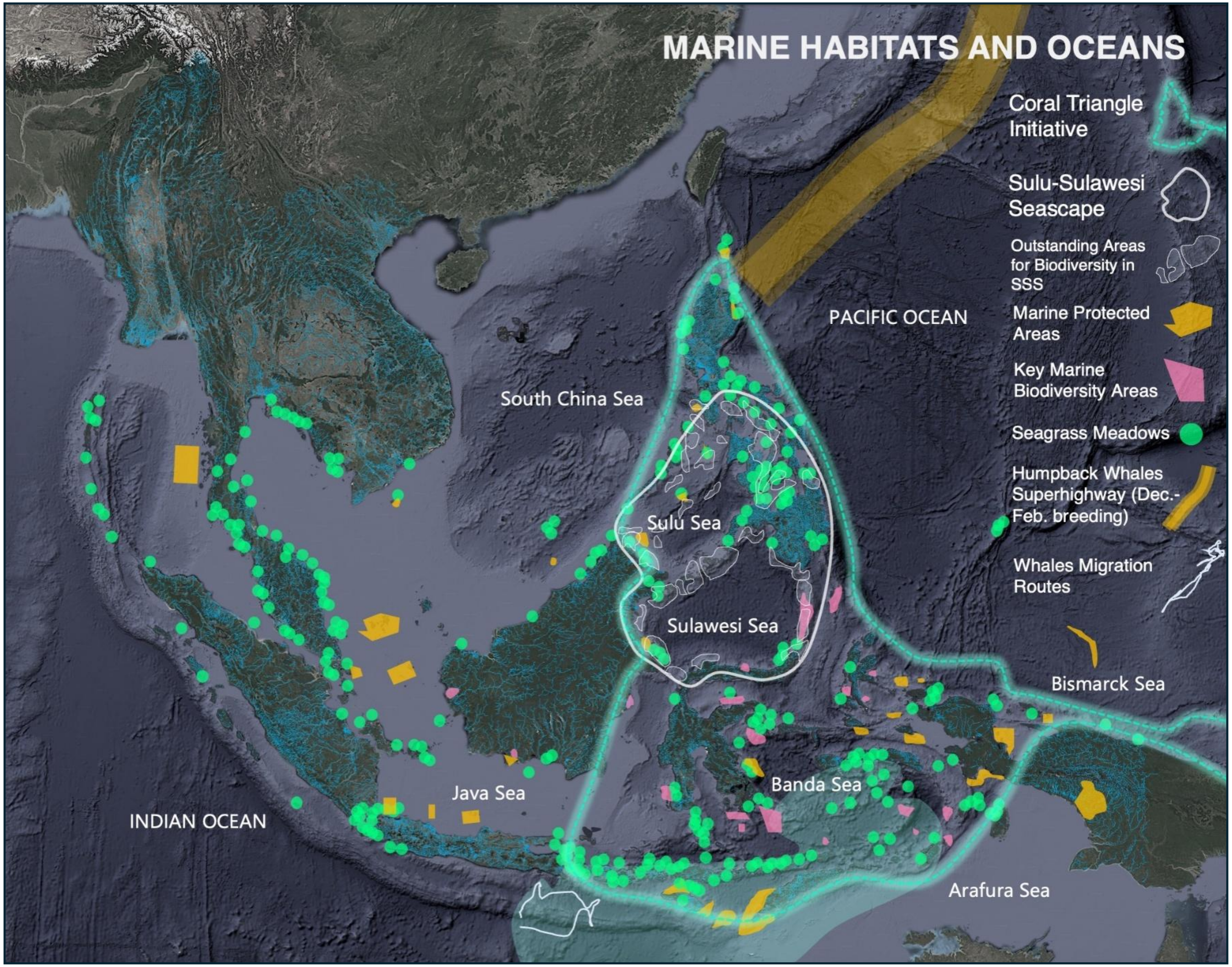
Beyond habitat restoration, integrating sustainable and healthy marine aquaculture systems is crucial for easing pressure on wild fish stocks. In Viet Nam’s Mekong Delta, integrated aquaculture systems that combine fish farming with mangrove restoration are proving successful in maintaining ecological balance while supporting local communities. Similarly, in Thailand, **seaweed aquaculture** is being promoted not only as a source of income but also as an important contributor to ocean health, providing carbon sequestration and enhancing biodiversity in coastal waters.

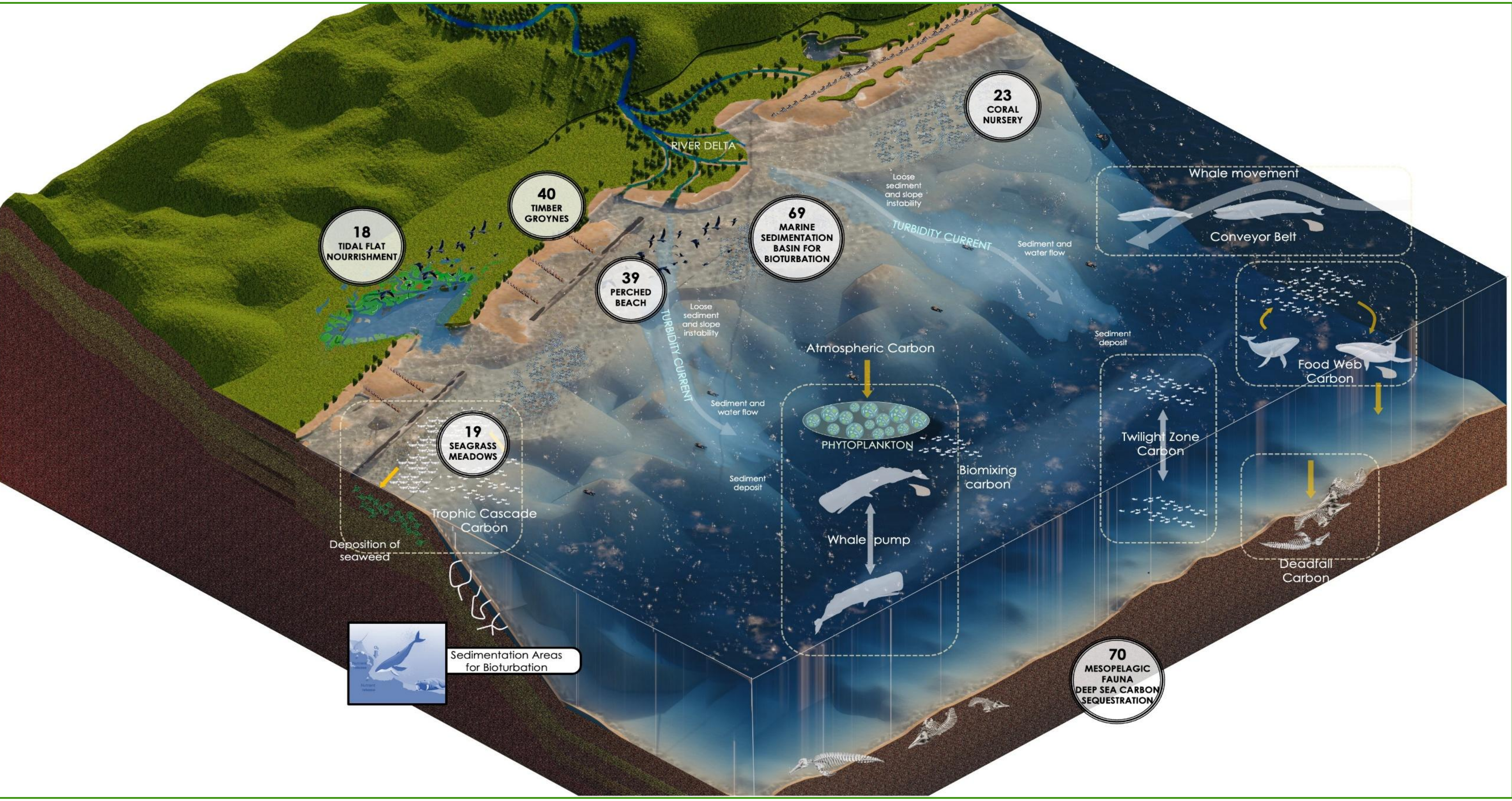
Artificial reefs and **rich marine revetments** are an innovative solution to enhance biodiversity and provide protection to coastal areas. These structures, which can be made from natural materials like **limestone** or even **artificial mats**, serve as habitats for a variety of marine organisms, boosting local fisheries and improving the resilience of coastal ecosystems.

The deep-sea environment, often overlooked in marine conservation efforts, is also a focus for regenerative strategies. In particular, the creation of **marine sedimentation basins and** the **sequestration of mesopelagic fauna**—organisms that inhabit the deep sea—are emerging as important methods for enhancing deep-sea biodiversity and improving the health of ocean ecosystems. These methods are being explored in regions like the South China Sea and the Sulu Sea, where deep-sea habitats host a rich diversity of species that play a critical role in the global carbon cycle.

The creation of community-led marine-protected areas (MPAs) is central to ensuring the long-term health of Southeast Asia's marine ecosystems. In Indonesia, the implementation of MPAs in regions like Raja Ampat and Komodo National Park has helped safeguard critical biodiversity hotspots and supported sustainable fisheries, benefiting both marine life and the livelihoods of local communities.

The integration of these NbS for marine habitats and oceans in Southeast Asia presents a holistic approach to restoring and enhancing coastal and marine ecosystems. These solutions, such as **coral reef nurseries**, **sustainable aquaculture**, **artificial reefs**, and the **protection of mangrove** and **seagrass** ecosystems, not only contribute to environmental restoration but also increase resilience to climate change impacts, support biodiversity, and provide long-term socio-economic benefits for coastal communities.


MARINE HABITATS AND OCEANS
Coral Triangle Initiative
Sulu-Sulawesi Seascape
Outstanding Areas for Biodiversity in SSS
Marine Protected Areas
Key Marine Biodiversity Areas
Seagrass Meadows
Humpback Whales Superhighway (Dec.-Feb. breeding)
Whales Migration Routes
PACIFIC OCEAN
South China Sea
Sulu Sea
Sulawesi Sea
Bismarck Sea
Banda Sea
Java Sea
INDIAN OCEAN
Arafura Sea



RIVER DELTA
23 CORAL NURSERY
40 TIMBER GROYNES
18 TIDAL FLAT NOURRISHMENT
69 MARINE SEDIMENTATION BASIN FOR BIOTURBATION
39 PERCHED BEACH
Loose sediment and slope instability
TURBIDITY CURRENT
Sediment and water flow
Sediment deposit
Whale movement
Conveyor Belt
Atmospheric Carbon
PHYTOPLANKTON
Biomixing carbon
Whale pump
Twilight Zone Carbon
Food Web Carbon
Deadfall Carbon
19 SEAGRASS MEADOWS
Trophic Cascade Carbon
Deposition of seaweed
Sedimentation Areas for Bioturbation
70 MESOPELAGIC FAUNA DEEP SEA CARBON SEQUESTRATION

Presenting 70 NbS Practices applied in the context of Southeast Asia as a Toolbox for Sustainable Development and Climate Adaptation and Mitigation

To support national and local governments, diverse stakeholders, and communities, this collection of 70 NbS provides practical, economic, and technical insights into how nature-inspired projects contribute to climate resilience, disaster risk reduction, and sustainable development across nine key landscape categories in Southeast Asia. Each NbS is carefully illustrated and described in a structured two-page format, linking ecological benefits with actionable solutions that can be integrated and scaled up across different landscapes.

Structured and Engaging Double-Page Layout: Each NbS will be systematically documented in a two-page spread to ensure clarity and ease of understanding:

Page 1: Overview and Integration in Southeast Asia's Landscapes

- **NbS Number and Title**: Clear identification of the solution.
- **Illustration**: A visual representation of how the NbS integrates into a Southeast Asian landscape and its potential for upscaling.
- **Summary Description**: A concise introduction to the NbS and its core function.
- **Supported Landscape Categories**: Identification of the relevant landscapes benefiting from the NbS.
- **Ecosystem-based Approaches (EbA)**: The ecological principles behind the NbS.
- **Key Problems Addressed**: The specific environmental, social, and economic challenges tackled by the NbS.
- **Ecosystem Services and Actions**: Classification of the NbS's contributions in terms of supporting, regulating, provisioning, and social benefits.
- **Technical Implementation Insights**: If applicable, a brief section outlining essential technical considerations.

Page 2: Technical Visuals, Benefits, and Feasibility

- **Diagrams and Plans**: Clear illustrations, section diagrams, or plans explaining how the NbS functions.
- **Additional Visuals**: Complementary perspectives, such as 3D renderings or axonometric views.
- **Implementation Challenges and Risks**: A list of four key challenges and considerations when applying the NbS.
- **Co-Benefits and Indicators**: Six primary co-benefits (e.g., biodiversity gains, economic resilience, disaster risk reduction) with relevant **performance indicators**.
- **Summary Cost Analysis**: A one-sentence evaluation of direct/indirect costs and benefits, time horizon, and risk assessment.
- **Project References and Implementation Opportunities**: Case studies of similar projects and locations across Southeast Asia where the NbS is applicable or has potential for implementation.

This structured format ensures that each NbS is clear, accessible, and applicable for decision-makers and practitioners working towards climate resilience and sustainable land and water management in Southeast Asia. By linking science with practical implementation, this approach promotes scalable, adaptable, and nature-driven solutions for urban, coastal, riverine, agricultural, and forested landscapes.

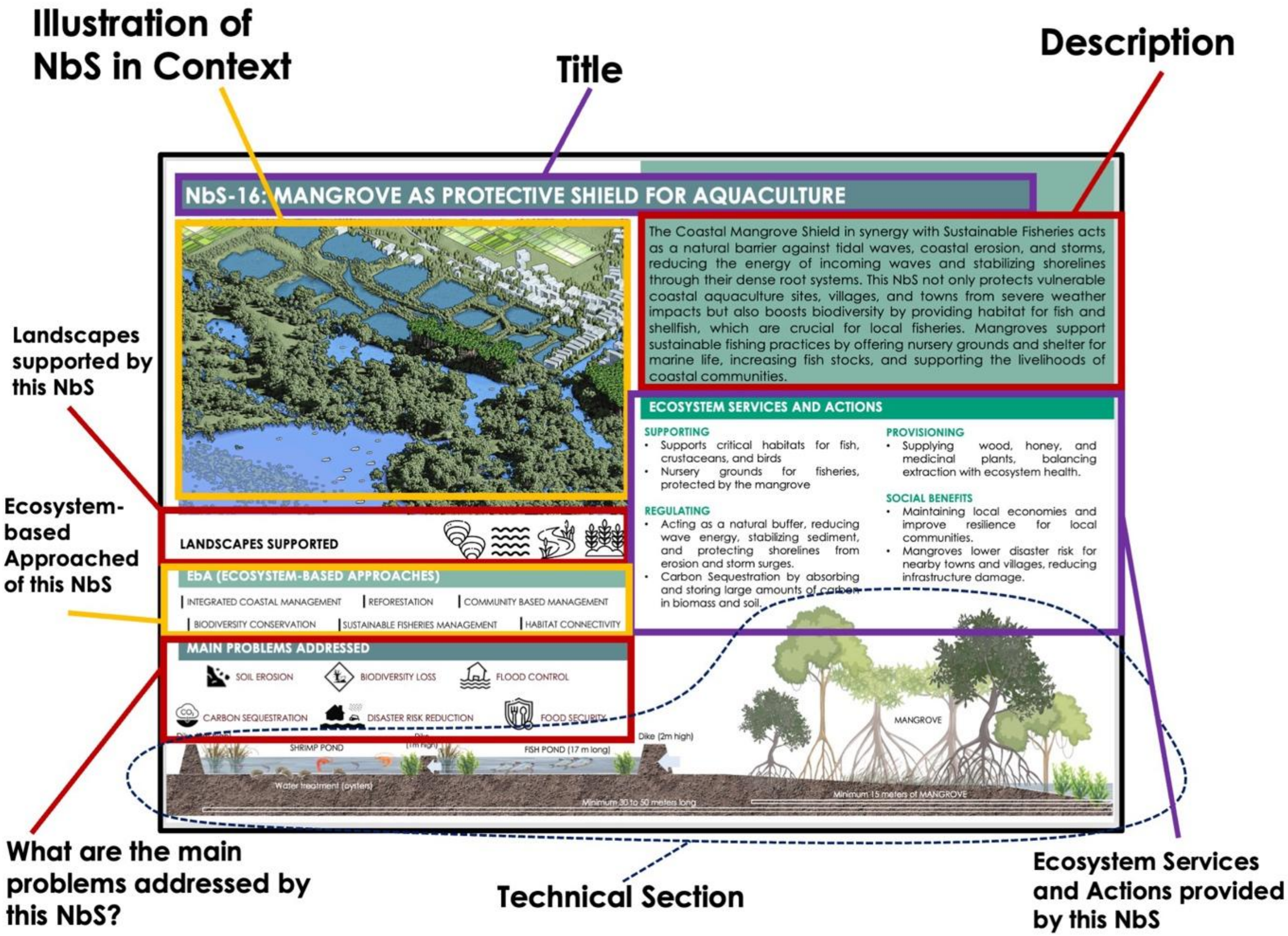
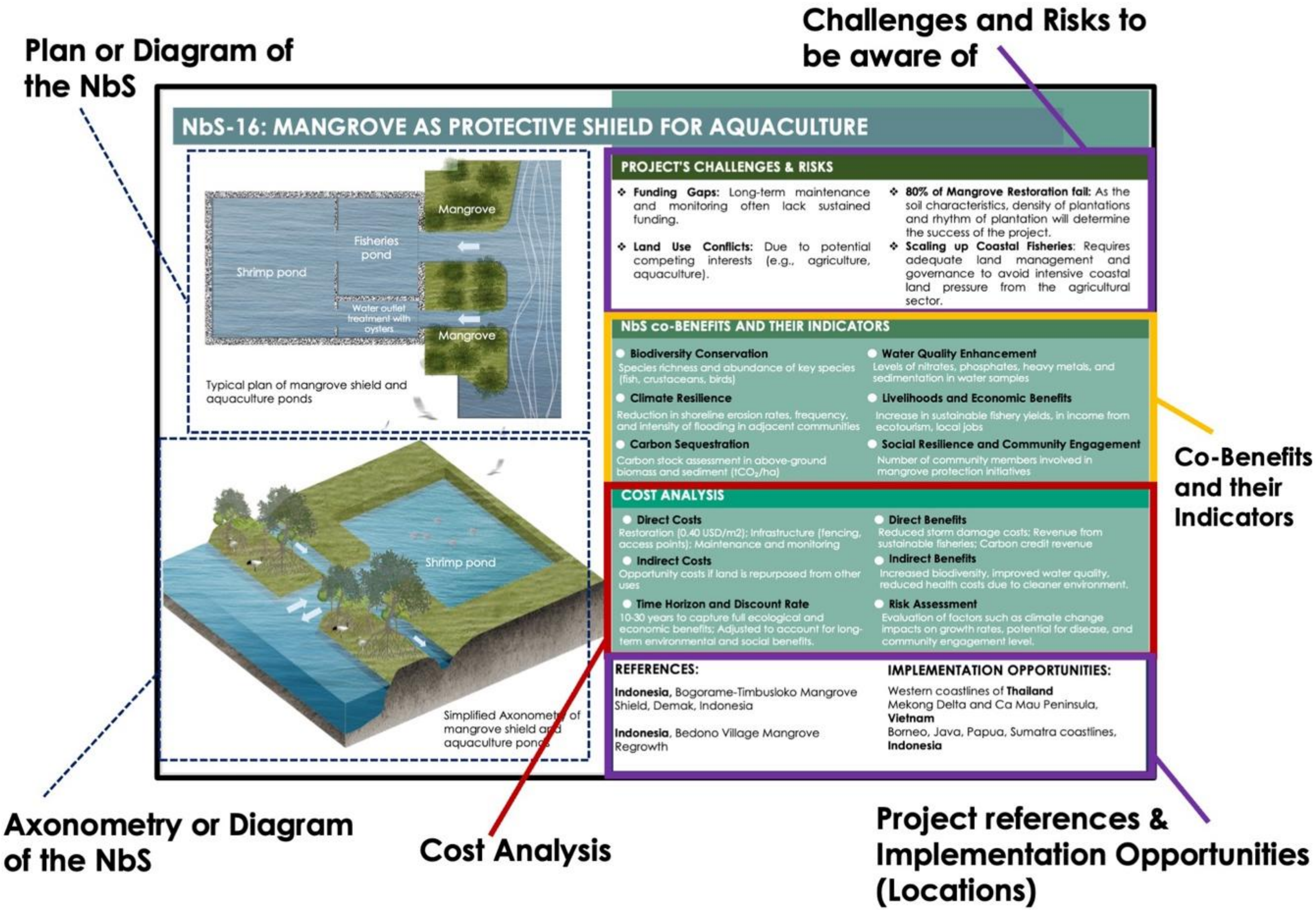


Illustration of NbS in Context
Title
Description
NbS-16: MANGROVE AS PROTECTIVE SHIELD FOR AQUACULTURE
The Coastal Mangrove Shield in synergy with Sustainable Fisheries acts as a natural barrier against tidal waves, coastal erosion, and storms, reducing the energy of incoming waves and stabilizing shorelines through their dense root systems. This NbS not only protects vulnerable coastal aquaculture sites, villages, and towns from severe weather impacts but also boosts biodiversity by providing habitat for fish and shellfish, which are crucial for local fisheries. Mangroves support sustainable fishing practices by offering nursery grounds and shelter for marine life, increasing fish stocks, and supporting the livelihoods of coastal communities.
ECOSYSTEM SERVICES AND ACTIONS
SUPPORTING
• Supports critical habitats for fish, crustaceans, and birds
• Nursery grounds for fisheries, protected by the mangrove
REGULATING
• Acting as a natural buffer, reducing wave energy, stabilizing sediment, and protecting shorelines from erosion and storm surges.
• Carbon Sequestration by absorbing and storing large amounts of carbon in biomass and soil.
PROVISIONING
• Supplying wood, honey, and medicinal plants, balancing extraction with ecosystem health.
SOCIAL BENEFITS
• Maintaining local economies and improve resilience for local communities.
• Mangroves lower disaster risk for nearby towns and villages, reducing infrastructure damage.
Landscapes supported by this NbS
LANDSCAPES SUPPORTED
Ecosystem-based Approached of this NbS
EbA (ECOSYSTEM-BASED APPROACHES)
INTEGRATED COASTAL MANAGEMENT
REFORESTATION
COMMUNITY BASED MANAGEMENT
BIODIVERSITY CONSERVATION
SUSTAINABLE FISHERIES MANAGEMENT
HABITAT CONNECTIVITY
MAIN PROBLEMS ADDRESSED
SOIL EROSION
BIODIVERSITY LOSS
FLOOD CONTROL
CARBON SEQUESTRATION
DISASTER RISK REDUCTION
FOOD SECURITY
SHRIMP POND
FISH POND (17 m long)
Dike (2m high)
MANGROVE
Water treatment (oysters)
Minimum 30 to 50 meters long
Minimum 15 meters of MANGROVE
What are the main problems addressed by this NbS?
Technical Section
Ecosystem Services and Actions provided by this NbS



Plan or Diagram of the NbS
Challenges and Risks to be aware of
NbS-16: MANGROVE AS PROTECTIVE SHIELD FOR AQUACULTURE
Mangrove
Fisheries pond
Shrimp pond
Water outlet treatment with oysters
Mangrove
Typical plan of mangrove shield and aquaculture ponds
Shrimp pond
Simplified Axonomet of mangrove shield a d aquaculture pon
PROJECT'S CHALLENGES & RISKS
Funding Gaps: Long-term maintenance and monitoring often lack sustained funding.
Land Use Conflicts: Due to potential competing interests (e.g., agriculture, aquaculture).
80% of Mangrove Restoration fail: As the soil characteristics, density of plantations and rhythm of plantation will determine the success of the project.
Scaling up Coastal Fisheries: Requires adequate land management and governance to avoid intensive coastal land pressure from the agricultural sector.
NbS co-BENEFITS AND THEIR INDICATORS
Biodiversity Conservation
Species richness and abundance of key species (fish, crustaceans, birds)
Climate Resilience
Reduction in shoreline erosion rates, frequency, and intensity of flooding in adjacent communities
Carbon Sequestration
Carbon stock assessment in above-ground biomass and sediment (tCO_2/ha)
Water Quality Enhancement
Levels of nitrates, phosphates, heavy metals, and sedimentation in water samples
Livelihoods and Economic Benefits
Increase in sustainable fishery yields, in income from ecotourism, local jobs
Social Resilience and Community Engagement
Number of community members involved in mangrove protection initiatives
COST ANALYSIS
Direct Costs
Restoration (0.40 USD/m2); Infrastructure (fencing, access points); Maintenance and monitoring
Indirect Costs
Opportunity costs if land is repurposed from other uses
Time Horizon and Discount Rate
10-30 years to capture full ecological and economic benefits; Adjusted to account for long-term environmental and social benefits.
Direct Benefits
Reduced storm damage costs; Revenue from sustainable fisheries; Carbon credit revenue
Indirect Benefits
Increased biodiversity, improved water quality, reduced health costs due to cleaner environment.
Risk Assessment
Evaluation of factors such as climate change impacts on growth rates, potential for disease, and community engagement level.
REFERENCES:
Indonesia, Bogorame-Timbusloko Mangrove Shield, Demak, Indonesia
Indonesia, Bedono Village Mangrove Regrowth
IMPLEMENTATION OPPORTUNITIES:
Western coastlines of Thailand
Mekong Delta and Ca Mau Peninsula, Vietnam
Borneo, Java, Papua, Sumatra coastlines, Indonesia
Co-Benefits and their Indicators
Axonometry or Diagram of the NbS
Cost Analysis
Project references & Implementation Opportunities (Locations)

Complete list of the 70 NbS practices presented in the context of Southeast Asia through nine landscape categories:

NbS supporting mainly Inland and Freshwater Systems

1. Inland Natural Wetlands
2. Constructed Wetlands
3. River Levee Setbacks
4. Reconnecting Oxbow Lake and River
5. Riverbank Stabilisation
6. Sediment Capture Traps
7. Riparian Buffer Zone, Bed Renaturation
8. Gully Plugging
9. Plastic Waste Capture Biofence
10. Managed Aquifer Recharge (MAR)
11. Bioretention Ponds and Swales
12. Water Bunds
13. Small Sand Dams
14. Terraced Green Riverfronts
15. Log Terracing (Water-Delay Infrastructure)
16. River Stream Restoration and Culverting

NbS supporting mainly Coastal and Marine Systems

17. Salt Marsh Restoration
18. Tidal Flat Nourishment
19. Artificial Seagrass Meadows
20. Mangrove Forest Restoration
21. Paludiculture Associated Peatland
22. Planting Mats and Rich Revetments
23. Coral Reef Restoration and Nurseries
24. Coastal Reforestation
25. Artificial Oyster Reefs

NbS supporting mainly Urban Green-Blue Infrastructure

26. Permeable Green Streets and Roads
27. Green & Blue Roofs and Facades
28. Urban Water Buffer
29. Sponge City Park & Urban Oxbow
30. Urban Forest and Tree Canopy
31. Landfill Regeneration Park
32. Tidal Park
33. Urban Agriculture
34. Pollinator Habitats and Corridors

NbS supporting mainly Coastal Protection and Sediment Management

35. Mangrove as Protective Shield and Fisheries
36. Grassed Waterways
37. Beach Nourishment
38. Frontal Dune
39. Constructed Perched Beach with Seagrass
40. Natural Timber Groyne
41. Constructed Nature Island
42. Sand Trapping Fences
43. Windbreaks and Shelterbelts

NbS supporting mainly Agriculture and Land Management

44. Flood-Based Agriculture
45. Polyculture and Crop Rotation
46. Wastewater-Fed Aquaculture & Treatment Ponds
47. Biochar and Crop Nutrient Management
48. Agri-Waste Smart Soils
49. Anti-Salt Bunds
50. Rainforestation Farming
51. Floating Treatment Wetlands & Phytofiltration
52. Drainage Reduction in Rice Paddy Fields
53. Seaweed Aquaculture
54. Vetiver Grass Systems (VGS)

NbS supporting mainly Soil and Land Restoration

55. Soil Microorganisms and Biofertilisers
56. Bioengineering Remediation of Contaminated Soils
57. Upland Reforestation, Afforestation, and Agroforestry
58. Forest Fire Management

NbS supporting mainly Ecological Connectivity and Wildlife Protection

59. Wildlife Mobility Linkages
60. Ecological Bridges and Underpasses
61. Eco-Sensitive Railway Infrastructure
62. Phytoremediation Forest Corridors
63. Ecological Airfield Buffer, Habitat Enhancement System & Carbon Compensation System

NbS supporting mainly Infrastructure and Bioengineering

64. Roadside Bioengineering & Slope Management
65. Electrowetlands
66. Gravel Wetlands

NbS supporting mainly Marine and Deep-Sea Solutions

67. Vertical Dock Reefs
68. Artificial Floating Reefs
69. Marine Sedimentation Basins for Bioturbation
70. Deep-Sea Sequestration of Mesopelagic Fauna

NbS-01: INLAND NATURAL WETLANDS

Riparian wetland restoration and preservation focuses on rejuvenating critical freshwater ecosystems by reinstating their natural hydrology and vegetation. Restoration efforts often involve reconnecting floodplains to their rivers by breaching levees, removing barriers, or regrading streambanks to allow seasonal flooding. This hydrological reconnection fosters sediment deposition and nutrient exchange, rebuilding the wetland platform and creating conditions for plant growth.

Techniques such as using biodegradable materials, like coir mats or straw bales, help stabilize banks and retain sediments, while channels, pools, and meanders are reintroduced to restore the natural features of the wetland. These modifications enhance water circulation and provide diverse habitats for fish, amphibians, and aquatic invertebrates.

Native flood-tolerant vegetation, is planted to anchor soils, filter water, and provide shade and habitat.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- FOREST LANDSCAPE RESTORATION
- ECOSYSTEM-BASED DISASTER RISK REDUCTION
- ECOSYSTEM BASED ADAPTATION
- GREEN INFRASTRUCTURE
- INTEGRATED WATER RESOURCES MANAGEMENT

MAIN PROBLEMS ADDRESSED

- SOIL EROSION
- BIODIVERSITY LOSS
- FLOOD CONTROL
- DISASTER RISK REDUCTION
- CARBON SEQUESTRATION
- FOOD SECURITY

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Provide habitats for plants, animals, migratory birds, fish.
- Recycle essential nutrients, maintain soil fertility.
- Trap sediments during floods, stabilizing riverbanks.

REGULATING

- Act as natural buffers by absorbing and slowing floodwaters, protecting downstream areas.
- Allow water to percolate into aquifers, maintaining base flows during dry periods.
- Regulate local temperatures and store carbon in wetland soils and vegetation.

PROVISIONING

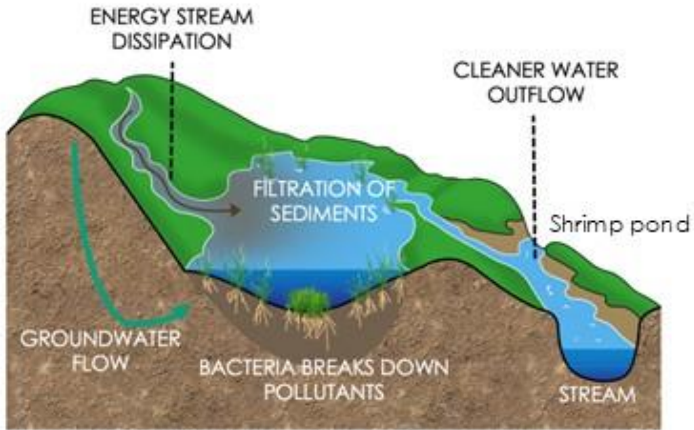
- Store and regulate freshwater for domestic, agricultural, and industrial use.
- Support fisheries, rice cultivation, and wild edible plants.
- Provide resources like reeds, wood, and medicinal plants.

SOCIAL BENEFITS

- Offer opportunities for studying river dynamics, biodiversity, and wetland ecology.
- Recreation and ecotourism, cultural heritage around rivers.

NbS-01: INLAND NATURAL WETLANDS

INLAND NATURAL WETLAND ALONG RIVER



3D section, inspired by University of Edimburgh

NATURAL WETLAND SECTION.

PROJECT'S CHALLENGES & RISKS

- ❖ **Pollution:** Agricultural runoff, industrial waste, and untreated sewage contaminate wetlands, harming biodiversity and reducing water quality.
- ❖ **Sea level rise:** Coastal wetlands, including mangroves, are at risk of submersion due to rising sea levels.
- ❖ **Governance challenges:** Competing demands for agriculture, urban development, and water resources lead to wetland degradation.
- ❖ **Natural Subsidence**: Wetland areas can naturally subside over time, compounded by human activities like groundwater extraction.

NbS co-BENEFITS AND THEIR INDICATORS

- **Enhanced Biodiversity Conservation**
  Population trends of key indicator species.
  Presence of migratory bird species during critical seasons.
- **Improved Water Quality**
  Levels of pollutants (e.g., nitrogen, phosphorus) in wetland and downstream water, sediment load reduction in river systems.
- **Flood Risk Reduction**
  Reduction in flood peak levels during heavy rains.
  Number of downstream communities protected from flooding.
- **Increased Food Security:**
  Area of agricultural land supported by wetland irrigation.
  Annual fish catch or wild food harvest.
- **Reduced Disaster Recovery Costs:**
  Estimated savings from reduced flood damages.

COST ANALYSIS

- **Direct Costs**
  Restoration, monitoring, infrastructure.
  \$5,000–\$30,000 per hectare restoration cost
- **Indirect Costs**
  Loss of income from alternative land uses (e.g., agriculture or development).
- **Time Horizon**
  Initial establishment and functional optimization (3–10 years).
  Full operational lifespan (10–50 years or more)
- **Direct Benefits**
  Flood risk reduction, water quality improvement, resource harvesting.
- **Indirect Benefits**
  Policy and Regulatory Costs (Enforcement of wetland protection laws), capacity building and education.
- **Risk Assessment**
  Sea level rise, urbanization, funding gaps for long-term management and the reliability of revenue.

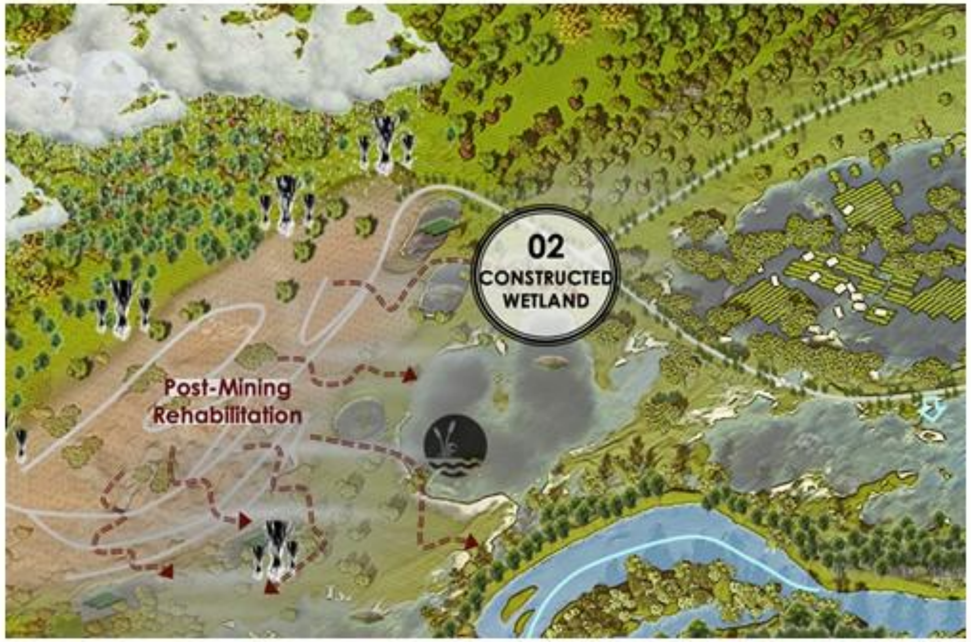
REFERENCES:

Cambodia, Tonle Sap Lake and Floodplain Wetlands.
Australia, Barmah-Millewa Forest (riverine wetlands).
UK, Tophill Low Nature Reserve, small wetlands fed by the River Hull in East Yorkshire.

IMPLEMENTATION OPPORTUNITIES:

Vietnam, Mekong Delta Wetlands, particularly in the Plain of Reeds and U Minh wetlands.
Indonesia, preserve and restore wetlands in the Mahakam River Basin in Kalimantan.

NbS-02: CONSTRUCTED WETLANDS



Constructed wetlands are artificial systems designed to replicate the vital ecological functions of natural wetlands. These wetlands are strategically placed along riverbanks or within floodplains to treat water, improve water quality, and enhance biodiversity. The primary focus is on managing water flow, reducing pollutants, and providing habitat for aquatic species in river systems.

It involves designing channels, shallow ponds, and marshy areas that allow for water filtration, sediment retention, and nutrient cycling. These features are integrated into the landscape to mimic the natural hydrology of riverine wetlands, helping to manage floodwaters and stabilize riverbanks. The artificial wetlands often include elements such as sedimentation zones, reed beds, and vegetated swales that improve the river's water quality by filtering out excess nutrients, sediments, and pollutants, particularly from agricultural or urban runoff.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOSYSTEM RESTORATION
- ECOSYSTEM-BASED DISASTER RISK REDUCTION
- ECOSYSTEM BASED ADAPTATION
- GREEN INFRASTRUCTURE
- INTEGRATED WATER RESOURCES MANAGEMENT

MAIN PROBLEMS ADDRESSED

- SOIL EROSION
- BIODIVERSITY LOSS
- FLOOD CONTROL
- DISASTER RISK REDUCTION
- CARBON SEQUESTRATION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Creates habitats for aquatic and terrestrial species.
- Supports soil formation and stability.
- Facilitates the natural cycling of nutrients like nitrogen and phosphorus.

REGULATING

- Store excess water during heavy rainfall, mitigating flood risks.
- Purifies water through sediment filtration.
- Stabilizes riverbanks to prevent erosion.
- Moderate local temperatures.

PROVISIONING

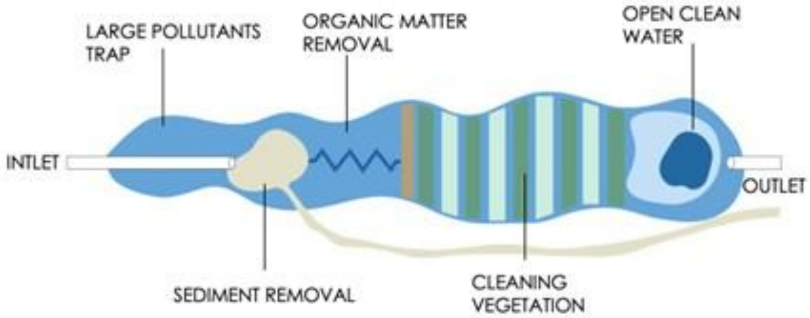
- Recharge groundwater and maintain base flows in rivers.
- Supports fish populations and can be used for sustainable aquaculture.

SOCIAL BENEFITS

- Serve as natural laboratories for studying ecosystems, biodiversity, and hydrology.
- Wetlands enhances mental well-being and provides spaces for relaxation and connection to nature.

NbS-02: CONSTRUCTED WETLANDS

Constructed wetland for storm water management - section



Schematic Plan View

Schematic section

PROJECT'S CHALLENGES & RISKS

- **Pollutant Overload:** Wetlands may become overwhelmed if pollutant loads exceed their natural capacity to filter and process waste.
- **Biodiversity Risks:** Introducing non-native or invasive species during wetland construction may disrupt local ecosystems.
- **Design Complexity:** Creating a wetland that mimics natural processes requires expertise in hydrology, ecology, and engineering.
- **High Initial Costs:** Constructed wetlands require significant upfront investment for design, construction, and planting.

NbS co-BENEFITS AND THEIR INDICATORS

- **Carbon sequestration**
  Amount of carbon stored in wetland vegetation and soil (measured in tonnes of CO_2 equivalent).
- **Soil erosion control**
  Reduction in sediment loads in adjacent waterways.
- **Cost Savings in Flood Management:**
  Reduction in flood damage costs compared to baseline before wetland construction.
- **Water Quality Enhancement**
  Reduction in sediment, nutrient, and pollutant levels (nitrogen, phosphorus, heavy metals).
- **Improved Hydrological Balance:**
  Stabilization of river flow regimes (e.g., reduction in seasonal flow variability).
- **Disaster Risk Reduction**
  Reduction in the frequency and severity of flood and drought events in the surrounding area.

COST ANALYSIS

- **Direct Costs**
  Land acquisition, construction, monitoring, and equipment and materials.
- **Indirect Costs**
  Loss of income from alternative land uses (e.g., agriculture or development.
- **Time Horizon**
  Initial establishment and functional optimization (3–10 years).
  Full operational lifespan (10–50 years or more)
- **Direct Benefits**
  Flood risk reduction, water quality improvement, resource harvesting.
- **Indirect Benefits**
  Biodiversity gains, climate regulation, recreation, health benefits.
- **Risk Assessment**
  Budget , wetland underperformance, delays in securing permits, declining performance due to sedimentation, pollutant overload...

REFERENCES:

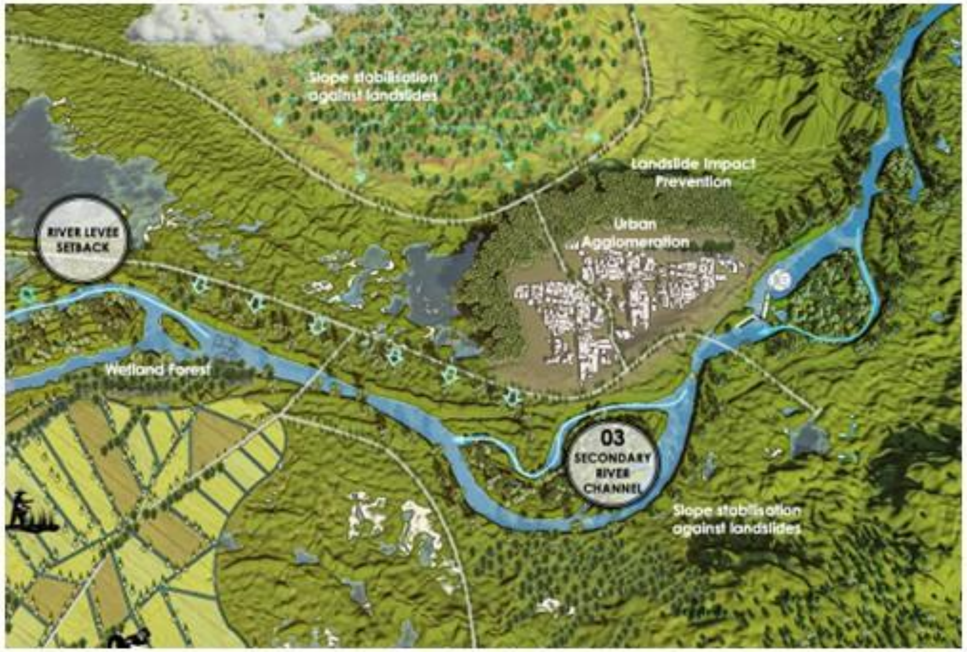
Malaysia, Putrajaya Constructed Wetland
Canada, Ontario, Amherstview Constructed Wetland
USA, Ohio, Olentangy River Wetland Research Park (Columbus)

IMPLEMENTATION OPPORTUNITIES:

Indonesia, Jakarta, Ciliwung river to address industrial and domestic pollution.

Philippines, Central Luzon , to treat pesticide and fertilizer runoff from rice paddies.

NbS-03: RIVER LEVEE SETBACKS & SECONDARY CHANNELS



River Levee Setbacks focus on restoring natural river dynamics by relocating levees away from the river's floodplain, creating space for the river to flood naturally during high-water events.

This process reconnects floodplains with rivers, promoting sediment deposition, nutrient cycling, and ecosystem regeneration. It includes breaching or moving levees and regrading the area to encourage natural flooding, which revitalizes the landscape by creating meanders and pools that support biodiversity.

Native flood-tolerant plants are then introduced to stabilize soils, filter water, and provide habitat for aquatic species like fish, amphibians, and invertebrates. These efforts improve water quality, mitigate flood risks, and restore vital riverine ecosystems.

Secondary river channels are natural or restored waterways branching off from a primary river, designed to mimic or enhance natural hydrological processes. These channels can reduce flood risks by diverting excess water during heavy rains, improve sediment flow to prevent siltation, and restore habitats for aquatic and riparian biodiversity. Integrating secondary river channels into regional water management strategies not only mitigates disaster risks but also promotes sustainable development and resilience for vulnerable communities.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- DISASTER RISK REDUCTION
- ECOSYSTEM RESTORATION
- INTEGRATED WATER RESOURCES MANAGEMENT
- ECOSYSTEM BASED ADAPTATION
- GREEN INFRASTRUCTURE
- SUSTAINABLE LAND MANAGEMENT

MAIN PROBLEMS ADDRESSED


SOIL EROSION


BIODIVERSITY LOSS


FLOOD CONTROL


DISASTER RISK REDUCTION


CARBON SEQUESTRATION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Creates habitats for diverse species
- Supports soil formation.
- Enhances nutrient cycling for ecosystem productivity.

REGULATING

- Reduces flood risks by absorbing overflow.
- Purifies water through sediment filtration.
- Stabilizes riverbanks to prevent erosion.
- Recharges groundwater and sequesters carbon in soil.

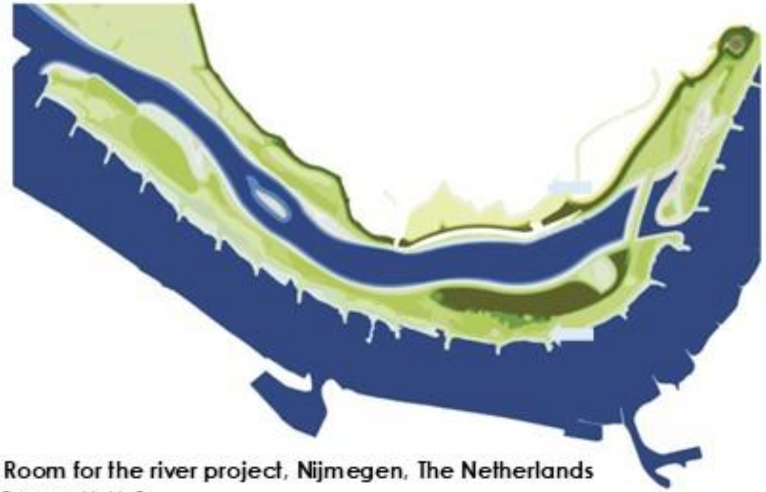
PROVISIONING

- Provides clean water.
- Supplies renewable materials like wood and reeds.

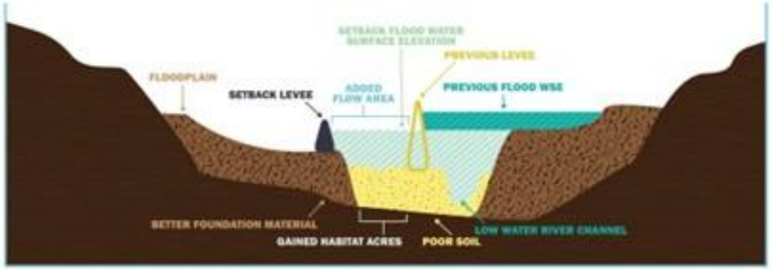
SOCIAL BENEFITS

- Offers recreation and tourism opportunities.
- Protects the community against floods.

NbS-03: RIVER LEVEE SETBACKS & SECONDARY CHANNELS



Room for the river project, Nijmegen, The Netherlands
Source: H+N+S



Cross section, river setback levee, Missouri River, US
Source: US Army corps of engineers

Source : Miles Project, US National science foundation

PROJECT'S CHALLENGES & RISKS

- **Land Use Conflicts :** Moving levees away from rivers often requires land acquisition or repurposing
- **High initial costs:** The upfront costs of planning, acquiring land, and constructing levee setbacks are substantial.
- **Displacement :** The creation of setback areas may displace people, wildlife, or existing ecosystems.
- **Maintenance and Monitoring Needs :** Although levee setbacks offer long-term benefits, they may require ongoing monitoring and maintenance to ensure they continue functioning as intended.

NbS co-BENEFITS AND THEIR INDICATORS

- **Carbon sequestration**
  Amount of carbon sequestered per hectare.
  Increased biomass cover in the setback area.
- **Soil Fertility and Agricultural Productivity**
  Organic soil matter and nutrient levels in floodplain soils.
  Crop yields improvement in surrounding agricultural areas.
- **Water Quality Enhancement**
  Reduction in sediment, nutrient, and pollutant levels (nitrogen, phosphorus).
- **Groundwater Recharge**
  Aquifer recharge rates.
  Water quality of groundwater sources.
- **Disaster Risk Reduction**
  Frequency or severity of downstream flooding events.

COST ANALYSIS

- **Direct Costs**
  Land acquisition, construction, monitoring, and ecosystem restoration costs.
- **Indirect Costs**
  Displacement, legal costs and uncertainty in flood protection.
- **Time Horizon**
  50–100 years for ecosystem recovery and long-term flood mitigation.
- **Direct Benefits**
  Flood risk reduction, biodiversity restoration, carbon sequestration, water quality improvement.
- **Indirect Benefits**
  Groundwater recharge, recreation, reduced urban heat, and climate resilience..
- **Risk Assessment**
  Environmental, social, financial, and climate-related risks that could affect project success.

REFERENCES:

Room for the river project, Nijmegen, The Netherlands

Reconnecting the Missouri River Floodplain, US

IMPLEMENTATION OPPORTUNITIES:

Thailand, Chao Phraya River basin, Upper and central floodplain areas outside of urbanized zones.

Indonesia, Jakarta, Ciliwung River, Upstream and midstream areas.

NbS-04: RECONNECT OXBOW LAKE AND RIVER

Reconnecting an oxbow lake and its river involves re-establishing the natural hydrological connection between an oxbow lake (a crescent-shaped lake formed by a meander of a river) and the main river channel. Over time, oxbow lakes can become isolated from the river due to natural processes like sediment deposition or human intervention, such as levee construction or channelization. Reconnection efforts aim to restore the flow of water between the river and the oxbow, enhancing the health of both water bodies.

This process often involves breaching or removing physical barriers, such as levees or embankments, that have cut off the oxbow from the river. By restoring this connection, water can flow freely between the river and the oxbow, allowing for seasonal flooding, nutrient exchange, and sediment deposition. These actions help improve water quality, increase biodiversity, and create new habitats for fish, amphibians, and other aquatic species.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

INTEGRATED WATER RESOURCES MANAGEMENT | ECOSYSTEM-BASED DISASTER RISK REDUCTION | ECOSYSTEM BASED ADAPTATION | GREEN INFRASTRUCTURE | ECOSYSTEM RESTORATION

MAIN PROBLEMS ADDRESSED


SOIL EROSION


BIODIVERSITY LOSS


FLOOD CONTROL

CARBON SEQUESTRATION


DISASTER RISK REDUCTION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Create habitats for a wide range of species, including migratory birds, amphibians, and aquatic organisms.
- Reconnection enhances genetic diversity and strengthens ecosystem resilience by improving habitat connectivity.

REGULATING

- Act as natural flood buffers, storing excess water during heavy rainfall and reducing downstream flood risks.
- Filter sediments, nutrients, and pollutants, reducing eutrophication risks.
- Water exchange between the oxbow lake and the river helps replenish aquifers and maintain groundwater levels.

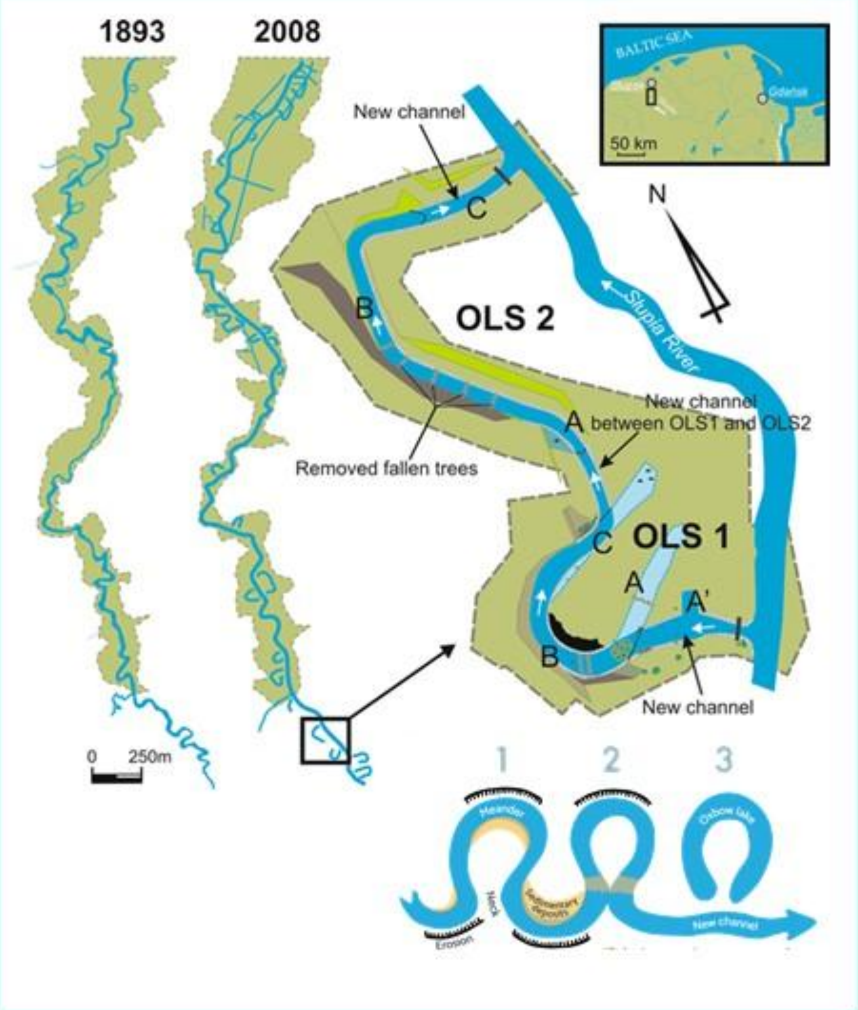
PROVISIONING

- Reconnection improves the quality and quantity of freshwater resources available for domestic, agricultural, and industrial use.
- Enhance fish populations by providing spawning and nursery habitats, supporting local fisheries.

SOCIAL BENEFITS

- Serve as valuable sites for environmental education and scientific studies on ecology and hydrology.
- Provide opportunities for birdwatching, kayaking, fishing, and eco-tourism, boosting local economies.

NbS-04: RECONNECT OXBOW LAKE AND RIVER



Hydrological system of the Słupia River (Poland) before its regulation (1893) and after restoration (2008), which involved reconnection of oxbow lakes (OLS1 and OLS2) to the main channel.
Source: Springer Nature

PROJECT'S CHALLENGES & RISKS

- **Water quality:** Oxbow lakes can have different water quality characteristics than the main river (lower oxygen levels, higher temperatures, increased sedimentation). It may lead to changes in water chemistry.
- **Species Displacement:** Species that have adapted to the isolated environment of the oxbow lake may be vulnerable to change.
- **Flow Alterations:** The natural flow of water in the river may be altered due to the reintroduction of water to the oxbow lake.
- **Sustainability of the Reconnection:** it requires ongoing management to ensure the long-term health and stability of the reconnected ecosystem.

NbS co-BENEFITS AND THEIR INDICATORS

- **Biodiversity Enhancement**
  The number and diversity of species (e.g., fish, aquatic plants, amphibians) before and after the reconnection.
- **Water Quality Improvement**
  Nutrient Concentrations (e.g., Nitrogen and Phosphorus), dissolved oxygen levels, turbidity.
- **Soil and Habitat Restoration**
  Increased soil quality , vegetation recovery.
- **Flood Control and Hydrological Regulation**
  Flood frequency and extent, water retention capacity, flow variability.
- **Local Economic and Social Benefits**
  Changes in the yield or quality of fish in the restored ecosystem.
  Number of visitors, eco-tourism revenues.

COST ANALYSIS

- **Direct Costs**
  Planning & Design, Construction ($130,000–$600,000)
  Monitoring & Maintenance ($15,000–$80,000/year)
- **Indirect Costs**
  Economic disruptions (land use, local activities), risk management (flooding, insurance), regulatory compliance, stakeholder engagement.
- **Time Horizon**
  Short-Term (1-3 years): Planning & Construction, Long-Term (10+ years): ecosystem stabilization.
- **Direct Benefits**
  Water quality improvement, enhanced biodiversity, flood mitigation, carbon sequestration.
- **Indirect Benefits**
  Ecotourism and jobs, community resilience, education & stewardship.
- **Risk Assessment**
  Ecological risks (invasive species, water quality), hydrological risks (flooding, erosion).

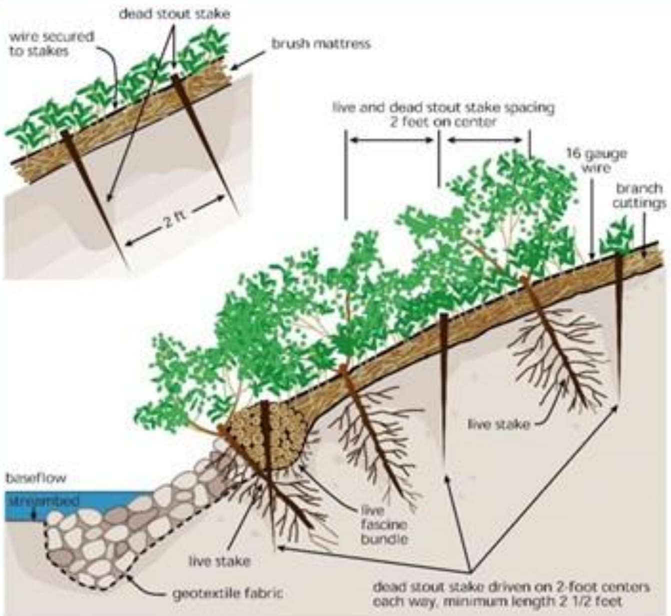
REFERENCES:

USA, Mississippi river oxbow lake restoration project (lower Mississippi alluvial valley).
Poland, Pomerania , Słupia River, oxbow lakes in its floodplain, in the lower reaches of the river.

IMPLEMENTATION OPPORTUNITIES:

Cambodia, oxbow lakes along the Tonle Sap River.
Indonesia, the middle Mahakam Lakes are large oxbow lakes formed by past meanders of the Mahakam River.

NbS-05: RIVERBANK STABILISATION



Source : Federal Interagency Stream Restoration Working Group (FISRWG)

Riverbank stabilisation prevents erosion and protects riverbanks from further degradation while maintaining the natural integrity of the river system. This process is essential for preserving soil, reducing sedimentation in water, and preventing the loss of valuable land or infrastructure. Stabilisation techniques are employed to reinforce and protect riverbanks from the erosive forces of flowing water, especially during high-water events.

Efforts often involve a combination of structural and vegetative approaches. Structural methods can include the installation of large rocks or gravel, retaining walls, or engineered mats to physically support the riverbank. Native, flood-tolerant plants such as grasses, shrubs, and trees are planted to anchor the soil with their root systems, reducing the impact of water flow and promoting soil cohesion. These plants also help filter excess nutrients, improve water quality, and provide habitat for various species.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| FOREST LANDSCAPE RESTORATION | ECOSYSTEM-BASED DISASTER RISK REDUCTION
| ECOSYSTEM BASED ADAPTATION | GREEN INFRASTRUCTURE

MAIN PROBLEMS ADDRESSED

SOIL EROSION

BIODIVERSITY LOSS

FLOOD CONTROL

DISASTER RISK REDUCTION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Stabilised riverbanks create and maintain habitats for aquatic and riparian species, including fish, amphibians, birds, and insects.
- Riparian vegetation aids in nutrient uptake and cycling, reducing nutrient runoff into rivers.
- Vegetation on riverbanks prevents soil erosion, helping maintain soil health and fertility over time.

REGULATING

- Reduces the risk of riverbank collapse and sedimentation.
- Stabilised banks with healthy vegetation slow down water flow, reducing flood risks downstream.
- Riparian vegetation acts as a natural filter, trapping pollutants, sediments, and nutrients before they enter the river.

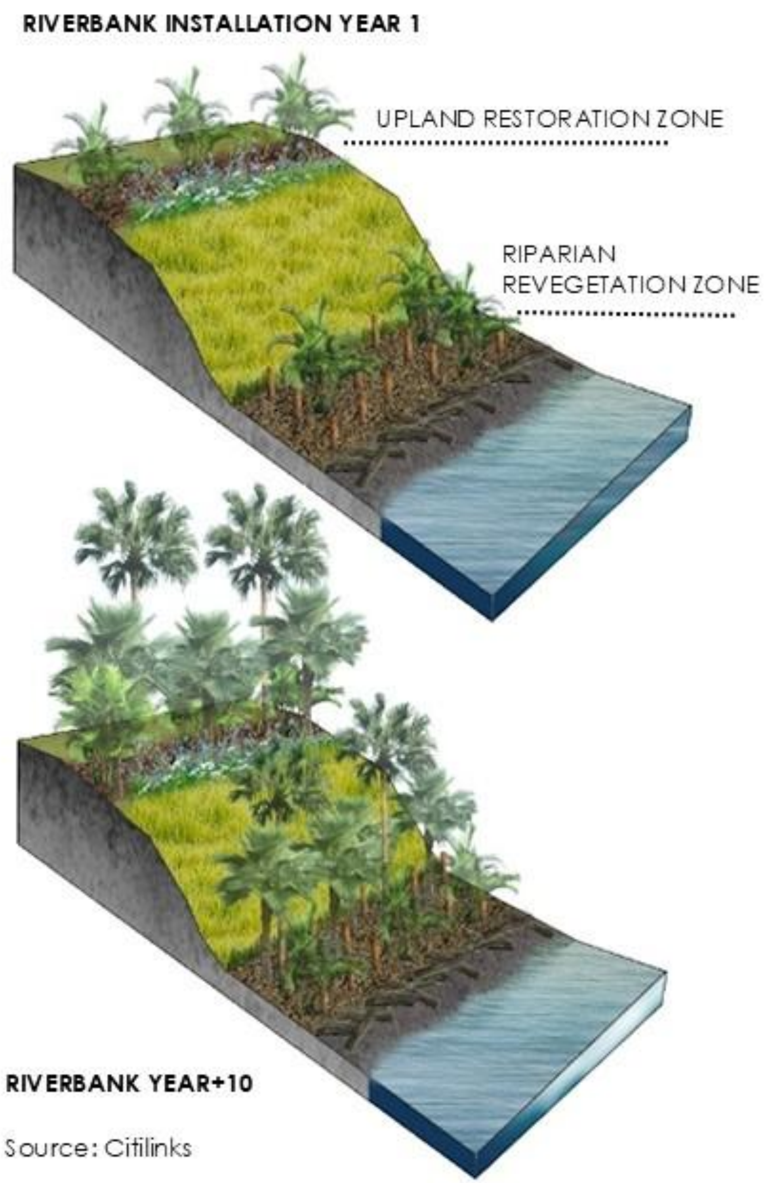
PROVISIONING

- Produce renewable materials such as reeds, bamboo, and timber.
- Ensure better water retention and quality for human consumption, agriculture, and industrial use.
- Support fish populations.

SOCIAL BENEFITS

- Enhance access to safe areas for activities like fishing, boating, hiking, and birdwatching.
- Green, stabilised riverbanks contribute to scenic landscapes, improving quality of life and attracting tourism.
- Many communities consider rivers and their banks sacred and central to their cultural identity.

NbS-05: RIVERBANK STABILISATION



Source: Citilinks

PROJECT'S CHALLENGES & RISKS

- **Loss of Biodiversity:** Poorly planned stabilisation methods (e.g., excessive use of hard structures) can destroy habitats instead of restoring them.
- **High Initial Costs:** Stabilisation projects, especially those involving green infrastructure or reforestation, can have significant upfront costs
- **Unpredictable Events :** Extreme weather events like floods or storms may damage or overwhelm stabilisation structures.
- **Maintenance Requirements:** Vegetation-based solutions require ongoing management, such as replanting or clearing debris.

NbS co-BENEFITS AND THEIR INDICATORS

- **Improved Water Quality**
  Decrease in turbidity levels, lower nutrient concentrations (e.g., nitrogen and phosphorus).
- **Habitat Restoration**
  Increase in biodiversity indices, presence of key species, area of restored habitat.
- **Biodiversity Conservation**
  Growth of endangered species, number of species present.
- **Disaster Risk Reduction**
  Reduction in flood-related damages and losses, fewer evacuation incidents.
- **Enhanced Livelihoods**
  Income generated from riparian resource use, community surveys of resource availability.

COST ANALYSIS

- **Direct Costs**
  Planning, materials, construction, monitoring $20,000–$1,000,000
- **Indirect Costs**
  Opportunity Costs (loss of land for agriculture). Governance and coordination.
- **Time Horizon**
  Short-term costs, planning, construction, and initial vegetation establishment (1–3 years)
  Long-term benefits (10+ years)
- **Direct Benefits**
  Reduced infrastructure repair costs, water quality improvement, increased agricultural productivity.
- **Indirect Benefits**
  Enhanced biodiversity, resilience to floods, Improved aesthetics and tourism
- **Risk Assessment**
  Delays or cost overruns due to weather, regulatory issues, or unforeseen technical challenges, climate change impacts.

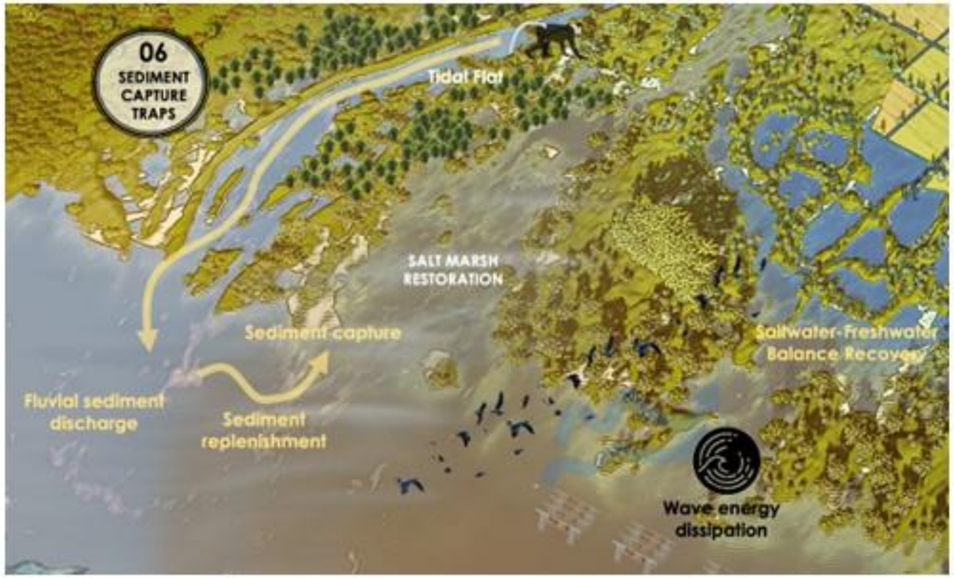
REFERENCES:

Singapore, Bishan-Ang Mo Kio Park, Kallang river.
USA, Oregon, Willamette River Riparian Restoration
UK, London, Thames Riverbank Restoration

IMPLEMENTATION OPPORTUNITIES:

Malaysia, Sabah, Kinabatangan River, key biodiversity hotspot, erosion has impacted the surrounding floodplain and wildlife.
Indonesia, West Java, Bandung region, Citarum River, severe pollution and erosion.

NbS-06: SEDIMENT CAPTURE TRAPS



Sediment capture traps are designed to capture and retain sediments that would otherwise be carried downstream by river currents. These traps play a crucial role in controlling sediment transport, reducing erosion, and improving water quality by preventing excessive sedimentation in downstream habitats.

They can be engineered elements such as sediment basins, weirs, or dams, or natural features like gravel bars or vegetated floodplains. These modifications slow down water flow, allowing sediments to settle and helping to retain valuable nutrients and organic matter that might otherwise be lost.

This retention improves soil fertility, supports the growth of aquatic vegetation, and enhances overall ecosystem health. By reducing suspended solids in the water, sediment capture traps help improve water clarity and quality, preventing pollution and habitat degradation.

This is especially important in river systems near urban, industrial or agricultural areas, where excessive sedimentation can contribute to water quality issues and harm aquatic habitats.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| SUSTAINABLE LAND MANAGEMENT | INTEGRATED WATER RESSOURCE MANAGEMENT

| ECOSYSTEM BASED ADAPTATION | GREEN INFRASTRUCTURE | ECOSYSTEM RESTORATION

MAIN PROBLEMS ADDRESSED

SOIL EROSION

BIODIVERSITY LOSS

FLOOD CONTROL

CARBON SEQUESTRATION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Trapping systems help retain nutrients that would otherwise be lost, promoting nutrient cycling and improving soil fertility in agricultural or forested areas.
- Protect aquatic and terrestrial habitats by reducing the smothering of critical habitats.

REGULATING

- Stabilise the soil in areas prone to erosion by capturing sediments before they can be carried downstream.
- Helps maintain the capacity of river channels, preventing flooding.
- Prevent pollutants that may be carried with the sediment from reaching water bodies.

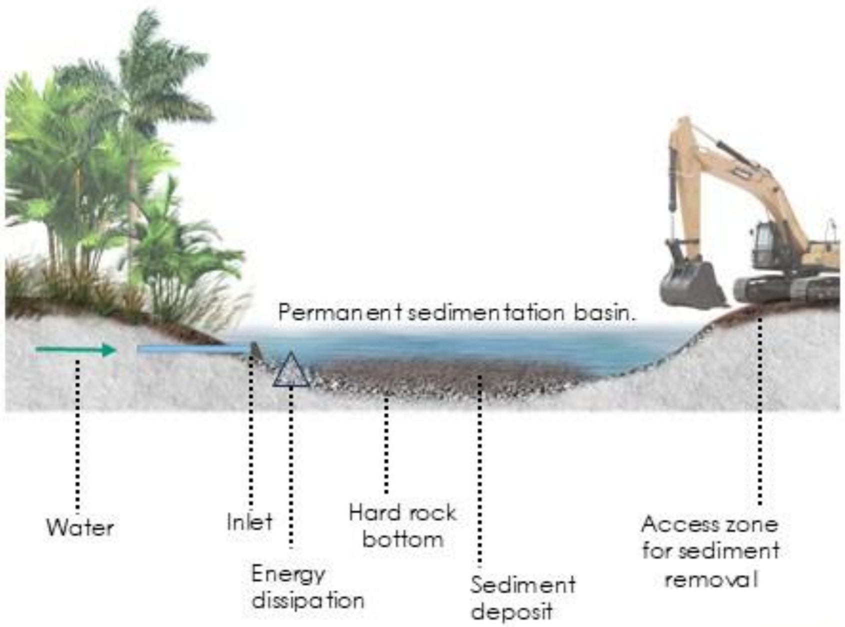
PROVISIONING

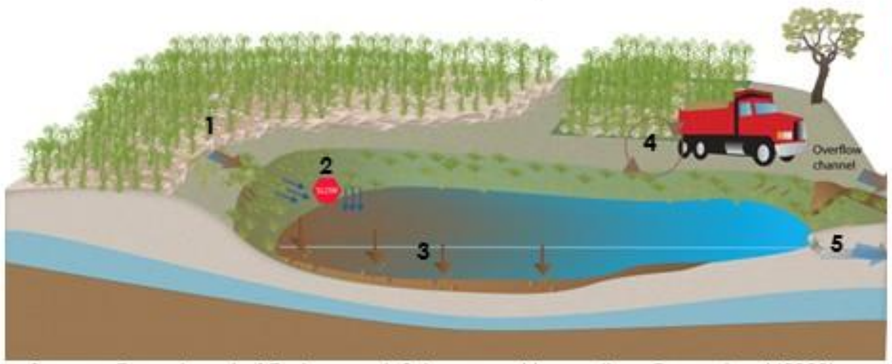
- Contribute to agricultural productivity by reducing soil erosion and preserving fertile soils.
- In forest areas, prevents soil erosion, which in turn maintains forest health and contributes to the availability of timber and other forest resources.

SOCIAL BENEFITS

- Preserving these landscapes (wetlands, rivers, floodplains) through sediment management contributes to cultural heritage.

NbS-06: SEDIMENT CAPTURE TRAPS





Source : Department of Environment, Science and Innovation, Queensland (2022)

1 Water run-off carrying sediment particules and dissolved pollutants.

2 Slowing of run-off and reducing flow velocity. Increase in sediment deposition.

3 Deposition of coarse and medium sized sediments.

4 The deposited particules are removed from the sedimentation basin and can be reused as soil fertiliser.

5 Cleaner water exit.

PROJECT'S CHALLENGES & RISKS

- **Extreme Weather Events**: Sediment traps can be overwhelmed by extreme rainfall, floods, or storms, leading to system failure.
- **Water Quality Issues**: Accumulated sediments can become a source of pollution if they release trapped nutrients, heavy metals, or organic matter back into the water.
- **Land Use Conflicts**: Sediment traps may require significant space, which can conflict with other land uses like agriculture, urban development, or recreation.
- **High Costs:** Designing, building, and maintaining sediment capture systems can be expensive, especially in urban or heavily engineered environments.

NbS co-BENEFITS AND THEIR INDICATORS

- **Improved Water Quality**
  Reduction in turbidity, decrease in suspended solids concentration (mg/L), levels of pollutants (e.g., phosphorus, nitrogen, heavy metals).
- **Enhanced Soil Fertility and Agricultural Productivity**
  Soil organic matter content (%), crop yield increases (kg/ha), nutrient levels in retained sediment.
- **Carbon Sequestration**
  Carbon sequestration rate (tCO_2/year), vegetation cover percentage(%).
- **Groundwater Recharge**
  Groundwater table levels (m), recharge rate (mm/year).
- **Flood Risk Reduction**
  Reduction in flood frequency (flood events/year), water retention capacity of the system (m³).

COST ANALYSIS

- **Direct Costs**
  Design, engineering, construction ($50,000–$500,000 + $5,000–$50,000/year maintenance).
- **Indirect Costs**
  Land Acquisition, opportunity costs : $10,000–$1M (depending on land value and mitigation needs).
- **Time Horizon**
  1–5 years for implementation, 20–50 years for operation.
- **Direct Benefits**
  Improved water quality, flood control, erosion prevention.
- **Indirect Benefits**
  Improved habitats for aquatic and riparian species, carbon sequestration, recreational value, agricultural productivity.
- **Risk Assessment**
  Overload, sediment starvation, habitat disruption, high maintenance costs.

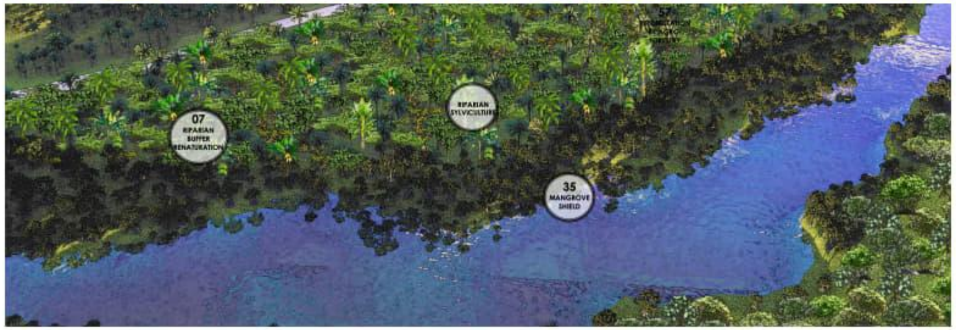
REFERENCES:

South Korea, Seoul, Cheonggyecheon stream (sediment traps, vegetated wetlands).
Netherlands, port of Rotterdam, sediment traps installed to manage sediment flow and reduce dredging.

IMPLEMENTATION OPPORTUNITIES:

Thailand, Bangkok, Chao Phraya River, faces significant sedimentation and water pollution.
Malaysia, Port Klang, sedimentation in its navigation channels and berths, leading to frequent dredging.

NbS-07: RIPARIAN BUFFER RENATURATION



Restoring and rehabilitating natural vegetated zones along riverbanks is essential for improving ecosystem functions and protecting water quality. These buffers, consisting of native grasses, shrubs, and trees, act as a protective barrier between the land and the river, filtering pollutants, stabilizing soil, and controlling sedimentation. Restoration efforts focus on reintroducing native plant species, enhancing biodiversity, and reestablishing the natural dynamics of riparian ecosystems that have been impacted by human activities such as urbanization, agriculture, and deforestation.

The natural input of organic materials, such as leaf litter, branches, and other debris, which fall from the riparian zone into the river contribute to nutrient cycling, provide habitat for aquatic organisms, and help filter sediments and pollutants from the water. By enhancing the health of riparian buffers, this approach reduces erosion, improves water quality, supports wildlife habitat, and fosters the overall health of river ecosystems.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOSYSTEM-BASED DISASTER RISK REDUCTION
- INTEGRATED WATER RESSOURCE MANAGEMENT
- ECOSYSTEM BASED ADAPTATION
- GREEN INFRASTRUCTURE
- ECOSYSTEM RESTORATION

MAIN PROBLEMS ADDRESSED

- SOIL EROSION
- BIODIVERSITY LOSS
- FLOOD CONTROL
- CARBON SEQUESTRATION
- AIR QUALITY IMPROVEMENT

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Provide crucial habitats for a wide range of aquatic and terrestrial species.
- The natural decay of plant material in riparian buffers contributes to the cycling of nutrients, maintaining the health and productivity of both terrestrial and aquatic ecosystems.
- Help maintain ecological corridors that connect fragmented habitats.

REGULATING

- Filter nutrients, pesticides, and sediments from runoff before they enter the river.
- The root systems of riparian plants stabilize riverbanks, reducing soil erosion.
- Vegetation in riparian buffers captures and stores carbon dioxide, provides shade and regulates water temperature.

PROVISIONING

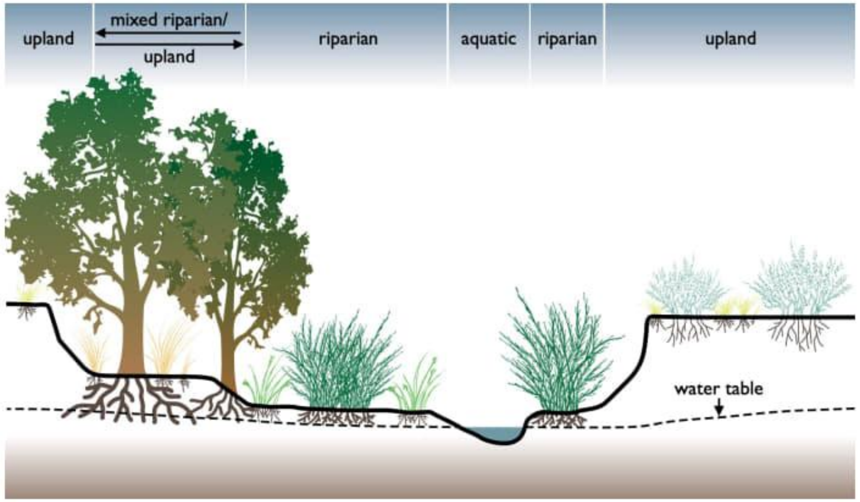
- Vegetation in riparian zones can be a source of raw materials such as timber, medicinal plants, and other forest products for local communities.
- Riparian buffers support pollinators, which are crucial for agricultural productivity and the health of wild plant species.

SOCIAL BENEFITS

- Riparian zones offer opportunities for environmental education and scientific research.
- Supports recreational activities such as fishing, kayaking, birdwatching, and hiking.

NbS-07: RIPARIAN BUFFER RENATURATION

Leaf litter and fine organic material from the riparian zone are a major source of carbon entering streams.



Riparian area, transition from aquatic area to upland area.
Source : United States Department of Agriculture

PROJECT'S CHALLENGES & RISKS

- **Land Ownership and Access Issues**: Difficulty securing land for restoration, especially if it's privately owned or used for agriculture/urban development.
- **External Threats:** Ongoing urbanization, agricultural expansion, or infrastructure projects may place continuous pressure on riparian zones, preventing the restoration of natural river functions.
- **Invasive Species and Biodiversity Risks**: The presence of invasive plant species can lead to reduced biodiversity, further degradation of the riparian ecosystem.
- **High Costs:** Riparian buffer renaturation requires significant financial investment in restoration activities such as planting native vegetation, stabilizing riverbanks, and long-term monitoring.

NbS co-BENEFITS AND THEIR INDICATORS

- **Improved biodiversity**
  Species richness , abundance of native species, habitat quality index, biodiversity indices (e.g., Shannon diversity index).
- **Flood Mitigation**
  Reduction in peak discharge during flood events, floodplain area or capacity restored, frequency and severity of flood events in the area.
- **Air Quality Improvement**
  Air pollutant levels (e.g., PM2.5, NOx), tree canopy coverage,
- **Water Quality Improvement**
  Reduction in sediment concentration (mg/L), Nitrogen and phosphorus levels in water
- **Flood Risk Reduction**
  Reduction in flood frequency (flood events/year), water retention capacity of the system (m^3).

COST ANALYSIS

- **Direct Costs**
  Site preparation, planting and vegetation, erosion control measures: $20,000 - $85,000/ha
- **Indirect Costs**
  Ongoing maintenance, monitoring and evaluation, $9,000 - $23,000/year.
- **Time Horizon**
  Short-Term (1-5 years) : site preparation, planting. Long-Term (20+ years):management, adaptive strategies.
- **Direct Benefits**
  Water quality improvement, flood regulation, erosion control, biodiversity support.
- **Indirect Benefits**
  Carbon sequestration, recreational opportunities, Improved property values.
- **Risk Assessment**
  Climate risks, invasive species, funding and budgeting risks, pollution or unforeseen environmental damage.

REFERENCES:

USA, Indiana, Indianapolis, Lilly ARBOR Project (1,400 native trees along the White River to restore the riparian floodplain).
Canada, Alberta, Riparian restoration in Medicine Hat.

IMPLEMENTATION OPPORTUNITIES:

Indonesia, Upper Citarum River Basin, West Java (industrial discharge, urban waste, and deforestation along its riparian zones.)
Philippines, Metro Manila, Pasig River, (pollution from industrial, residential, and commercial sources).

NbS-08: GULLY PLUGGING

Gully plugging is a low-cost, nature-based solution (NbS) designed to slow water flow, reduce erosion, and promote sediment deposition, particularly in hilly or mountainous regions.

It involves constructing small barriers across gullies using locally sourced materials like bamboo and stones, which are abundant and sustainable. Bamboo gully plugs are lightweight, biodegradable, and effective in trapping sediment and fostering vegetation growth, though they require periodic maintenance due to material degradation.

Stone gully plugs, on the other hand, are more durable, handle higher water flows, and provide a semi-permeable barrier that allows water infiltration while retaining soil upstream. Both approaches are often complemented by planting vegetation on slopes to further stabilize soil, enhance water retention, and increase long-term resilience.

Similar NbS, such as check dams and contour bunding, also address erosion control and water management, making them applicable in regions like Indonesia and the Philippines, where heavy rainfall and steep slopes exacerbate soil degradation.

Gully plugging supports regenerative agriculture by restoring degraded land, reducing sedimentation in downstream waterways, promoting groundwater recharge, and improving the sustainability of rural livelihoods.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

EROSION CONTROL & SOIL CONSERVATION | INTEGRATED WATERSHED MANAGEMENT | SUSTAINABLE WATER MANAGEMENT | AGROECOLOGICAL RESTORATION

MAIN PROBLEMS ADDRESSED

- SOIL EROSION
- FLOOD CONTROL
- DISASTER RISK REDUCTION
- FOOD SECURITY

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Enhances soil formation and fertility by reducing erosion and promoting sediment deposition.

REGULATING

- Regulates water flow, reducing runoff velocity and increasing groundwater recharge.

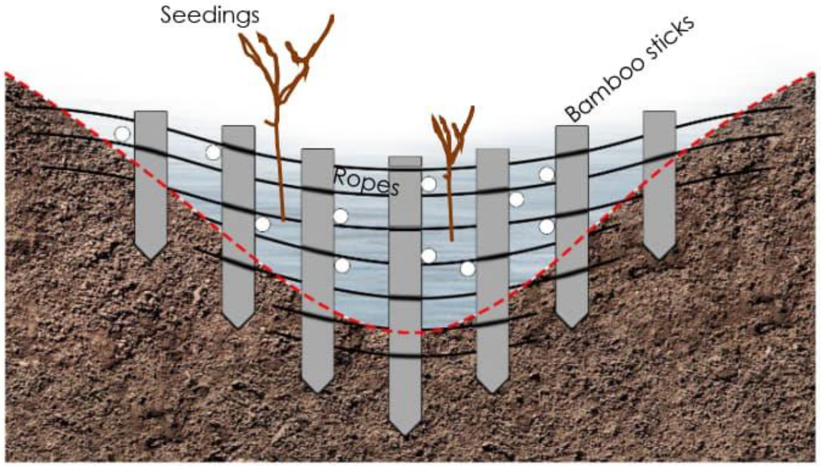
PROVISIONING

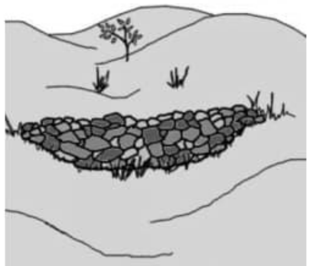
- Provides improved soil conditions for agriculture, increasing crop productivity in downstream areas.

SOCIAL BENEFITS

- Reduces the risk of floods and landslides, improving community resilience to climate extremes.

NbS-08: GULLY PLUGGING





PROJECT'S CHALLENGES & RISKS

- **Material degradation**: Bamboo gully plugs may degrade quickly in tropical climates, requiring frequent maintenance and replacement.
- **Extreme weather events**: Intense rainfall or flash floods can overtop or destroy gully plugs, reducing their effectiveness.
- **Sediment clogging**: Accumulated debris and sediment can block water flow, necessitating regular cleaning and monitoring.
- **Community engagement**: Lack of local awareness or involvement in construction and maintenance can lead to project neglect or failure.

NbS co-BENEFITS AND THEIR INDICATORS

- **Erosion control**
  Reduction in annual soil loss by up to 50% in treated gullies.
- **Groundwater recharge**
  Increased water table levels by 10–20% in adjacent areas.
- **Biodiversity enhancement**
  Growth of native vegetation and habitat restoration along gullies within 1–2 years.
- **Flood mitigation**
  Reduction in peak runoff flow during heavy rainfall events by 30–40%.
- **Agricultural productivity**
  Improved crop yields by 15–25% in downstream areas due to better soil quality.
- **Community benefits**
  Engagement of 50–100 households in gully plugging projects, creating jobs and raising environmental awareness.

COST ANALYSIS

- **Direct Costs**
  Gully plugging construction costs range from $2000 per structure, depending on materials like bamboo or stones.
- **Indirect Costs**
  Maintenance, monitoring, and community training can add $500–$1,000 per year per site.
- **Time Horizon**
  Benefits typically accrue over 10–20 years with a discount rate of 5–7% for cost-benefit analyses.
- **Direct Benefits**
  Soil retention and improved land productivity.
- **Indirect Benefits**
  Groundwater recharge and biodiversity enhancement contribute to long-term ecosystem services.
- **Risk Assessment**
  Potential failure under extreme floods.

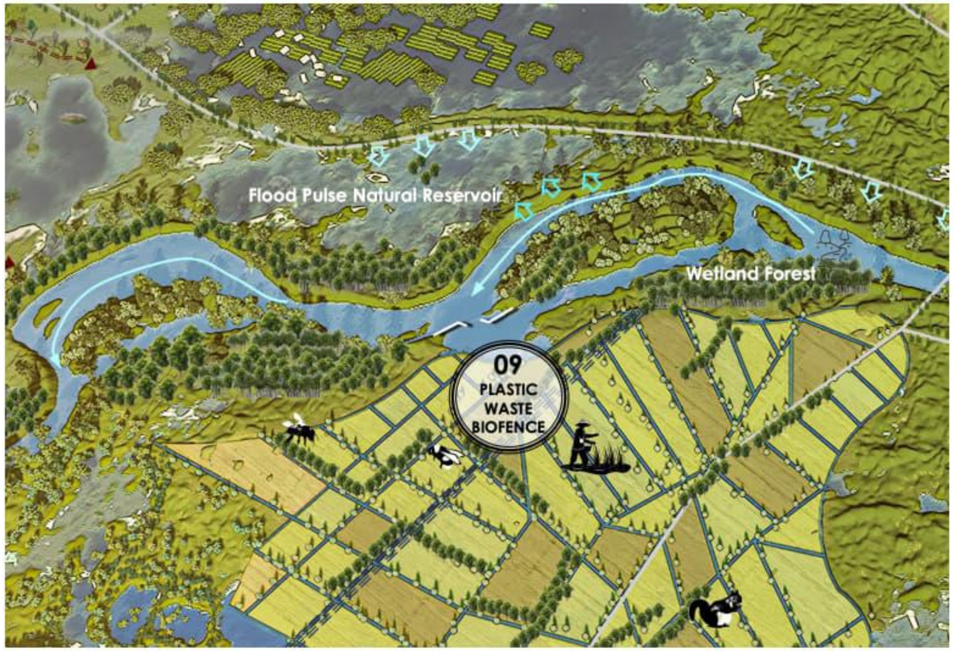
REFERENCES:

India, Maharashtra, Integrated Watershed Management Program.
Indonesia, Yogyakarta, Gunungkidul, Rainwater Harvesting and Gully Plugging Project.

IMPLEMENTATION OPPORTUNITIES:

Northern Thailand (Chiang Mai and Mae Hong Son Provinces).
Philippines, Central Luzon.
Southern Laos, Bolaven Plateau.

NbS-09: PLASTIC WASTE CAPTURE BIODEFENCE



Implementing plastic waste capture systems in rivers is a crucial strategy for preventing marine pollution and protecting aquatic ecosystems. These systems, designed as barriers or floating devices, intercept plastic waste before it reaches the sea, reducing the devastating impact of plastic on marine biodiversity. Strategically placed in river channels, these barriers effectively trap floating debris without obstructing the natural flow of water or the movement of aquatic organisms. The captured plastic waste is then collected and transported for proper recycling or disposal, promoting sustainable waste management practices. This approach not only prevents the accumulation of plastic in marine environments but also fosters cleaner rivers and healthier ecosystems. By integrating these biodefense systems with community-led cleanup efforts and educational initiatives, we can raise awareness about the consequences of plastic pollution and encourage responsible waste disposal.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| INTEGRATED COASTAL ZONE MANAGEMENT | INTEGRATED WATER RESSOURCE MANAGEMENT

| ECOSYSTEM BASED ADAPTATION | GREEN INFRASTRUCTURE | ECOSYSTEM RESTORATION

MAIN PROBLEMS ADDRESSED

DISASTER RISK REDUCTION

BIODIVERSITY LOSS

FLOOD CONTROL

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Healthy river ecosystems supported by waste capture systems provide habitats for aquatic and riparian species.
- Cleaner water promotes the growth of aquatic plants and phytoplankton, which form the base of the food web.

REGULATING

- By capturing plastic waste, the system reduces contamination, enhancing the river's ability to naturally purify water.
- Preventing plastic waste accumulation reduces blockages in rivers and drainage systems, mitigating flood risks.

PROVISIONING

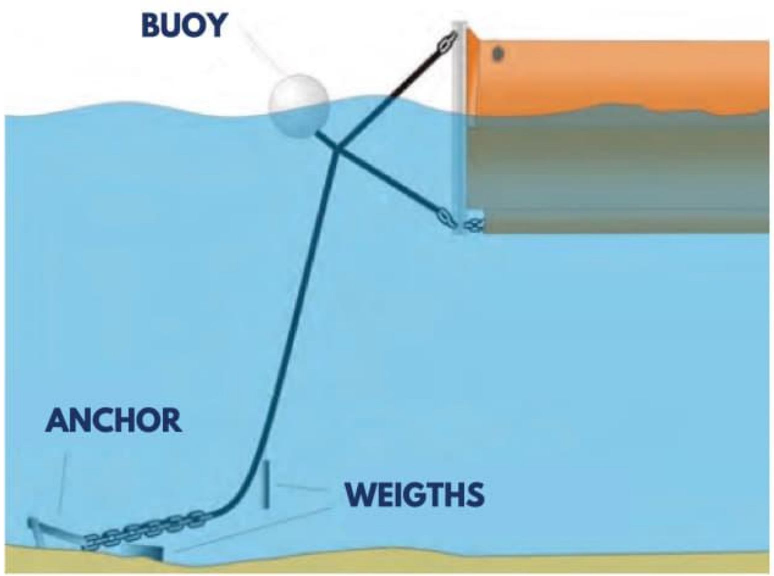
- By reducing plastic pollution, the system ensures cleaner water for drinking, agriculture, and industrial use.
- Support fisheries and other resources vital for local communities.
- Recovered plastic waste can be recycled into raw materials, contributing to circular economies.

SOCIAL BENEFITS

- Encourage activities like fishing, boating, and eco-tourism.
- Reducing visible pollution enhances the natural beauty of river landscapes.
- Fosters environmental awareness and encourages sustainable practices in communities.

NbS-09: PLASTIC WASTE CAPTURE BIODEFENCE

Dominican Republic, Ozama river, river boom
Source : PROMAR (Prevention of Marine Litter in the Caribbean Sea)



Anchor attachments of a river boom to the bottom of the river.
Source : PROMAR (Prevention of Marine Litter in the Caribbean Sea)

PROJECT'S CHALLENGES & RISKS

- **System Efficiency**: Ensuring that barriers effectively capture plastic without obstructing natural water flow or harming aquatic life.
- **Maintenance**: Regular cleaning and maintenance of the waste capture systems can be labour-intensive and costly.
- **Scalability**: Designing solutions that work effectively across different river sizes, flow rates, and pollution levels.
- **Waste Disposal**: Collected plastic waste must be processed sustainably; otherwise, it may contribute to pollution elsewhere.
- **Extreme Weather Events**: Floods, storms, may damage or overwhelm the system.

NbS co-BENEFITS AND THEIR INDICATORS

- **Improved Water Quality**
  Reduction in levels of plastic and other pollutants in river water (measured in microplastics per liter).
- **Reduced Flood Risk**
  Reduction in debris-related blockages in rivers and drainage systems.
  Frequency and severity of flood events in areas where systems are implemented.
- **Improved Public Health**
  Reduction in waterborne diseases linked to plastic pollution (e.g., gastrointestinal illnesses).
- **Job Creation**
  Number of new jobs created in system maintenance, recycling, and community outreach.
- **Community Engagement**
  Increase in public awareness about plastic pollution (surveys or educational event attendance).

COST ANALYSIS

- **Direct Costs**
  System design, materials ,installation, operational costs and maintenance : $42,500 /barrier.
- **Indirect Costs**
  Administrative and Regulatory Compliance.
- **Time Horizon**
  Short-Term: 1-2 years (installation, testing, early benefits)
  Long-Term: 5-10 years or more (sustainability, scaling, and long-term impact).
- **Direct Benefits**
  Reduction in plastic waste, cleaner waterways, job creation.
- **Indirect Benefits**
  Biodiversity protection, flood risk reduction, improved public health.
- **Risk Assessment**
  System malfunction or inefficiency, harm to aquatic life.

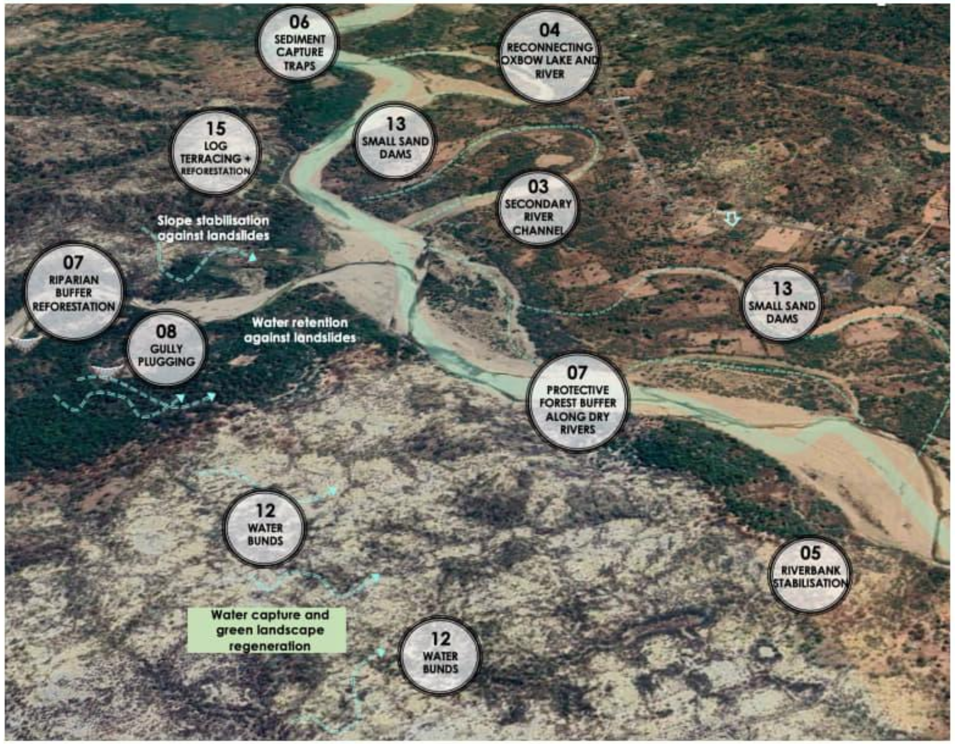
REFERENCES:

Belgium, Scheldt river, floating barrier intercepting plastic debris.
Dominican republic, Ozama river, river booms intercept solid waste.
Indonesia, Bandung, Cikapunding river cleanup.

IMPLEMENTATION OPPORTUNITIES:

Indonesia, Bengawan Solo River (Central and East Java) faces severe plastic pollution issues.
Philippines, Metro Manila, Pasig River, is heavily polluted, with plastics.

NbS-10: MANAGED AQUIFER RECHARGE (MAR)



Managed Aquifer Recharge (MAR) is a nature-based solution (NbS) that uses surface water to replenish aquifers, enhancing water availability and providing environmental benefits. In Southeast Asia, where challenges like seasonal rainfall variability, groundwater overuse, saltwater intrusion, and water quality issues are common, MAR offers a sustainable approach. By storing water underground, MAR minimizes evaporation losses and ensures reliable water supplies, especially in drought-prone regions.

MAR restores depleted aquifers, prevents land subsidence, and mitigates saltwater intrusion. It also improves water quality through methods like bank filtration and surface infiltration. Ecologically, MAR supports aquatic ecosystems and preserves natural hydrological cycles.

Techniques include infiltration ponds, recharge dams, and runoff harvesting to enhance water infiltration and manage stormwater. For areas with low-permeability soils, direct injection via wells or boreholes replenishes aquifers. MAR reduces reliance on surface reservoirs, cutting infrastructure costs while securing water for agriculture, industry, and households.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| FLOOD AND STORMWATER MANAGEMENT | WATER STORAGE AND REGULATION

| SOIL & WATER REGENERATION | WATER QUALITY IMPROVEMENT | IN-STREAM FLOW MAINTENANCE

MAIN PROBLEMS ADDRESSED

SOIL EROSION

BIODIVERSITY LOSS

FLOOD CONTROL

DISASTER RISK REDUCTION

FOOD SECURITY

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Soil and Water Regeneration:** MAR supports soil moisture retention and prevents erosion, which enhances soil fertility and agricultural productivity.

REGULATING

- **Flood and Stormwater Management:** By intercepting runoff and enhancing infiltration through recharge dams and sand dams, MAR helps reduce flood risks and improves water quality by filtering stormwater.

PROVISIONING

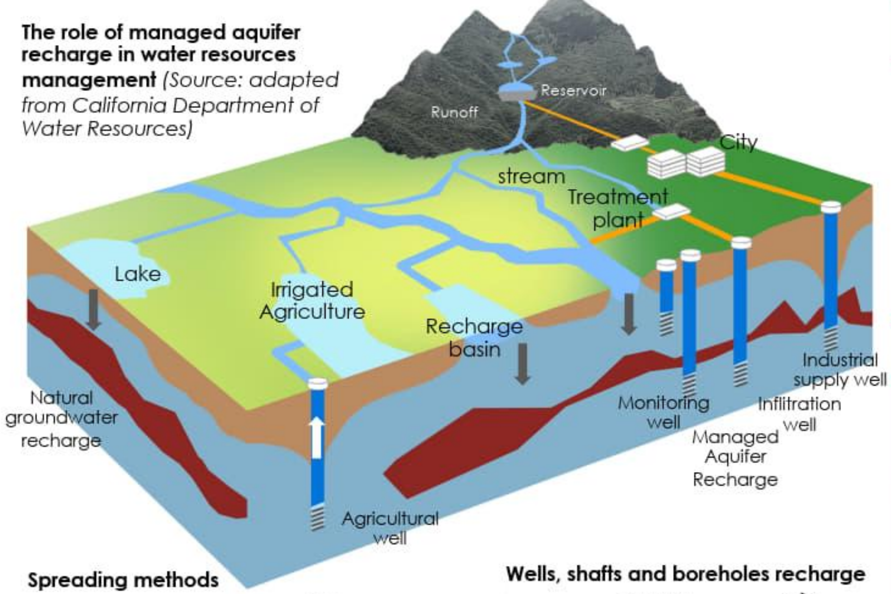
- **Water Storage and Supply:** MAR provides a reliable underground water storage system, ensuring water availability during dry seasons and supporting agriculture, industry, and domestic water use.

SOCIAL BENEFITS

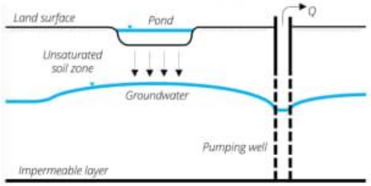
- **Community Engagement:** MAR promotes local participation in water management, creating opportunities for community involvement and strengthening resilience.

NbS-10: MANAGED AQUIFER RECHARGE (MAR)

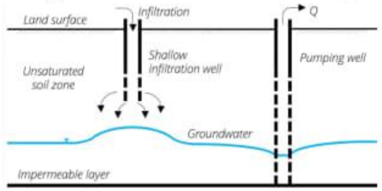
The role of managed aquifer recharge in water resources management *(Source: adapted from California Department of Water Resources)*



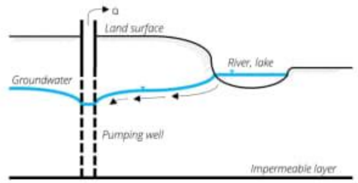
Spreading methods



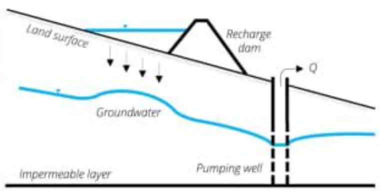
Wells, shafts and boreholes recharge



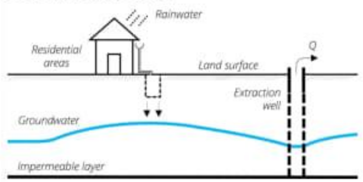
Induced bank filtration



In-channel modifications



Runoff harvesting



Techniques referring primarily to getting water infiltrated and to intercepting the water. *Source: INOWAS (Innovative Groundwater Solutions)*

PROJECT'S CHALLENGES & RISKS

- **Hydrological Uncertainty:** Variability in regional hydrogeology and rainfall patterns can complicate the accurate assessment of recharge potential and long-term effectiveness of MAR systems.
- **Water Quality Risks:** Inadequate monitoring and treatment of water used for recharge may lead to the contamination of aquifers with pollutants or pathogens, affecting water quality.
- **Clogging and Maintenance Issues:** Over time, clogging of recharge infrastructure, such as wells and infiltration ponds, can reduce efficiency, requiring regular maintenance and intervention.

NbS co-BENEFITS AND THEIR INDICATORS

- **Improved Water Security**
  Increased groundwater levels and sustained water supply during dry seasons.
- **Enhanced Agricultural Productivity**
  Increased crop yield due to improved soil moisture availability from groundwater recharge.
- **Flood Mitigation**
  Reduced flood events and damage in areas with MAR interventions like recharge dams and sand dams.
- **Water Quality Improvement**
  Decreased levels of pollutants and improved water clarity in recharged aquifers.
- **Coastal Resilience**
  Reduced incidences of saltwater intrusion in coastal aquifers, improving freshwater availability.
- **Climate Change Adaptation**
  Increased resilience to droughts and extreme weather events as a result of enhanced groundwater storage.

COST ANALYSIS

- **Direct Costs**
  Wells, recharge ponds, and pumps have an average cost range of $100k to $300k per project (depending on scale).
- **Indirect Costs**
  Maintenance costs, monitoring, and long-term management, estimated at $10k to $50k/year.
- **Time Horizon**
  Typical time horizon is 20-30 years, with a discount rate ranging from 3% to 7% based on local economic conditions.
- **Direct Benefits**
  Increased water availability.
- **Indirect Benefits**
  Enhanced agricultural productivity and flood mitigation
- **Risk Assessment**
  Risks of clogging, water quality degradation, and hydrological uncertainty.

REFERENCES:

Vietnam, Mekong Delta Integrated Climate Resilience and Sustainable Livelihoods Project.
Indonesia, The Mara River Basin Groundwater Recharge Project.

IMPLEMENTATION OPPORTUNITIES:

Vietnam, coastal regions, Mekong Delta.
Indonesia, Bali.
Philippines, Mindanao.
Southeast Thailand, Chonburi, Rayong.

NbS-11: BIORETENTION PONDS AND SWALES

Bioretention ponds and swales can enhance flood management and urban resilience by mimicking natural hydrological processes to capture, store, and treat stormwater runoff. These systems are particularly relevant in Southeast Asia, where rapid urbanization and monsoonal rains contribute to flash floods and water pollution.

Bioretention ponds are shallow, vegetated basins designed with layers of soil, sand, and gravel to filter and depollute water, while swales are gently sloping channels that convey and infiltrate runoff, reducing peak flows and recharging groundwater.

Together, they mitigate flood risks, improve water quality through pollutant filtration and sedimentation, and support biodiversity by creating green habitats.

Beyond technical benefits, they enhance urban landscapes, foster community awareness, and reduce reliance on costly engineered infrastructure, making them suitable for both cities and villages.

Singapore's ABC Waters Program exemplifies their successful implementation, while areas like the Mekong Delta or rural Indonesia could adopt these systems to address localized flooding, sedimentation, and water resource challenges, promoting resilience and sustainability in diverse settings.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| STORMWATER MANAGEMENT | POLLUTION MITIGATION | GROUNDWATER RECHARGE | COMMUNITY RESILIENCE | HABITAT CREATION | URBAN HEAT ISLAND MITIGATION

MAIN PROBLEMS ADDRESSED

BIODIVERSITY LOSS

FLOOD CONTROL

DISASTER RISK REDUCTION

AIR QUALITY IMPROVEMENT

URBAN HEAT ISLAND

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Enhance biodiversity** by creating habitats for flora and fauna within urban and peri-urban areas.

REGULATING

- **Manage stormwater** by reducing runoff, peak flows, and flash flooding through natural filtration and infiltration.

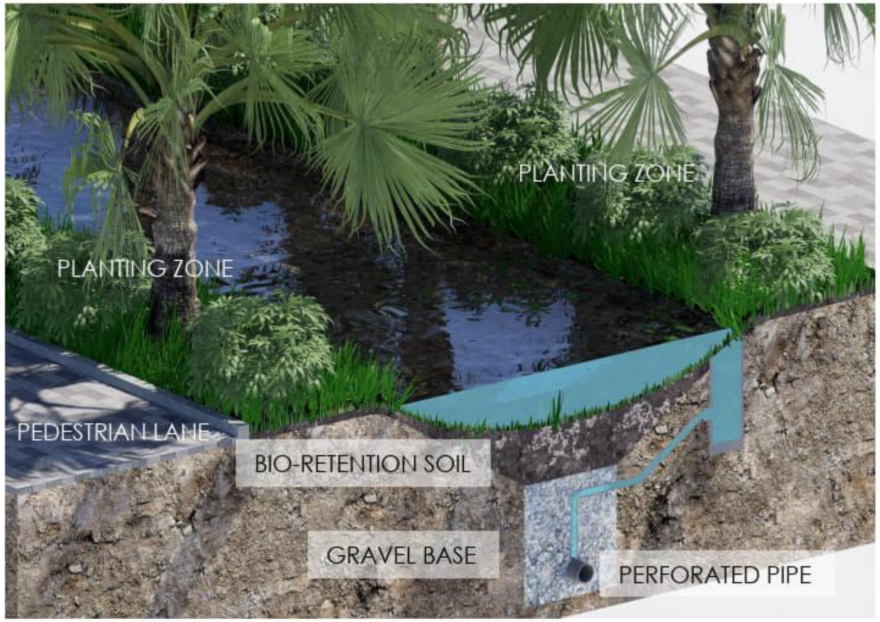
PROVISIONING

- **Replenish groundwater resources** by facilitating aquifer recharge during storm events.

SOCIAL BENEFITS

- **Improve urban aesthetics and public spaces**, fostering recreational opportunities and community engagement in climate resilience efforts.

NbS-11: BIORETENTION PONDS AND SWALES



Bioswale typical section. Source: Citilinks

Bioswale in Kronsberg, Germany

PROJECT'S CHALLENGES & RISKS

- **Space Constraints**: Rapid urbanization and high population density often limit the availability of land for implementing bioretention ponds and swales.
- **Maintenance Challenges**: Inadequate maintenance can lead to clogging, reduced infiltration capacity, and poor vegetation health, undermining long-term functionality.
- **Climate Variability**: Extreme rainfall or prolonged droughts can reduce the effectiveness of bioretention systems, causing overflow or drying out.
- **Pollutant Overload**: High pollutant loads from industrial and urban runoff may exceed the filtration capacity, leading to potential contamination of nearby soil and groundwater.

NbS co-BENEFITS AND THEIR INDICATORS

- **Flood Mitigation**
  Reduction in urban flooding frequency by managing peak stormwater flows.
- **Water Quality Improvement**
  Decrease in nutrient and pollutant concentrations in runoff, measured through water quality testing.
- **Biodiversity Enhancement**
  Increase in native plant and animal species in and around urban green spaces.
- **Groundwater Recharge**
  Measurable increase in local aquifer levels due to infiltration.
- **Urban Heat Island Reduction**
  Reduction in ambient temperatures in areas with bioretention systems, tracked via thermal imaging.
- **Community Liveability**
  Increased recreational use and positive feedback from residents in areas with well-maintained bioretention features.

COST ANALYSIS

- **Direct Costs**
  Initial construction costs range from $15k to $50k/ha, depending on design complexity and materials.
- **Indirect Costs**
  Annual maintenance costs are estimated at $1k to $5k/ha, covering vegetation upkeep and sediment removal.
- **Time Horizon**
  20-30 year lifespan, with a discount rate of 5-8% for long-term economic evaluations.
- **Direct Benefits**
  Flood damage mitigation can save $10k to $30k annually per urban block during heavy rains.
- **Indirect Benefits**
  Improved ecosystem services, such as groundwater recharge and air quality.
- **Risk Assessment**
  Potential failure due to poor maintenance or extreme weather events.

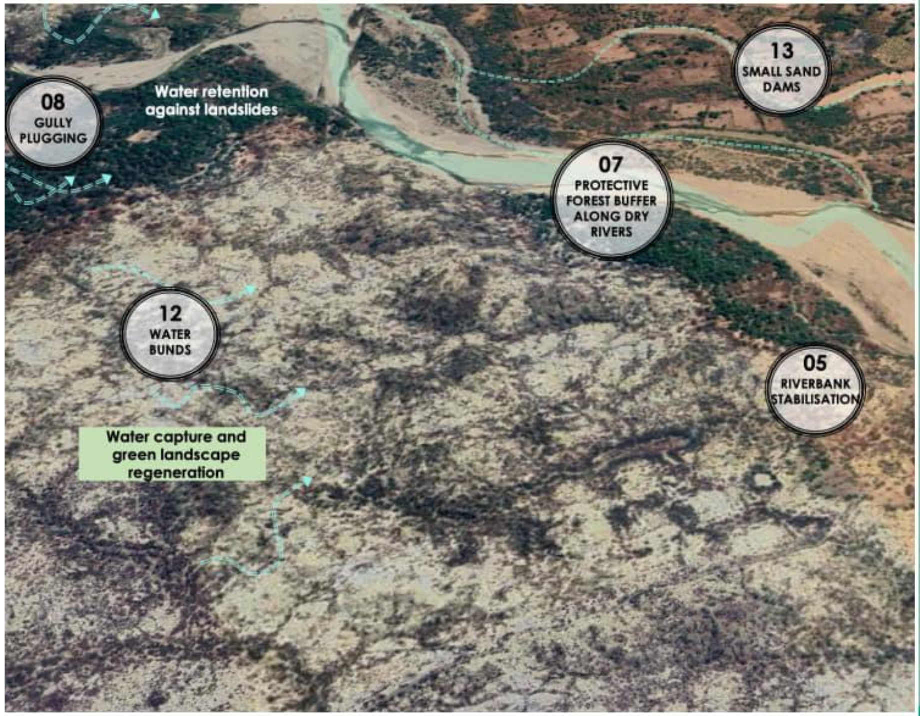
REFERENCES:

Singapore, Bishan-Ang Mo Kio Park : urban park integrating bioretention swales and ponds.
Singapore, East Coast Park.
Australia, Sydney Water's Stormwater Project: Network of bioretention swales and rain gardens.

IMPLEMENTATION OPPORTUNITIES:

Indonesia, Jakarta.
Thailand, Bangkok.
Vietnam, Ho Chi Minh City.
Philippines, Cebu City.

NbS-12: WATER BUNDS



Water bunds are designed to collect, store, and manage water, playing a crucial role in improving agricultural productivity, preventing soil erosion, and recharging groundwater. Typically built as embankments or earthen ridges along contour lines, water bunds slow down surface runoff during rains, allowing water to infiltrate the soil and be stored for future use. This technique is especially beneficial in the dry and semi-dry regions such as northeastern Cambodia, central and northern Thailand, and upland Laos, where erratic rainfall and water scarcity challenge agricultural livelihoods. Lessons from similar practices in dry regions of East Africa demonstrate that water bunds effectively conserve moisture, improve soil fertility, and support resilient farming systems even under harsh climatic conditions. Water bunds mitigate soil erosion by reducing water velocity, trap sediments and organic matter, and enhance the so. it's capacity to retain moisture. On a landscape scale, water bunds stabilize degraded terrains, promote vegetative cover, and support ecosystem restoration. Socially and economically, they improve crop yields, reduce vulnerability to droughts, and enhance groundwater availability, directly benefiting farmers and local communities. By fostering participatory approaches, such as community-driven bund construction and maintenance, water bunds also build social cohesion and promote sustainable land and water management.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

SUSTAINABLE AGRICULTURE | WATER MANAGEMENT | ECOSYSTEM RESTORATION | BIODIVERSITY SUPPORT | CLIMATE RESILIENCE | SOIL CONSERVATION

MAIN PROBLEMS ADDRESSED

SOIL EROSION | FLOOD CONTROL | FOOD SECURITY | DISASTER RISK REDUCTION | BIODIVERSITY LOSS

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Soil fertility maintenance**: By reducing erosion and enhancing water retention, water bunds support soil health and agricultural productivity.
- **Biodiversity promotion**: Water bunds provide microhabitats that support local flora and fauna.

REGULATING

- **Water regulation**: Water bunds capture runoff and promote groundwater recharge, helping to maintain stable water levels for agriculture.
- **Erosion control**: They help prevent soil erosion by slowing down water movement, stabilizing the soil structure.

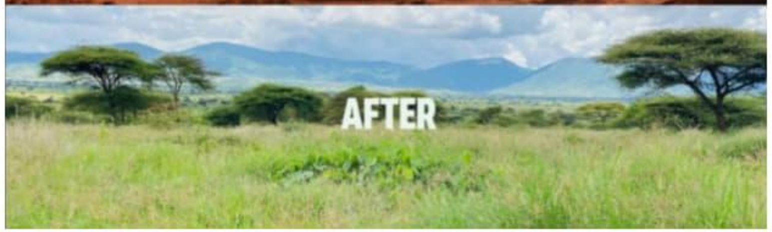
PROVISIONING

- **Improved agricultural productivity**: Water bunds increase crop yields, contributing to food security.
- **Water supply for irrigation** by storing water, ensuring a continuous water supply for irrigation.

SOCIAL BENEFITS

- **Community resilience**: By improving water availability and reducing erosion, water bunds contribute to stronger farming communities.
- **Economic benefits**: Increased agricultural productivity and reduced costs from soil erosion.

NbS-12: WATER BUNDS



PROJECT'S CHALLENGES & RISKS

- **Maintenance and Durability**: Silt accumulation, structural degradation, or damage from floods can reduce effectiveness over time.
- **Climate variability**: Erratic rainfall patterns and extreme weather events, such as heavy storms or droughts, can undermine the capacity of water bunds to store and manage water effectively.
- **Land-use conflicts**: In densely populated areas, land competition for agricultural or urban use can limit the space available for water bunds.
- **Inadequate technical knowledge**: Lack of proper design, construction, and management expertise may lead to poorly constructed water bunds that fail to achieve desired outcomes.

NbS co-BENEFITS AND THEIR INDICATORS

- **Increased Agriculture Productivity**
  Higher crop yields due to improved water management, measured by increased crop output per hectare.
- **Erosion Control**
  Reduction in soil erosion, indicated by less sedimentation in surrounding water bodies or lower soil loss rates.
- **Improved Groundwater Recharge**
  Increased groundwater levels, measured through water table monitoring or increased well water availability.
- **Enhanced Biodiversity**
  Creation of microhabitats, measured by the presence of a variety of plant and animal species in and around the bunds.
- **Climate Change Resilience**
  Improved capacity to withstand climate extremes, indicated by fewer crop failures during dry periods or reduced flooding during wet periods.
- **Social and Economic Benefits**
  Improved livelihoods, measured by increased income from more reliable agriculture or reduced costs associated with water scarcity.

COST ANALYSIS

- **Direct Costs**
  Initial construction for water bunds range around 800 USD/ha, depending on the scale and materials used.
- **Indirect Costs**
  Land acquisition, labor for construction, and monitoring may add 10%-20% to the total project cost.
- **Time Horizon**
  Benefits can be realized over 10 to 20 years, with a typical discount rate of 3%-5% for long-term investments.
- **Direct Benefits**
  Increased crop productivity and water retention could result in direct benefits, depending on local conditions.
- **Indirect Benefits**
  Enhanced ecosystem services, such as soil stabilization and biodiversity, potentially leading to long-term environmental savings.
- **Risk Assessment**
  Repair costs due to extreme weather or poor construction.

REFERENCES:

Peru, Ica Valley.
Vietnam, Central Plateau.
India, The Thar Desert.
Kenya, Kitui and Baringo Counties.
Tanzania, Shinyanga, Dodoma and Singida Regions.

IMPLEMENTATION OPPORTUNITIES:

Indonesia, East Nusa Tenggara.
Northern **Cambodia.**
Laos' Savannakhet Province.

NbS-13: SMALL SAND DAMS

Small sand dams support the resilience of dry river landscapes by capturing and storing water within sandy riverbeds, offering a sustainable water source for local communities, agriculture, and ecosystems. Typically constructed from concrete or stone, these dams trap sand and sediment carried by rivers during seasonal floods, creating a natural reservoir that stores water while reducing evaporation and replenishing groundwater. This improves water availability during dry periods, strengthens food security, and ensures access to clean water for drinking and irrigation. In the watersheds of dry rivers in Western Timor, Indonesia, where water scarcity and flash floods often threaten livelihoods, sand dams can stabilize riverbanks, mitigate soil erosion, and reduce flood risks downstream. Additionally, they provide critical support for riparian reforestation and biodiversity conservation, promoting ecosystem health and sustainable agriculture. Given Western Timor's rugged terrain and prolonged dry seasons, sand dams offer a cost-effective, community-driven approach to improve water security, manage floods, and support regenerative farming, aligning with local needs and ecological conditions.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- INTEGRATED WATER RESOURCES MANAGEMENT
- BIODIVERSITY CORRIDORS
- SOIL AND WATER CONSERVATION
- CLIMATE-SMART AGRICULTURE
- RIPARIAN BUFFER RESTORATION
- SUSTAINABLE LIVELIHOODS APPROACH

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Groundwater Recharge**: Enhances aquifer replenishment by capturing and storing water in sand-filled reservoirs.

REGULATING

- **Flood Mitigation**: Reduces the impact of sudden floods by slowing water flow and storing it in riverbeds.

PROVISIONING

- **Clean Water Supply**: Provides a reliable source of water for drinking, irrigation, and livestock during dry seasons.

SOCIAL BENEFITS

- **Food Security**: Supports agricultural productivity by ensuring year-round water availability for crops and livestock.

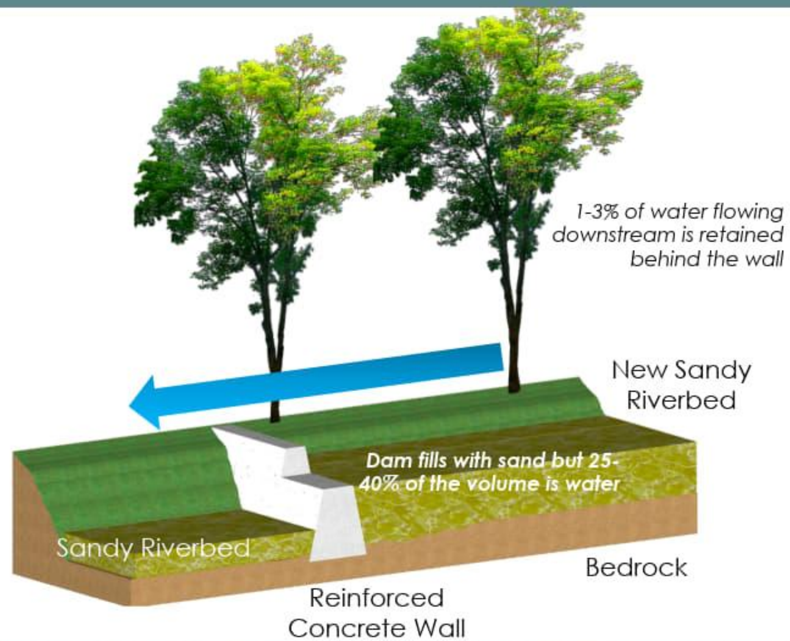
MAIN PROBLEMS ADDRESSED

SOIL EROSION

DISASTER RISK REDUCTION

FLOOD CONTROL

NbS-13: SMALL SAND DAMS



PROJECT'S CHALLENGES & RISKS

- **Site Suitability**: Identifying appropriate locations with adequate sand accumulation and stable bedrock can be challenging and resource-intensive.
- **Community Engagement**: Insufficient involvement of local communities in planning and maintenance may lead to lack of ownership and project sustainability.
- **Sediment Management**: Poorly designed sand dams risk excessive sediment deposition, reducing storage capacity and effectiveness over time.
- **Seasonal Water Flow Variability**: Highly irregular or minimal seasonal water flows, common in Western Timor, can limit the ability of sand dams to consistently recharge groundwater.

NbS co-BENEFITS AND THEIR INDICATORS

- **Enhanced Groundwater Recharge**
  Small sand dams increase groundwater storage, with water table levels rising by up to 3–5 meters in adjacent areas.
- **Flood Mitigation**
  Sand dams regulate sudden water flows during floods, reducing downstream flood intensity by 20–40%.
- **Agricultural Productivity**
  Irrigation availability increases crop yields by 50–100% in regions dependent on dryland farming.
- **Improved Water Access**
  Communities gain year-round access to clean water, with up to 1,500 people benefiting from a single sand dam.
- **Biodiversity Support**
  Sand dams create microhabitats for aquatic and terrestrial species, with a 30–50% increase in vegetation cover near dams.
- **Climate Adaptation**
  Strengthened water storage buffers communities against droughts, reducing water scarcity risk by 30% in arid regions.

COST ANALYSIS

- **Direct Costs**
  Construction of a small sand dam costs $7k–15k, depending on local materials and labor availability.
- **Indirect Costs**
  Costs for community engagement, training, and maintenance range from $1k–3k per dam annually.
- **Time Horizon**
  Lifespan of 30–50 years, with a discount rate of 5–7% typically applied for cost-benefit analysis.
- **Direct Benefits**
  Annual water savings for agriculture and domestic use can be valued at $5k–10k per community.
- **Indirect Benefits**
  Enhanced crop productivity and reduced drought-related losses generate $10k–25k in economic value annually.
- **Risk Assessment**
  Mitigating risks such as sediment overflow or structural failure typically requires an additional 10–15% of initial costs for monitoring and reinforcements.

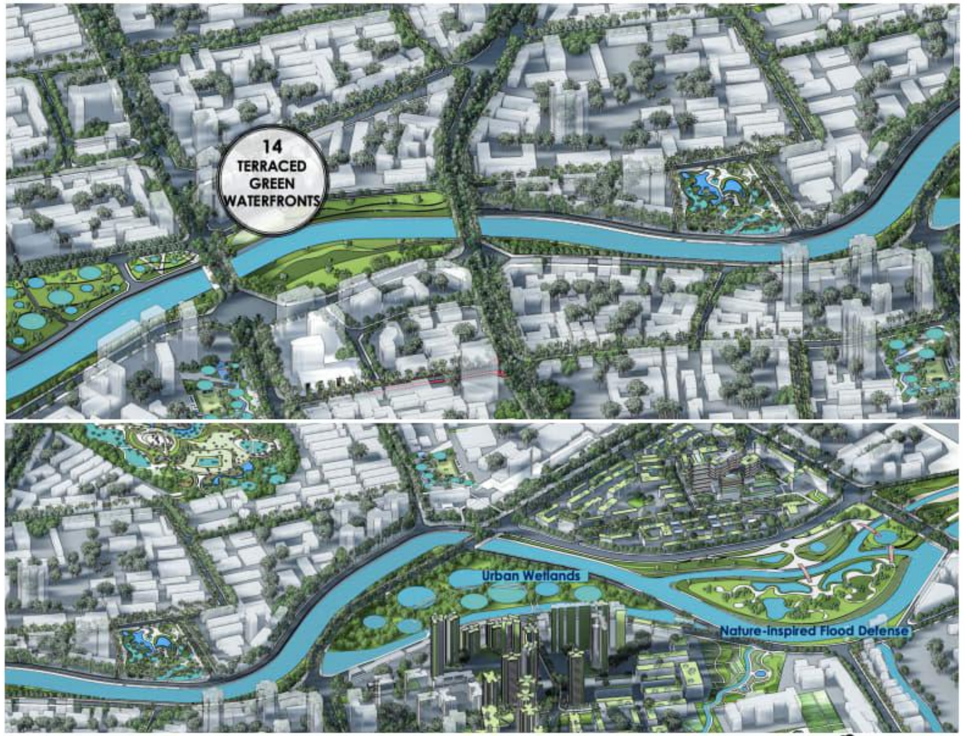
REFERENCES:

Philippines, community-based Bohol Sand Dam project,
Kenya, Kitui and Machakos Sand Dam project.
India, Saurashtra Sand Dams for Drylands in Gujarat.

IMPLEMENTATION OPPORTUNITIES:

Western Timor, Noelmina and Benain Rivers.
Myanmar , Central Dry Zone's Ayeyarwady River tributaries.

NbS-14 TERRACED GREEN RIVERFRONTS



Terraced green riverfronts are a multifunctional nature-based solution (NbS) designed to enhance flood management, climate adaptation, and urban resilience, blending technical, landscape, and social benefits.

These riverfronts utilize tiered landscaping, vegetated gabion walls, and permeable surfaces to reduce flood risks, improve water retention, and stabilize riverbanks, while integrating vegetation to absorb stormwater and filter pollutants. Acting as part of the sponge city approach, they mitigate urban heat islands, promote biodiversity corridors, and support aquifer recharge. Their design fosters community engagement by creating recreational spaces, local markets, and tourism opportunities, while also contributing to walkability and urban quality of life. Contextually, terraced green riverfronts are well-suited to Southeast Asia's flood-prone cities and rural settlements, offering scalable, climate-resilient solutions that align with both urban development and ecosystem preservation. Lessons from successful implementations demonstrate their economic viability and ability to enhance quality of life in diverse settings.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| WATER SENSITIVE URBAN DESIGN | INTEGRATED WATER RESOURCE MANAGEMENT | SUSTAINABLE LAND MANAGEMENT | ECOSYSTEM RESTORATION | GREEN INFRASTRUCTURE

MAIN PROBLEMS ADDRESSED

- BIODIVERSITY LOSS
- FLOOD CONTROL
- URBAN HEAT ISLAND
- DISASTER RISK REDUCTION
- CARBON SEQUESTRATION
- AIR QUALITY IMPROVEMENT

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Biodiversity Habitat:** Provides habitats for aquatic species and terrestrial wildlife, enhancing local biodiversity along riverbanks.
- **Soil Formation:** Stabilizes soil through vegetative cover and bioengineering, preventing erosion.

REGULATING

- **Flood Regulation:** Absorbs and slows down stormwater runoff, mitigating flood risks by using permeable surfaces and green infrastructure.
- **Climate Regulation:** Helps in urban cooling by increasing green cover and water retention, contributing to heat island mitigation.

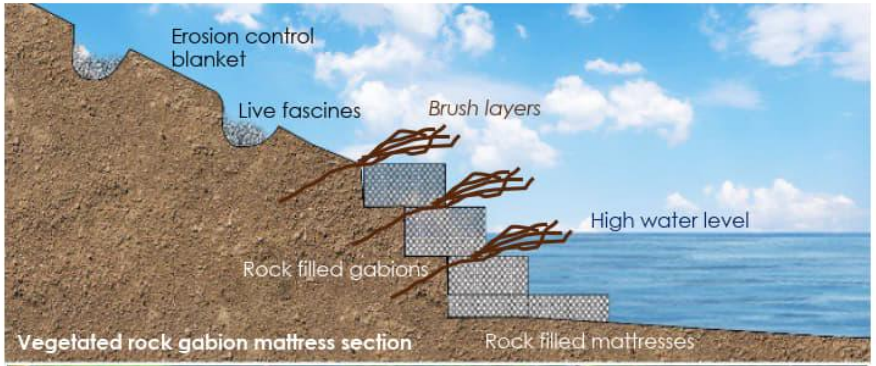
PROVISIONING

- **Raw Materials:** Vegetation can provide materials like timber, medicinal plants, and other natural resources for local use.

SOCIAL BENEFITS

- **Recreation and Well-being:** Creates green spaces for public use, offering opportunities for leisure, relaxation, and community engagement.
- **Cultural and Aesthetic Values:** Enhances the aesthetic appeal of the riverfront, contributing to community identity and heritage.

NbS-14 TERRACED GREEN RIVERFRONTS



PROJECT'S CHALLENGES & RISKS

- **Possible Erosion Risk:** Improper design or maintenance of terraced structures can lead to erosion, especially during intense rainfall, affecting the stability of the riverbank.
- **Invasive Species:** The introduction of non-native plant species for green cover could disrupt local ecosystems and threaten native biodiversity.
- **Conflicting Land Use:** Urban development and industrial activities along riverfronts may suffer from space limitations.
- **High Initial Investment:** The construction of terraced green riverfronts requires important upfront investment, which may pose financial challenges for local governments.

NbS co-BENEFITS AND THEIR INDICATORS

- **Flood Mitigation**
  Reduction in flood peak flow and increased water absorption capacity during heavy rainfall.
- **Biodiversity Enhancement**
  Increase in local plant and animal species diversity along the riverfront area.
- **Carbon Sequestration**
  Amount of carbon dioxide absorbed by vegetation along the riverfront (tons/year)
- **Recreational Opportunities**
  Increase in public use of green spaces, measured by foot traffic or park visits.
- **Improved Water Quality**
  Reduction in pollutants in river water, such as suspended solids or nutrient levels.
- **Social Cohesion**
  Community engagement in riverfront stewardship activities or participation in events like clean-up programs.

COST ANALYSIS

- **Direct Costs**
  Direct costs include materials such as gabion walls, planting, and labor, ranging from USD 50 to 200/ m2
- **Indirect Costs**
  Long-term maintenance (irrigation, plant care, and monitoring) estimated at USD 10-30/m2 /year.
- **Time Horizon**
  Typically 10-20 years, with a discount rate of 3-5% for long-term cost-benefit analysis.
- **Direct Benefits**
  Direct benefits include enhanced flood resilience and improved water quality, which could reduce costs from flood damage.
- **Indirect Benefits**
  Social, aesthetic and recreational value, resulting in increased tourism or local business activity.
- **Risk Assessment**
  Potential risks include damage from extreme weather events or lack of community engagement.

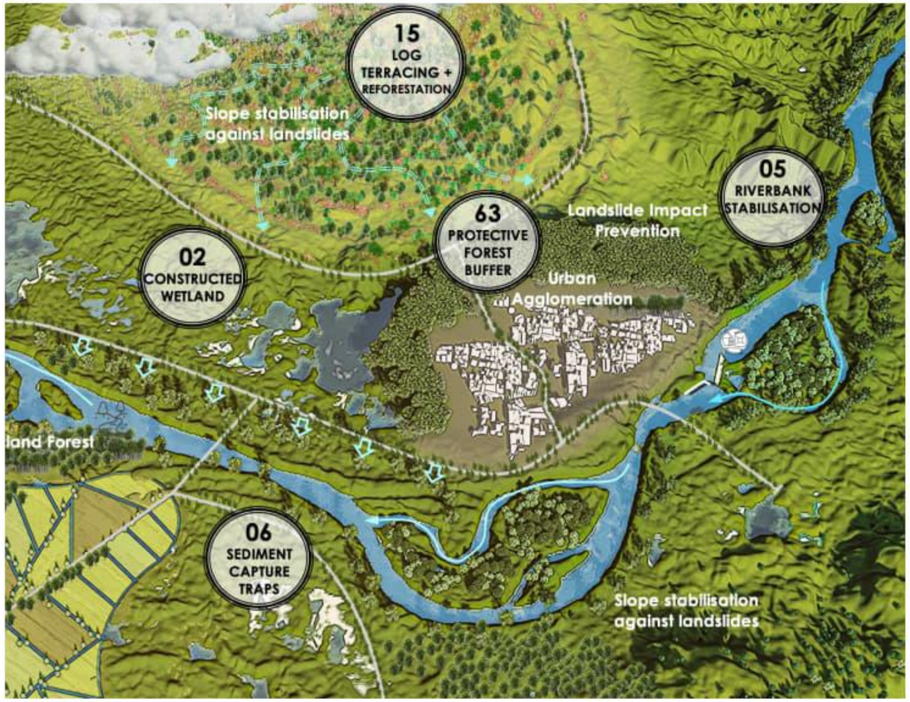
REFERENCES:

Thailand, Bangkok, Chao Phraya Riverfront Development, riverfront revitalization effort, using vegetated terraces, riprap, and gabion walls.
Singapore, River Promenade.
Cambodia, Phnom Pehn, Mekong River Flood Protection and Green Infrastructure.

IMPLEMENTATION OPPORTUNITIES:

Vietnam , Hanoi, Red River waterfronts
HCMC, Saigon River.
Indonesia, Surabaya Brantas River.
Philippines, Manila, Pasig River.

NbS-15: LOG TERRACING (WATER DELAY INFRASTRUCTURE)



Log terracing, a water-delay infrastructure is a sustainable method for stabilizing slopes, preventing landslides, and supporting reforestation and agriculture in the diverse landscapes of Southeast Asia.

This technique involves arranging logs along contour lines to form terraces that slow water runoff, reduce soil erosion, and improve water infiltration. Over time, these terraces promote the accumulation of fertile soil, enabling the growth of native vegetation and agroforestry crops. Tropical tree species such as *Albizia saman* (rain tree), *Gliricidia sepium* (mother of cacao), and *Leucaena leucocephala* (ipil-ipil) are often used for reforestation in log terracing due to their fast growth, nitrogen-fixing properties, and ability to stabilize soil.

In addition to stabilizing degraded slopes, log terraces create microhabitats for biodiversity, improve local water cycles, and support sustainable livelihoods by enabling agriculture in hilly areas.

Socially, this approach strengthens community involvement in land management while providing tangible benefits like improved food security and resilience to climate-related disasters.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- AGROFORESTRY SYSTEMS
- FOREST LANDSCAPE RESTORATION
- INTEGRATED WATERSHED MANAGEMENT
- SUSTAINABLE LAND MANAGEMENT

MAIN PROBLEMS ADDRESSED


SOIL EROSION


FLOOD CONTROL


DISASTER RISK REDUCTION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Soil formation and nutrient cycling:** Enhances soil stability and supports soil regeneration through reduced erosion and increased organic matter retention.
- **Biodiversity habitat:** Provides a habitat for various species by creating a stable micro-environment and fostering plant regeneration on terraced slopes.

REGULATING

- **Water regulation:** Reduces surface runoff and controls water flow, preventing soil erosion and mitigating the risk of flooding in downstream areas.

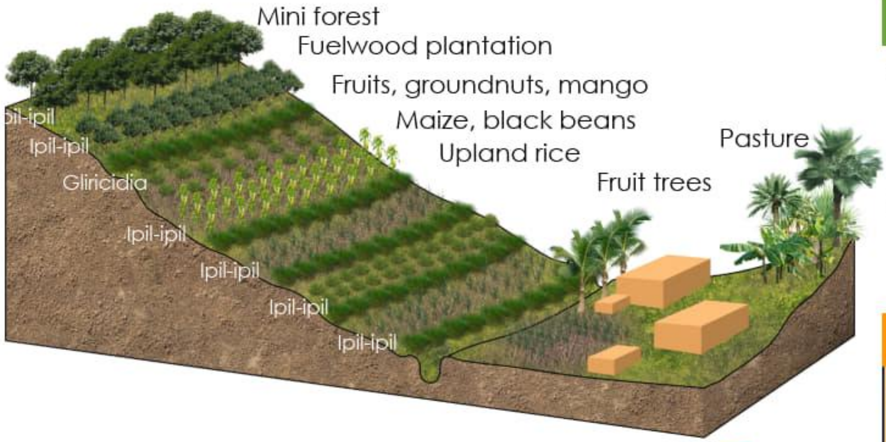
PROVISIONING

- **Timber and non-timber forest products:** Supports sustainable harvesting of forest resources, such as timber and medicinal plants, from reforested areas.
- **Agroforestry products:** Provides crops and food products from sustainable agriculture integrated with reforestation efforts, benefiting local communities.

SOCIAL BENEFITS

- **Enhanced community resilience:** Reduces vulnerability to landslides and flooding, increasing the safety and well-being of local populations.

NbS-15: LOG TERRACING (WATER DELAY INFRASTRUCTURE)



PROJECT'S CHALLENGES & RISKS

- **High initial investment:** The construction of log terraces requires significant upfront financial resources, including the costs of materials and labor, which can be challenging for local communities to afford.
- **Maintenance challenges:** Log terraces require ongoing maintenance to prevent degradation and ensure their effectiveness in controlling erosion and stabilizing slopes over time.
- **Ecological compatibility:** Inappropriate species selection for both the logs and the plant species involved in the terracing can lead to poor results, such as soil erosion or lack of vegetation coverage.

NbS co-BENEFITS AND THEIR INDICATORS

Improved Soil Stability
Reduces soil erosion on upland slopes, measurable by a 30–50% decrease in annual sediment loss within reforested areas.

Increased Water Retention
Enhances carbon storage, with an estimated 5–10 tons of CO_2 absorbed per hectare annually in mature forests.

Enhanced Biodiversity
Improves watershed health, indicated by a 20–40% increase in groundwater recharge and reduced surface runoff during rainy seasons.

Reduced Flooding Risks
Supports wildlife habitats, with a measurable increase of 15–25% in species richness in project areas over 5 years.

Livelihood Enhancement
Provides sustainable income through agroforestry crops like coffee or spices.

Climate Change Resilience
Mitigates landslide risks, shown by a 60–80% reduction in landslide frequency in reforested regions over a decade.

COST ANALYSIS

Direct Costs
Direct costs range from $2,000 to $5,000 per hectare, covering materials (logs, plants), labor, and equipment.

Indirect Costs
Ongoing maintenance (e.g., replanting, monitoring), potentially around $500 to $1,000 per year per hectare.

Time Horizon
5-10 years, discount rate of 5-7% annually, long-term environmental and social benefits.

Direct Benefits
Improved soil stability and water retention, which can lead to increased agricultural productivity.

Indirect Benefits
Enhanced biodiversity, improved water quality, and carbon sequestration may provide societal benefits valued at around $1,000-$3,000 per ha.

Risk Assessment
Potential failure to secure sustainable funding or community buy-in.

REFERENCES:

the Philippines, Ifugao Province's Reforestation and Stabilisation projects.
Indonesia, Central Java's Agrosilvopastoral Systems in Slope Areas, Lao Cai and Yen Bai Province Forest restoration efforts.

IMPLEMENTATION OPPORTUNITIES:

Laos upland regions.
Northern Thailand, Chiang Mai.
Myanmar, Shan State.

NbS-16 RIVER STREAM RESTORATION AND CULVERTING

River stream restoration and daylighting (or deculverting) involves uncovering buried streams or restoring degraded rivers to their natural states, thereby addressing urban flooding, enhancing biodiversity, and improving urban and rural resilience to climate events in Southeast Asia. Techniques include full channel restoration (removal of culverts and concrete), stream naturalization (reintroducing meanders, riparian vegetation, and wetlands), and partial daylighting (exposing sections of buried streams while maintaining infrastructure). Iconic examples like the Cheonggyecheon River Restoration in Seoul, South Korea, demonstrate how transforming a culverted urban river into a vibrant green corridor can significantly reduce urban heat, improve air quality, and enhance social cohesion.

In rural areas, river daylighting projects such as restoring irrigation canals or small river streams support agricultural sustainability and aquifer recharge. These projects promote ecological connectivity, mitigate urban heat islands, and create recreational green spaces, making cities and rural landscapes more livable and resilient. In Southeast Asia, such initiatives are particularly valuable for cities like Jakarta, Bangkok, and Hanoi, where heavy rainfall, urbanization, and aging drainage systems necessitate innovative flood management. The approach also revitalizes biodiversity, supports local economies through ecotourism, and fosters environmental stewardship.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOLOGICAL RESTORATION
- ECO-DRR
- CLIMATE ADAPTATION
- INTEGRATED WATER RESRORUCE MANAGEMENT
- URBAN BIODIVERSITY CONSERVATION
- SUSTAINABLE URBAN DRAINAGE SYSTEMS
- NATURE-COMPATIBLE INFRASTRUCTURE

MAIN PROBLEMS ADDRESSED

- BIODIVERSITY LOSS
- FLOOD CONTROL
- URBAN HEAT ISLAND
- DISASTER RISK REDUCTION
- AIR QUALITY IMPROVEMENT

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Habitat creation**: Restores natural habitats for aquatic and riparian species, promoting biodiversity.

REGULATING

- **Flood mitigation**: Enhances natural water retention, reduces urban flooding, and stabilizes streambanks.

PROVISIONING

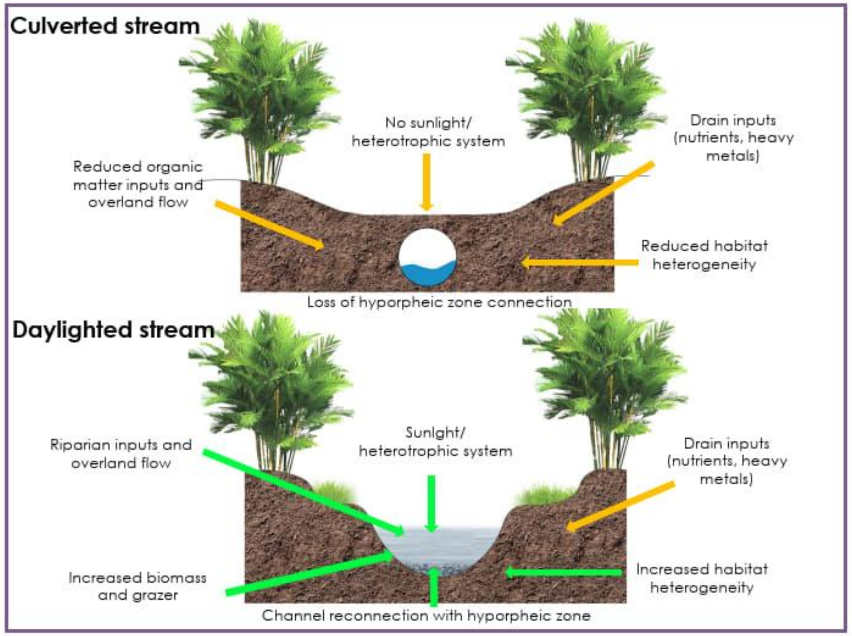
- **Water resource enhancement**: Improves water quality and availability for agricultural, domestic, or industrial use.

SOCIAL BENEFITS

- **Recreational spaces**: Provides green and blue spaces for community interaction, health, and well-being.
- **Cultural revitalization**: Reconnects communities with historical and cultural significance of waterways.

NbS-16 RIVER STREAM RESTORATION AND CULVERTING

Seoul, Cheonggyecheon Stream Restoration



PROJECT'S CHALLENGES & RISKS

- **High implementation costs**: River stream restoration and daylighting projects often require substantial investment in infrastructure, land acquisition, and long-term maintenance.
- **Urbanization constraints**: In densely urbanized areas, available space for stream restoration may be limited, complicating the integration of natural features.
- **Community opposition**: Local communities and industries may resist changes to existing river infrastructure, especially if they perceive disruptions to current use or property values.

NbS co-BENEFITS AND THEIR INDICATORS

- **Biodiversity Enhancement**
  Increased biodiversity index in restored river sections.
- **Flood Resilience**
  Reduced frequency of local flooding events after restoration.
- **Water Quality Improvement**
  Increased water quality metrics, such as lower concentrations of pollutants (e.g., nitrogen, phosphates).
- **Urban Livability**
  Increased public use and satisfaction of green spaces along restored rivers.
- **Climate Mitigation**
  Reduced urban heat island effect and carbon footprint in surrounding areas.
- **Economic Revitalization**
  Increased local economic activity, such as tourism revenue or property price growth.

COST ANALYSIS

- **Direct Costs**
  Excavation, landscaping, and infrastructure costs range from $1 million to $10 million per km.
- **Indirect Costs**
  Vegetation upkeep and flood management systems costs can reach $200,000 annually.
- **Time Horizon**
  10- to 50-year time horizon, with a discount rate of 3% to 5%.
- **Direct Benefits**
  Benefits from increased biodiversity, improved water quality, and reduced flooding.
- **Indirect Benefits**
  Increased property values, tourism revenue, and enhanced social well-being from green spaces.
- **Risk Assessment**
  Disruption of existing infrastructure, unexpected flooding, and ecological imbalances.

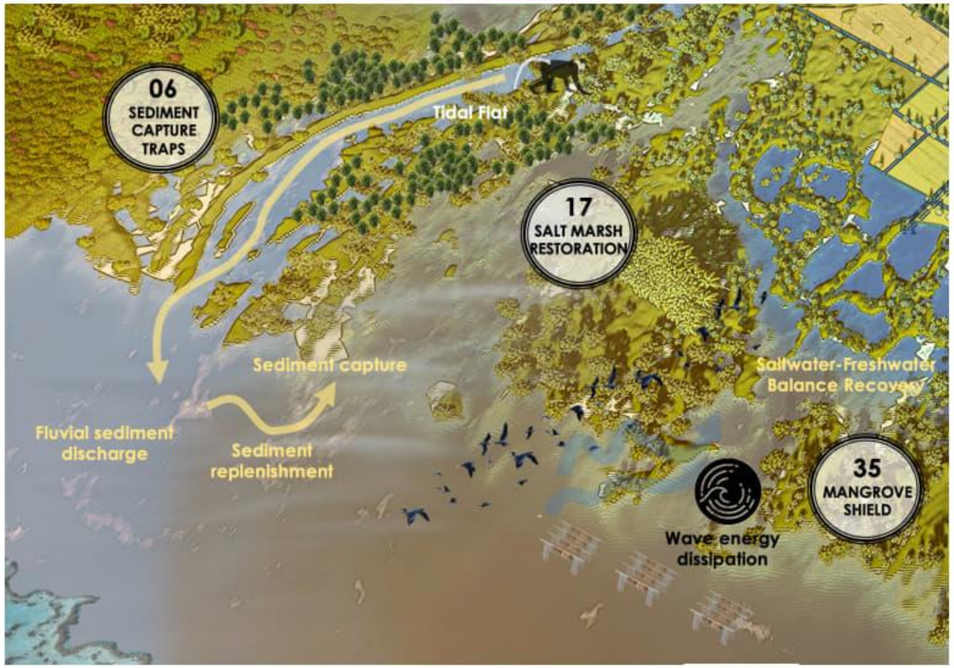
REFERENCES:

South Korea , Seoul, Cheonggyecheon Stream Restoration.
Singapore, Kallang River Daylighting.
USA, Los Angeles River Revitalization.

IMPLEMENTATION OPPORTUNITIES:

Thailand, Bangkok has several covered and heavily modified waterways, including the Klongs (canals).
Vietnam, Ho Chi Minh City's network of canals.
Manila's Pasig River, which is heavily encumbered by pollution and urban development.
Jakarta's Ciliwung River.

NbS-17: SALT MARSH RESTORATION



Salt Marsh Restoration focuses on rehabilitating tidal wetlands in coastal and port areas to restore their ecological functions and benefits. These habitats, characterized by salt-tolerant vegetation such as grasses, sedges, and mangrove-associated plants, are vital for supporting biodiversity, buffering against storm surges, improving water quality, and capturing carbon.

Restoration efforts often include re-establishing natural tidal flows, removing invasive species, and planting native vegetation suited to local conditions. In areas with degraded or subsided land, sediment nourishment or the strategic use of dredged materials can rebuild marsh platforms and enhance their functionality.

Projects frequently adopt a holistic approach by integrating salt marshes with nearby habitats, such as mangroves, mudflats, and seagrass beds, to create interconnected ecological networks.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOSYSTEM BASED ADAPTATION
- ECOSYSTEM-BASED DISASTER RISK REDUCTION
- ECOSYSTEM RESTORATION
- INTEGRATED COASTAL ZONE MANAGEMENT
- GREEN INFRASTRUCTURE

MAIN PROBLEMS ADDRESSED

- SOIL EROSION
- BIODIVERSITY LOSS
- FLOOD CONTROL
- DISASTER RISK REDUCTION
- CARBON SEQUESTRATION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Offer breeding, feeding, and nursery grounds for a wide range of species, including fish, shellfish, birds, and invertebrates.
- Play a key role in cycling nitrogen and phosphorus.
- Contributes to soil formation over time by accumulation of organic matter and sediments.

REGULATING

- Buffer against storm surges, wave energy, and erosion, reducing risks to coastal infrastructure.
- Sequester and store significant amounts of carbon helping to mitigate climate change.
- Filter pollutants, sediments, and excess nutrients from water
- Reduce the impact of coastal and riverine flooding, by absorbing and holding water.

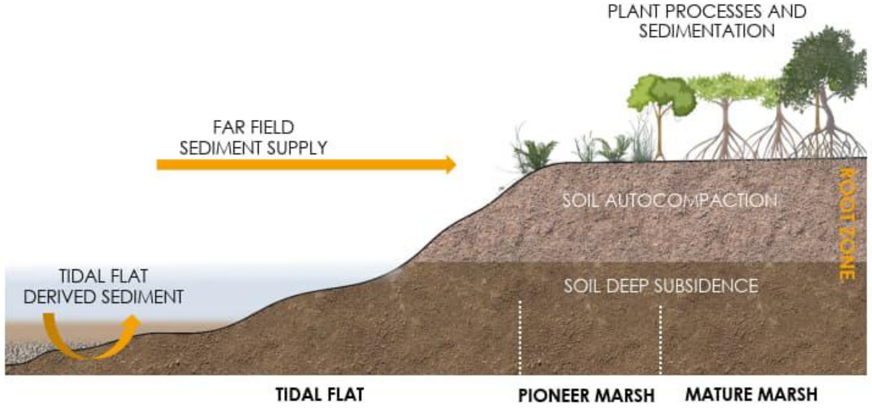
PROVISIONING

- Certain salt-tolerant plants are collected as culinary ingredients.
- Biomass from salt marsh plants, such as reeds and grasses, can be used for thatching, weaving, or as organic matter in soil enrichment.
- Marsh vegetation can serve as grazing material for livestock in some coastal communities.
- Plants and organisms in salt marshes may contain compounds with pharmaceutical applications.
- Decomposed plant material from salt marshes can be used as a fuel source or in bioenergy production.

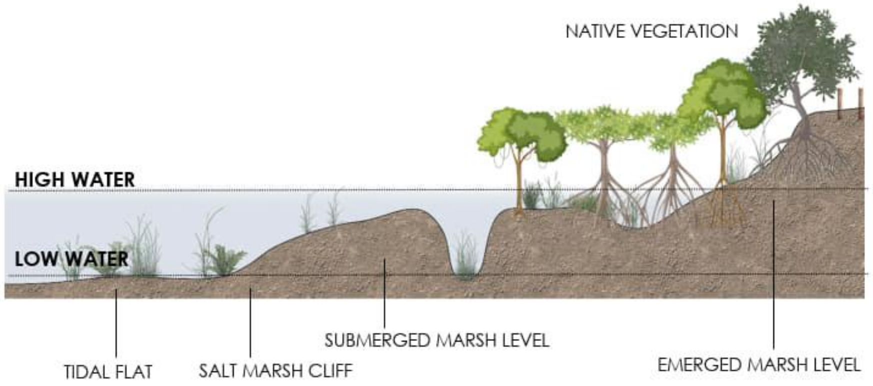
SOCIAL BENEFITS

- Attract birdwatchers, photographers, and eco-tourists.
- Serve as natural laboratories for studying ecosystems and climate resilience.

NbS-17: SALT MARSH RESTORATION



Process of saltmarshes, dynamic interactions between vegetation and sedimentation.
Source : CITILINKS



Profile of a saltmarsh and mudflat with local vegetation
Source : CITILINKS

PROJECT'S CHALLENGES & RISKS

- **Pollution and Contamination :** Industrial runoff, heavy metals, and nutrient loading can degrade restored areas. Contaminated sites may require costly remediation before proceeding.
- **Sediment Availability :** It can be limited by upstream dams, dredging, or erosion control structures.
- **Complexity of Ecosystem Recovery :** Restoring the full functionality of a salt marsh, including hydrology, vegetation, and biodiversity, requires careful planning and expertise.
- **Monitoring and Maintenance :** Ensuring long-term success requires sustained monitoring and adaptive management.

NbS co-BENEFITS AND THEIR INDICATORS

- **Biodiversity Enhancement**
  Increased abundance and diversity of bird, fish, and invertebrate, species using the restored area as breeding or feeding grounds.
- **Carbon Sequestration**
  Soil organic carbon levels (tons per hectare), rate of carbon accumulation in sediments.
- **Fisheries Support**
  Increase in fish biomass and abundance, particularly juvenile stages.
- **Water quality improvement**
  Decrease in nutrient concentrations (nitrogen, phosphorus) in adjacent waters, presence of clear water-tolerant species.
- **Livelihood Opportunities**
  Number of people employed in restoration activities or sustainable harvesting .
  Increase in income from fisheries and eco-tourism related to the restored marsh.

COST ANALYSIS

- **Direct Costs**
  Site, planning, restoration, equipment, monitoring, maintenance : $270,000 - $1,300,000 /ha.
- **Indirect Costs**
  Opportunity costs, ecosystem service losses during transition : $100,000- $850,000/ha.
- **Time Horizon**
  Short-term (1-5 years): Initial restoration actions,
  Long-term (15-50 years): Full restoration benefits are realized.
- **Direct Benefits**
  Flood control, carbon sequestration, improved water quality, and biodiversity support.
- **Indirect Benefits**
  Improved public health, and tourism revenue.
- **Risk Assessment**
  Climate change impacts, invasive species, and unpredicted ecological changes.
  Funding challenges and competing land uses.

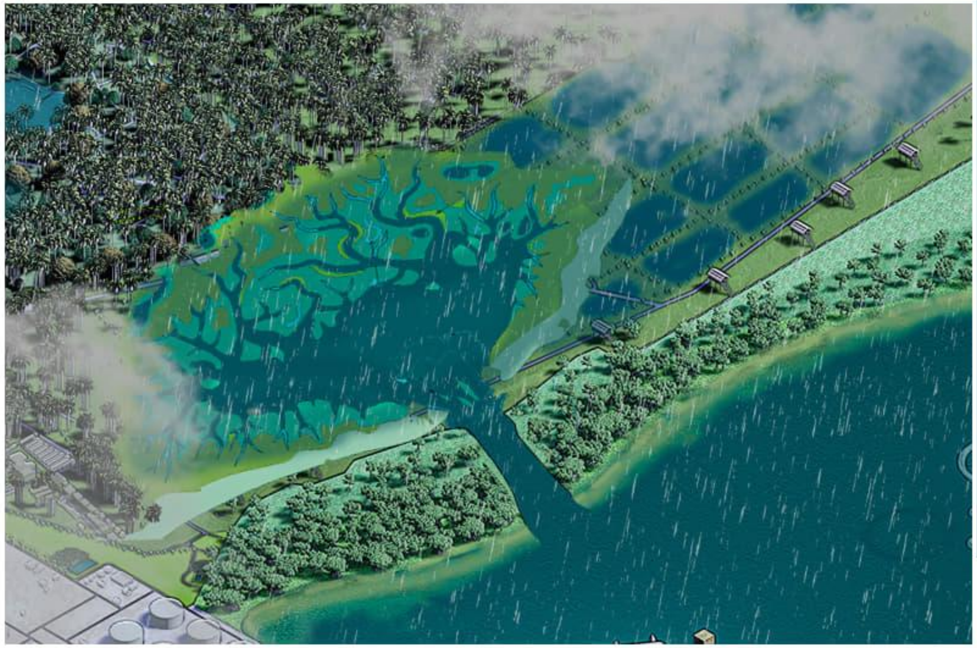
REFERENCES:

England , Essex, Colne Estuary, saltmarsh restoration.
US, California, Napa River Salt Marsh Restoration Project.
US, South San Francisco Bay , Salt Pond Restoration Project.

IMPLEMENTATION OPPORTUNITIES:

Thailand, Krabi Estuary, Krabi Province (loss of wetlands due to urban development, tourism, and agriculture).
Vietnam, Tràm Chim National Park, Mekong Delta (saltwater intrusion due to rising sea levels and human activities).

NbS-18 TIDAL FLAT NOURISHMENT



Tidal flat nourishment focuses on restoring and stabilizing soft, silty shorelines through a blend of natural and eco-engineered materials. Tidal flats are coastal areas that are exposed during low tide and submerged during high tide, often serving as critical habitats for wildlife, including migratory birds and marine organisms. This method combines traditional sand nourishment with biodegradable elements like sediment mats, coir logs, and organic substrates to reinforce unstable muddy surfaces. The added sand facilitates sediment accretion, reduces erosion, and fosters the growth of coastal vegetation such as mangroves and salt marsh grasses, which play a critical role in stabilizing sediments. By promoting biodiversity, improving water clarity, and curbing sediment runoff, tidal flat nourishment enhances the ecological balance of coastal zones.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOSYSTEM BASED ADAPTATION
- ECOSYSTEM-BASED DISASTER RISK REDUCTION
- ECOSYSTEM RESTORATION
- INTEGRATED COASTAL ZONE MANAGEMENT
- GREEN INFRASTRUCTURE

MAIN PROBLEMS ADDRESSED

- BIODIVERSITY LOSS
- FLOOD CONTROL
- DISASTER RISK REDUCTION
- CARBON SEQUESTRATION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Maintain biodiversity by providing habitats for diverse species, including breeding and feeding grounds.
- Enable nutrient cycling, ensuring the availability of essential nutrients for plants and animals.
- Foster soil formation and stabilization, preventing land degradation and promoting ecosystem health.

REGULATING

- Buffer against storm surges, wave energy, and erosion, reducing risks to coastal infrastructure.
- Sequester and store significant amounts of carbon.
- Filter pollutants, sediments, and excess nutrients from water, improving water quality.
- Reduce the impact of coastal and riverine flooding by absorbing and holding water.

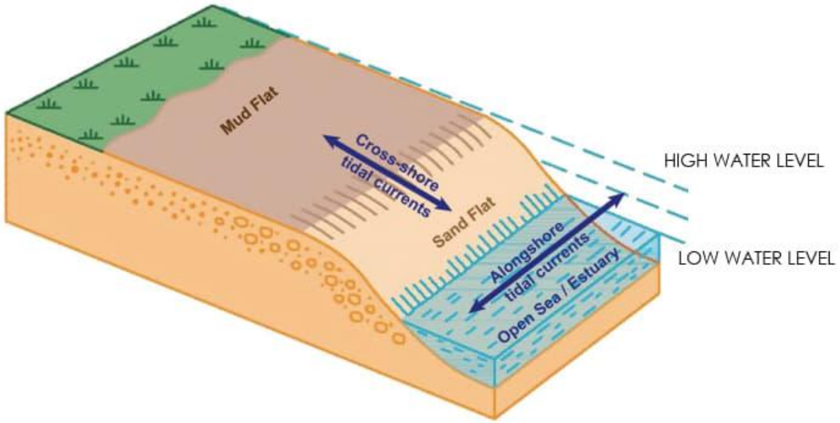
PROVISIONING

- Provide food, including fish, shellfish, fruits, and crops essential for nutrition and livelihoods.
- Supply freshwater for drinking, agriculture, and industrial purposes.
- Deliver raw materials such as timber, fuel, and fibers for construction and energy needs.
- Offer medicinal resources, including plants and organisms used in traditional and modern medicine.

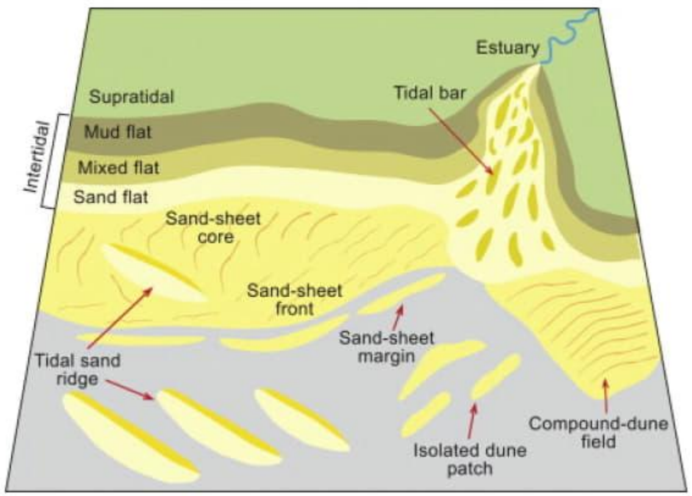
SOCIAL BENEFITS

- Provide recreational opportunities such as hiking, bird-watching, and snorkeling, promoting well-being.
- Serve as a resource for education and scientific discovery, deepening knowledge and innovation.

NbS-18 TIDAL FLAT NOURISHMENT



Profile sand-mud tidal flat influenced by cross-shore and alongshore tidal currents
Source : Journal of Geophysical Research, Oceans



Environments of deposition within a tidal flat system, including the subtidal, intertidal, and supratidal zones.
Source : Desjardins et al., 2012

PROJECT'S CHALLENGES & RISKS

- **Sediment Quality and Contamination:** The sediment used for nourishment must closely match the natural sediment in the tidal flat to ensure compatibility and protect the ecosystem.
- **Erosion and Redistribution :** High-energy environments can erode or redistribute the nourished sediment, making the effort less effective.
- **Ecological Disruption:** The nourishment process can disturb existing habitats, smother benthic organisms, and temporarily disrupt the ecological balance.
- **Economic and Logistical Constraints :** Tidal flat nourishment projects can be expensive and logistically complex.

NbS co-BENEFITS AND THEIR INDICATORS

Biodiversity Enhancement
Increased abundance and diversity of bird, fish, and invertebrate, species using the restored area as breeding or feeding grounds.

Coastal Protection
Reduction in wave height and energy, rate of shoreline erosion (before and after nourishment).

Flood Mitigation
Reduction in floodwater levels during storm events, area of land protected from flooding.

Water quality improvement
Levels of nitrogen, phosphorus, and pollutants in water, turbidity reduction (water clarity).

Fishery Productivity
Increase in fish and shellfish populations. Catch per unit effort (CPUE) for fisheries.

Community resilience
Number of households benefiting from reduced flood risks, community engagement in restoration.

COST ANALYSIS

Direct Costs
Materials, transport, labor, equipment :$350,000 - $1,200,000/ha.

Indirect Costs
Assessments, community engagement, opportunity costs : $30,000 - $80,000/ha.

Time Horizon
Short-term (1-5 years): project setup, material placement, and initial monitoring.
Long-term (15+ years): full restoration benefits.

Direct Benefits
Flood mitigation, erosion control, biodiversity boost.

Indirect Benefits
Carbon sequestration, water quality, community resilience.

Risk Assessment
Overnourishment may smother existing ecosystems or alter water flow, poor sediment placement or inadequate materials could lead to project failure.

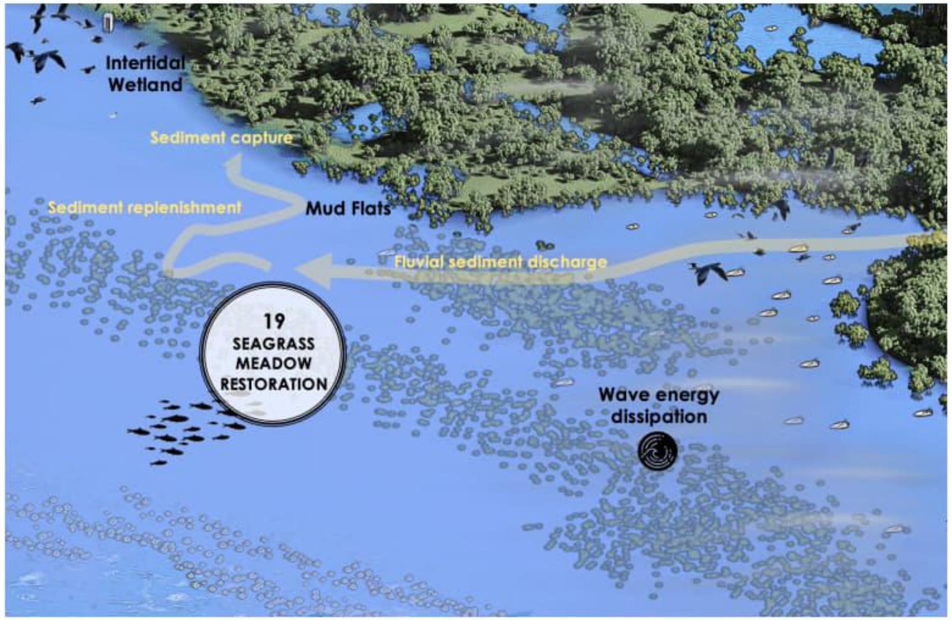
REFERENCES:

Netherlands, Oosterschelde (Eastern Scheldt), Galgeplaat.
New Zealand, Stewart island, natural tidal flats.
Ireland, North Slob, Wexford, natural tidal flats.

IMPLEMENTATION OPPORTUNITIES:

Indonesia, Demak Regency, Central Java (conditions favourable for tidal flat recovery and mangrove regrowth).
Vietnam, Ca Mau Peninsula, Mekong delta (severe erosion and land loss and degraded tidal flats).

NbS-19: ARTIFICIAL SEAGRASS MEADOWS



Artificial seagrass meadows aim to restore and enhance the ecological functions of marine ecosystems by establishing seagrass beds using both natural and engineered materials. This approach involves planting or embedding seagrass species in areas where they have been depleted, using biodegradable substrates like coir mats, seed-containing bioengineered structures, or sediment-based inoculants. These materials facilitate the establishment of seagrass by providing a stable substrate for growth, reducing erosion, and supporting the accumulation of organic matter. The artificial meadows improve water quality by increasing sediment stability, enhancing nutrient cycling, and reducing turbidity. They also provide critical habitat for marine life, support biodiversity, and contribute to carbon sequestration, while boosting the resilience of coastal environments against storm surges and sea-level rise.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOSYSTEM BASED ADAPTATION
- ECOSYSTEM-BASED DISASTER RISK REDUCTION
- ECOSYSTEM BASED MITIGATION
- ECOSYSTEM RESTORATION
- INTEGRATED COASTAL ZONE MANAGEMENT
- MARINE SPATIAL PLANNING

MAIN PROBLEMS ADDRESSED

- BIODIVERSITY LOSS
- FLOOD CONTROL
- CARBON SEQUESTRATION
- DISASTER RISK REDUCTION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Provides shelter and breeding grounds for marine species.
- Enhances nutrient exchange and cycling between water, sediment, and marine organisms.
- Traps and binds sediments, reducing resuspension and promoting substrate stability.

REGULATING

- Reduces turbidity by trapping sediments and filtering excess nutrients from the water column.
- Acts as a carbon sink by absorbing CO_2 and storing it in biomass and sediments.
- Stabilizes coastal sediment, reducing erosion and protecting shorelines from wave energy.
- Buffers wave action, mitigating coastal flooding and reducing the impact of storm surges.

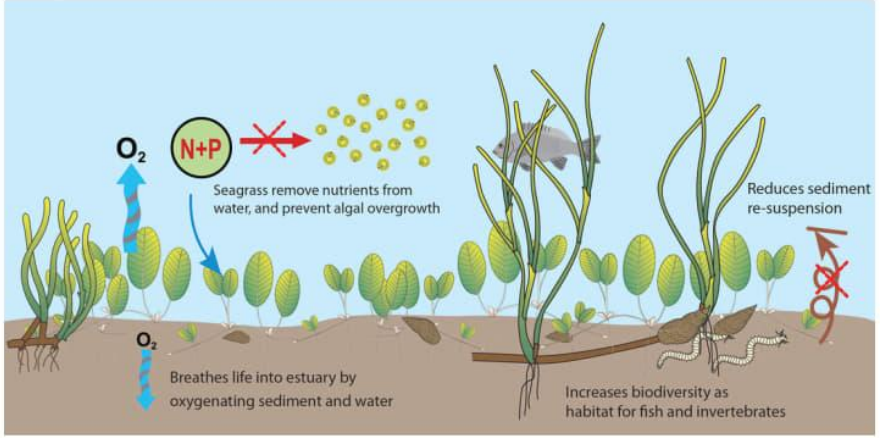
PROVISIONING

- Enhances fishery productivity by providing habitats for commercially important fish and shellfish species.
- contribute to sustainable harvests of seagrass for certain local industries
- Supports biodiversity, preserving genetic material that may have potential for pharmaceuticals, food, or other uses.

SOCIAL BENEFITS

- Offers a platform for research, environmental education, and raising awareness about marine conservation.
- Enhances the visual appeal of underwater environments and provides opportunities for activities such as snorkelling, diving, and eco-tourism centred on marine ecosystems.

NbS-19: ARTIFICIAL SEAGRASS MEADOWS



Process of seagrass meadow supporting marine ecosystems
Source : Oyster harbour catchment group

Seagrass meadow in Cabo de Gata, Spain
Source : Global system typology

PROJECT'S CHALLENGES & RISKS

- **Incompatibility with native ecosystems**: Artificial structures may disrupt the natural balance of local ecosystems.
- **Hydrodynamic forces**: Strong currents, wave action, or storm events can dislodge artificial seagrass.
- **Invasive species**: Artificial substrates can unintentionally create habitats for invasive species.
- **Rising sea levels and warming oceans**: Climate change may alter the environmental conditions required for seagrass survival.
- **Water quality**: Polluted or turbid waters can hinder the growth of seagrass or reduce light availability, impacting the success of the meadow.

NbS co-BENEFITS AND THEIR INDICATORS

Biodiversity Enhancement
Species richness and abundance, genetic diversity within restored areas.

Coastal Protection
Wave attenuation rates, sediment accretion rates, shoreline stability.

Water Quality Improvement
Turbidity levels, nutrient concentrations, reduction in harmful algal blooms.

Fisheries and Food Security
Fish biomass and catch rates in and around the meadow, economic value of fisheries supported by the meadow.

Recreational and Tourism Value
Economic benefits from tourism, number of visitors or tourists engaging in marine activities, ublic awareness levels about marine conservation.

COST ANALYSIS

Direct Costs
Materials, labor, permits and approvals : $70,000 to $200,000/ha.

Indirect Costs
Opportunity costs, long term maintenance, research and development : $130,000/ha (10y)

Time Horizon
Short-term (1–5 years): Initial implementation and stabilization of the artificial meadow.
Long-term (>15 years): fully established.

Direct Benefits
Erosion control and coastal protection, increased fishery productivity, carbon sequestration, improved water quality.

Indirect Benefits
Biodiversity enhancement, food prevention, tourism revenue.

Risk Assessment
Failure due to poor site selection, invasive species colonization, stakeholder conflicts with fisheries or tourism.

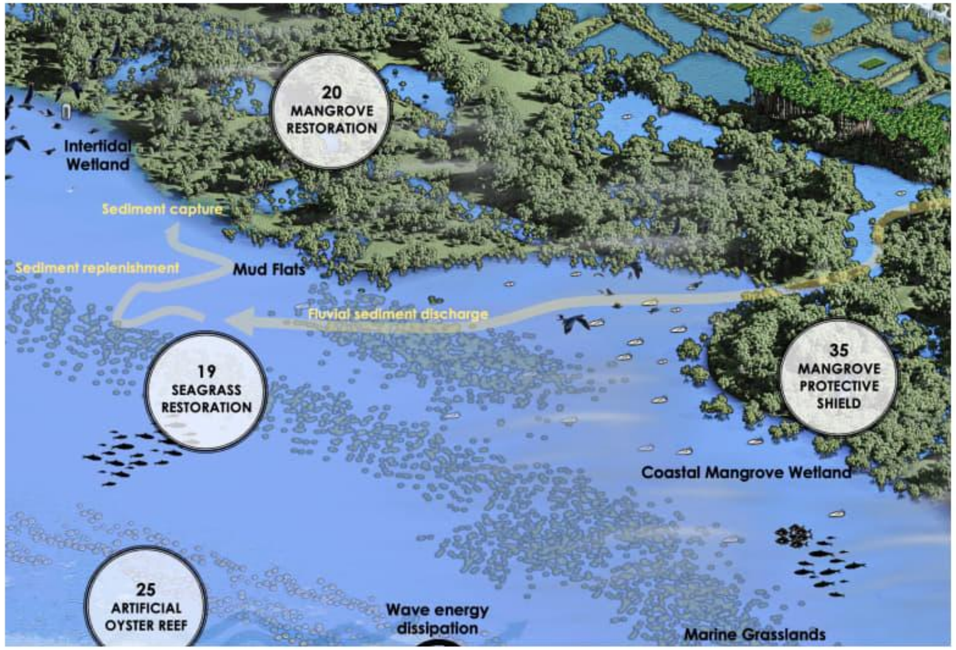
REFERENCES:

Singapore: Large-scale seagrass restoration project at Kusu island and Lazarus island.
Indonesia : Seagrass restoration in West Yensawai village, on the island of Batanta.
Malaysia : Kuala Selangor Nature Park.

IMPLEMENTATION OPPORTUNITIES:

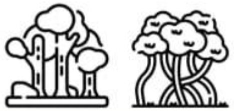
Philippines: The Tubbataha Reefs Natural Park.
Vietnam: The Ca Mau Peninsula in the Mekong Delta.
Indonesia: The Bali Strait, particularly around Tulamben.

NbS-20: MANGROVE FOREST RESTORATION



Mangrove Forest Restoration focuses on rehabilitating tropical and subtropical coastal ecosystems dominated by salt-tolerant mangrove trees. These forests are critical for supporting biodiversity, providing nursery habitats for marine life, protecting coastlines from erosion and storm surges, improving water quality, and storing significant amounts of carbon. Restoration efforts often involve replanting native mangrove species, restoring natural tidal hydrology, and removing barriers such as dikes or seawalls that hinder water flow. In areas where soil degradation or erosion has occurred, sediment enhancement or stabilization techniques may be employed to create suitable conditions for mangrove regrowth. Successful projects typically adopt a holistic approach, connecting mangroves with adjacent ecosystems like salt marshes, seagrass beds, and coral reefs to establish resilient and interconnected coastal landscapes.

LANDSCAPES SUPPORTED



EbA (ECOSYSTEM-BASED APPROACHES)

- ECOSYSTEM BASED ADAPTATION
- ECOSYSTEM-BASED DISASTER RISK REDUCTION
- ECOSYSTEM RESTORATION
- INTEGRATED COASTAL ZONE MANAGEMENT
- FOREST LANDSCAPE RESTORATION

MAIN PROBLEMS ADDRESSED

- DISASTER RISK REDUCTION
- BIODIVERSITY LOSS
- FLOOD CONTROL
- CARBON SEQUESTRATION
- FOOD SECURITY

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Serve as nurseries and breeding grounds for fish, crustaceans, and other marine species.
- Play a key role in nutrient cycling, recycling organic matter and maintaining soil fertility in coastal areas.
- Contribute to high rates of carbon sequestration and biomass production.

REGULATING

- Act as natural barriers against storm surges, tsunamis, and coastal erosion.
- Sequester large amounts of carbon, reducing greenhouse gas emissions.
- Filter pollutants, sediments, and nutrients, improving water quality and reducing eutrophication in coastal waters.
- Regulate tidal flows and reduce the risk of coastal flooding during extreme weather events.

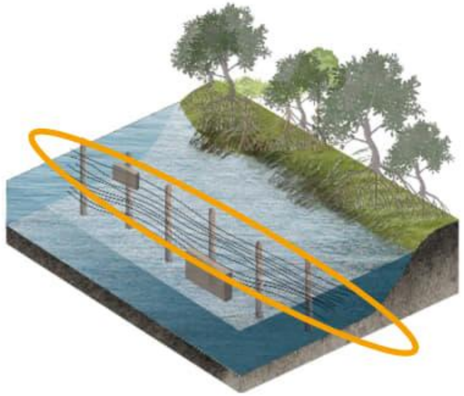
PROVISIONING

- Source of wood for construction, firewood, and traditional practices.
- Harvest of honey, medicinal plants, and tannins derived from mangrove bark.
- Enhances productivity of nearby aquaculture farms by maintaining water quality and providing habitat for aquaculture species.

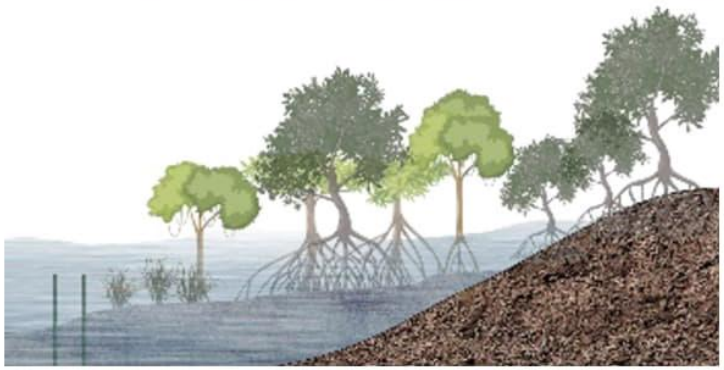
SOCIAL BENEFITS

- Support traditional fishing communities and local economies dependent on mangrove resources.
- Serve as living laboratories for environmental education, promoting awareness of coastal conservation and climate resilience.

NbS-20: MANGROVE FOREST RESTORATION



Small water permeable dams filter sediments creating a fertile environment for mangrove trees to grow and develop. They are semi permeable and made from woden poles and mesh.



Over time, there is sediment deposition regain that allows mangrove to grow and expand. The mature mangrove belt can then better protect the coastline.

Mangrove forest restoration and growth.
Source : Citilinks

PROJECT'S CHALLENGES & RISKS

- **Site Unsuitability**: Restoring mangroves in areas with altered hydrology, poor soil conditions, or excessive erosion can lead to project failure.
- **Biodiversity Imbalance**: Poor species selection or monoculture planting can lead to reduced ecological diversity and functionality.
- **Conflicting Land Use**: Mangrove restoration often competes with other land uses such as aquaculture, agriculture, or urban development.
- **Overreliance on Planting**: Some projects focus too heavily on planting mangroves without addressing underlying ecological issues, such as hydrology or sediment flow.

NbS co-BENEFITS AND THEIR INDICATORS

- **Biodiversity Enhancement**
  Increased species richness and abundance of flora and fauna, presence of indicator species such as mangrove crabs, fish, or birds.
- **Carbon Sequestration**
  Rate of carbon dioxide absorption by restored mangroves, reduction in greenhouse gas emissions from adjacent degraded areas.
- **Improved Ecosystem Connectivity**
  Movement patterns of marine species across restored habitats.
- **Disaster Risk Reduction**
  Decrease in damages caused by storm surges and tidal flooding, reduced coastal erosion and land loss.
- **Sustainable Fisheries and Aquaculture**
  Increased fish and shellfish catch volume and diversity, improved yields from aquaculture farms near mangrove areas,

COST ANALYSIS

- **Direct Costs**
  Planning, planting, restoration, hydrological improvements, maintenance : $26K to $160K/ha.
- **Indirect Costs**
  Opportunity costs, community engagement and education, governance.
- **Time Horizon**
  Short-term (1-5 years): Initial planting, monitoring, and immediate community benefits.
  Long-Term (20+ years): Full ecosystem services.
- **Direct Benefits**
  Biodiversity recovery, coastal protection, carbon sequestration.
- **Indirect Benefits**
  Improved livelihoods, climate resilience, air quality improvement.
- **Risk Assessment**
  Hydrological risks, storms and natural disasters, invasive species, financial risks.

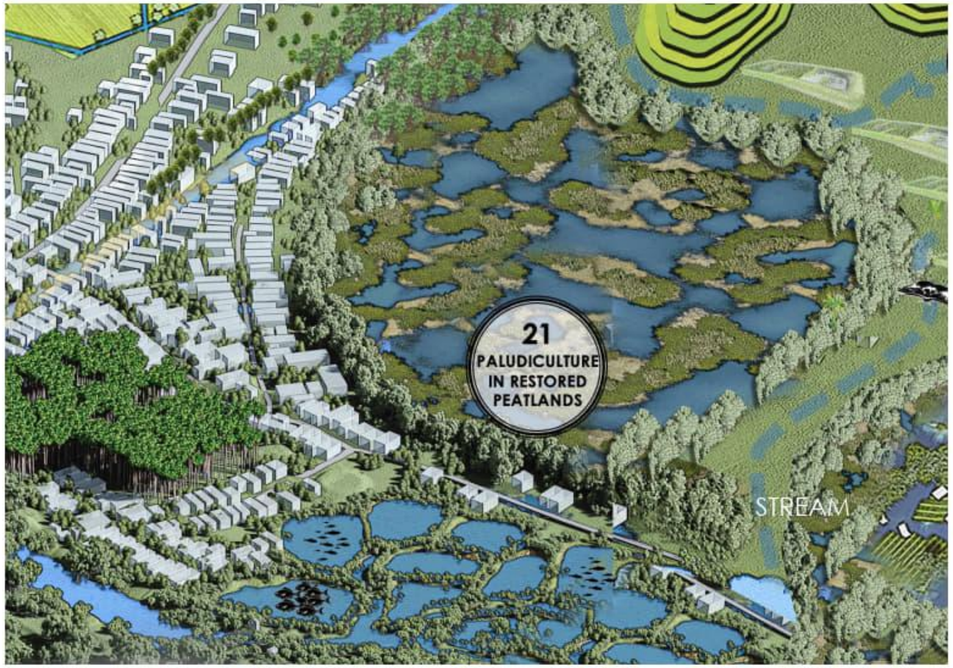
REFERENCES:

Indonesia, Mahakam Delta, Total E&P Indonesia planted over 3.5 million mangrove trees, covering an area of 646 hectares.
Singapore, Pulau Tekong, The National Parks Board (NParks) initiated coastal protection and restoration works.

IMPLEMENTATION OPPORTUNITIES:

Philippines, Palawan, UNESCO Biosphere Reserve.
Myanmar, the Ayeyarwady Delta has lost extensive mangrove cover due to agriculture, shrimp farming, and timber extraction.

NbS-21: PALUDICULTURE ASSOCIATED PEATLAND



Paludiculture associated peatland is an innovative ecological approach focused on restoring and enhancing peatland ecosystems while supporting biodiversity, carbon sequestration, and ecosystem resilience. By cultivating water-loving vegetation such as sphagnum moss, reeds, mangroves, aquatic grasses, and marsh plants in waterlogged peatland areas, paludiculture helps stabilize soils, reduce erosion, and restore the natural hydrology of these vital ecosystems. These plants play a crucial role in carbon capture, preventing the release of greenhouse gases from drained peatlands, while providing habitats for diverse wildlife. In tropical Southeast Asia, paludiculture can contribute to the restoration of degraded peatlands, improve water quality, and promote sustainable land use practices. This approach not only supports biodiversity but also offers economic opportunities by providing sustainable resources for local communities.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOSYSTEM RESTORATION
- ECOSYSTEM ADAPTATION
- SUSTAINABLE LAND MANAGEMENT
- INTEGRATED WATER RESOURCES MANAGEMENT
- ECOSYSTEM-BASED MITIGATION

MAIN PROBLEMS ADDRESSED

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Support the recovery of biodiversity by providing habitats for a variety of plant and animal species in restored peatland ecosystems.
- Aid in soil formation and stabilization by cultivating water-loving vegetation that prevents further degradation of peat soils.

REGULATING

- Help mitigate climate change by sequestering carbon in peatlands and preventing the release of stored greenhouse gases.
- Regulate water flow and reduce flood risks by maintaining natural hydrological processes through waterlogged conditions in peatlands.
- Improve water quality by filtering excess nutrients and pollutants from water passing through restored peatland areas.

PROVISIONING

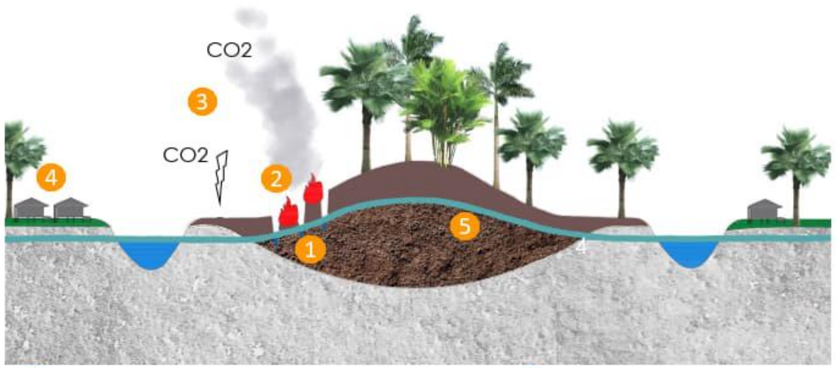
- Provide a sustainable source of raw materials, such as mosses, reeds, and aquatic plants, for use in various eco-friendly products.
- Offer valuable resources like food and medicinal plants from wetland species cultivated in paludiculture systems.
- Ensure a steady supply of freshwater by maintaining the natural water regulation capacity of peatland ecosystems.

SOCIAL BENEFITS

- Support local livelihoods by offering sustainable, economic opportunities through the cultivation of wetland plants and products.
- Mitigate the impacts of flooding and extreme weather events, to help protect the well-being and resilience of local communities.

NbS-21: PALUDICULTURE ASSOCIATED PEATLAND

Degraded peatland



1. Drained peat with increased fire risk
2. Smoke from peat fires poses significant health risks
3. Drained peatlands are prone to oxidation and highly susceptible to burning, releasing large amounts of CO_2 into the atmosphere.
4. Habitat and crops loss
5. Lower water table, high fire risk

Restored peatland

1. Reforestation on deep peat zone supports the ecosystem
2. Conservation area on deep peat
3. Raised water table reduces fire risk
4. Healthy peatland allows high levels of carbon sequestration

Peatland associated risks and restoration
Source : CITILINKS

PROJECT'S CHALLENGES & RISKS

- Maintaining appropriate water levels is critical for peatland restoration. Incorrect water management can lead to drying out, soil degradation, and the release of stored carbon, as well as increased fire risk.
- Competing land uses, such as agriculture or industrial development, can create conflicts over land rights.
- Certain plant species used in paludiculture may attract pests or become invasive, competing with native vegetation.
- Extreme droughts or floods, can affect the viability of paludiculture. Droughts can dry out peatlands, excessive rainfall can disrupt the stability of planted vegetation and lead to erosion.

NbS co-BENEFITS AND THEIR INDICATORS

Biodiversity Conservation
Number of species present in restored peatland areas, assessment of habitat suitability for different species.

Carbon sequestration
Amount of carbon stored in peatlands, annual rate at which carbon is captured or stored in the peatland ecosystem.

Soil Erosion Prevention and Soil Fertility
Rate of soil loss before and after restoration.

Water Regulation and Quality Improvement
Volume of water retained in the peatland during different seasons, reduced frequency and severity of floods in restored peatland areas, concentrations of pollutants (before and after restoration).

Livelihood and Economic Opportunities
Revenue generated from paludiculture products (e.g., plants, raw materials, bioenergy), number of local jobs created through project implementation and related industries.

COST ANALYSIS

Direct Costs
Land acquisition, vegetation planting, water management infrastructure, labor :

Indirect Costs
Administrative overhead, training, opportunity costs, legal and regulatory compliance.

Time Horizon
Short-term (1–5 years): setup costs, planting, and initial monitoring.
Long-term (10+): ecosystem services established.

Direct Benefits
Carbon sequestration, improved water quality, flood control, sustainable harvest.

Indirect Benefits
Biodiversity improvement, resilience to climate events, community health and well-being.

Risk Assessment
Incorrect water level management can lead to peatland drying or flooding, insufficient funding or financial instability , extreme weather events.

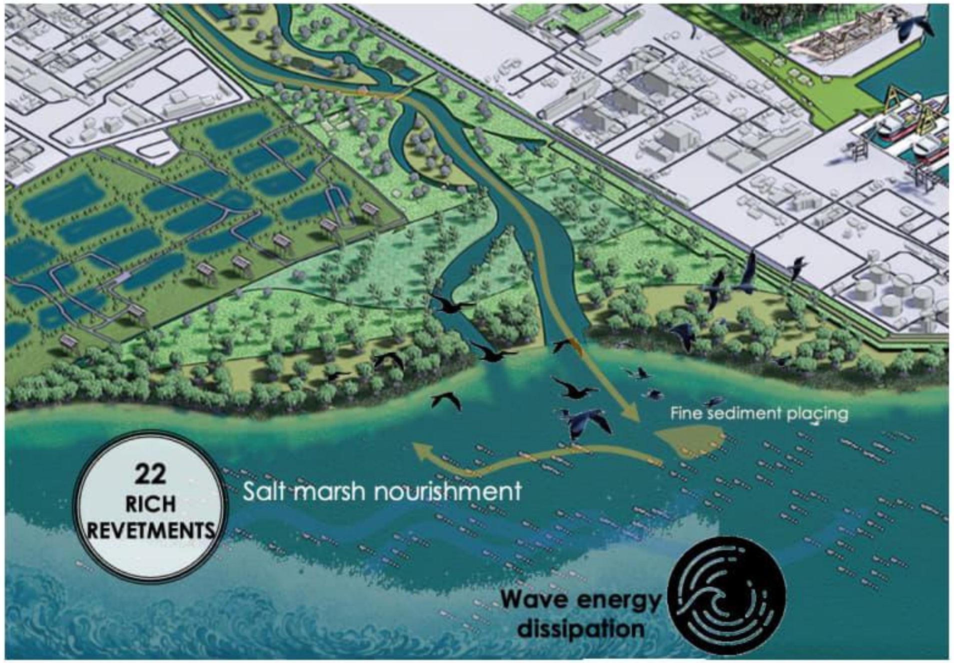
REFERENCES:

Vietnam, Ca Mau Province , Mangrove and Peatland Restoration.
Indonesia, Restoration of Peatland Ecosystems in Central Kalimantan.
Thailand, Kuan Kreng Peat swamp forest.

IMPLEMENTATION OPPORTUNITIES:

Philippines, Mindanao (Ligawasan Marsh)
Laos, Champasak Province, Beung Kiat Ngong wetland
Vietnam, Mekong delta region, U Minh Ha and U Minh Thuong National Parks.

NbS-22: PLANTING MATS AND RICH REVETMENTS



Planting mats and rich revetments are innovative ecological solutions aimed at restoring and enhancing marine and coastal environments while supporting biodiversity and ecosystem resilience. Planting mats, typically made from biodegradable or durable materials, provide a stable substrate for aquatic vegetation such as seagrasses, mangroves, or marsh plants to anchor and grow, stabilizing sediments and reducing erosion. Rich revetments improve traditional coastal defence structures by incorporating textured surfaces, eco-friendly materials, and features like eco-basins or tide pools to create habitats for marine life, including algae, shellfish, and fish. Together, these approaches enhance water quality, foster habitat complexity, and attract diverse marine species. In coastal and port areas, they contribute to sediment stabilization, mitigate wave energy, and offer recreational and educational opportunities while promoting the recovery of marine ecosystems.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOSYSTEM RESTORATION
- ECOSYSTEM-BASED DISASTER RISK REDUCTION
- INTEGRATED COASTAL ZONE MANAGEMENT
- GREEN INFRASTRUCTURE

MAIN PROBLEMS ADDRESSED

- BIODIVERSITY LOSS
- FLOOD CONTROL
- CARBON SEQUESTRATION
- DISASTER RISK REDUCTION
- SOIL EROSION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Create stable habitats for marine organisms, including algae, seagrasses, shellfish, and fish, fostering biodiversity in degraded port areas.
- Facilitate nutrient exchange and cycling through the growth of aquatic vegetation and filter-feeding organisms.

REGULATING

- Reduce pollution by supporting filter-feeding organisms like shellfish and mussels, which remove contaminants, heavy metals, and organic waste from port waters.
- Stabilize sediments to prevent the resuspension of pollutants commonly found in port areas.
- Reduce wave energy and mitigate erosion by stabilizing sediments and dampening wave impact.

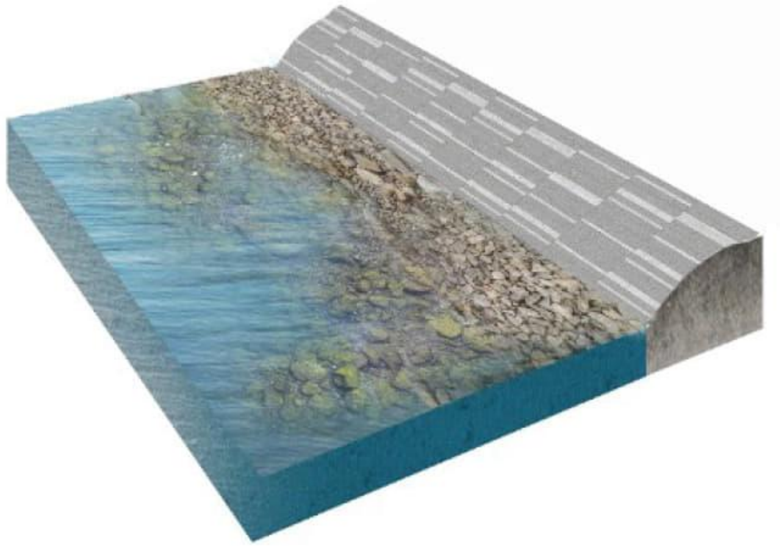
PROVISIONING

- Support the recovery of fish and shellfish populations, including species affected by port pollution.
- Provide a sustainable source of biomass for ecological restoration or bioproducts while improving degraded environments.

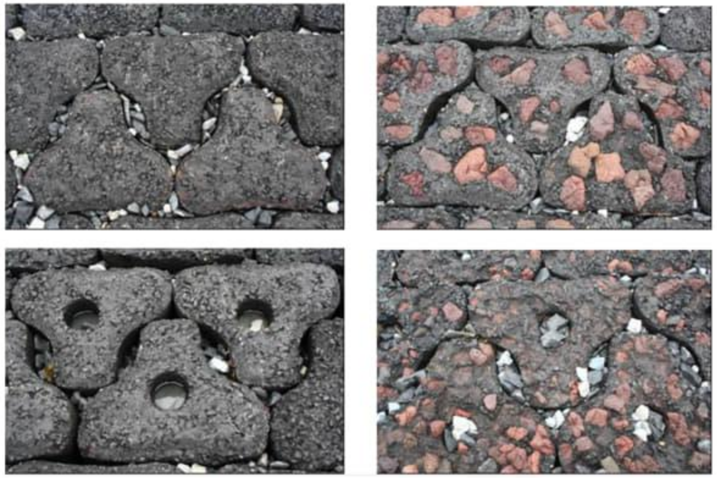
SOCIAL BENEFITS

- Improve the visual appeal and ecological health of polluted or industrialized port environments, fostering a stronger connection between communities and marine ecosystems.
- Enhance water clarity and marine life diversity, making port areas more attractive for eco-tourism, diving, and other recreational activities.

NbS-22: PLANTING MATS AND RICH REVETMENTS



Rich marine revetments along coastline.
Source : Author



Holes in revetment stones to attract marine organisms.
Source : EcoShape

PROJECT'S CHALLENGES & RISKS

- Ports often have polluted seabeds with heavy metals, hydrocarbons, or chemicals that may hinder vegetation establishment or harm marine life attracted by these structures.
- High boat traffic, propeller wash, and frequent dredging activities in ports create strong currents and turbulence, which may damage planting mats.
- Limited available space for ecological installations due to the density of port infrastructure (docks, seawalls, shipping lanes).
- Limited connectivity between created habitats within ports may reduce their effectiveness for supporting larger marine populations or restoring ecological functions.

NbS co-BENEFITS AND THEIR INDICATORS

Biodiversity Enhancement
Measurement of habitat diversity created by the installation of mats and revetments .

Coastal Protection
Reduction in the rate of shoreline retreat or sediment loss, increase in sediment accumulation.

Water Quality Improvement
Decrease in heavy metals, hydrocarbons, or organic pollutants in the water column, increase in dissolved oxygen levels.

Resilience to climate
Frequency and intensity of flooding events before and after implementation, reduction in the impact of storm surges and high waves on port infrastructure and surrounding areas.

Pollution migration in port environments
Amount of contaminants (e.g., hydrocarbons, heavy metals) removed by the planting mats and rich revetments over time, reduction in the levels of pollutants in port sediments, such as oils, heavy metals, and other toxic substances.

COST ANALYSIS

Direct Costs
Site preparation, materials, construction and labor, monitoring : \$180–\$460 per m².

Indirect Costs
Opportunity costs, operational disruptions, long term maintenance.

Time Horizon
Short-term (1–5 years): Site preparation, installation, monitoring and maintenance.
Long-term (5-50 years): long term maintenance.

Direct Benefits
Improved water quality, biodiversity recovery, coastal protection, carbon sequestration.

Indirect Benefits
Enhanced resilience to climate change, economic growth (eco-tourism and fisheries).

Risk Assessment
Pollution resurgence, failure of vegetation establishment, damage from port operations, climate change impacts.

REFERENCES:

The Netherlands,
Rotterdam, the Green Gateway.
Zeelandbrug, foreshore strengthening.
Australia, Sydney harbour, Seawall enhancement with eco-friendly revetments.

IMPLEMENTATION OPPORTUNITIES:

Indonesia, Batam, industrial and port city with significant coastal development.
Philippines, Manilla Bay.
Cambodia, port of Sihanoukville.

NbS-23: CORAL REEF RESTORATION AND NURSERIES

Coral reef restoration and nurseries aim to rehabilitate and enhance the ecological functions of degraded coral reef ecosystems by cultivating and transplanting coral species. This approach involves growing corals in dedicated underwater or land-based nurseries using techniques such as micro-fragmentation, coral gardening, or 3D-printed substrates. Once mature, these corals are transplanted onto damaged reefs to promote recovery. Restoration efforts utilize innovative materials like biodegradable structures, mineral accretion technology, or eco-engineered frameworks to facilitate coral attachment and growth, while enhancing reef complexity. Coral nurseries support biodiversity by providing habitat for marine life, improve ecosystem resilience to climate change by increasing coral genetic diversity, and aid in carbon sequestration. They also strengthen coastal protection against erosion and storm surges.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOSYSTEM BASED ADAPTATION
- ECOSYSTEM-BASED DISASTER RISK REDUCTION
- ECOSYSTEM BASED MITIGATION
- ECOSYSTEM RESTORATION
- INTEGRATED COASTAL ZONE MANAGEMENT
- MARINE SPATIAL PLANNING

MAIN PROBLEMS ADDRESSED

- BIODIVERSITY LOSS
- FLOOD CONTROL
- CARBON SEQUESTRATION
- DISASTER RISK REDUCTION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Provides shelter, breeding grounds, and nursery habitats for marine species.
- Enhances nutrient cycling between coral ecosystems and surrounding marine organisms.
- Supports primary production, forming the base of marine food webs.

REGULATING

- Sequesters carbon and regulates CO_2 levels.
- Stabilizes sandy substrates, reducing sedimentation and erosion.
- Act as natural breakwater and protects coastlines by dissipating wave energy, reducing storm surge impacts.
- Improves water quality by trapping sediments and filtering pollutants.
- Increases ecosystem resilience by restoring coral genetic diversity.

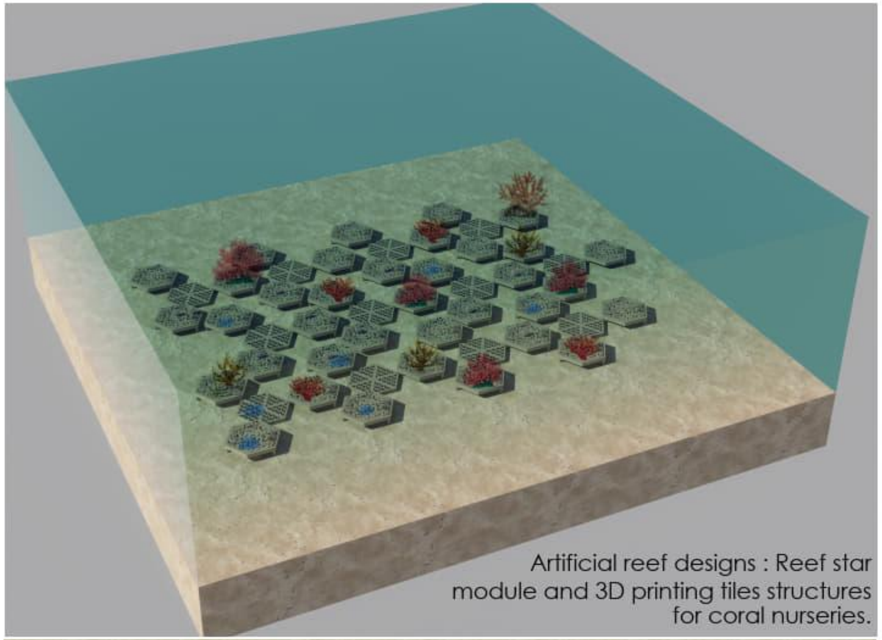
PROVISIONING

- Supports sustainable fisheries by enhancing fish and invertebrate populations.
- Provides raw materials like calcium carbonate for various industries.
- Supplies bioactive compounds for the development of medicines.
- Boosts aquaculture potential by restoring marine habitats.

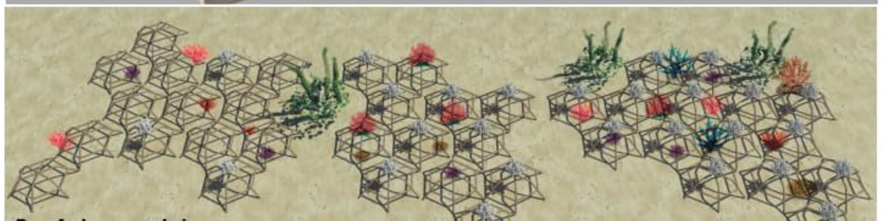
SOCIAL BENEFITS

- Creates opportunities for recreational activities, such as diving and ecotourism.
- Strengthens cultural and spiritual ties to marine ecosystems for local communities.
- Provides inspiration for education, art, and conservation awareness.

NbS-23: CORAL REEF RESTORATION AND NURSERIES



Artificial reef designs : Reef star module and 3D printing tiles structures for coral nurseries.



Reef star modules
Source : MARS CORAL REEF RESTORATION

PROJECT'S CHALLENGES & RISKS

- Rising sea temperatures can cause coral bleaching, reducing the survival rates of restored corals.
- Ocean acidification weakens coral skeletons, making them more susceptible to damage.
- Introducing non-native coral species or substrates may disrupt existing ecosystems.
- Current techniques are labor-intensive and costly, making it difficult to scale projects to the size needed.
- Long-term monitoring is essential to ensure success, but it requires significant time, expertise, and resources.
- Conflicts with activities like fishing, tourism, or coastal development can hinder restoration efforts.

NbS co-BENEFITS AND THEIR INDICATORS

Biodiversity Enhancement
Species richness and abundance, genetic diversity within restored areas.

Coastal Protection
Wave attenuation rates, erosion rates, coastal flood risk reduction.

Water Quality Improvement
Turbidity levels, nutrient concentrations, amount of sediment trapped by restored reefs.

Resilience to climate
Percentage of restored coral colonies surviving extreme conditions.
Speed at which reefs recover after disturbances (e.g., bleaching events or storms).

Educational and Research Opportunities
Number of local schools, universities, and community groups involved in restoration or monitoring activities.
Level of awareness or behavior change in local communities regarding marine conservation.

COST ANALYSIS

Direct Costs
Coral nursery setup, labor and expertise, materials, monitoring and maintenance : $481 per m²

Indirect Costs
Opportunity costs, Potential ecological risks associated with large-scale restoration activities.

Time Horizon
Short-term (1–3 years): Establishment of nurseries, planting of corals, initial monitoring.
Long-term (>10 years): fully established.

Direct Benefits
Biodiversity, coastal protection, carbon sequestration, tourism revenue.

Indirect Benefits
Climate resilience, educational and research opportunities, local community involvement.

Risk Assessment
Coral disease, invasive species, vulnerability to changes in sea temperature, ocean acidification, and extreme weather.

REFERENCES:

Indonesia, Makassar, Mars Assisted Reef Restoration System (MARRS) .
Philippines , Tubbataha Reefs , Coral Triangle Initiative (CTI-CFF) Marine Protected Areas .

IMPLEMENTATION OPPORTUNITIES:

Indonesia , Raja Ampat, known as the "Amazon of the Oceans'' holds some of the highest marine biodiversity in the world.
Cambodia, Koh Rong reefs are biologically diverse but have suffered from tourism-related damage and overfishing.

NbS-24: COASTAL REFORESTATION

Coastal reforestation in wetland and sandy beach environments aims to restore natural vegetation adapted to saline, waterlogged, or nutrient-poor soils. On sandy beaches, reforestation focuses on stabilizing dunes and loose sands using hardy species like sea oats, beach grass, and native shrubs. These plants anchor the soil, reduce erosion, and form windbreaks, creating a microhabitat that fosters further vegetation growth and protects inland areas from storm surges and salt spray.

In wetland coasts, mangroves, saltmarsh grasses, and other halophytic (salt-tolerant) species play a pivotal role. These plants trap sediment, reduce wave energy, and buffer coastlines from flooding. Their intricate root systems also provide essential habitat for aquatic life and improve water quality by filtering pollutants.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOSYSTEM BASED ADAPTATION
- ECOSYSTEM-BASED DISASTER RISK REDUCTION
- FOREST LANDSCAPE RESTORATION
- INTEGRATED COASTAL ZONE MANAGEMENT
- GREEN INFRASTRUCTURE

MAIN PROBLEMS ADDRESSED

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Restore habitats for wildlife, promoting species diversity and ecosystem health in coastal environments.
- Stabilise sandy or eroded coastal soils with plant roots, promoting the development of healthy soil layers.

REGULATING

- Regulate climate by sequestering carbon in coastal forests and wetlands, helping mitigate climate change.
- Improve water quality by filtering pollutants and excess nutrients through the roots of coastal vegetation, reducing contamination in coastal waters.
- Mitigate storm surge impacts by creating natural barriers like mangroves and wetlands that absorb wave energy and reduce the risk of flooding.

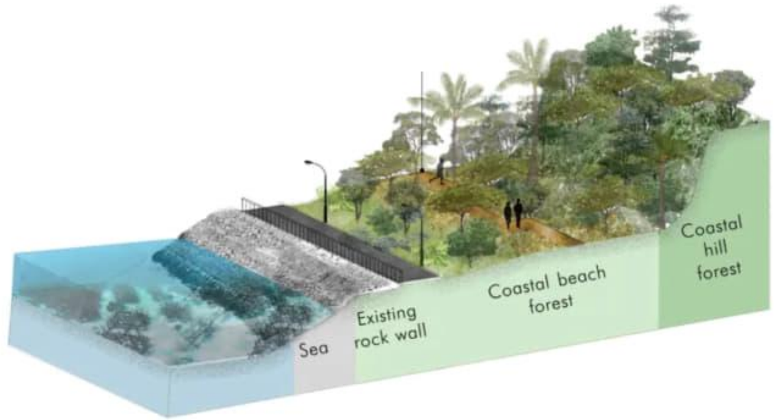
PROVISIONING

- Provide fibers and materials for clothing, textiles, and other products derived from coastal vegetation like cotton, hemp, and bamboo.
- Offer freshwater by improving the flow and quality of water from coastal watersheds, supporting human consumption and agricultural needs.
- Provide food by supporting sustainable fisheries and coastal agriculture through healthy, productive ecosystems like mangroves and seagrass meadows.

SOCIAL BENEFITS

- Support cultural heritage by preserving sacred natural areas like coastal forests, mangroves, and wetlands that have traditional significance for local and indigenous communities.

NbS-24: COASTAL REFORESTATION



Coastal forest restoration, Labrador nature reserve Singapore
Source : USDA, Climate Change Impacts to Coastal Forests

Coastal forest restoration in coastal wetland context

PROJECT'S CHALLENGES & RISKS

- **Harsh Climatic Conditions and extreme weather events** as high temperatures, intense sunlight, and strong winds can stress newly planted vegetation.
- **Invasive Species**: Non-native species introduced for reforestation can outcompete local plants and disrupt native ecosystems.
- **Limited Resources**: High costs of irrigation systems, soil amendments, and other interventions can limit the scalability of the project.
- **Land Use Conflicts**: Competing interests, such as tourism development or aquaculture, may limit areas available for reforestation.

NbS co-BENEFITS AND THEIR INDICATORS

Climate regulation:
Carbon stored in biomass , soil organic carbon content, reduction in atmospheric CO2 levels in the region.

Soil Stabilization and Erosion Control:
Reduction in soil erosion rates , increase in soil organic matter and fertility.

Water quality improvement
Levels of pollutants (e.g., nitrates, phosphates, heavy metals) , reduction in algal blooms.

Disaster Risk Reduction
Reduction in flood extent or severity in restored areas, measured wave energy absorption during storms, reduced economic losses from natural disasters.

Enhanced Biodiversity
Increase in species richness and abundance, area of restored habitat, connectivity between habitats (e.g., wildlife corridors, linked ecosystems).

COST ANALYSIS

Direct Costs
Planting, irrigation, infrastructure, monitoring : $6,500–$22,000 per hectare.

Indirect Costs
Opportunity costs, administrative costs : $3,500–$12,000 per project.

Time Horizon
Short-term (1–3 years): Establishment phase with intensive planting, irrigation, and initial monitoring.
Long-term (10+ years): Full ecosystem maturity.

Direct Benefits
Flood protection, fisheries, timber products.

Indirect Benefits
Carbon credits, ecotourism, public health.

Risk Assessment
Extreme weather events damaging restored areas, invasive species disrupting the growth of native vegetation, insufficient funding for long-term maintenance.

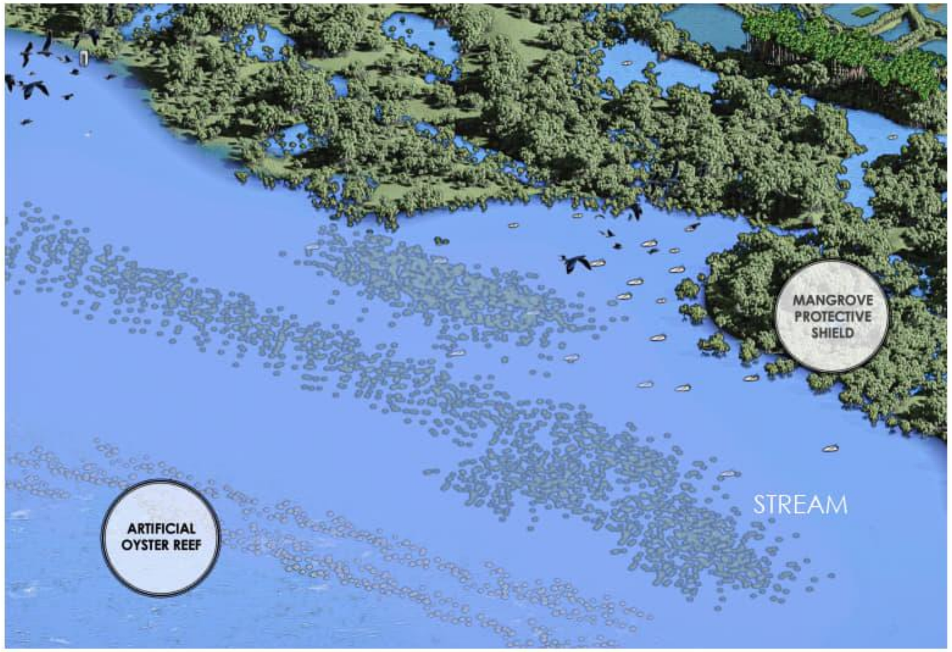
REFERENCES:

Singapore, Labrador nature reserve
Fiji, Sigatoka Sand Dunes National Park.
Puerto Rico, the Tamarindo Beach coastal reforestation Restoration on Culebra Island.
Netherlands Antilles ,Coastal reforestation project on St. Eustatius and Saba .

IMPLEMENTATION OPPORTUNITIES:

Indonesia, Lombok (Tanjung Aan Beach)
Philippines, Palawan (El Nido beaches)
Vietnam, Cua Dai Beach, Hoi An
Cambodia, Koh Rong Island

NbS-25: ARTIFICIAL OYSTER REEFS



Artificial oyster reef restoration aims to rehabilitate and enhance the ecological functions of degraded marine environments by creating and nurturing oyster populations. This process involves constructing artificial reef structures, often using materials like recycled oyster shells, limestone, or eco-friendly substrates, which provide a foundation for oyster larvae to settle and grow. These structures are typically placed in areas that have been depleted of natural oyster beds. As the oysters mature, they filter water, improve water quality, and provide habitat for a variety of marine species. Artificial oyster reefs contribute to coastal protection by reducing wave energy, promoting sediment stabilization, and enhancing biodiversity. In port areas, artificial oyster reefs offer additional benefits by helping to stabilize sediments, reducing erosion, and mitigating the impact of waves on infrastructure. They can also serve as a natural method for reducing port-related pollution, enhancing water clarity, and promoting the recovery of marine life.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOSYSTEM RESTORATION
- ECOSYSTEM-BASED DISASTER RISK REDUCTION
- GREEN INFRASTRUCTURE
- INTEGRATED COASTAL ZONE MANAGEMENT
- MARINE SPATIAL PLANNING

MAIN PROBLEMS ADDRESSED

- BIODIVERSITY LOSS
- FLOOD CONTROL
- CARBON SEQUESTRATION
- DISASTER RISK REDUCTION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Provides shelter, breeding grounds, and nursery habitats for marine species in sandy beach and port areas.
- Enhances nutrient cycling by filtering water, supporting water quality and the health of surrounding ecosystems.
- Supports primary production by promoting plankton growth, forming the base of marine food webs.

REGULATING

- Reduces coastal erosion, mitigates flood risks by stabilizing sediments and dampening wave energy.
- Improves water clarity and quality by filtering excess nutrients, pollutants, and sediment from the water.
- Contributes to carbon sequestration by trapping carbon in oyster shells and surrounding sediments.

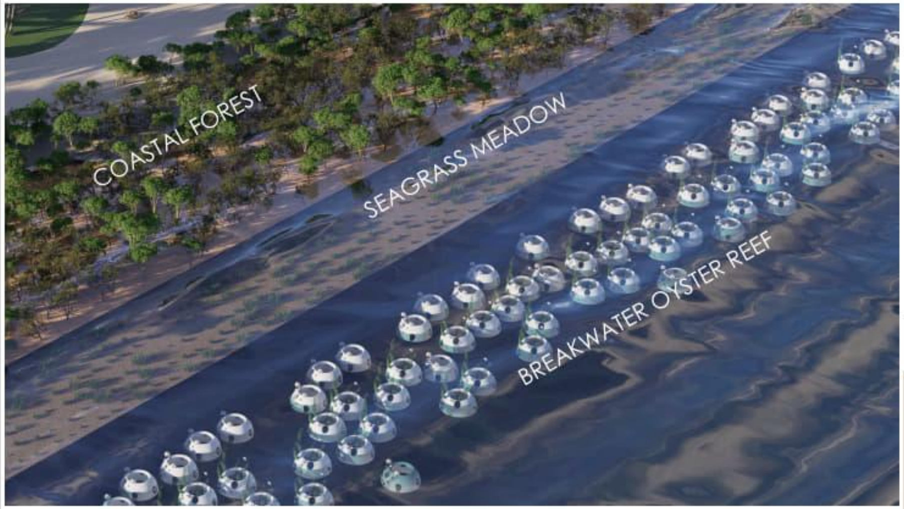
PROVISIONING

- Supports local food security and commercial fishing through sustainable shellfish harvesting.
- Provides materials for other ecosystem services, such as repurposing shells for new reef restoration projects or construction.

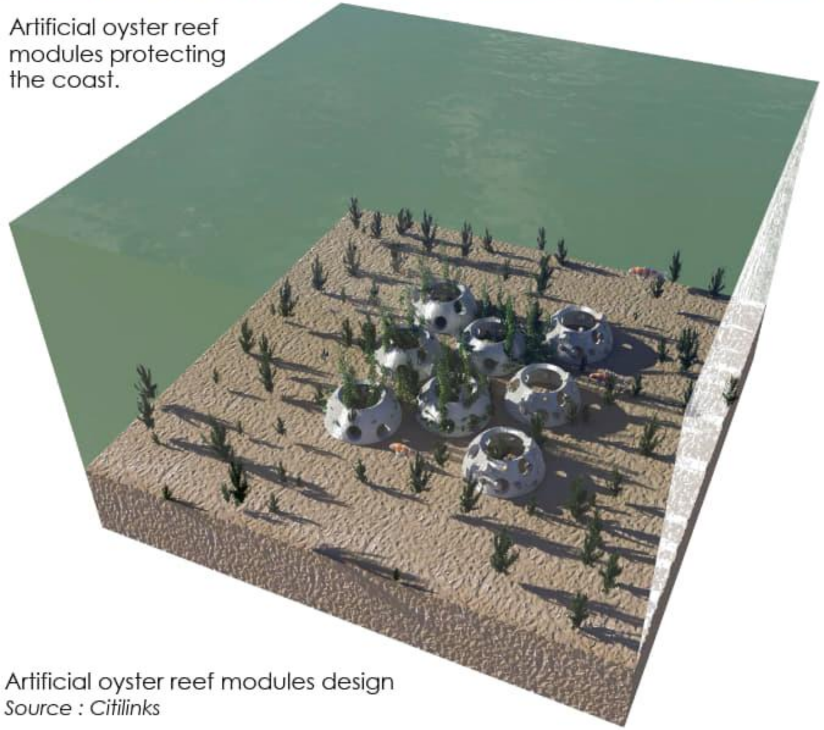
SOCIAL BENEFITS

- Enhances community resilience by improving coastal protection and supporting sustainable resource management.

NbS-25: ARTIFICIAL OYSTER REEFS



Artificial oyster reef modules protecting the coast.



Artificial oyster reef modules design
Source : Citilinks

PROJECT'S CHALLENGES & RISKS

- Port areas often experience fluctuating water quality due to pollutants, shipping activities, and industrial discharge.
- The presence of frequent sediment resuspension in port areas may hinder the settlement and growth of oysters.
- Coastal water quality can be impacted by agricultural runoff, wastewater discharge, or stormwater.
- Sandy environments with shifting sediments may pose difficulties in ensuring the stability of artificial reef structures.
- Due to the dynamic nature of sandy coasts, artificial reefs in these areas may require frequent maintenance, repairs, or repositioning.

NbS co-BENEFITS AND THEIR INDICATORS

Biodiversity Enhancement
Species richness and abundance, genetic diversity within restored areas.

Coastal Protection
Wave attenuation rates, erosion rates, coastal flood risk reduction.

Water Quality Improvement
Nutrient and heavy metal concentrations, water clarity, dissolved oxygen in water.

Resilience to climate
Reduced vulnerability to climate change impacts (e.g., lower incidence of coastal flooding, erosion).

Sustainable Fisheries and Resource Management
Improvements in fishery yields, decrease in the need for artificial or overexploited methods of resource extraction (e.g., wild capture fisheries vs. reef-based harvesting).

COST ANALYSIS

Direct Costs
Materials, labor, design and engineering, monitoring, maintenance : $155 - $530/m2

Indirect Costs
Opportunity costs, economic displacement, permit, legal costs.

Time Horizon
Short-term (1–3 years): Establishment of nurseries, planting of corals, initial monitoring.
Long-term (>10 years): fully established.

Direct Benefits
Water quality improvement, coastal protection, sustainable fisheries production, eco-tourism.

Indirect Benefits
Climate change mitigation, community health and resilience, biodiversity enhancement.

Risk Assessment
Water pollution, excessive sediment accumulation, uncertain return on investment (ROI).

REFERENCES:

USA, Chesapeake Bay The Oyster Reef Restoration Project.
Singapore, Changi Beach, Oyster Reef Restoration.
Australia, Queensland, Moreton Bay.

IMPLEMENTATION OPPORTUNITIES:

- **Indonesia :** Sunda Strait, Ujung Kulon National Park known for terrestrial conservation, The park's coastal zones are exposed to sedimentation and pollution.
- **Vietnam** : Ho Chi Minh City Coastal Area, along the Can Gio Mangrove Forest.

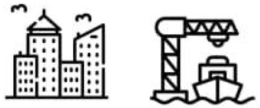
NbS-26: PERMEABLE GREEN STREETS AND ROADS

Permeable green streets in urban and industrial environments are designed to address flood control, to mitigate urban heat stress, and to reduce land subsidence in cities prone to heavy rainfall, high temperatures, and over-extraction of groundwater.

These streets integrate permeable pavements, bioswales, and urban greenery, allowing rainwater to infiltrate the ground, recharge aquifers, and reduce surface runoff, thereby alleviating urban flooding. The green coverage provided by street trees and vegetation enhances shade and evapotranspiration, lowering ambient temperatures and improving air quality.

These streets also contribute to healthier urban mobility by promoting walkability and cycling, creating more liveable and visually appealing urban spaces. Technically, they combine stormwater management with urban landscape design, while socially, they foster community well-being and climate resilience by improving public spaces and reducing disaster risks.

LANDSCAPES SUPPORTED



EbA (ECOSYSTEM-BASED APPROACHES)

- URBAN WATER MANAGEMENT
- CLIMATE REGULATION
- BIODIVERSITY ENHANCEMENT
- SOIL AND LAND CONSERVATION
- COMMUNITY RESILIENCE
- SUSTAINABLE URBAN DESIGN

MAIN PROBLEMS ADDRESSED

- FLOOD CONTROL
- AIR QUALITY IMPROVEMENT
- URBAN HEAT ISLAND

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Soil health improvement**: Facilitates nutrient cycling and soil aeration through enhanced water infiltration.

REGULATING

- **Flood mitigation**: Reduces stormwater runoff and prevents urban flooding by increasing water infiltration.
- **Urban cooling**: Lowers ambient temperatures by reducing heat island effects through greenery and water retention.

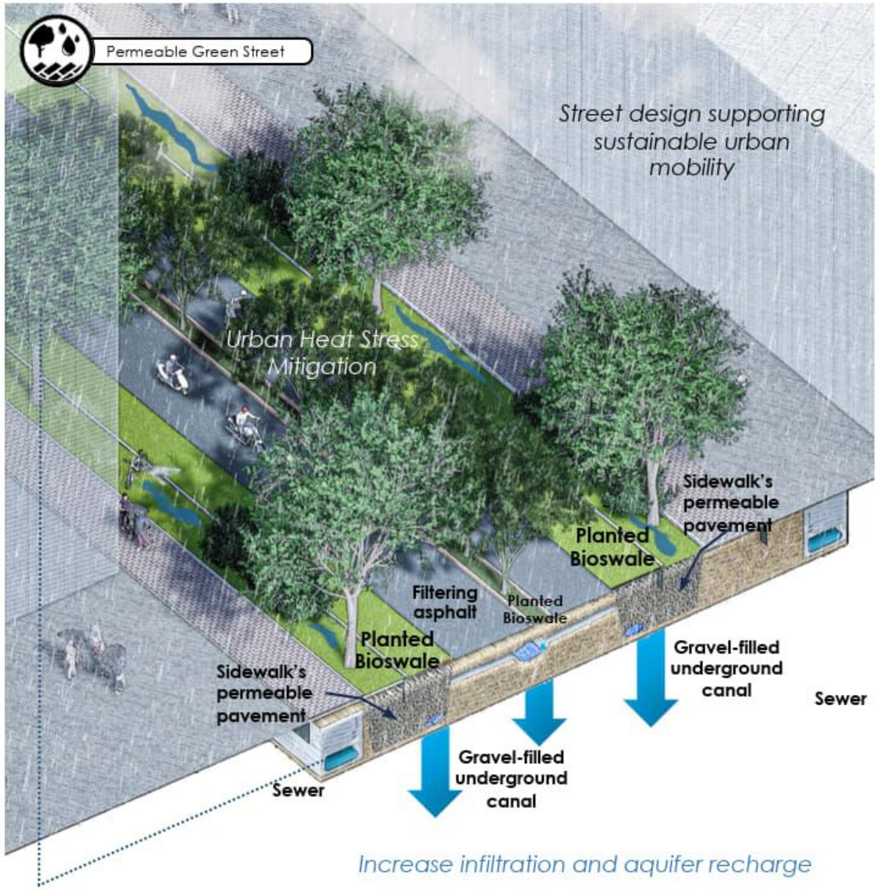
PROVISIONING

- **Groundwater recharge**: Replenishes local aquifers by allowing rainwater to percolate into the ground.

SOCIAL BENEFITS

- **Improved walkability and liveability**: Enhances urban aesthetics and encourages pedestrian-friendly environments.
- **Disaster resilience**: Builds community resilience against climate impacts like floods and heatwaves.

NbS-26: PERMEABLE GREEN STREETS AND ROADS



Permeable Green Street Section. *Source: Citilinks*

PROJECT'S CHALLENGES & RISKS

- **High initial costs**: Permeable paving, integrated drainage systems, and green infrastructure can be costly, deterring widespread adoption in resource-constrained cities.
- **Limited maintenance capacity**: Many cities lack the expertise and resources to maintain permeable surfaces.
- **Space constraints in dense urban areas**: Retrofitting green streets with limited land availability can be challenging without disrupting existing infrastructure.
- **Uncertain hydrological performance**: When high rainfall intensity exceed the infiltration capacity of permeable surfaces, several flood prone NbS should be combined to support each other.

NbS co-BENEFITS AND THEIR INDICATORS

Improved Flood Management
Reduced surface runoff by at least 30% during peak rainfall events.

Mitigation of Urban Heat Islands
Lower surrounding temperatures by 2–3°C through increased green cover and shaded streets.

Enhanced Groundwater Recharge
Increased infiltration rates, contributing to a 20% rise in local aquifer levels annually.

Air Quality Improvement
Reduction in particulate matter (PM2.5) levels by 10% due to vegetation filtering pollutants.

Improved Pedestrian Safety and Mobility
15% increase in walkability scores due to shaded, cooler, and greener streets.

Biodiversity Enhancement
Increased sightings of urban wildlife, such as pollinators and birds, by 25% in project areas.

COST ANALYSIS

Direct Costs
Permeable pavements and green infrastructure costs around $300k–500k per km, depending on materials and urban density.

Indirect Costs
Maintenance costs range between $10k–20k per km annually.

Time Horizon
20–30 year lifespan with a discount rate of 3–5% for economic feasibility assessments.

Direct Benefits
Flood damage reduction and water savings valued at $100k–200k annually per km in high-risk urban areas.

Indirect Benefits
Heat stress mitigation, improved walkability, and increased property values

Risk Assessment
Moderate risk of clogged permeable surfaces, requiring timely maintenance costing an additional $5k–10k annually.

REFERENCES:

Thailand, Bangkok, Chulalongkorn University Centenary Park.
Singapore, Kallang River Bishan-Ang Kio Park.
Indonesia, Jakarta, Pluit City Integrated Urban Development.

IMPLEMENTATION OPPORTUNITIES:

Most of urban agglomerations in ASEAN require such approach with tactical pilot projects.

NbS-27: GREEN & BLUE ROOFS AND FACADES

Green and blue roofs, along with vegetated facades can mitigate urban heat island effects and enhance resilience to climate events, as they integrate vegetation layers that provide cooling through evapotranspiration and shade, reducing ambient and building temperatures. Blue roofs incorporate water retention systems to manage stormwater, effectively mitigating risks from intense rainfall and cloudbursts. In Southeast Asia, where rapid urbanization, high humidity, and frequent extreme weather events amplify vulnerability to climate impacts, they can support urban farming, enhance biodiversity by attracting pollinators, and host solar panels to optimize energy generation, all while providing recreational spaces for urban dwellers. These hybrid NbS can also incorporate smart technologies for dynamic water storage management, helping cities to address seasonal flooding. Socially and economically, green and blue roofs can improve urban liveability by creating aesthetic landscapes, reducing energy costs for cooling, and supporting local economies through urban agriculture or green jobs. Integrating native, drought-tolerant, and water-absorbent plant species that enhance functionality and reduce maintenance needs, green roofs foster climate resilience by promoting sustainable urban ecosystems and increasing community adaptation capacity.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| URBAN HEAT MITIGATION | STORMWATER MANAGEMENT | BIODIVERSITY ENHANCEMENT | WATER CYCLE REGULATION | FLOOD RESILIENCE | ENERGY EFFICIENCY

MAIN PROBLEMS ADDRESSED

FLOOD CONTROL

AIR QUALITY IMPROVEMENT

URBAN HEAT ISLAND

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Habitat creation for biodiversity, including pollinators and urban wildlife.
- Soil formation and nutrient cycling through planted systems and organic matter accumulation.

REGULATING

- Mitigating the urban heat island effect through evapotranspiration and shading.
- Managing stormwater by retaining and slowing runoff, reducing urban flooding risks.

PROVISIONING

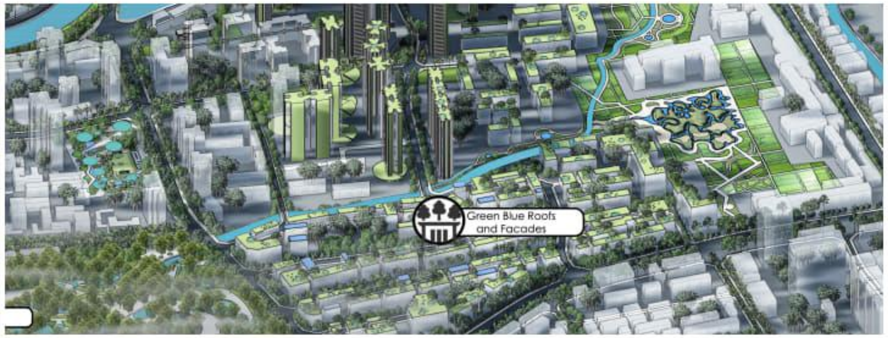
- Supporting urban agriculture and rooftop farming for local food production.
- Capturing and storing rainwater for reuse in irrigation or building systems.

SOCIAL BENEFITS

- Providing green recreational spaces that improve mental health and community cohesion.
- Enhancing urban aesthetics and property values, creating more attractive and livable cities.

NbS-27: GREEN & BLUE ROOFS AND FACADES

Green roof layer scenarios and landscape and climate functions : Sedum roof, Herbaceous roof and roof garden



PROJECT'S CHALLENGES & RISKS

- **High Maintenance Costs**: Regular upkeep, including irrigation, pest control, and structural inspections, can be expensive and resource-intensive.
- **Structural Limitations**: Many buildings in Southeast Asia, especially older or informal structures, may lack the load-bearing capacity to support green or blue roof systems.
- **Climate-Specific Plant Selection**: Identifying and sourcing resilient native plants that can thrive in extreme heat and humidity while withstanding heavy rains can be challenging.

NbS co-BENEFITS AND THEIR INDICATORS

Urban Heat Island Mitigation
Reduction in surface temperatures by 2–4°C, measurable via infrared thermal imaging.

Stormwater Management
Retention of rainfall, monitored through water runoff volume sensors.

Improved Air Quality
Reduction in particulate matter (PM2.5) levels, tracked using air quality monitors near installations.

Biodiversity Enhancement
Increase in pollinator visits and bird species diversity, assessed through regular biodiversity surveys.

Energy Efficiency
Decrease in building cooling energy demand by 10–15%, measured through energy consumption logs.

Social Well-being
Increased use of rooftop spaces for recreation or urban farming, quantified through user surveys and activity counts.

COST ANALYSIS

Direct Costs
Installation costs range from \$75 to \$250 /m2 for green roofs and \$150 to \$400 /m2 for blue roofs.

Indirect Costs
Maintenance expenses, including irrigation and structural inspections, typically range from \$5 to \$15/m2 annually.

Time Horizon
Project lifespan of 20–50 years, with discount rates between 3–7% for long-term sustainability projects in Southeast Asia.

Direct Benefits
Energy savings of \$1–\$3/m2/year from reduced cooling needs, and stormwater fee reductions ranging from \$0.50 to \$2/m2/year

Indirect Benefits
Enhanced property values and avoided health costs due to better air quality.

Risk Assessment
structural damage from improper design or maintenance.

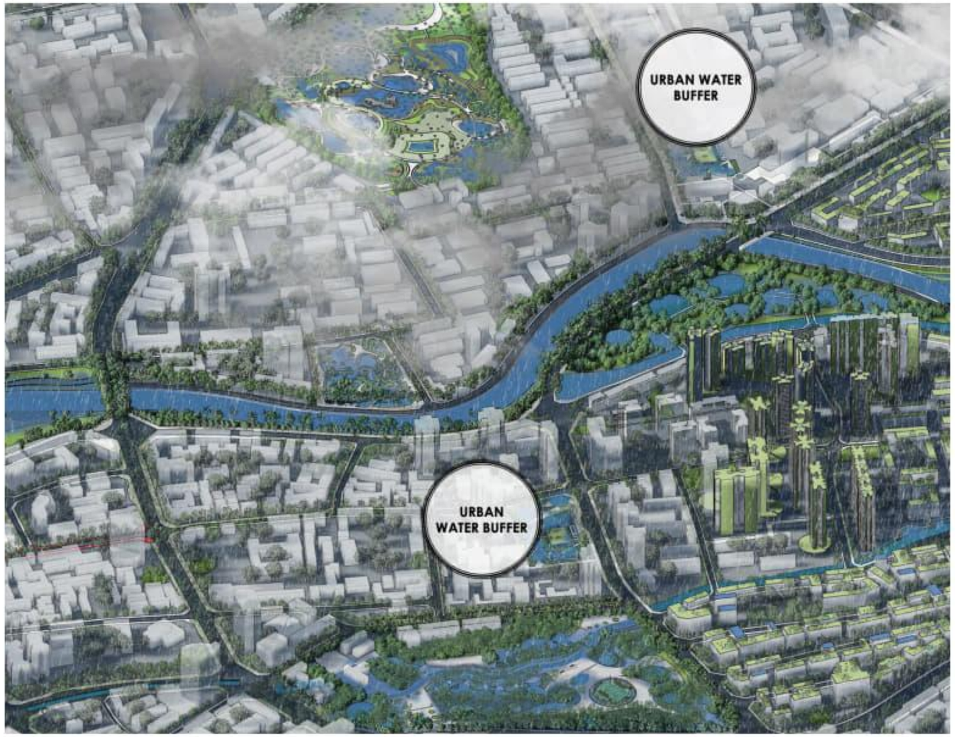
REFERENCES:

Singapore : Marina Barrage Green Roof 10,000 m2 rooftop garden and Kampung Admiralty, vertical urban village.
Netherlands, Smart Green-Blue Roofs of Resilio Project, Amsterdam.

IMPLEMENTATION OPPORTUNITIES:

Jakarta: Menteng and Sudirman areas.
Metro Manila: Quezon City and Makati.
Bangkok: Sukhumvit and Silom.
Cambodia, Phnom Penh: Tonle Bassac, BKK1.
Myanmar, Yangon central urban districts: Dagon Township.

NbS-28: URBAN WATER BUFFER



The urban water buffers is a NbS designed to enhance resilience to floods, aquifer depletion, land subsidence, and other climate-related risks. These systems collect, store, and infiltrate excess stormwater into aquifers during heavy rainfall, mitigating urban flooding, replenishing groundwater supplies, and preventing land subsidence caused by excessive groundwater extraction. In industrial zones and along transport infrastructure, water buffers can reduce runoff, improve water quality through natural filtration, and serve as reservoirs for non-potable water use.

Drawing inspiration from the Netherlands, urban water buffer systems in Southeast Asia can implement similar multifunctional solutions that integrate technical features (retention ponds, underground reservoirs, and bioretention cells) with landscape attributes like green corridors, public parks, and biodiversity habitats. Economically, these buffers lower infrastructure repair costs from flood damage and support urban water security, while socially, they enhance urban aesthetics, provide recreational spaces, and foster community engagement in water stewardship. The application of urban water buffers in cities like Jakarta, Bangkok, and Ho Chi Minh City could significantly improve climate resilience while addressing urban water challenges in diverse settings.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| INTEGRATED WATER RESOURCE MANAGEMENT | GREEN INFRASTRUCTURE DEVELOPMENT

| CLIMATE ADAPTATION | ECOSYSTEM RESTORATION | SUSTAINABLE URBAN DRAINAGE SYSTEMS

MAIN PROBLEMS ADDRESSED

DISASTER RISK REDUCTION

FLOOD CONTROL

URBAN HEAT ISLAND

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Groundwater recharge:** They enhance aquifer infiltration, maintaining water cycles and hydrological balance.
- **Habitat creation** provide wetland-like conditions that support biodiversity in urban areas.

REGULATING

- **Flood regulation:** They store excess rainwater during heavy storms, reducing flood risks in cities.
- **Climate regulation:** They mitigate urban heat islands by maintaining cooler microclimates.

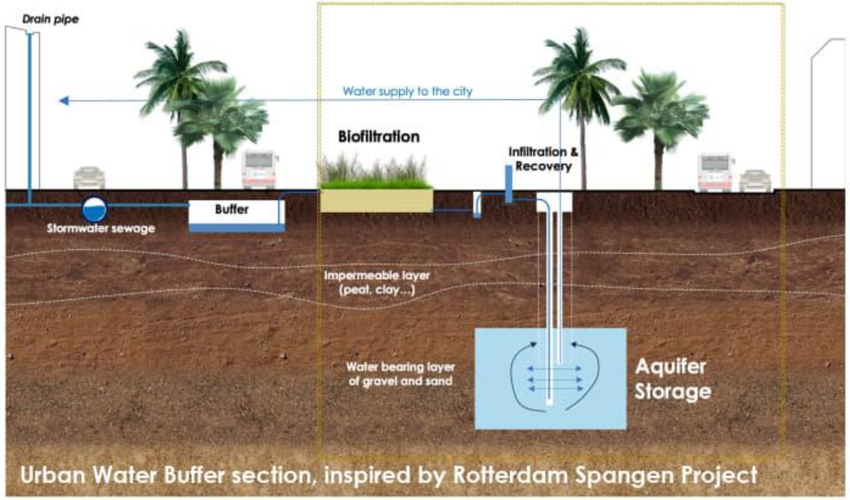
PROVISIONING

- **Water supply:** Buffers store and purify stormwater, contributing to non-potable water supplies for irrigation or industrial uses.
- **Soil stabilization:** Buffers prevent soil erosion and land subsidence.

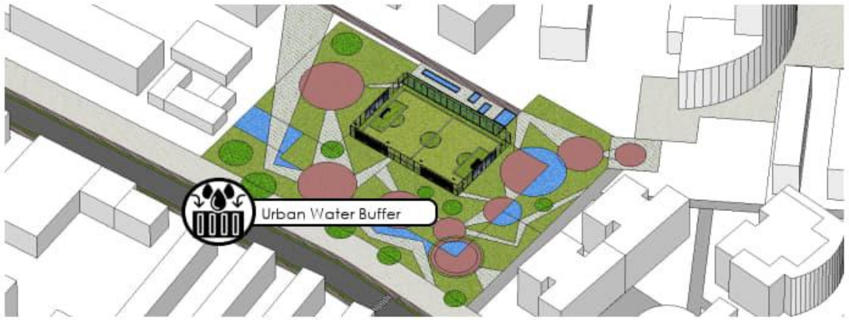
SOCIAL BENEFITS

- **Urban aesthetics and recreation:** Water buffers improve quality of life with recreational opportunities.
- **Community resilience:** They raise awareness and engage communities in sustainable water management practices.

NbS-28: URBAN WATER BUFFER



Urban Water Buffer section, inspired by Rotterdam Spangen Project



PROJECT'S CHALLENGES & RISKS

- **Space constraints:** In densely populated cities, finding available land for large-scale water buffers can be challenging due to limited space.
- **Maintenance requirements:** Urban water buffers require consistent maintenance to prevent blockages, ensure water quality, and manage vegetation.
- **Water contamination:** Urban runoff may carry pollutants, and without proper filtration systems, water buffers can be contaminated.
- **Climate change impacts:** Increased frequency and intensity of storms due to climate change can overwhelm urban water buffers.

NbS co-BENEFITS AND THEIR INDICATORS

Flood Risk Reduction
Reduction in flood-related damages and frequency of urban flooding events.

Aquifer Recharge
Increased groundwater levels in nearby wells and aquifers over time.

Water Quality Improvement
Decrease in suspended solids and pollutants in runoff water.

Climate Resilience
Enhanced resilience of urban areas to stormwater runoff and prolonged dry periods.

Biodiversity Enhancement
Increased species richness and abundance in areas with water buffer systems.

Social Well-being
Increased community engagement and usage of green spaces around water buffer areas.

COST ANALYSIS

Direct Costs
Initial investment includes land acquisition, design, and installation of infrastructure: ranges from $100k to $500k/ha.

Indirect Costs
Long-term costs for maintenance, monitoring, and operations can range from $10k to $30k/year.

Time Horizon
Typically 20 to 50 years, with a discount rate between 3% and 6% applied to future benefits.

Direct Benefits
Direct benefits include flood reduction, which can save $50k to $200k annually in flood damage reduction.

Indirect Benefits
Increased quality of life and enhanced tourism, can generate valuable economic returns (long term).

Risk Assessment
Risk of improper implementation or maintenance due to water quality degradation or infrastructure failure.

REFERENCES:

Singapore : Marina Barrage Water Management Project.
Thailand, Bangkok, Chao Phraya River Flood Control Project.
Indonesia, Jakarta, Kanal Banjir Timur diverting floodwaters.

IMPLEMENTATION OPPORTUNITIES:

Vietnam, Ho Chi Minh City, along Saigon River.
Malaysia, Kuala Lumpur in the Klang Valley.
Indonesia, Jakarta flood-prone areas.
Philippines, Metro Manila flood-prone areas.

NbS-29: SPONGE CITY PARK & URBAN OXBOW

Sponge city parks and urban oxbows integrate green infrastructure to address urban flooding, water quality, and climate resilience. Technically, they allow absorption and storing of rainwater through permeable surfaces, vegetation, and bioswales, reducing runoff and replenishing groundwater, while urban oxbows (natural or restored meandering river sections) act as water retention and filtration systems addressing riverine flood risks. These solutions are particularly effective in cities facing rapid urbanization, such as Ho Chi Minh City or Jakarta, where traditional drainage systems are overwhelmed by heavy rains. Landscape-wise, these NbS create green corridors that enhance urban biodiversity, provide recreational spaces, and improve air quality. They offer community benefits such as flood protection, improved public health through green spaces, and educational opportunities on sustainable urban water management. Sponge city parks and urban oxbows represent holistic, multifunctional approaches to enhancing the resilience of cities in the face of climate change while improving the quality of life for residents.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- WATER QUALITY IMPROVEMENT
- SOIL EROSION CONTROL
- FLOOD RISK MITIGATION
- BIODIVERSITY CONSERVATION
- GROUNDWATER RECHARGE
- CLIMATE REGULATION

MAIN PROBLEMS ADDRESSED

- BIODIVERSITY LOSS
- FLOOD CONTROL
- DISASTER RISK REDUCTION
- URBAN HEAT ISLAND

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Biodiversity Habitat**: Provide habitats for wildlife, fostering urban biodiversity in both plant and animal species.

REGULATING

- **Flood Regulation**: Absorb and store rainwater, reducing surface runoff and mitigating urban flooding.

PROVISIONING

- **Water Quality Enhancement**: Filter pollutants and sediments from stormwater, improving water quality for downstream ecosystems.

SOCIAL BENEFITS

- **Recreation and Well-being**: Offer green spaces for leisure, physical activity, and social interaction, enhancing public health and community well-being.

NbS-29: SPONGE CITY PARK & URBAN OXBOW

PROJECT'S CHALLENGES & RISKS

- **Limited Space in Dense Urban Areas**: Finding available land for sponge city parks can be challenging due to high competition for space.
- **Maintenance Complexity**: These projects require ongoing maintenance of green infrastructure and water management systems, which can be difficult to sustain.
- **Funding Constraints**: Securing sufficient funding for the initial setup and long-term upkeep of these infrastructure projects can be a barrier, especially in developing urban areas with competing priorities.

NbS co-BENEFITS AND THEIR INDICATORS

- **Flood Mitigation**
  Reduction in peak flood discharge and stormwater runoff volumes during cloudbursts.
- **Water Quality Improvement**
  Decrease in concentrations of pollutants in river water after passing through the park.
- **Biodiversity Enhancement**
  Increase in the number of aquatic and terrestrial species observed in and around the park area.
- **Urban Heat Island Mitigation**
  Measurable reduction in ambient temperature in areas within and around the sponge city park.
- **Carbon Sequestration**
  Amount of CO2 captured and stored in the soil, measured through biomass growth and soil carbon content.
- **Recreational and Aesthetic Value**
  Increased number of visitors and positive community feedback on the use of the park for leisure.

COST ANALYSIS

- **Direct Costs**
  Initial construction costs : $200k to $500k/ha, covering land preparation, vegetation, water management systems, and infrastructure.
- **Indirect Costs**
  Annual maintenance costs: from $10k to $20k/ha, including vegetation care, water quality monitoring.
- **Time Horizon and Discount Rate**
  Average lifespan of 20–30 years, with a discount rate of 3–7%.
- **Direct Benefits**
  Annual savings of $30k to $70k per ha in avoided damages and treatment costs.
- **Indirect Benefits**
  Urban cooling and biodiversity enhancement can provide $10k to $20k/ha/year.
- **Risk Assessment**
  Risk factors such as flooding or ecosystem degradation could incur $10k to $30k per ha for repairs and adaptive measures.

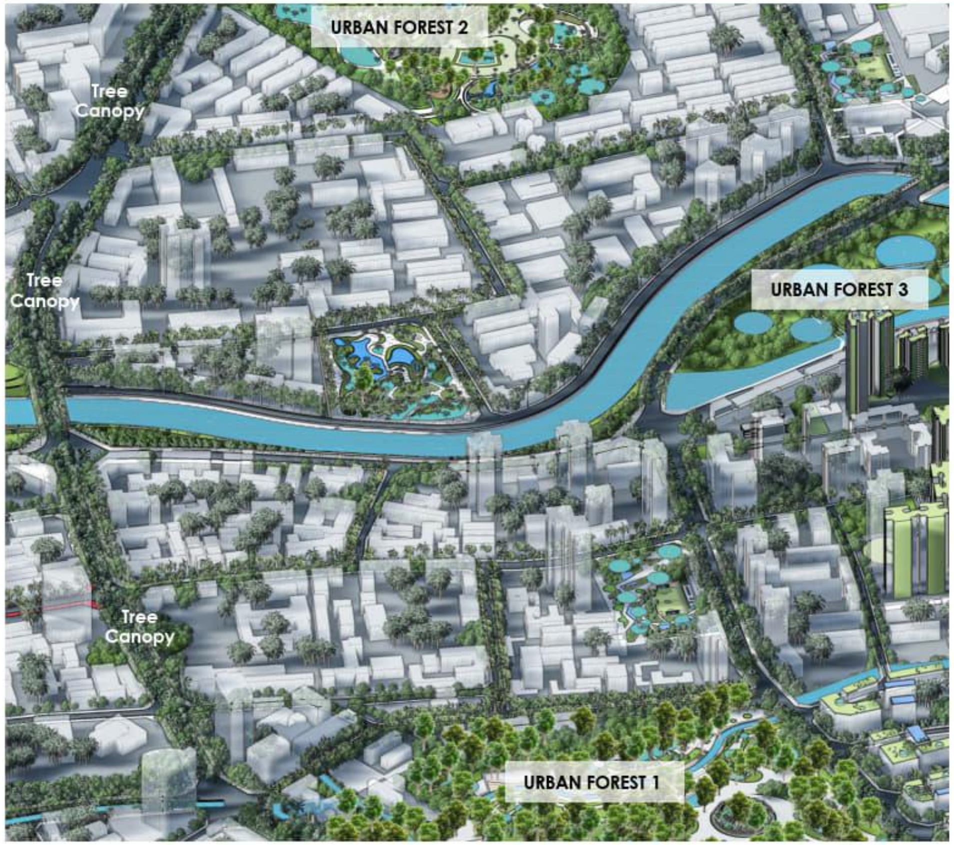
REFERENCES:

Singapore, Bishan-Ang Mo Kio Park.
Malaysia,Kuala Lumpur, River of Life Project.
Vietnam, Hanoi's Red River Parks.
China, Suzhou Creek Sponge City Project.

IMPLEMENTATION OPPORTUNITIES:

Indonesia, Jakarta's riverbanks of Ciliwung River.
Vietnam, HCMC's riverside parks along Saigon River.
Philippines, Manila, Pasig River agglomeration.

NbS-30: URBAN FOREST AND TREE CANOPY



Urban forests and tree canopies play a critical role in addressing a range of climate challenges in cities of Southeast Asia, such as urban heat islands, flooding, and biodiversity loss. In tropical and equatorial climates, these green infrastructures provide multiple benefits, including temperature regulation through shading and evapotranspiration, improving air quality, enhancing stormwater management through water retention, and mitigating flooding risks.
Urban forests and linear street tree canopies also create biodiversity corridors, supporting wildlife while enhancing the aesthetic and recreational value of urban spaces. These green areas are particularly valuable in densely populated cities and industrial zones, as they reduce the impacts of heat stress, improve resilience to extreme weather events, and support the livelihoods of local communities through enhanced quality of life. The social and economic advantages are further realized in terms of reduced energy costs, increased property values, and enhanced public health. For example, Singapore's extensive urban greening programs have demonstrated how integrating green cover into urban planning can enhance resilience, while cities like Jakarta and Manila can benefit from expanded green corridors to manage floodwaters and boost urban resilience to climate change.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| BIODIVERSITY CONSERVATION | SOIL EROSION PREVENTION | POLLUTION CONTROL | CLIMATE REGULATION | WATER MANAGEMENT

MAIN PROBLEMS ADDRESSED

BIODIVERSITY LOSS — FLOOD CONTROL — URBAN HEAT ISLAND AND AIR QUALITY IMPROVEMENT

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING
- Habitat provision for local wildlife, promoting biodiversity.
- Soil formation and nutrient cycling, supporting healthy ecosystems.

REGULATING
- Temperature regulation through shading, reducing the urban heat island effect.
- Stormwater management by enhancing water infiltration and reducing surface runoff.

PROVISIONING
- Provision of timber, fruits, and medicinal plants for local communities.
- Access to wood products and other natural resources for sustainable livelihoods.

SOCIAL BENEFITS
- Improved mental and physical health by providing green spaces for recreation and relaxation.
- Increased community cohesion and engagement through public involvement in tree planting and forest management initiatives.

NbS-30: URBAN FOREST AND TREE CANOPY

Riverside continuous linear tree canopy crossing green avenue

Green avenue section

Benchakitti Park, Bangkok

PROJECT'S CHALLENGES & RISKS

- **Land Availability**: Limited space in densely populated urban areas can restrict the planting and maintenance of urban forests and tree canopies.
- **Invasive Species**: The introduction of non-native tree species may disrupt local ecosystems, threatening biodiversity and ecosystem balance.
- **Climate Change**: Rising temperatures and erratic rainfall patterns can affect the survival and growth of certain tree species in urban environments.
- **Maintenance Costs**: Regular care, watering, and pruning of trees in urban areas can be resource-intensive, especially in rapidly growing cities with limited budgets.

NbS co-BENEFITS AND THEIR INDICATORS

Urban Heat Island Mitigation
Reduction in surface temperatures by up to 5°C in tree-covered areas.

Flood Management and Water Retention
Increase in stormwater retention capacity by 30-50% in green urban spaces.

Biodiversity Support
Increase in species diversity in urban areas, with a recorded 15% rise in urban bird populations.

Air Quality Improvement
Reduction of PM2.5 by up to 30% in areas with dense tree canopies.

Carbon Sequestration
Carbon sequestration of 1-2 tons of CO_2 per hectare per year in urban forests.

Social and Recreational Benefits
Increased public park visitation by 20-40%, promoting physical and mental well-being.

COST ANALYSIS

Direct Costs
Initial costs (tree selection, installation, infrastructure adjustments) from $10k–$50k/ha (depends on tree species and urban context).

Indirect Costs
Ongoing maintenance (pruning, watering, and pest management) from $1k–$5k/year/hectare.

Time Horizon
Benefits accrue over a long time period, often 20-50 years, with a discount rate of 3-5% for long-term urban planning.

Direct Benefits
Cost savings from reduced energy use due to urban heat island mitigation and reduced flooding.

Indirect Benefits
Social and health benefits, such as improved mental well-being and increased property values.

Risk Assessment
Potential risks include high maintenance costs, especially in densely built areas, and tree mortality from disease or extreme weather.

REFERENCES:

Singapore : Park Connector Network (PCN) green walkable corridors.
Indonesia, Jakarta, Taman Kota, Urban Forests.
Thailand, Bangkok, Benchakitti Park.

IMPLEMENTATION OPPORTUNITIES:

Vietnam, Hanoi, along new metro lines and stations along with green transit-oriented development.
Ho Chi Minh City along the river.
Thailand, Bangkok along transport corridors.

NbS-31 LANDFILL REGENERATION PARK

A landfill regeneration park is an innovative NbS that transforms decommissioned or underused landfills into multifunctional green spaces, addressing soil remediation, urban heat island mitigation, biodiversity restoration, flood resilience, and waste management challenges.

Technically, these parks utilize engineered soil layers and phytoremediation with native plants to stabilize contaminated land, sequester pollutants, and restore degraded ecosystems.

Their design can integrate urban forests, wetlands, and recreational spaces that enhance local biodiversity, absorb stormwater, and reduce flood risks, while cooling urban areas and mitigating heat stress. Contextually, landfill regeneration parks can be adapted to cities and industrial zones, offering new uses for otherwise unutilized land near transport infrastructure or densely populated areas. Socially and economically, they provide accessible green spaces, improve public health, create jobs in park management and environmental monitoring, and enhance property values around the regenerated sites. Lessons from existing projects demonstrate their potential to combine ecological restoration with community engagement, creating resilient, vibrant urban ecosystems.

LANDSCAPES SUPPORTED

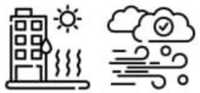
EbA (ECOSYSTEM-BASED APPROACHES)

- PHYTOREMEDIATION
- WATER SENSITIVE URBAN DESIGN
- GREEN INFRASTRUCTURE
- CLIMATE ADAPTATION AND MITIGATION
- HABITAT RESTORATION

MAIN PROBLEMS ADDRESSED

BIODIVERSITY LOSS

FLOOD CONTROL



URBAN HEAT ISLAND AND AIR QUALITY IMPROVEMENT

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Soil regeneration through phytoremediation and organic matter accumulation.
- Habitat creation for native flora and fauna, fostering biodiversity.

REGULATING

- Stormwater retention and filtration to mitigate flood risks.
- Reduction of urban heat island effects through vegetation cover.

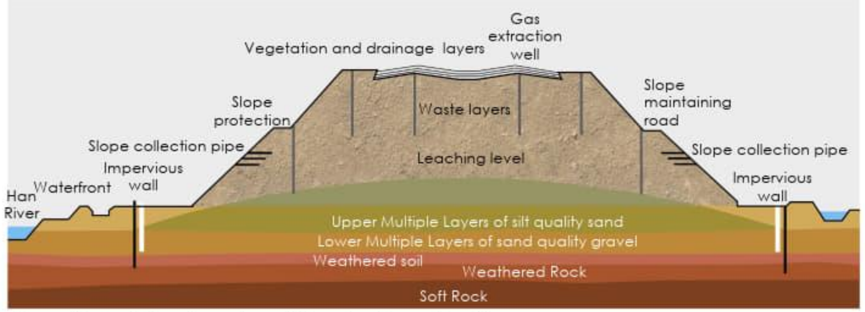
PROVISIONING

- Renewable resources such as compost from organic waste treatment.
- Provision of green spaces for urban agriculture or community gardening.

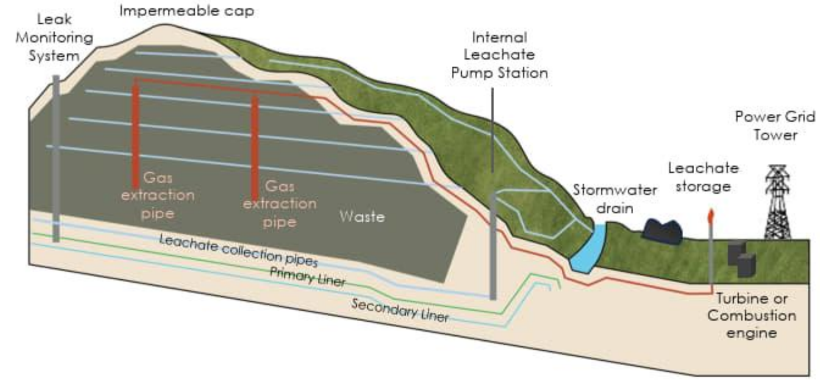
SOCIAL BENEFITS

- Creation of recreational and cultural spaces for community engagement.
- Enhanced public health through improved air quality and access to green areas.

NbS-31 LANDFILL REGENERATION PARK



Nanjido Ecological Park, South Korea



PROJECT'S CHALLENGES & RISKS

- **Soil Contamination Risks**: Legacy pollutants in landfill soils may require costly remediation and careful management to ensure safe regeneration.
- **Climate Suitability**: High rainfall in the region can cause leachate issues, increasing the risk of groundwater contamination if not adequately addressed.
- **Maintenance and Monitoring**: Long-term upkeep of vegetation and infrastructure, especially in tropical climates, can be resource-intensive and challenging.

NbS co-BENEFITS AND THEIR INDICATORS

- **Biodiversity Restoration**
  Increase in native plant species diversity, measured by the number of species introduced and thriving in the park.
- **Urban Heat Island Mitigation**
  Reduction in surface temperatures, monitored through thermal imaging before and after park development.
- **Flood Resilience**
  Improved stormwater absorption, indicated by reduced runoff volume during rainfall events.
- **Community Well-being**
  Increased park usage for recreation, tracked through visitor surveys or footfall counts.
- **Carbon Sequestration**
  Enhanced carbon storage, quantified by the biomass growth of trees and vegetation over time.
- **Waste Management Awareness**
  Greater community engagement in recycling programs, assessed through participation rates in park-led waste education initiatives.

COST ANALYSIS

- **Direct Costs**
  Site remediation, vegetation, and infrastructure development cost around $300k–$1M/ha, depending on contamination levels and park design.
- **Indirect Costs**
  Maintenance and community engagement programs add $20k–$50k annually per hectare.
- **Time Horizon**
  Project benefits typically span 20–50 years with a discount rate of 5–7%.
- **Direct Benefits**
  Increased land value and recreational revenue yield up to $50k–$100k/ha annually , depending on urban proximity and park facilities.
- **Indirect Benefits**
  Flood control, air quality improvement, and carbon sequestration.
- **Risk Assessment**
  Potential cost overruns due to unforeseen contamination issues or community opposition.

REFERENCES:

South Korea, Sudokwon Landfill Site: multifunctional ecological park with wetlands, recreational areas, and renewable energy generation facilities.
Singapore, Kallang Riverside Park: The project park illustrates innovative reuse of degraded or industrial land for urban green space.

IMPLEMENTATION OPPORTUNITIES:

Philippines, Manila, Smokey Mountain: Historical dumpsite to be transformed into a green park for flood mitigation, biodiversity restoration, and recreational use.
Indonesia, Jakarta, Bantar Gebang: The region's largest landfill could host a regeneration project to mitigate urban heat islands, improve water retention, and become an urban green space.

NbS-32 TIDAL PARK

Tidal park development transforms urban coastal or riverine areas into vibrant spaces that harmonize natural tidal ecosystems with human activity. These parks are designed around the natural tidal processes of water bodies, where areas are periodically submerged and exposed due to tidal fluctuations. Through careful planning, tidal park development utilizes natural and eco-engineered elements such as native vegetation, permeable pathways, and bio-shoreline reinforcements to restore degraded habitats, support biodiversity, and mitigate urban flood risks. These spaces often include features like tidal wetlands, estuarine lagoons, and dynamic flood basins to absorb storm surges and reduce erosion. By providing recreational and educational opportunities, and reconnecting urban populations with marine and coastal environments, tidal parks represent a sustainable approach to urban development in harmony with nature.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOSYSTEM BASED ADAPTATION
- ECOSYSTEM-BASED DISASTER RISK REDUCTION
- ECOSYSTEM RESTORATION
- ECOSYSTEM BASED MITIGATION
- GREEN INFRASTRUCTURE

MAIN PROBLEMS ADDRESSED

- BIODIVERSITY LOSS
- FLOOD CONTROL
- URBAN HEAT ISLAND
- DISASTER RISK REDUCTION
- CARBON SEQUESTRATION
- AIR QUALITY IMPROVEMENT

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Promote nutrient recycling by integrating natural cycles into urban green spaces, supporting healthy soils and vegetation.
- Facilitate soil stabilization in developed areas through vegetation, preventing erosion and supporting infrastructure.
- Create ecological corridors to connect fragmented urban ecosystems, allowing wildlife to thrive amidst city development.

REGULATING

- Manage urban flooding by using wetlands, tidal zones, and green infrastructure to absorb and store excess water.
- Regulate temperature by reducing urban heat through shaded areas and cooling from water bodies.
- Enhance water quality by filtering runoff through bioengineered wetlands and permeable surfaces.

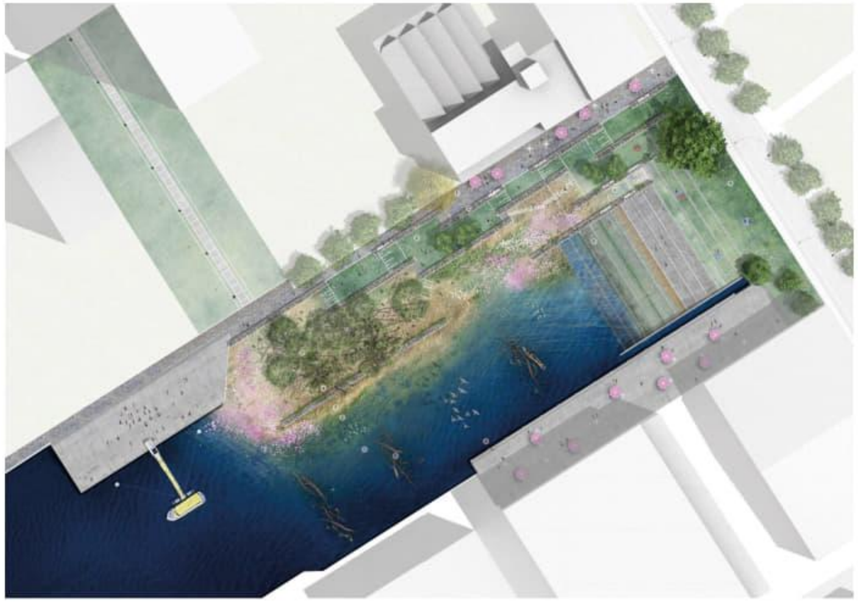
PROVISIONING

- Offer clean water sources by protecting and restoring urban aquifers and surface water systems.
- Provide fresh food through urban agriculture, community gardens, or aquaculture integrated into tidal parks.

SOCIAL BENEFITS

- Enhance recreation opportunities by offering spaces for walking, birdwatching, kayaking, and other outdoor activities.
- Promote environmental education through interactive urban parks that highlight biodiversity, climate adaptation, and ecosystem functions.
- Boost mental health by providing tranquil, green spaces that reduce stress and improve well-being for urban residents.

NbS-32 TIDAL PARK



Tidal park Keilehaven in Rotterdam
Source : DE URBANISTEN

Nature reserve and tidal park, The Zwin, Belgium
Source : STIJLGROEP

PROJECT'S CHALLENGES & RISKS

- **Pollution and Water Quality Degradation:** Urban runoff and industrial discharge can contaminate tidal park waters, degrading water quality and threatening aquatic life.
- **Space Availability :** Limited land availability in urban areas increases competition for space, which can delay the development of tidal parks.
- **Extreme weather events:** Rising sea levels and extreme weather events may overwhelm tidal parks' protective functions, causing erosion and flooding.
- **Safety Risks:** Lack of public understanding of tidal parks' benefits, coupled with safety risks in tidal areas may discourage community participation.

NbS co-BENEFITS AND THEIR INDICATORS

Disaster risk reduction
Frequency and intensity of flood events, reduction in flood-related damages to infrastructure and property, volume of water absorbed or stored by the park during high tides or heavy rainfall

Urban heat island mitigation
Average temperature difference between urban areas with and without tidal parks, surface temperature reduction in adjacent urban areas.

Carbon Sequestration
Carbon sequestration rate, changes in soil organic carbon levels, vegetation cover and health.

Water Quality Improvement
Levels of pollutants (e.g., nitrogen, phosphorus, heavy metals), water turbidity, frequency of harmful algal blooms.

Economic Revitalization
Increase in property values, job creation associated with park maintenance, management, and tourism.

COST ANALYSIS

Direct Costs
Construction, ecosystem restoration, maintenance, monitoring : $65,000 - $2,150,000/ha.

Indirect Costs
Opportunity costs, public access infrastructure and services.

Time Horizon
Short-term (1-5 years): park construction, initial maintenance, and ecosystem restoration.
Long-term (20+ years): Sustaining park health.

Direct Benefits
Flood mitigation, improved water quality, carbon sequestration..

Indirect Benefits
Biodiversity and habitat creation, public health.

Risk Assessment
Extreme weather, pollution, or invasive species could degrade park ecosystems.
With fluctuating tides, strong currents, and rough terrain, public safety is a concern.

REFERENCES:

The Netherlands, Rotterdam, Keilehaven Tidal Park combines a city park with a natural estuary system.
UK, London, Thames Barrier Park, reduces flood risk offers green space, promotes biodiversity, and helps improve water quality in the estuary.

IMPLEMENTATION OPPORTUNITIES:

Indonesia, Jakarta, along the northern coastline.
Philippines, Manila, Manila bay.
Vietnam, Ho Chi Minh City, Saigon River area or along the coastline.

NbS-33 URBAN AGRICULTURE

Urban agriculture can serve as a multifunctional nature-based solution (NbS) for Southeast Asian cities, addressing food security, climate adaptation, and sustainable green infrastructure.
By integrating farming practices into urban spaces like rooftops, vacant lots, and peri-urban areas, it helps mitigate the urban heat island effect, improves air quality, and enhances water retention.
Urban agriculture can contribute to soil bioremediation through the use of biochar and organic farming practices, while green roofs and vertical gardens provide additional space for crop cultivation, reducing pressure on rural lands.
In tropical and equatorial climates, urban agriculture offers year-round productivity, supporting local food systems and reducing reliance on food imports, while also creating green jobs and fostering community engagement.
Additionally, urban agriculture enhances biodiversity by providing habitats for pollinators and promoting ecosystem services, such as nutrient cycling and carbon sequestration, making it a holistic solution for climate resilience and sustainable urban living.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| BIODIVERSITY CONSERVATION | INTEGRATED FOOD-WATER-ENERGY SYSTEMS
AGROECOLOGY & SUSTAINABLE LAND MANAGEMENT | CLIMATE-SMART AGRICULTURE
| WATER SENSITIVE URBAN DESIGN | SOIL BIOREMEDIATION | GREEN INFRASTRUCTURE

MAIN PROBLEMS ADDRESSED

BIODIVERSITY LOSS
FLOOD CONTROL
URBAN HEAT ISLAND
AIR QUALITY IMPROVEMENT
FOOD SECURITY

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Soil formation and nutrient cycling**: Enhances soil health through composting and organic farming practices.
- **Habitat creation**: Provides urban habitats for pollinators, beneficial insects, and birds.

REGULATING

- **Climate regulation**: Reduces urban heat islands and mitigates greenhouse gas emissions through carbon sequestration in plants and soil.
- **Water management**: Improves water retention and reduces urban flooding through rainwater harvesting and permeable farm designs.

PROVISIONING

- **Food production**: Supplies fresh, locally grown produce to urban populations, enhancing food security.
- **Renewable resources**: Generates organic matter for biochar, compost, and renewable energy inputs like biogas.

SOCIAL BENEFITS

- **Community engagement**: Builds social cohesion and participation through urban farming initiatives and community gardens.
- **Educational opportunities**: Promotes awareness of sustainable agriculture and environmental stewardship through training and workshops.

NbS-33 URBAN AGRICULTURE

South Taihu Lake project, Huzhou, China. Source: Sasaki

Shongzhuang Arts and Agriculture City, China. Source: Sasaki

PROJECT'S CHALLENGES & RISKS

- **Land availability and tenure insecurity**: Limited access to urban land and unclear land ownership can hinder long-term urban agriculture initiatives.
- **Soil contamination**: Urban soils in Southeast Asia often face pollution from industrial and municipal waste, posing risks to food safety and public health.
- **Water resource competition**: Urban agriculture can strain already limited freshwater supplies in densely populated cities, especially during dry seasons.

NbS co-BENEFITS AND THEIR INDICATORS

- **Enhanced Food Security**
  Increased availability of fresh produce, measured by the number of urban households participating in urban farming.
- **Improved Climate Resilience**
  Reduction in urban heat island effects, tracked through localized temperature measurements.
- **Biodiversity Restoration**
  Increased presence of pollinators and beneficial insects, indicated by species diversity assessments in agricultural sites.
- **Waste Management**
  Reduction in organic waste sent to landfills, quantified by the volume of composted material used in urban farming.
- **Economic Opportunities**
  Creation of green jobs, measured by the number of employment opportunities generated in urban agriculture projects.
- **Community Engagement**
  Strengthened social cohesion, indicated by the number of community-led urban farming initiatives or workshops.

COST ANALYSIS

- **Direct Costs**
  Soil preparation, irrigation, and infrastructure, ranges from \$5–\$15/m2 (depends on scale/location.
- **Indirect Costs**
  Maintenance, training, and operational expenses, such as labour and fertilizers, amount to approximately \$2–\$5/m2/year.
- **Time Horizon**
  Projects typically have a 10–15 year timeframe with a discount rate of 5–7% applied to assess long-term benefits.
- **Direct Benefits**
  Increased food production valued depending on crop types and yield.
- **Indirect Benefits**
  Pollination and reduced stormwater runoff, avoided costs of infrastructure upgrades.
- **Risk Assessment**
  Potential risks such as land-use conflicts or pest outbreaks .

REFERENCES:

Thailand, Bangkok Urban Agriculture Initiative : Chulalongkorn University Centenary Park.
Philippines, Quezon City Urban Farming Program.
Singapore's Sky Greens Vertical Farm: Large-scale vertical farming project that demonstrates high-tech, space-efficient urban agriculture.

IMPLEMENTATION OPPORTUNITIES:

Indonesia, Jakarta's green roofs and rehabilitated flood-prone areas.
Vietnam, Ho Chi Minh City's vacant urban lots and rooftop spaces.
Cambodia, Kampong rural-urban transition zones.

NbS-34 POLLINATOR HABITATS AND CORRIDORS

Pollinators play a critical role in biodiversity conservation, urban farming, and regenerative agriculture, while also contributing to wildlife corridors and mitigating human-wildlife conflicts.

Pollinator habitats and corridors, ranging from wildflower strips in urban parks and green roofs to grassed waterways in agricultural lands, serve as habitat linkages, enhance ecological connectivity, and support species migration.

Southeast Asia is home to diverse pollinators, including native bees (e.g., Apis cerana and stingless bees), butterflies, moths, beetles, flies, and birds like sunbirds. These pollinators not only sustain ecosystems but also boost crop productivity and maintain forest regeneration, essential in tropical and equatorial climates. Practical NbS include urban pollinator gardens, rehabilitated forest edges, and integrated landscape management to create pollinator corridors between agricultural fields and forest reserves. By supporting biodiversity hotspots, promoting ecosystem services, and facilitating coexistence with wildlife (e.g., linking elephant migration paths with biodiverse landscapes), pollinator-focused NbS offer social benefits such as food security, education, and aesthetic value, while providing technical and economic gains like improved yields and climate resilience.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOLOGICAL CONNECTIVITY
- AGROECOLOGY
- HABITAT RESTORATION
- CLIMATE-SMART AGRICULTURE
- INTEGRATED LANDSCAPE MANAGEMENT
- URBAN BIODIVERSITY ENHANCEMENT
- WILDLIFE CORRIDOR DEVELOPMENT

MAIN PROBLEMS ADDRESSED

- BIODIVERSITY LOSS
- FOOD SECURITY

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Biodiversity Support**: Provide habitats and corridors for pollinators, maintaining species diversity and ecological interactions.

REGULATING

- **Pollination Regulation**: Enhance crop pollination and natural vegetation growth, improving ecosystem productivity.

PROVISIONING

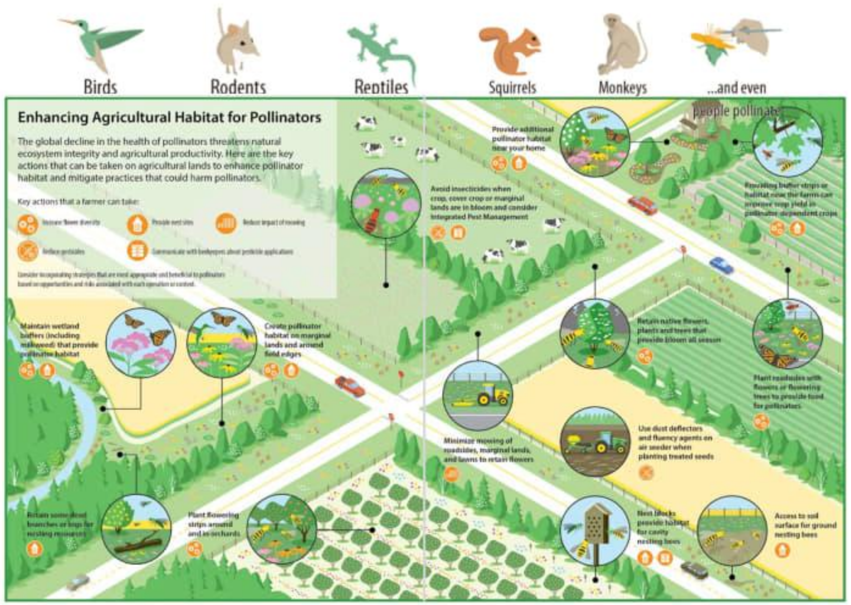
- **Agricultural Yield Improvement**: Support higher yields of pollinator-dependent crops, enhancing food security and farmer livelihoods.

SOCIAL BENEFITS

- **Community Engagement**: Create opportunities for education and participation in pollinator-friendly practices and urban greening.
- **Aesthetic and Recreational Value**: Enhance the visual appeal and recreational potential of green spaces through pollinator-attracting flowers and vegetation.

NbS-34 POLLINATOR MODULES AND CORRIDORS

Pollinator Park Pathway



Enhancing Agricultural Habitat for Pollinators. *Source: Technical Guide for Preserving and Creating Habitat for Pollinators on Ontario's farms*

PROJECT'S CHALLENGES & RISKS

- **Habitat Fragmentation**: Urbanization and agricultural expansion may disrupt the connectivity of pollinator corridors, reducing their effectiveness.
- **Pesticide Use**: Widespread use of chemical pesticides and herbicides in Southeast Asia poses significant risks to pollinator health and survival.
- **Climate Sensitivity**: Changes in temperature and precipitation patterns can affect the flowering cycles of plants and the activity of pollinators, reducing their mutual benefits.
- **Invasive Species**: Introduction of non-native plant or animal species may outcompete native flora and fauna, disrupting local pollinator ecosystems.

NbS co-BENEFITS AND THEIR INDICATORS

Biodiversity Conservation
Increased diversity of native pollinator species, measured by species richness and abundance surveys.

Agricultural Productivity
Enhanced crop yields in farms near pollinator corridors, monitored by harvest data.

Climate Resilience
Improved resilience of ecosystems through pollination of climate-adaptive plant species, assessed by vegetation health indices.

Community Engagement
Greater participation in pollinator conservation initiatives, tracked through community-driven projects.

Urban Aesthetic and Liveability
Visually appealing green spaces in urban areas.

Education and Awareness
Increased awareness of pollinator importance, gauged by the number of educational campaigns and outreach events conducted.

COST ANALYSIS

Direct Costs
Initial establishment costs for native plantings, habitat modules range from $5k to $10k/ha.

Indirect Costs
Maintenance costs, including vegetation management and monitoring, may be around $500 to $1,000 /ha/year.

Time Horizon
Projects typically span 10–20 years, with a discount rate of 5–7% for long-term ecological benefits.

Direct Benefits
Increased crop yields from enhanced pollination services can generate valuable benefits in agricultural contexts.

Indirect Benefits
Ecosystem services like biodiversity conservation and community well-being contribute to societal value.

Risk Assessment
Potential failure due to habitat fragmentation or invasive species incurs financial for mitigation efforts.

REFERENCES:

Philippines Pollinator Initiative.

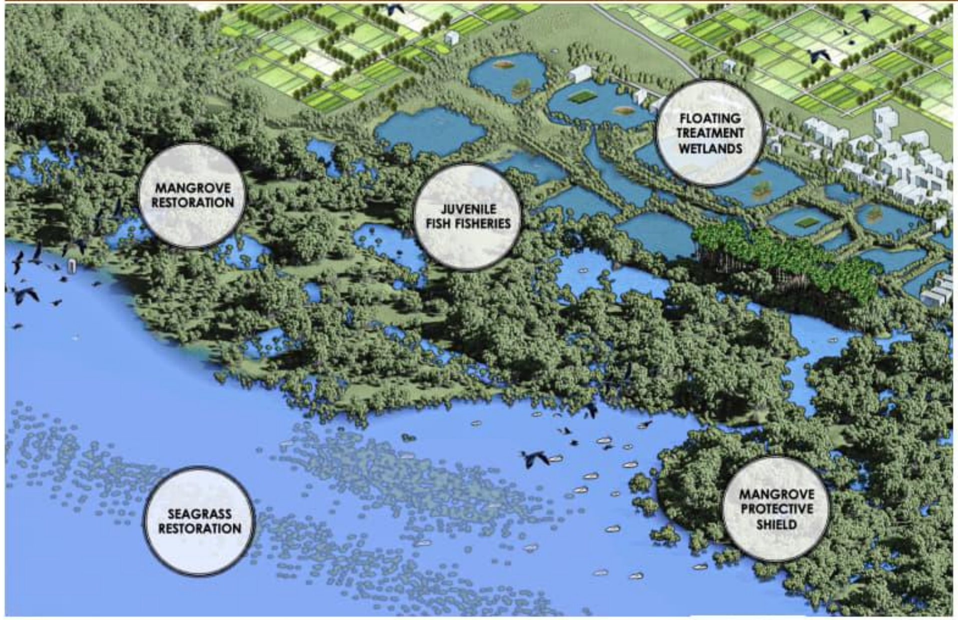
Singapore's Nature Ways.

China, Hong Kong, Kadoorie Farm and Botanic Garden.

IMPLEMENTATION OPPORTUNITIES:

Philippines, Central Luzon Agricultural Zone.
Indonesia , Jambu and Riau Provinces.
Singapore's expanding of Nature Ways into urban core.
Mekong River Delta Region's ecosystems.
Thailand, Chiang Mai's urban green roofs and urban farming lands.

NbS-35: MANGROVE AS PROTECTIVE SHIELD FOR AQUACULTURE



The Coastal Mangrove Shield in synergy with Sustainable Fisheries acts as a natural barrier against tidal waves, coastal erosion, and storms, reducing the energy of incoming waves and stabilizing shorelines through their dense root systems. This NbS not only protects vulnerable coastal aquaculture sites, villages, and towns from severe weather impacts but also boosts biodiversity by providing habitat for fish and shellfish, which are crucial for local fisheries. Mangroves support sustainable fishing practices by offering nursery grounds and shelter for marine life, increasing fish stocks, and supporting the livelihoods of coastal communities.

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Supports critical habitats for fish, crustaceans, and birds
- Nursery grounds for fisheries, protected by the mangrove

REGULATING

- Acting as a natural buffer, reducing wave energy, stabilizing sediment, and protecting shorelines from erosion and storm surges.
- Carbon Sequestration by absorbing and storing large amounts of carbon in biomass and soil.

PROVISIONING

- Supplying wood, honey, and medicinal plants, balancing extraction with ecosystem health.

SOCIAL BENEFITS

- Maintaining local economies and improve resilience for local communities.
- Mangroves lower disaster risk for nearby towns and villages, reducing infrastructure damage.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| INTEGRATED COASTAL MANAGEMENT | REFORESTATION | COMMUNITY BASED MANAGEMENT | BIODIVERSITY CONSERVATION | SUSTAINABLE FISHERIES MANAGEMENT | HABITAT CONNECTIVITY

MAIN PROBLEMS ADDRESSED

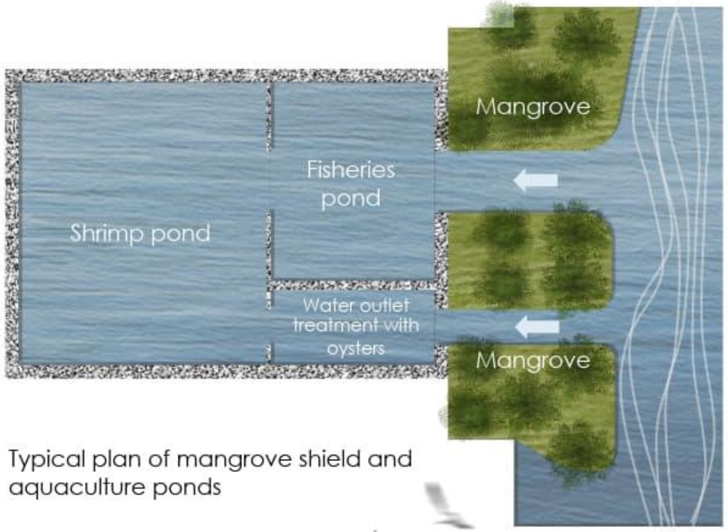
SOIL EROSION

BIODIVERSITY LOSS

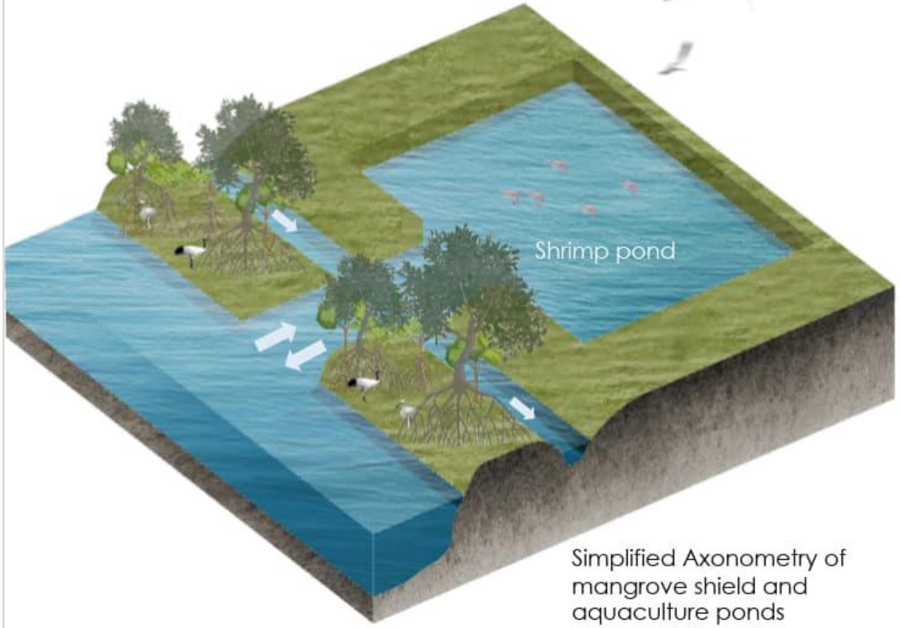
FLOOD CONTROL

DISASTER RISK REDUCTION

NbS-35: MANGROVE AS PROTECTIVE SHIELD FOR AQUACULTURE



Typical plan of mangrove shield and aquaculture ponds



Simplified Axonometry of mangrove shield and aquaculture ponds

PROJECT'S CHALLENGES & RISKS

- **Funding Gaps:** Long-term maintenance and monitoring often lack sustained funding.
- **Land Use Conflicts:** Due to potential competing interests (e.g., agriculture, aquaculture).
- **80% of Mangrove Restoration fail:** As the soil characteristics, density of plantations and rhythm of plantation will determine the success of the project.
- **Scaling up Coastal Fisheries**: Requires adequate land management and governance to avoid intensive coastal land pressure from the agricultural sector.

NbS co-BENEFITS AND THEIR INDICATORS

Biodiversity Conservation
Species richness and abundance of key species (fish, crustaceans, birds).

Climate Resilience
Reduction in shoreline erosion rates, frequency, and intensity of flooding in nearby communities.

Carbon Sequestration
Carbon stock assessment in above-ground biomass and sediment (tCO_2/ha).

Water Quality Enhancement
Levels of nitrates, phosphates, heavy metals, and sedimentation in water samples.

Livelihoods and Economic Benefits
Increase in sustainable fishery yields, in income from ecotourism, local jobs.

Social Resilience and Community Engagement
Number of community members involved in mangrove protection initiatives .

COST ANALYSIS

Direct Costs
Restoration (0.40 USD/m2), infrastructure (fencing, access points), maintenance and monitoring.

Indirect Costs
Opportunity costs if land is repurposed from other uses.

Time Horizon and Discount Rate
10-30 years to capture full ecological and economic benefits, adjusted to account for long-term environmental and social benefits.

Direct Benefits
Reduced storm damage costs, revenue from sustainable fisheries, carbon credit revenue.

Indirect Benefits
Increased biodiversity, improved water quality, reduced health costs due to cleaner environment.

Risk Assessment
Evaluation of factors such as climate change impacts on growth rates, potential for disease, and community engagement level.

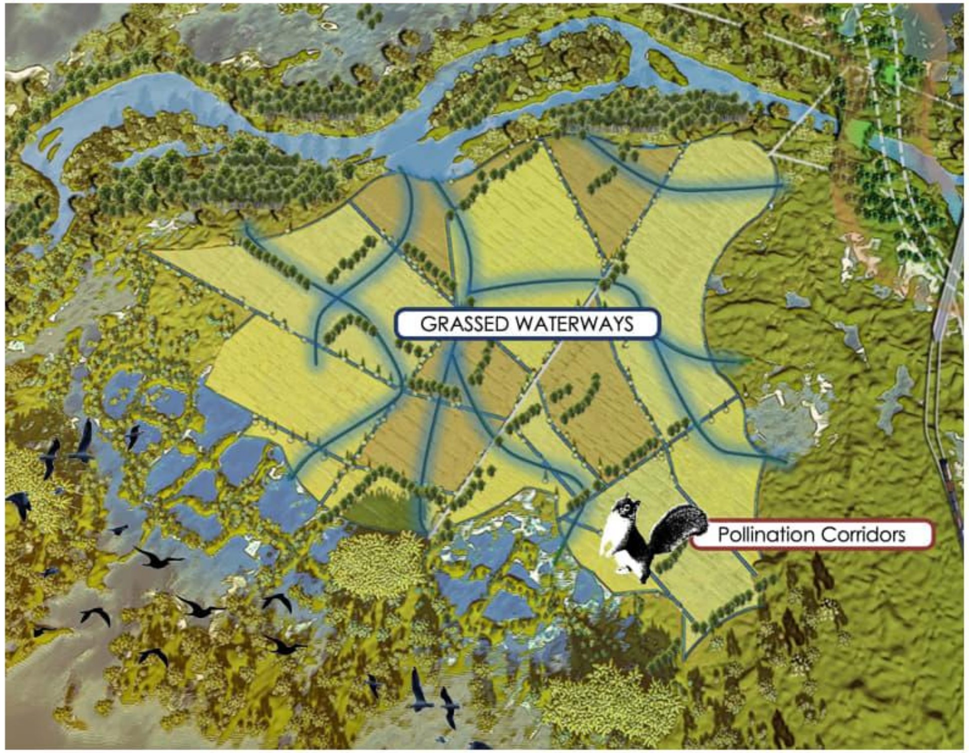
REFERENCES:

Indonesia, Bogorame-Timbusloko Mangrove Shield, Demak.
Bedono Village Mangrove Regrowth.

IMPLEMENTATION OPPORTUNITIES:

Thailand , Western coastlines of Mekong Delta.
Vietnam, Ca Mau Peninsula.
Indonesia , Borneo, Java, Papua, Sumatra coastlines.

NbS-36: GRASSED WATERWAYS



Grassed waterways are gently sloped, vegetated channels are designed to direct surface water runoff, reducing soil erosion, sedimentation, and nutrient loss while fostering water infiltration into the soil. They address regenerative agriculture, flood management, and biodiversity preservation in Southeast Asia, particularly in regions prone to soil erosion and water runoff, such as the Mekong River Basin. Technically, they enhance landscape permeability and act as natural drainage systems, minimizing flood risks during heavy rainfall. Ecologically, grassed waterways create wildlife corridors that support biodiversity by connecting fragmented habitats and providing cover for small animals and pollinators.

Socially, they promote sustainable farming practices by stabilizing soils and improving water quality, contributing to food security and community resilience. Grassed waterways not only support healthy ecosystems but also offer aesthetic and recreational benefits, strengthening the link between human activity and natural landscapes.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

EROSION CONTROL & SOIL CONSERVATION | AGROECOLOGY | HABITAT RESTORATION

INTEGRATED WATER MANAGEMENT | CLIMATE-SMART LANDSCAPES | GREEN INFRASTRUCTURE

MAIN PROBLEMS ADDRESSED

SOIL EROSION

DISASTER RISK REDUCTION

FLOOD CONTROL

FOOD SECURITY

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Enhancing soil fertility** by reducing erosion and improving organic matter retention.
- **Providing habitat** for a variety of wildlife, fostering biodiversity and promoting ecosystem resilience.

REGULATING

- **Reducing surface water runoff** and helps manage flood risks by allowing water to slowly infiltrate the ground.
- **Filtering water**, improving water quality by trapping sediments, nutrients, and pollutants.

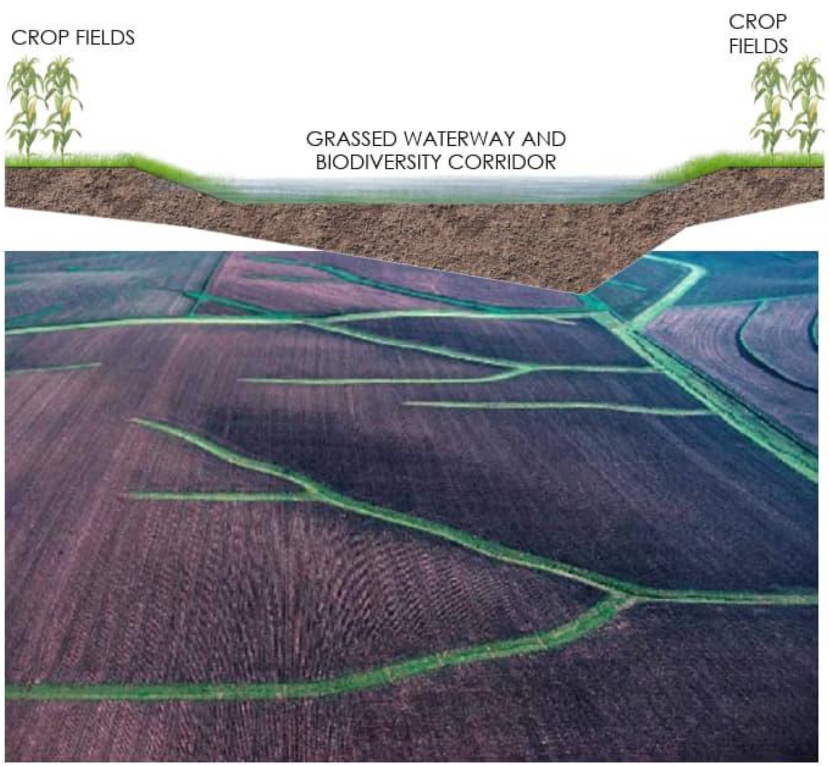
PROVISIONING

- **Supporting agricultural productivity** by maintaining healthy soils and improving water retention for crops.

SOCIAL BENEFITS

- **Enhancing community resilience to floods**, promoting sustainable livelihoods for farmers and local populations.
- **Offering recreational and educational opportunities**, improving the quality of life and fostering environmental awareness.

NbS-36: GRASSED WATERWAYS



PROJECT'S CHALLENGES & RISKS

- **Land competition and availability**: Grassed waterways require significant land areas, which might conflict with other agricultural or development needs.
- **Maintenance and management**: Regular maintenance is essential to prevent clogging and overgrowth, and may be challenging in areas with limited access to skilled labor or resources.
- **Initial costs**: Implementing grassed waterways can have high upfront costs, especially for large-scale applications.
- **Climate variability**: Grassed waterways may be less effective in areas with extreme weather patterns, such as intense droughts or heavy floods, which can affect their stability and efficiency.

NbS co-BENEFITS AND THEIR INDICATORS

- **Improved Water Quality**
Reduction in sediment and nutrient runoff entering water bodies, measured by water quality improvement metrics.
- **Enhanced Soil retention, erosion control**
Decrease in soil erosion rates, assessed by soil loss monitoring and visual observation.
- **Increased Biodiversity**
Increased number of species in adjacent areas, measured through biodiversity indices or species count surveys.
- **Flood Mitigation**
Reduced peak flow and faster water infiltration, measured by hydrological monitoring and flood risk assessments.
- **Improved Agricultural Productivity**
Higher crop yields and soil fertility, measured by yield data and soil nutrient levels.
- **Social Benefits and Community Engagement**
Increased community participation in conservation activities, tracked through local project engagement and volunteer records.

COST ANALYSIS

- **Direct Costs**
Initial establishment costs for grassed waterways range from $1,000 to $3,000/ha, including seed, labor, and equipment.
- **Indirect Costs**
Opportunity costs for land use change and maintenance are estimated at $100 to $300/ha annually.
- **Time Horizon**
Typically assessed over a 20-year horizon with a discount rate of 5–7%.
- **Direct Benefits**
Grassed waterways could provide benefits of $500 to $1,500/ha annually through increased agricultural productivity.
- **Indirect Benefits**
Improved water quality and biodiversity enhancement could contribute $200 to $800/ha annually in non-market benefits.
- **Risk Assessment**
Poor maintenance, invasive species, and extreme weather impacts, which could lead to up to 30% additional re-establishment costs.

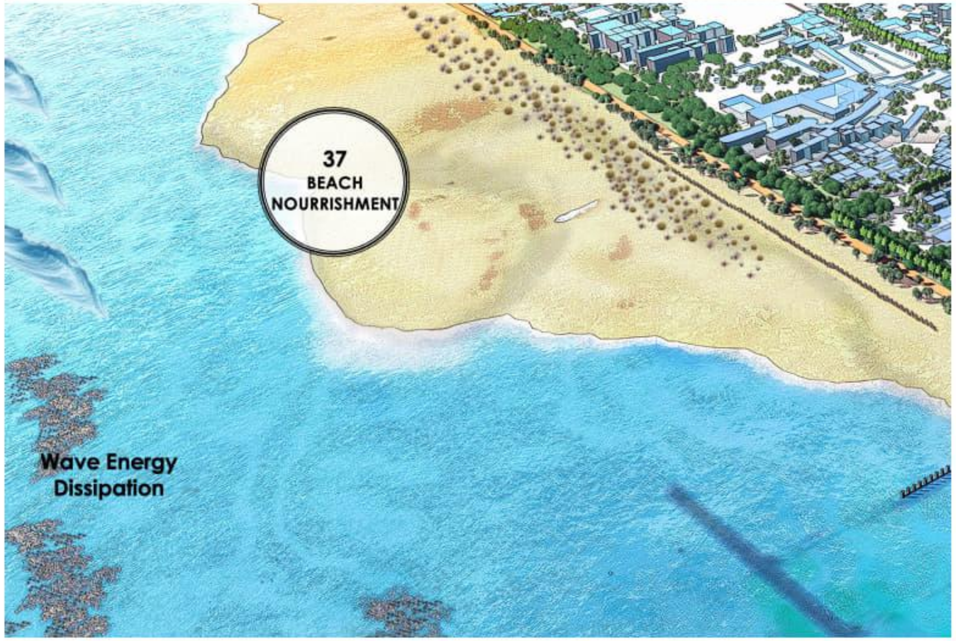
REFERENCES:

Indonesia, East Java, Kali Konto Watershed Management Project.
Nepal, Narayani River Watershed Project.
Australia, Murray-Darling Basin Project.

IMPLEMENTATION OPPORTUNITIES:

Philippines, Laguna de Bay Watershed.
Thailand, Chao Phraya Basin.
Indonesia, East Kalimantan post-mining landscapes.

NbS-37: BEACH NOURISHMENT



Beach nourishment involves replenishing sandy shorelines with materials compatible with the natural sediment, sourced from nearby areas. Materials are carefully selected to match the native sand's grain size and composition, minimizing ecological disruption and ensuring long-term stability. This method addresses coastal erosion, stabilizes beaches, and maintains ecological balance. Techniques include using dredged sands, engineered dunes, and vegetative plantings to enhance resilience against waves, storms, and rising seas.

Measures, such as planting native vegetation and using geotextile tubes, minimize erosion while allowing natural sediment flow.

Linking nourished beaches with coral reefs, seagrass beds, and mangroves creates interconnected habitats, reducing sediment runoff, supporting biodiversity, and strengthening coastal defences.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOSYSTEM BASED ADAPTATION
- ECOSYSTEM-BASED DISASTER RISK REDUCTION
- ECOSYSTEM RESTORATION
- INTEGRATED COASTAL ZONE MANAGEMENT
- ECOSYSTEM-BASED MITIGATION

MAIN PROBLEMS ADDRESSED

- SOIL EROSION
- BIODIVERSITY LOSS
- FLOOD CONTROL
- DISASTER RISK REDUCTION
- CARBON SEQUESTRATION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Provide habitats for various species, including shorebirds, crabs, and nesting sea turtles.
- Filter and cycle nutrients, supporting marine and coastal food webs.

REGULATING

- Reduce shoreline erosion, protecting inland ecosystems and human developments.
- Wider and more stable beaches absorb wave energy, reducing the impact of storm surges and flooding.
- Reduce sediment runoff into coastal waters, benefiting nearby coral reefs and seagrass beds.

PROVISIONING

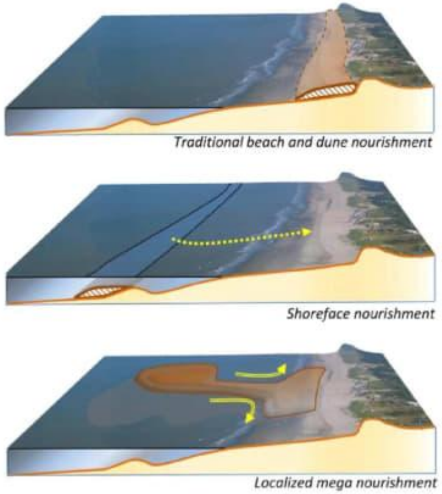
- Protects underlying freshwater aquifers from saltwater intrusion, ensuring a sustainable water supply for coastal settlements.
- Protects agricultural land near the coast by reducing saltwater intrusion and flooding during storm events, ensuring the viability of farming in these areas.

SOCIAL BENEFITS

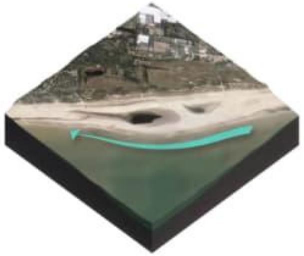
- Attracts visitors, boosts local economies through tourism and leisure activities.
- Offer spaces for relaxation, inspiration, and cultural activities, such as festivals or traditional fishing practices.

NbS-37: BEACH NOURISHMENT

The Netherlands, South Holland, Zand motor beach nourrishment
Source ; Rijkswaterstaat/Joop Van Houdt



Nourrishment strategies
Source : ResearchGate, Stive et al, 2013



Source : EcoShape

PROJECT'S CHALLENGES & RISKS

- **Disruption of local ecosystems:** Sand extraction and placement can disturb marine habitats, including seabeds, coral reefs, and benthic organisms.
- **Alteration of natural processes:** Nourishment can interfere with natural sediment transport and coastal dynamics, potentially causing imbalances elsewhere along the coast.
- **Impact on adjacent ecosystems:** Increased sediment runoff during nourishment can smother coral reefs, seagrass beds, and other habitats.
- **Frequent maintenance:** Nourished beaches require periodic re-nourishment due to natural erosion, which can be logistically complex and costly.

NbS co-BENEFITS AND THEIR INDICATORS

Disaster Risk Reduction:
Beach width and elevation stability over time.
Frequency and severity of storm surge impacts.
Reduction in wave height, changes in shoreline retreat or advance.

Erosion Control
Reduction in sediment runoff.
Stability of inland soil (measured by erosion rates).

Improved Coastal Biodiversity
Species richness and abundance in nourished areas.
Biodiversity indices in restored habitats.

Water quality
Reduction in sedimentation and turbidity levels.
Improved clarity of coastal waters. Decreased nutrient runoff affecting marine ecosystems.

Tourism Revenue
Increase in tourist numbers and spending on beach-related activities, revenue from local businesses.

COST ANALYSIS

Direct Costs
Planning, sand procurement and transport, construction : USD 900,000 to 2,900,000 /km

Indirect Costs
Ecosystem disruption, tourism business interruptions, and environmental risks.

Time Horizon
Short-term (0-2 years), medium-term (3-10 years), long-term (10+ years) for replenishments and monitoring.

Direct Benefits
Coastal protection, tourism, biodiversity, and carbon sequestration.

Indirect Benefits
Increased property values, improved community resilience, long-term sustainability.

Risk Assessment
Environmental disruption, cost overruns, effectiveness decline over time, and continued need for replenishment.

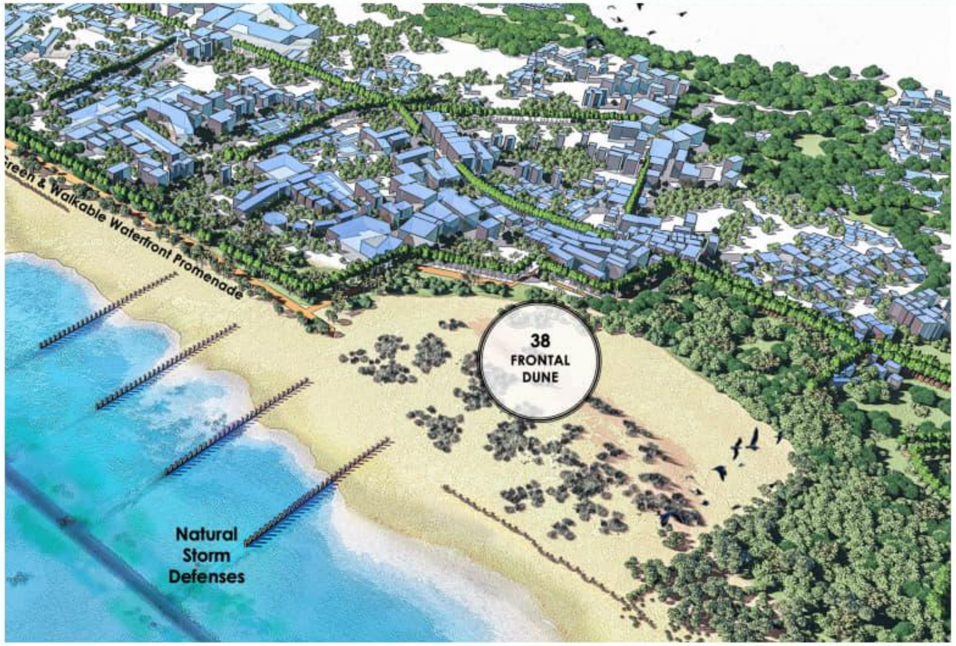
REFERENCES:

Singapore, East coast park beach nourishment.
Thailand, Pattaya Beach (use of sand dredged from nearby seabeds to expand the coastline).
Netherlands, South-Holland, Zandmotor (deposits a massive volume of sand offshore, allowing natural currents to redistribute it.

IMPLEMENTATION OPPORTUNITIES:

Vietnam : Ca Mau and Ben Tre provinces (intense coastal erosion), Hoi An beaches.
Cambodia: Sihanoukville, Ochheuteal Beach and Serendipity Beach.

NbS-38: FRONTAL DUNE



Frontal dune implementation focuses on the proactive establishment of dune systems as a Nature-Based Solution to enhance coastal resilience. This approach employs natural and eco-engineered techniques, including the planting of native vegetation with deep root systems to stabilize sand, and the use of biodegradable geotextiles and sand fences to encourage dune formation.

These initiatives serve as natural buffers against storm surges and rising sea levels, providing sustainable protection for coastal communities while supporting biodiversity. The implementation process often integrates frontal dunes with adjacent habitats, such as mangroves and seagrass meadows, creating interconnected ecosystems that reduce sediment runoff, improve water quality, and foster ecological balance.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOSYSTEM BASED ADAPTATION
- ECOSYSTEM-BASED DISASTER RISK REDUCTION
- ECOSYSTEM RESTORATION
- INTEGRATED COASTAL ZONE MANAGEMENT
- GREEN INFRASTRUCTURE

MAIN PROBLEMS ADDRESSED

- SOIL EROSION
- BIODIVERSITY LOSS
- FLOOD CONTROL
- DISASTER RISK REDUCTION
- CARBON SEQUESTRATION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Establishment of habitats for diverse flora and fauna, including dune-specific species and coastal wildlife.
- Supports interconnected ecosystems, such as mangroves, seagrass beds, and coral reefs, creating corridors for species movement.
- Stabilizes sandy substrates, preventing erosion and supporting the formation of fertile dune soils.

REGULATING

- Acts as a natural barrier against storm surges, high waves, and flooding, reducing risks to inland areas.
- Prevents sand loss through vegetation that anchors the substrate and traps wind-blown sand.
- Minimizes sediment runoff into marine ecosystems.

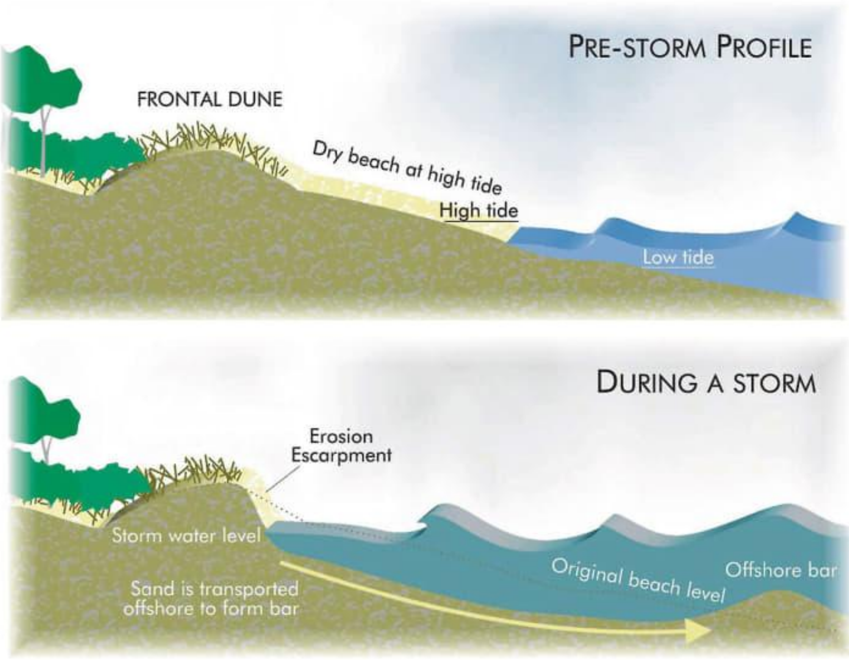
PROVISIONING

- Provides sustainable resources such as plant biomass, which can be used for traditional practices or crafts.
- Enhances fish and shellfish populations by stabilizing nearby ecosystems, like seagrass beds, which serve as nurseries.

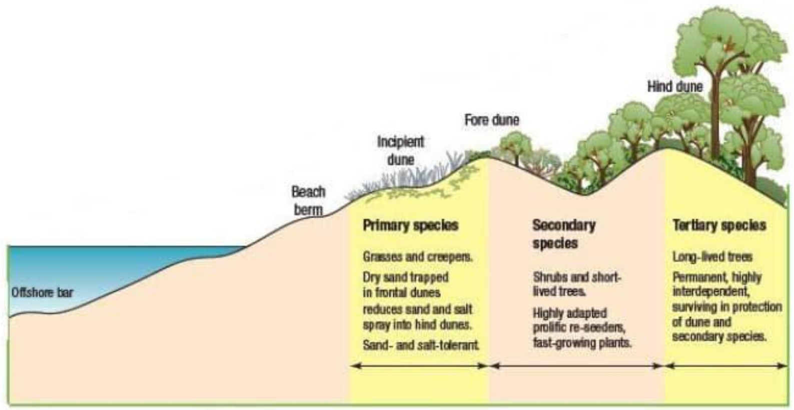
SOCIAL BENEFITS

- Enhances the safety and livelihoods of local populations by reducing exposure to coastal hazards and supporting ecosystem-based income sources.
- Creates aesthetic and accessible coastal landscapes, attracting eco-tourism and providing spaces for leisure activities.

NbS-38: FRONTAL DUNE



Natural dune dynamics
Source : Coastal restoration trust of New Zealand



Dune protective vegetation
Source : Springer Nature Link

PROJECT'S CHALLENGES & RISKS

- **Site Suitability**: Sandy beach environments vary in stability, wave energy, and sediment supply, making it challenging to select suitable sites for dune formation.
- **Maintenance Needs**: Dunes require ongoing maintenance to address erosion, invasive species, or damage caused by extreme weather events.
- **Climate Impacts**: Rising sea levels and increasing storm intensity may reduce the effectiveness or longevity of dunes as coastal defences.
- **Biodiversity Conflicts**: Introducing dunes in new areas may displace existing ecosystems or conflict with the needs of species that rely on flat, sandy beaches (e.g., turtle nesting sites).

NbS co-BENEFITS AND THEIR INDICATORS

Disaster Risk Reduction:
Assessment of the role of dunes in protecting human populations and infrastructure: reduced vulnerability index for coastal communities.

Water Quality Improvement:
Reduction in sediment runoff into coastal waters (measured in turbidity levels) and improvement in water clarity .

Flood mitigation
Frequency and severity of coastal flooding events
Increase in percolation capacity (l/m2).

Soil Stabilization
Rate of soil retention (tons of sediment retained annually).

Carbon Sequestration
Carbon stored in dune vegetation and soil.
Growth rate of vegetation biomass (kg/year).

COST ANALYSIS

Direct Costs
Planting, materials, labour, monitoring : $18,500–$51,000/ha

Indirect Costs
Opportunity costs, community engagement.

Time Horizon
Short-Term (1–3 years): Initial restoration activities
Medium-Term (3–10 years): Ecosystem establishment, monitoring, and adaptive management.

Direct Benefits
Coastal protection, biodiversity enhancement, and carbon sequestration.

Indirect Benefits
Tourism, community jobs, climate resilience.

Risk Assessment
Environmental risks, high initial costs, stakeholder opposition.

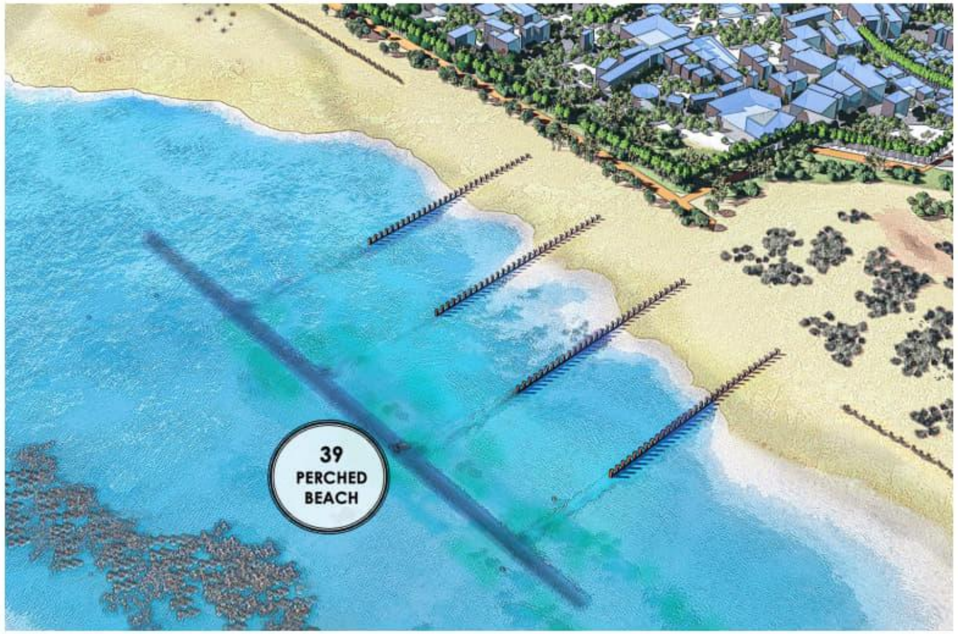
REFERENCES:

New Zealand, Ngarahae Bay (restoration of eroded dunes, planting of native vegetation).
Australia - Queensland, Kirra Beach (dune revegetation initiative).
The Netherlands, Hondsbossche Dunes (replacement of outdated dike with dunes.

IMPLEMENTATION OPPORTUNITIES:

- **Philippines Eastern Seaboard ,** Samar and Leyte (Prone to typhoons and wave erosion).
- **Malaysia**, Pahang coastline (impacted by monsoonal erosion).
- **Vietnam**, Phu Yen Province.

NbS-39: CONSTRUCTED PEARCHED BEACH WITH SEAGRASS



A constructed perched beach with seagrass is an eco-engineered coastal solution designed to address erosion, enhance biodiversity, and improve shoreline stability in sandy coastal areas. The perched beach is created by elevating the sandy shoreline using a subsurface structure such as a submerged berm or breakwater, which reduces wave energy and helps retain sand, mitigating coastal erosion and shoreline retreat.

Incorporating seagrass meadows into this system significantly enhances its ecological and protective functions. Seagrasses, with their dense root systems, stabilize the seabed, reduce sediment resuspension, and improve water clarity by trapping particles. They also serve as carbon sinks, sequestering substantial amounts of carbon dioxide, and provide critical habitats for diverse marine species, including fish, shellfish, and sea turtles.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOSYSTEM BASED ADAPTATION
- ECOSYSTEM-BASED DISASTER RISK REDUCTION
- ECOSYSTEM RESTORATION
- INTEGRATED COASTAL ZONE MANAGEMENT
- MARINE SPATIAL PLANNING

MAIN PROBLEMS ADDRESSED

- SOIL EROSION
- BIODIVERSITY LOSS
- FLOOD CONTROL
- DISASTER RISK REDUCTION
- CARBON SEQUESTRATION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Seagrass meadows provide essential habitats for marine species, contributing to the overall biodiversity of the coastal ecosystem.
- Seagrass and coastal ecosystems help cycle nutrients, maintaining the health of marine food webs and supporting primary production.

REGULATING

- The perched beach and seagrass act as buffers against coastal erosion and wave impacts, reducing the risk of damage from storms and sea-level rise.
- Seagrass traps sediments and filters water, improving water quality by reducing turbidity and controlling nutrient levels.
- Seagrasses sequester carbon, acting as carbon sinks and mitigating climate change.

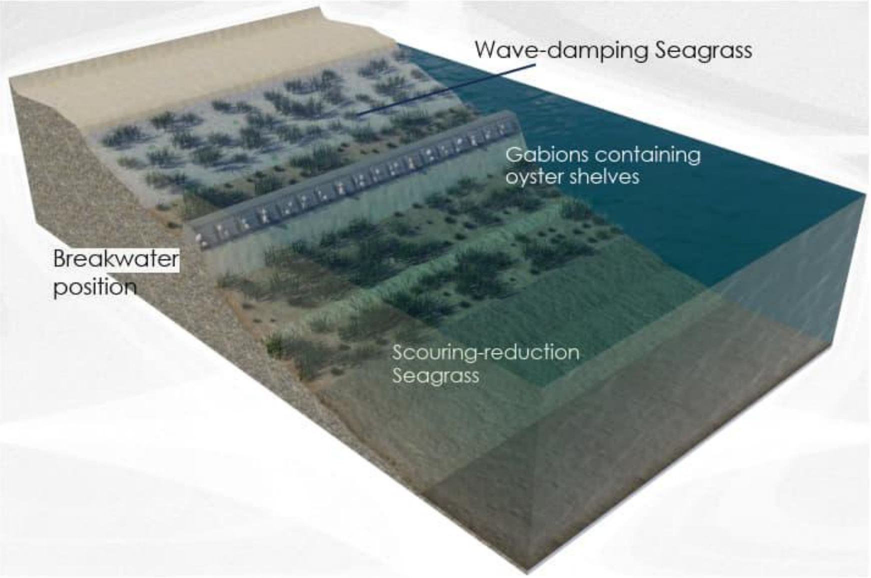
PROVISIONING

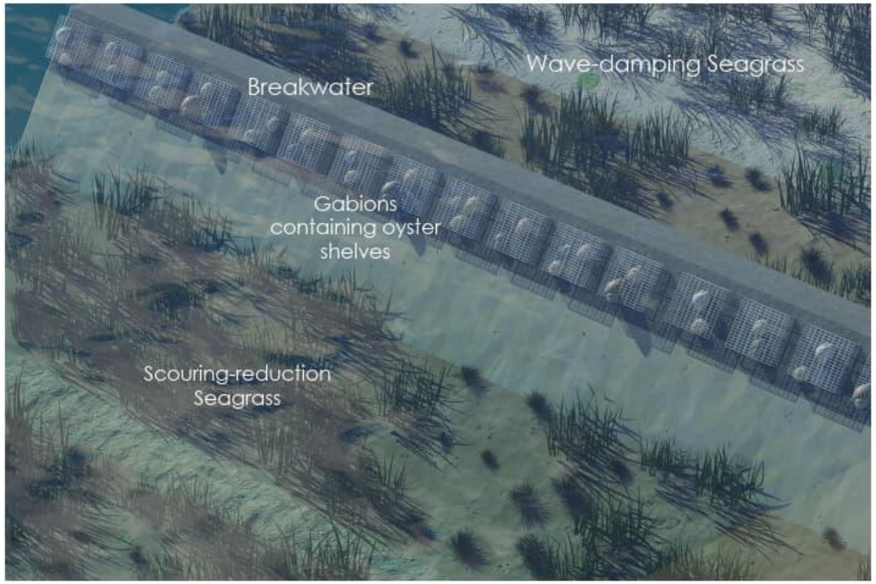
- The seagrass meadows provide breeding and nursery grounds for fish and shellfish, which support local fisheries.
- Seagrass beds can be a source of sustainable materials, such as for bio-based products or as a resource for local communities.

SOCIAL BENEFITS

- These systems provide opportunities for environmental education, research, and community engagement in coastal conservation efforts.
- The improved coastal environment, with its biodiversity and beauty, attracts tourists and supports eco-tourism and leisure activities.

NbS-39: CONSTRUCTED PEARCHED BEACH WITH SEAGRASS





PROJECT'S CHALLENGES & RISKS

- **Sediment Dynamics**: Ensuring that the perched beach maintain stability over time can be difficult due to changing coastal currents and sediment supply.
- **Seagrass Survival**: Seagrass meadows are sensitive to environmental stressors and physical disturbances, and their establishment may fail if conditions are not ideal.
- **Structural Integrity**: Ensuring the long-term stability of the submerged structures that support the perched beach can be challenging under high wave conditions.
- **Maintenance Costs**: The ongoing need for maintenance and monitoring of both the perched beach and seagrass meadows can strain budgets.

NbS co-BENEFITS AND THEIR INDICATORS

Biodiversity Enhancement:
Number and diversity of species, population of key marine species, health and coverage of seagrass beds over time.

Carbon Sequestration:
Amount of carbon stored in seagrass meadows, rate at which carbon is absorbed and stored by seagrasses over time (tons of CO_2 per year).

Water Quality Improvement
Measurement of water clarity , levels of nutrients like nitrogen and phosphorus, dissolved oxygen levels.

Coastal Protection and Erosion Control:
Rate of coastal erosion before and after implementation, reduction in wave height and energy near the shoreline.

Enhanced Livelihoods
Fishery yields, diversity of species caught in local fisheries.

COST ANALYSIS

Direct Costs
Structure construction, seagrass planting, material, labour : $15 - $30/m²

Indirect Costs
Maintenance & Monitoring, water quality management.

Time Horizon
Short-Term monitoring & maintenance (1 to 3 years), long-Term monitoring & maintenance, adaptative management (3 to 10+ years).

Direct Benefits
Coastal protection, tourism revenue.

Indirect Benefits
Carbon sequestration, biodiversity enhancement, water quality improvement.

Risk Assessment
Technical and construction risks, Insufficient maintenance, natural disasters, erosion and sediment loss.

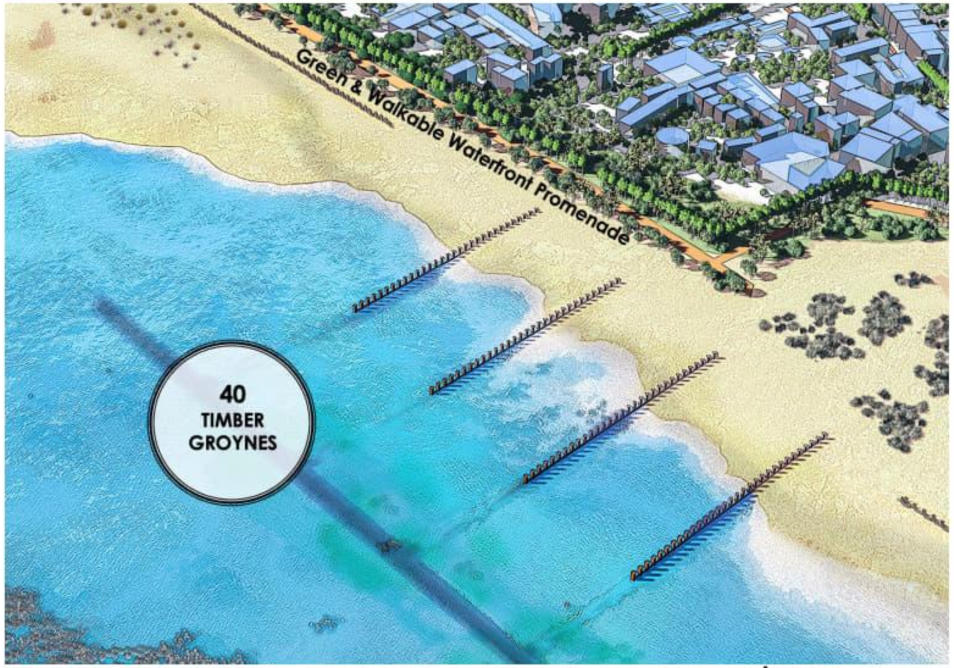
REFERENCES:

Italy, Calabria region, Calabaia beach restoration.

IMPLEMENTATION OPPORTUNITIES:

Thailand: Phuket, Krabi Koh Samui, Kho Phi Phi
Vietnam: Danang, Nha Trang, Phu Quoc Island
Indonesia: Lombok, Bali, Gili Islands

NbS-40: NATURAL TIMBER GROYNE



Natural timber groynes are soft solutions that use eco-friendly and locally-sourced hardwood, designed to manage erosion and stabilize shifting sands. These structures are installed perpendicular to the shore, interrupting wave action and reducing sand movement along the beach. By integrating biodegradable mats or mesh, timber groynes provide additional stabilization, helping accumulate sand and support dune growth, while blending harmoniously with the coastal environment. Similar to reef restoration, these projects can take a "coast-scape" approach, linking groyne systems with nearby seagrass and mangroves to form an interconnected habitat that limits sediment runoff, improves water clarity, and enhances biodiversity.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOSYSTEM BASED ADAPTATION
- ECOSYSTEM-BASED DISASTER RISK REDUCTION
- INTEGRATED COASTAL ZONE MANAGEMENT
- GREEN INFRASTRUCTURE

MAIN PROBLEMS ADDRESSED

- SOIL EROSION
- BIODIVERSITY LOSS
- FLOOD CONTROL
- DISASTER RISK REDUCTION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Creates structured habitats on sandy beaches that support coastal vegetation, invertebrates, and shorebirds.
- Links beach habitats with adjacent ecosystems, like seagrass beds and mangroves, enhancing nutrient flow and species movement.

REGULATING

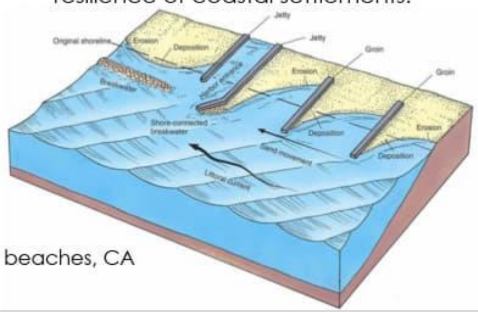
- Acts as natural barriers, reducing wave energy, stabilizing sand, and preventing shoreline erosion.
- Helps trap sediments and reduces sediment runoff into coastal waters, improving water clarity.
- Vegetation around groynes captures carbon, supporting climate mitigation.

PROVISIONING

- Provides shelter and breeding grounds for coastal species and stabilizes dune plants crucial for beach resilience.
- Groynes made from sustainably harvested timber contribute to renewable resource use.

SOCIAL BENEFITS

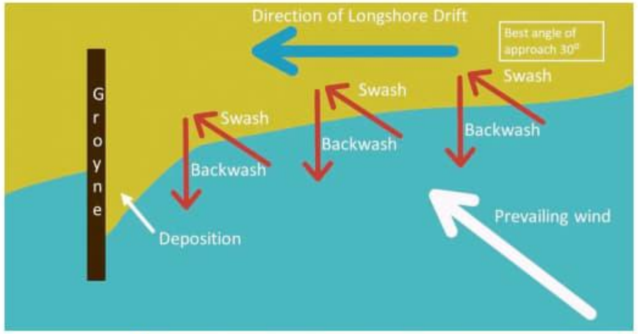
- Enhances scenic beauty, supporting beach-based tourism and recreational activities.
- Reduces risk of storm surge damage, contributing to the resilience of coastal settlements.



Source : Save our beaches, CA

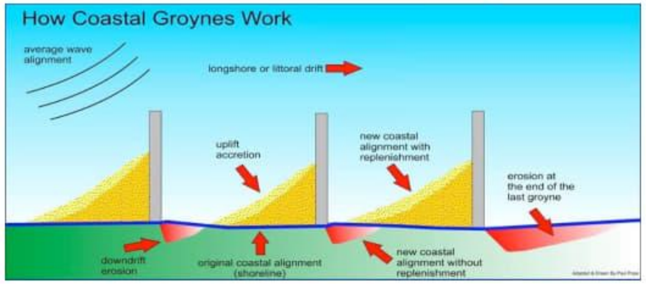
NbS-40: NATURAL TIMBER GROYNE

Timber groynes Eastbourne, UK
Source : Leo C. van Rijn



Longshore drift

Source : Classroom nation



Source : The beginners guide to Coastal Conservation

PROJECT'S CHALLENGES & RISKS

- **Timber Degradation**: Exposure to saltwater and marine organisms can quickly degrade timber, shortening the groyne's lifespan and necessitating regular maintenance and repair.
- **Wave and Storm Damage**: High-energy waves and storm surges can displace or damage timber groynes, especially in unprotected areas.
- **Sand Accumulation Imbalance**: Groynes can cause uneven sand buildup, potentially leading to erosion in adjacent areas, requiring precise design and placement to avoid negative impacts on nearby shorelines.

NbS co-BENEFITS AND THEIR INDICATORS

Biodiversity Conservation
Measure the variety and population of coastal species (such as fish, invertebrates, and birds) in areas with timber groynes compared to unprotected beaches.

Coastal Protection
Reduction in coastal erosion over time by comparing areas with and without timber groynes.

Water Quality Improvement
Measure the reduction in sedimentation and improvement in water clarity in the vicinity of groynes.

Habitat Connectivity
Assess the movement of species between groynes and adjacent ecosystems like seagrass beds or mangroves.

Community Engagement
Income generated from eco-tourism activities such as nature walks, birdwatching, or beach visits.

COST ANALYSIS

Direct Costs
Materials, labor, equipment, permits : $4,000–$10,000 per groyne.

Indirect Costs
Studies, maintenance, disruptions : $6,500–$19,500 (initial), $500–$1,500 annually.

Time Horizon
3–6 months for planning and installation.
10–20 years (depending on timber durability and environmental conditions).

Direct Benefits
Erosion control, flood protection.

Indirect Benefits
Biodiversity support, tourism and recreation, enhanced ecosystem services.

Risk Assessment
Potential for altering sediment dynamics downstream, high maintenance costs due to timber degradation in tropical climates.

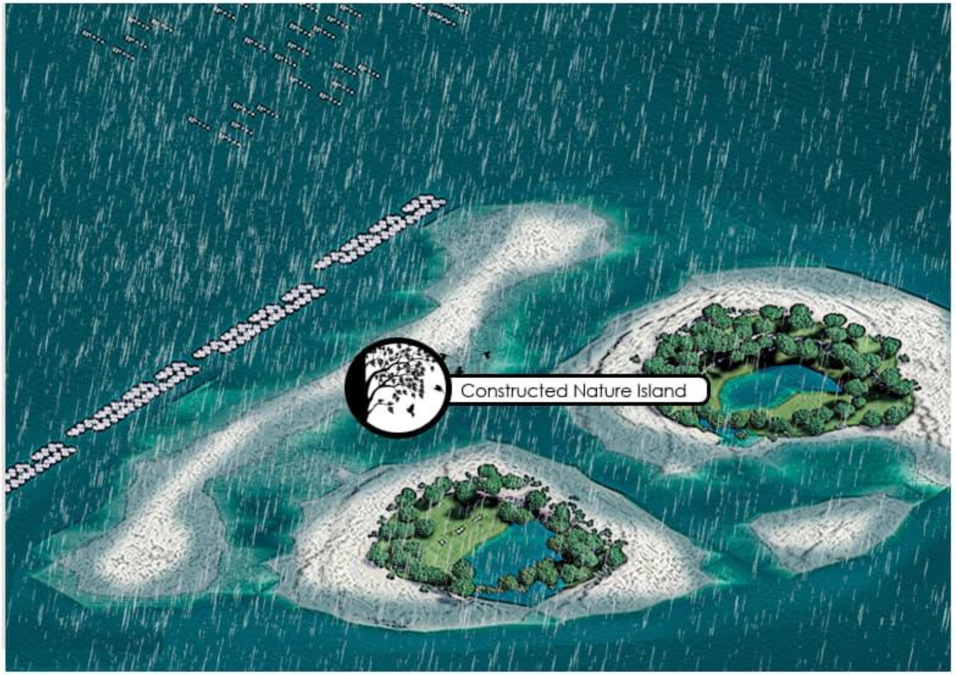
REFERENCES:

Netherlands , Zeeland coast.
UK, Cley Next the Sea, Norfolk
South Walney, Cumbria
Eastbourne

IMPLEMENTATION OPPORTUNITIES:

Philippines, Luzon: Particularly around areas that are vulnerable to coastal erosion.
Indonesia, Bintan Island: areas around Trikora Beach could benefit from timber groynes.

NbS-41: CONSTRUCTED NATURE ISLAND



Constructed nature islands focus on integrating eco-engineering and natural elements to create stable, biodiverse, and functional ecosystems while protecting coastlines from climatic events. These islands are designed to withstand the dynamic conditions of sandy substrates, including shifting sands, high wave energy, and sediment movement. Their construction often involves biodegradable geotextiles, sand-filled geocells, and lightweight structures like coir logs or bamboo frameworks to stabilize substrates, prevent erosion, and dissipate wave energy. Native vegetation, such as coastal grasses, shrubs, and mangroves, are planted to anchor sand, promote dune formation, and act as a natural buffer against storm surges and rising sea levels. To enhance ecological functionality, these islands incorporate habitat features like tidal pools, artificial nesting sites, and reef-like modules, serving as refuges for marine and terrestrial fauna while fostering biodiversity.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOSYSTEM BASED ADAPTATION
- ECOSYSTEM-BASED DISASTER RISK REDUCTION
- ECOSYSTEM RESTORATION
- INTEGRATED COASTAL ZONE MANAGEMENT
- GREEN INFRASTRUCTURE

MAIN PROBLEMS ADDRESSED

SOIL EROSION

BIODIVERSITY LOSS

FLOOD CONTROL

DISASTER RISK REDUCTION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Provide critical habitats for marine and terrestrial species, including breeding grounds for fish, nesting sites for birds, and shelter for invertebrates.
- Facilitate nutrient exchange between marine and terrestrial ecosystems through vegetation and sediment stabilization.

REGULATING

- Act as buffers against wave action, storm surges, and rising sea levels, reducing coastal erosion and protecting infrastructure.
- Stabilize sandy substrates and reduce vulnerability to extreme climatic events, such as cyclones and tsunamis.
- Filtration by mangroves, seagrasses, and tidal pools reduces pollutants and sedimentation.

PROVISIONING

- Improve groundwater recharge through vegetation and engineered drainage systems.
- Support fish stocks and other marine resources critical for local food security and livelihoods.

SOCIAL BENEFITS

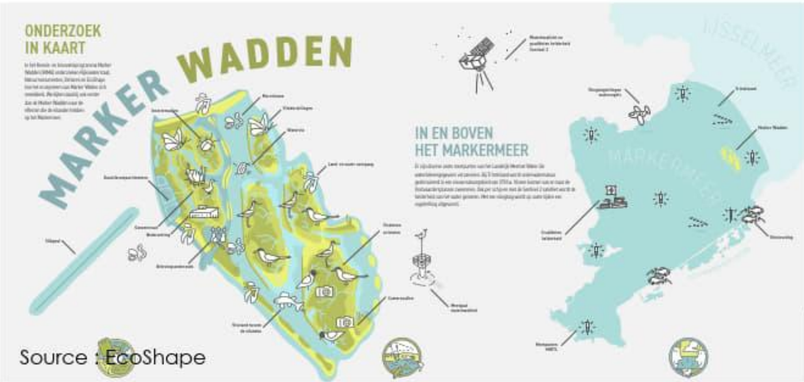
- Offer spaces for beach activities, snorkelling, birdwatching, and ecotourism, boosting local economies.
- Increase the safety of coastal communities by acting as natural barriers during extreme weather events.

NbS-41: CONSTRUCTED NATURE ISLAND


Source : EcoShape

Marker Wadden islands, The Netherlands


Source : Royal HaskoningDHV



Source : EcoShape

PROJECT'S CHALLENGES & RISKS

- **Erosion or Sediment Imbalance**: Improperly designed islands can alter coastal sediment dynamics, leading to unintended erosion or sedimentation.
- **Engineering Complexity**: Designing structures that withstand high wave energy, shifting sands, and climatic events demands advanced engineering.
- **Long-Term Maintenance**: Ensuring the stability and ecological health of the island over time requires ongoing monitoring and intervention.
- **High Initial Costs**: The design, construction, and ecological integration of these islands require significant financial investment.

NbS co-BENEFITS AND THEIR INDICATORS

Disaster Risk Reduction

Change in beach width over time, frequency and severity of storm surge impacts, soil erosion rates before and after construction.

Flood Control

Water level reduction during extreme weather events.

Water Quality Improvement

Reduction in nutrient levels (e.g., nitrates, phosphates),improved water clarity (turbidity).

Food Security

Fish catch rates and species diversity in nearby waters.

Tourism and Recreation

Visitor numbers and tourism revenue, number of educational or eco-tourism programs and events.

COST ANALYSIS

Direct Costs

Materials, labour, design, equipment, permits: $210,000–$630,000/ha .

Indirect Costs

Studies, monitoring and maintenance, disruptions : $25,000–$115,000/ha (initial).

Time Horizon

Construction Phase: 6–12 months.
Lifespan: 20–50 years (depends on maintenance and natural events).

Direct Benefits

Coastal protection, biodiversity habitat.

Indirect Benefits

Tourism, ecosystem services, community benefits.

Risk Assessment

Potential sedimentation issues or habitat disruption in nearby ecosystems, high initial costs and potential over-budgeting due to unforeseen challenges, ongoing maintenance costs.

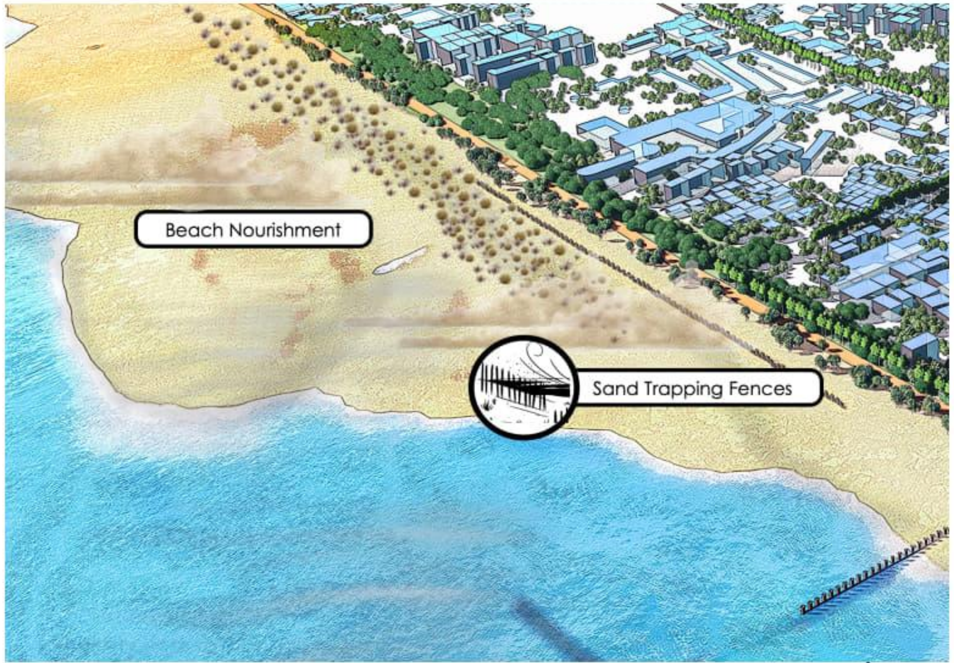
REFERENCES:

The Netherlands, Zuiderzee Works (IJsselmeer Polders) and Marker Wadden (wetland and dune restoration, saltmarsh creation).
Australia, The Great Barrier Reef Artificial Islands, coastal protection, habitats for marine species.

IMPLEMENTATION OPPORTUNITIES:

Philippines, Manila bay, Las Piñas-Parañaque critical habitat and ecotourismaArea.
Vietnam, Côn Đảo Archipelago (Critical habitat for sea turtles, coastal erosion).

NbS-42: SAND TRAPPING FENCES



Sand trapping fences in coastal areas use eco-friendly materials like coconut fibbers, bamboo, and recycled plastics to stabilize sandy beaches and reduce erosion. The fences are placed along the beach in strategic locations to trap windblown sand and promote dune formation. They are usually installed at angles to maximize sand accumulation and may be spaced at intervals to allow for effective trapping. These fences allow vegetation to grow, further securing the soil. Integrated with native plants, they create natural barriers against storm surges and rising sea levels, while enhancing local biodiversity. When combined with other sustainable practices like mangrove restoration, these fences help build resilient coastal ecosystems that protect both land and marine habitats, serving as refuges for marine and terrestrial fauna while fostering biodiversity.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOSYSTEM BASED ADAPTATION
- ECOSYSTEM-BASED DISASTER RISK REDUCTION
- ECOSYSTEM RESTORATION
- INTEGRATED COASTAL ZONE MANAGEMENT
- GREEN INFRASTRUCTURE

MAIN PROBLEMS ADDRESSED

- SOIL EROSION
- BIODIVERSITY LOSS
- FLOOD CONTROL
- DISASTER RISK REDUCTION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- By stabilizing the sand and supporting native plant growth, the fences help create habitats for various species of plants and animals, increasing local biodiversity.
- The accumulation of sand and organic material supported by the fences contributes to soil formation.

REGULATING

- Reduce coastal erosion by trapping sand, stabilizing dunes, and protecting shorelines from wind and water forces.
- Help reduce the impact of storm surges and rising sea levels by creating natural barriers that absorb wave energy and buffer coastal areas.

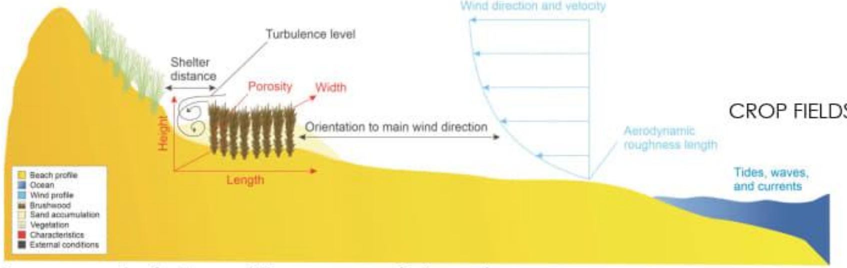
PROVISIONING

- The fences, made from materials like bamboo and coconut fibers, provide raw materials that can be sustainably harvested for construction, crafts, and other uses.

SOCIAL BENEFITS

- Help secure coastal areas by reducing erosion and enhance protection against storm damage, ensuring the safety and livelihood of local communities.
- Stabilized, healthy coastal ecosystems can attract eco-tourism, providing economic benefits to local communities.

NbS-42: SAND TRAPPING FENCES



Fences and wind conditions on sandy beach

Source : MDPI Environments, Sand Trapping Fences as a Nature-Based Solution for coastal protection.

(a) Brushwood fence
(b) Vertical planks fence
(c) Perforated recycled plastic fence

Source : MDPI Environments, Sand Trapping Fences as a Nature-Based Solution for coastal protection.

PROJECT'S CHALLENGES & RISKS

- **Material Durability and Degradation** : Biodegradable materials may degrade too quickly requiring frequent maintenance or replacement.
- **Effectiveness in Extreme Weather**: Severe storms or strong wave action could damage or displace the fences, especially if they are not properly anchored or positioned.
- **Impact on Local Wildlife**: If not carefully planned, the fences could disrupt local wildlife habitats. The presence of fences might limit access to nesting sites or migration routes.
- **Erosion Around the Fences** : While they are designed to reduce erosion, fences can sometimes cause sand accumulation in certain areas.

NbS co-BENEFITS AND THEIR INDICATORS

Disaster Risk Reduction

Frequency of coastal erosion events, reduction in storm surge impact, coastal flood risk assessments.

Soil Erosion

Erosion rate (soil loss per unit area), sediment deposition rates in coastal areas.

Flood Control

Coastal flood frequency and intensity, dune height and stability, reduction in wave energy impact.

Biodiversity Loss

Species diversity (plant and animal populations), habitat quality assessments (vegetation cover), presence of endangered or threatened species.

COST ANALYSIS

Direct Costs

Materials, labour, transportation, permits, monitoring, annual maintenance : $50–$200/m.

Indirect Costs

Training, ecosystem management :$10,000–$30,000 per project.

Time Horizon

Short-Term (1–3 Years) : Installation and initial vegetation growth. Long-Term (10+ Years) : Full ecosystem restoration with mature vegetation.

Direct Benefits

Coastal protection, biodiversity, tourism.

Indirect Benefits

Climate resilience, community income.

Risk Assessment

Poor-quality materials or improper installation, rising sea levels or intensified storms exceeding the protective capacity of fences.

REFERENCES:

Germany, East Frisian Islands: island of Langeoog (fences made from brushwood, help to stabilize dunes and reduce the risk of coastal erosion).

Netherlands, Callantsoog, coastal village in the province of North Holland.

IMPLEMENTATION OPPORTUNITIES:

Philippines, Dumaguete, coastal city in Negros Oriental (coastline vulnerable to erosion).

Vietnam, Vung Tau (to protect the beach and stabilize the dunes).

NbS-43: WINDBREAKS AND SHELTERBELTS

Windbreaks and shelterbelts are strategically planted rows of trees, shrubs, or vegetation designed to reduce wind speed, manage soil erosion, and enhance microclimates in rural farmlands and sandy shorelines.

In agricultural settings, windbreaks protect crops from wind damage, reduce evapotranspiration, and improve soil fertility through organic matter accumulation, supporting regenerative agriculture and sustainable yields. On sandy shorelines and dunes, shelterbelts stabilize sediments, prevent coastal erosion, and create natural barriers against storm surges. Types include single-row windbreaks (effective for smaller farmlands), multi-row shelterbelts (ideal for broader climate resilience), and dune vegetation belts (adapted for coastal landscapes). Technically, these structures reduce wind velocity by 30–50% and alter wind directions, fostering calmer microenvironments while serving as habitats for biodiversity. Contextually, they provide multifunctional benefits, including carbon sequestration, enhanced water retention, and livelihoods through agroforestry or coastal eco-tourism. With careful species selection (e.g., Casuarina, Acacia, and mangroves) and community engagement, windbreaks and shelterbelts contribute to climate resilience, sustainable landscapes, and socio-economic benefits for rural and coastal areas in Southeast Asia.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- INTEGRATED LANDSCAPE MANAGEMENT
- ECOSYSTEM RESTORATION
- AGROFORESTRY SYSTEMS
- BIODIVERSITY CONSERVATION
- COASTAL ZONE MANAGEMENT

MAIN PROBLEMS ADDRESSED

 SOIL EROSION

 BIODIVERSITY LOSS

 FLOOD CONTROL

 DISASTER RISK REDUCTION

ECOSYSTEM SERVICES AND ACTIONS

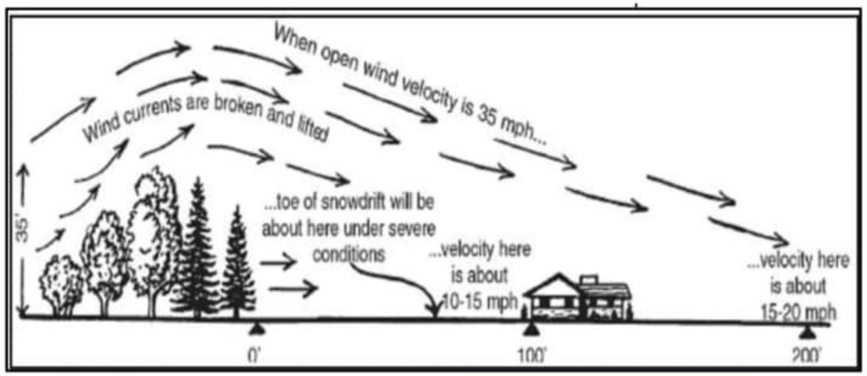
SUPPORTING
- Enhance soil formation and fertility by reducing erosion and improving organic matter through leaf litter deposition.

PROVISIONING
- Provide timber, fuelwood, and non-timber products (e.g., fruits, nuts, and medicinal plants) for local communities.

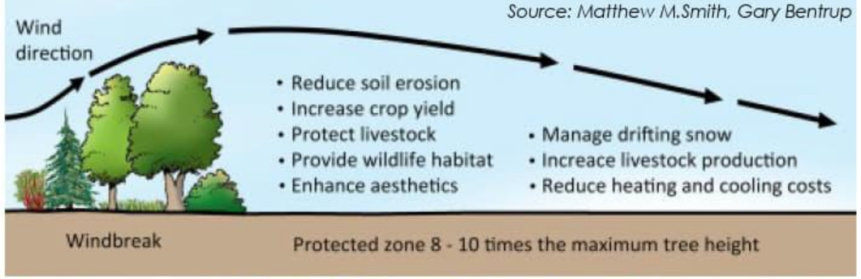
REGULATING
- Act as natural barriers to reduce wind velocity, prevent soil erosion, and limit the spread of airborne sand and salt in coastal and farmland areas.

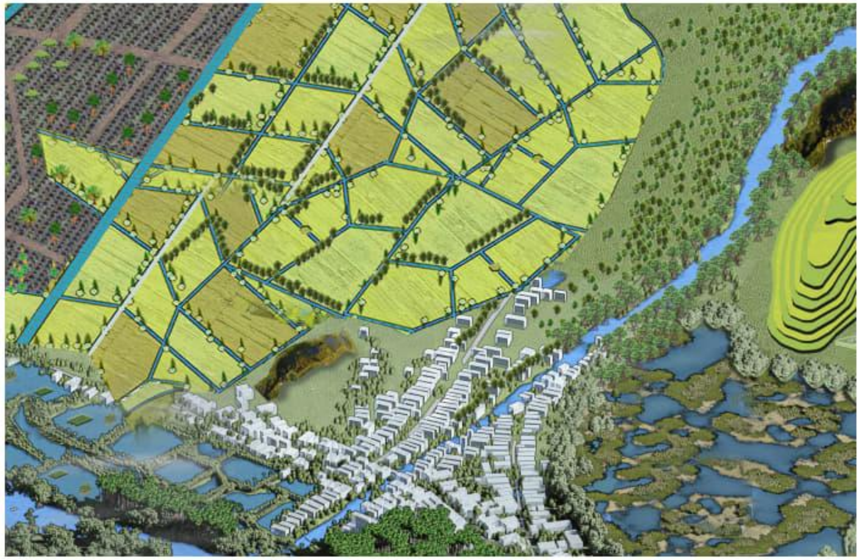
SOCIAL BENEFITS
- Improve agricultural yields by creating favourable microclimates and protecting crops, while also offering aesthetic and recreational value to rural landscapes.

NbS-43: WINDBREAKS AND SHELTERBELTS



Source: Matthew M.Smith, Gary Bentrup





PROJECT'S CHALLENGES & RISKS

- **Land Competition**: Limited availability of land in densely populated or heavily farmed regions may restrict the implementation of windbreaks and shelterbelts.
- **Maintenance and Upkeep**: Regular maintenance, including pruning and replanting, can be labor-intensive and costly for communities with limited resources.
- **Climate Suitability**: Selecting species that thrive under specific tropical or coastal conditions can be challenging, leading to potential failure of plantings in unsuitable areas.
- **Pests and Diseases**: Monoculture shelterbelts may attract pests or diseases that can spread to nearby agricultural fields, reducing their effectiveness.

NbS co-BENEFITS AND THEIR INDICATORS

Improved Agricultural Productivity
Reduction in crop damage from wind and soil erosion increases average yields by 10–20%.

Carbon Sequestration
Shelterbelt trees absorb up to 5–10 metric tons of CO_2 per hectare annually.

Biodiversity Enhancement
Increased habitat diversity supports a 30–40% rise in local bird and pollinator populations.

Microclimate Regulation
Wind velocity reduced by up to 50%, improving thermal comfort, reducing evapotranspiration in farms.

Livelihood Support
Agroforestry-integrated windbreaks provide additional income source (timber, fruits, fuelwood).

Soil Conservation
Erosion rates drop by 50–70% in fields protected by windbreaks, preserving arable land and reducing sedimentation in waterways.

COST ANALYSIS

Direct Costs
Tree planting, fencing, and maintenance, range from $2k–$5k/ha depending on site conditions.

Indirect Costs
Opportunity costs of land use for windbreaks may result in $500–$1,5k/ha in forgone agricultural income annually.

Time Horizon
Benefits typically accrue over 10–30 years, with discount rates of 5–10% commonly applied in Southeast Asia.

Direct Benefits
Increased agricultural productivity and timber revenues provide $1k–$3k/ha/year after establishment.

Indirect Benefits
Soil conservation, carbon sequestration, and enhanced biodiversity contribute non-market values.

Risk Assessment
Risks include tree mortality from drought or pests, requiring an additional contingency budget of 10–20% of direct costs.

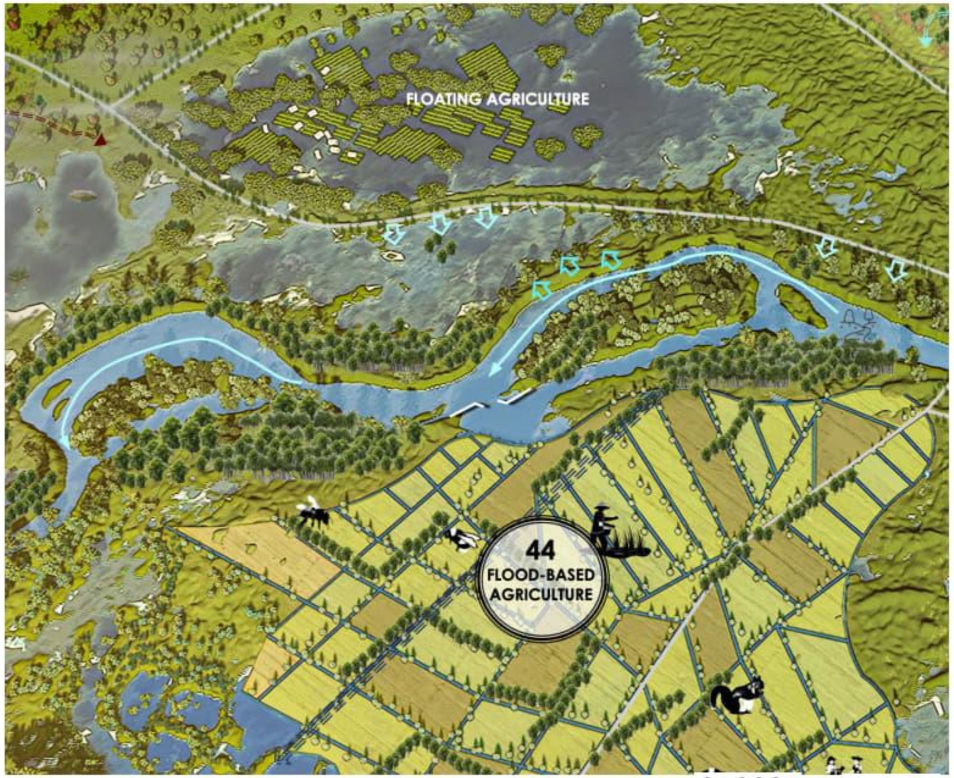
REFERENCES:

China's Three-North Large-scale Shelterbelt Program (Great Green Wall).
Vietnam , Mekong Delta Agroforestry Initiative.
India, Tamil Nadu Coastal Shelterbelt Project.

IMPLEMENTATION OPPORTUNITIES:

Myanmar, Dryland Farming Areas of Central.
Vietnam , Mekong Delta.
Indonesia, Sandy Shorelines of Central Java.
Philippines, Coastal Areas of Luzon.

NbS-44: FLOOD-BASED AGRICULTURE



Flood-based agriculture is a nature-based solution (NbS) that leverages seasonal floods to enhance agricultural productivity, improve food security, and build climate resilience in flood-prone areas of Southeast Asia, such as the Mekong River Delta and Tonle Sap Biosphere.

This approach utilizes the natural inundation cycles to deposit nutrient-rich sediments, replenish soil fertility, and provide water for crops, reducing reliance on synthetic fertilizers and irrigation.

Technically, it involves practices such as flood recession farming, floating crop cultivation, and integrated aquaculture-agriculture systems that maximize the benefits of water and sediment flows.

On a landscape level, it preserves floodplains, wetlands, and riparian ecosystems, which act as natural buffers against extreme weather events while enhancing biodiversity.

Socially, it supports rural livelihoods by offering sustainable income streams, promoting traditional knowledge, and strengthening community resilience to climate-induced disruptions such as droughts and floods.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- NUTRIENT CYCLING
- HABITAT CONSERVATION
- INTEGRATED WATER RESOURCES MANAGEMENT
- DISASTER RISK REDUCTION
- CARBON SEQUESTRATION
- SUSTAINABLE LAND MANAGEMENT

MAIN PROBLEMS ADDRESSED

- SOIL EROSION
- BIODIVERSITY LOSS
- FLOOD CONTROL
- DISASTER RISK REDUCTION
- FLOOD SECURITY

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Soil Fertility Restoration**: Seasonal floods deposit nutrient-rich sediments, replenishing soil organic matter and fertility.

REGULATING

- **Flood Regulation**: Preserves natural floodplains, reducing downstream flood risks and enhancing water retention in landscapes.

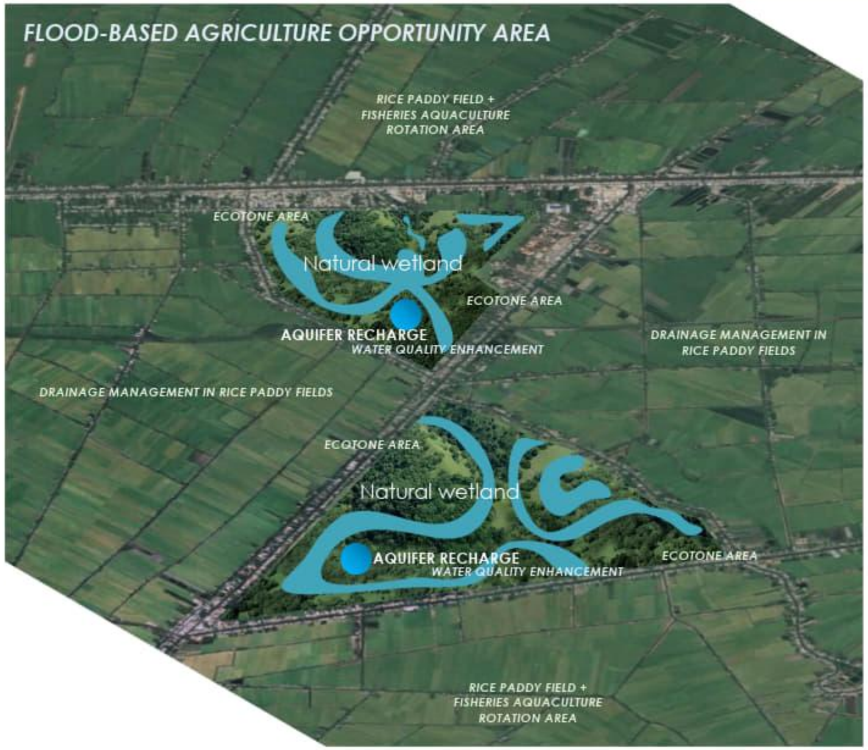
PROVISIONING

- **Enhanced Crop Production**: Provides nutrient-enriched soils and natural irrigation, improving agricultural yields and food availability.

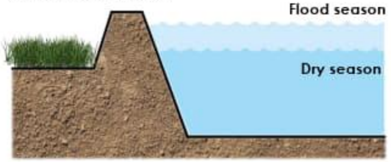
SOCIAL BENEFITS

- **Food Security and Livelihoods**: Supports rural communities with sustainable farming practices and diversified income opportunities.

NbS-44: FLOOD-BASED AGRICULTURE

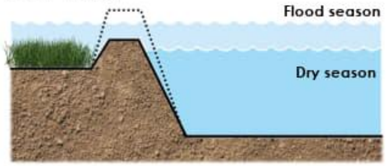


CURRENT AGRICULTURAL MODEL WITH HIGH DIKES



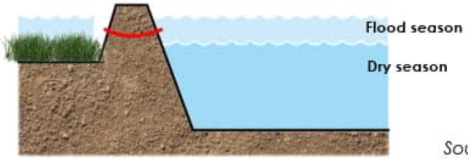
High dike constructed to prevent flood water

FLOOD-BASED AGRICULTURE WITH LOW DIKES



Low dike allowing water to enter during the flood season

FLOOD-BASED AGRICULTURE WITH HIGH DIKE WITH CULVERTS



High dike with culverts, allowing water to periodically enter in the flood season.

Source: RHDHV – ONE Architecture, 2021

PROJECT'S CHALLENGES & RISKS

- **Unpredictable Flood Patterns**: Climate change-induced variability in flood timing and intensity can disrupt agricultural cycles and reduce yields.
- **Land Use Conflicts**: Competing demands for floodplains, such as urban expansion or infrastructure development, can limit the availability of land for flood-based agriculture.
- **Community Adaptation**: Traditional knowledge of flood-based farming may be lost or insufficient, requiring significant training and capacity-building efforts.
- **Water Quality Issues**: Floodwaters may carry pollutants, such as agricultural runoff or industrial waste, posing risks to soil health and crop safety.

NbS co-BENEFITS AND THEIR INDICATORS

Increased Soil Fertility
Improvement in soil organic matter content and nutrient levels (e.g., nitrogen, phosphorus) after flood events.

Enhanced Water Retention
Higher groundwater recharge and sustained soil moisture during dry periods compared to non-flooded areas.

Improved Crop Resilience
Higher crop survival rates during droughts or extreme weather events due to better soil moisture and nutrient availability.

Biodiversity Conservation
Increased diversity of aquatic and terrestrial species in floodplain ecosystems, monitored through biodiversity indices.

Carbon Sequestration
Measurable increase in soil carbon stocks, tracked by soil carbon content assessments post-flooding.

Strengthened Local Livelihoods
Increased income from diversified agricultural activities and improved food security for local communities.

COST ANALYSIS

Direct Costs
The costs of land preparation, flood management, and crop inputs range from $300 to $500 per ha annually.

Indirect Costs
Between $50 to $150 per ha per year for training, extension services, and monitoring programs.

Time Horizon
10 to 20 years, with a discount rate of 5–7% to reflect long-term benefits like soil fertility and water management.

Direct Benefits
Increased crop yields provide direct economic benefits of $100 to $400 per ha annually.

Indirect Benefits
Flood regulation and improved biodiversity can save $50 to $150 per ha annually in disaster risk reduction and ecosystem health.

Risk Assessment
Unpredictable flood patterns may generate costs of $50 to $200 per ha annually for risk management or adaptive strategies.

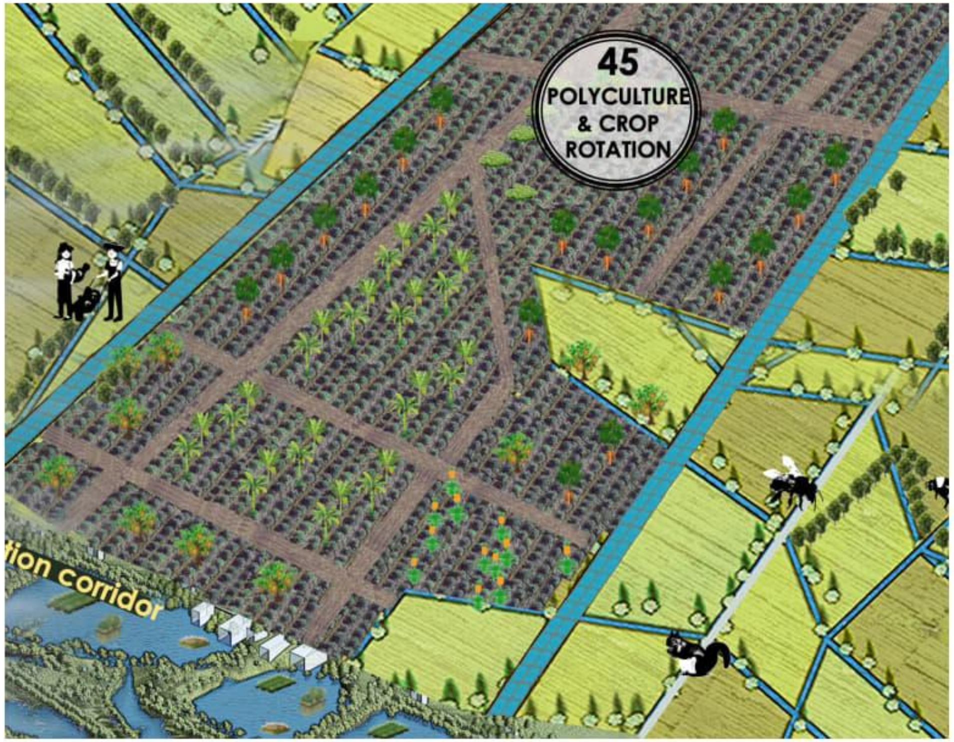
REFERENCES:

Vietnam and Cambodia, Integrated Rice-Fish Farming Systems in the Mekong River Delta.
Cambodia, Floating Agriculture in Tonle Sap.

IMPLEMENTATION OPPORTUNITIES:

Thailand, Chao Phraya Basin.
Myanmar, Irrawaddy Delta.
Indonesia, South Kalimantan.
Vietnam, Mekong River Delta.

NbS-45: POLYCULTURE & CROP ROTATION



Polyculture and crop rotation promote regenerative agriculture by improving soil health, increasing biodiversity, and reducing dependence on chemical inputs. Polyculture involves planting diverse crops in the same area, mimicking natural ecosystems to reduce pest outbreaks and enhance resource efficiency. In Southeast Asia, rice-fish farming is a prominent example of polyculture, where rice paddy fields are integrated with aquaculture. This system, widely practiced in countries like Vietnam, supports sustainable rice production while providing fish and improving soil fertility through nutrient cycling. Crop rotation alternates different crops in the same field across seasons, helping to break pest and disease cycles, restore soil nutrients, and improve water retention. In the Philippines, crop rotation with legumes such as mung beans and soybeans has been used in rice paddies to fix nitrogen, which replenishes soil nutrients and reduces the need for chemical fertilizers. In Indonesia, polyculture systems are being integrated into palm oil plantations, where companion crops like legumes, vegetables, and fruit trees are intercropped with palm oil. This helps to increase soil fertility, reduce erosion, and enhance biodiversity in the palm oil landscape. In the Mekong Delta in Vietnam, crop rotation is widely practiced to rejuvenate soils after intensive rice farming. By rotating rice with crops like peanuts or maize, farmers help restore soil health and improve water retention, reducing dependency on chemical fertilizers. These systems combine technical benefits, such as improved yields and lower input costs, with landscape and socio-economic co-benefits, including improved rural livelihoods, food security, and conservation of ecosystems that are critical for biodiversity, water retention, and climate resilience.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| AGROECOLOGY & SUSTAINABLE AGRICULTURE | INTEGRATED PEST MANAGEMENT (IPM)

| CLIMATE-SMART AGRICULTURE | AGROFORESTRY INTEGRATION | SOIL CONSERVATION & RESTORATION

MAIN PROBLEMS ADDRESSED

SOIL EROSION

BIODIVERSITY LOSS

FLOOD CONTROL

DISASTER RISK REDUCTION

CARBON SEQUESTRATION

FOOD SECURITY

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Biodiversity enhancement**: Promotes a diverse range of species, improving ecosystem resilience.
- **Soil health improvement**: Enhances soil structure, microbial diversity, and nutrient cycling.

REGULATING

- **Pest and disease control**: Interrupts pest life cycles and reduces disease outbreaks.
- **Climate regulation**: Increases carbon sequestration in soils and reduces GHG by minimizing synthetic fertilizer usage.

PROVISIONING

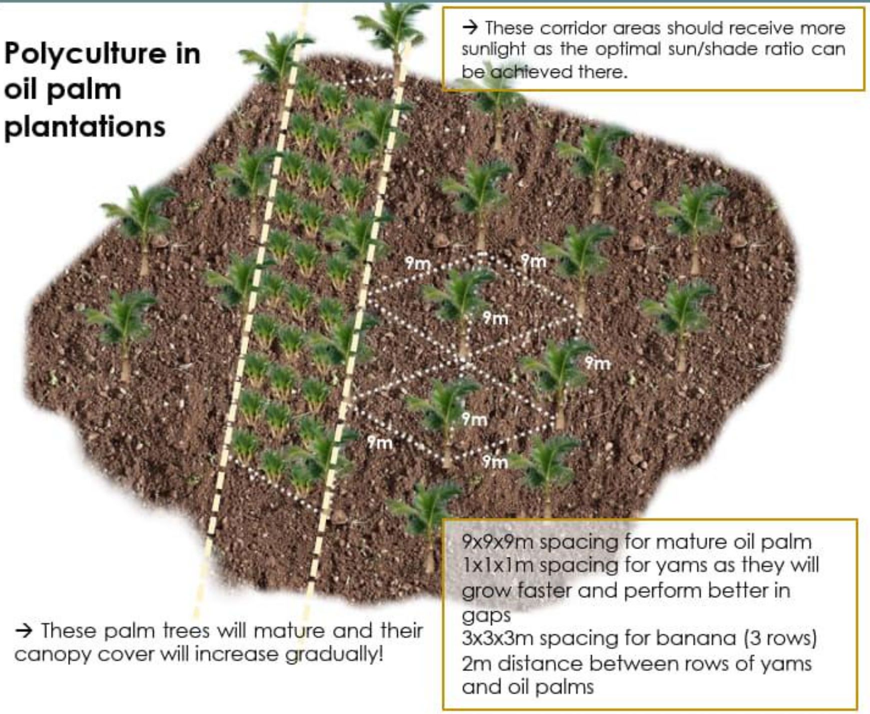
- **Increased food production**: Enhances yields and crop reliability by maintaining soil fertility.
- **Diverse agricultural products**: Provides multiple outputs, including staple crops, fruits, vegetables.

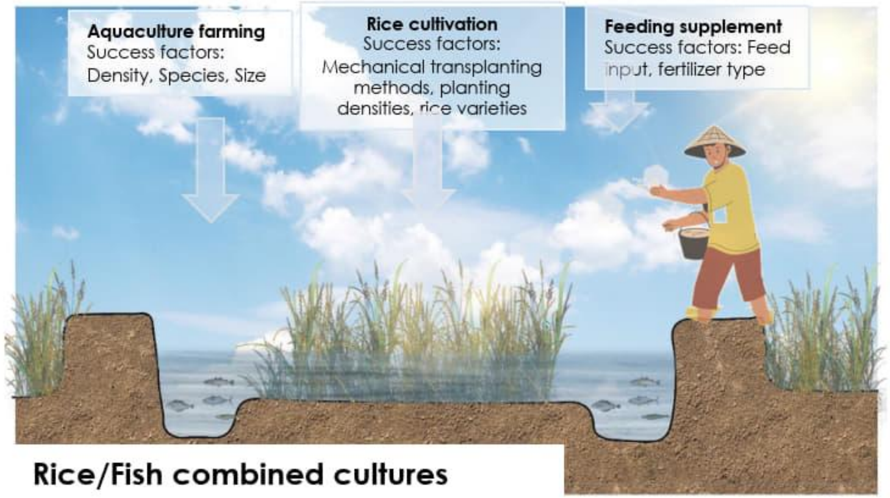
SOCIAL BENEFITS

- **Farmer livelihood enhancement**: Reduces input costs, diversifies income streams, and builds resilience to climate shocks.
- **Community food security**: Ensures a stable and diverse food supply.

NbS-45: POLYCULTURE & CROP ROTATION

Polyculture in oil palm plantations





Rice/Fish combined cultures

PROJECT'S CHALLENGES & RISKS

- **Knowledge and Training Gaps**: Lack of access to knowledge and training on effective polyculture and crop rotation techniques.
- **Market Accessibility and Demand**: Diverse crop production may face challenges in reaching markets that favour monoculture crops with established supply chains.
- **Initial Labor and Management Intensity**: Polyculture and crop rotation require more planning, labor and monitoring compared to conventional monoculture practices.
- **Climatic Variability and Pests**: Unpredictable weather patterns and emerging pests can disrupt crop cycles and affect the success of rotational or mixed farming systems.

NbS co-BENEFITS AND THEIR INDICATORS

- **Enhanced Soil Fertility**
  Increased organic matter and nutrient cycling, measured by higher soil organic carbon levels.
- **Improved Biodiversity**
  Greater species richness on farms, tracked through the number of plant, insect, and bird species observed.
- **Reduced Dependency on Chemical Inputs**
  Decreased use of synthetic fertilizers and pesticides, measured by lower annual expenditure on agrochemicals per hectare.
- **Climate Resilience**
  Increased yield stability during extreme weather events, measured by year-on-year production variability.
- **Livelihood Diversification**
  More income sources for farmers, tracked through the percentage of households with multiple crop-based revenue streams.
- **Water Efficiency**
  Improved water retention and reduced irrigation needs, measured by decreased water use per ton of crop yield.

COST ANALYSIS

- **Direct Costs**
  Seeds, tools, and training range around $1000/ha, depending on crop types and land preparation requirements.
- **Indirect Costs**
  Knowledge transfer and community engagement costs around $200/farmer/year.
- **Time Horizon**
  Implementation spans 2–5 years for significant results.
- **Direct Benefits**
  Increased crop yields and reduced input costs lead to net revenue gains of $300 to $700/ha/year.
- **Indirect Benefits**
  Ecosystem services like improved pollination and reduced soil erosion.
- **Risk Assessment**
  Risks from market volatility and pest outbreaks could cause losses of of projected revenues.

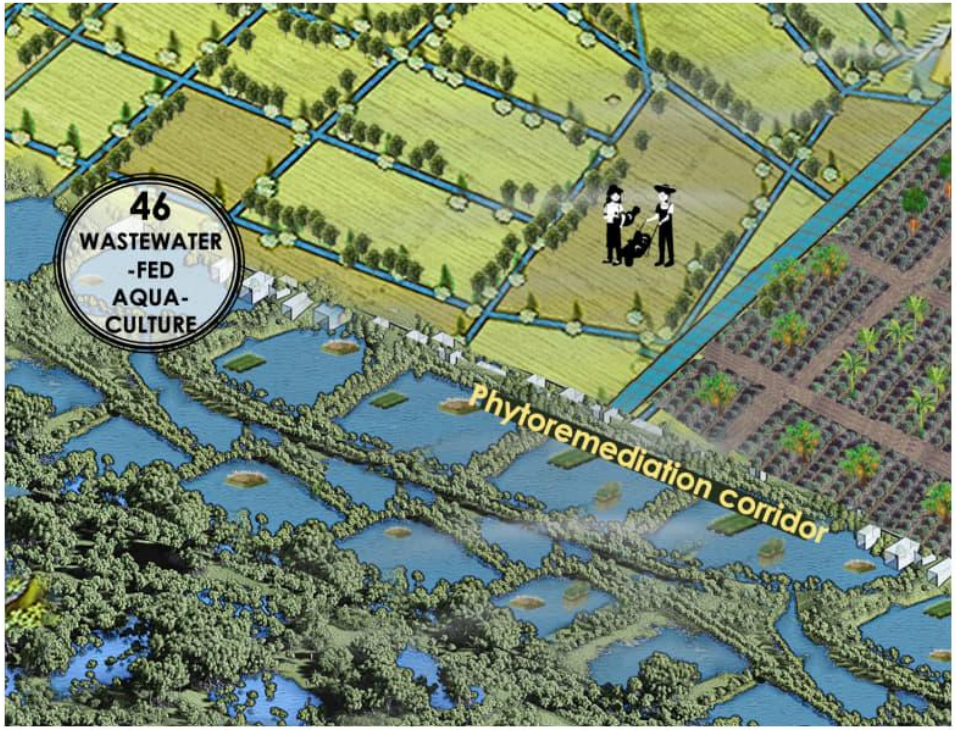
REFERENCES:

Integrated Farming Systems Project, Mindanao region, **Philippines**.
Agroecology Learning Alliance in Southeast Asia (ALiSEA), **Cambodia, Laos, Myanmar**
Zero Budget Natural Farming (ZBNF), **India**

IMPLEMENTATION OPPORTUNITIES:

Mekong Delta, Vietnam: Polyculture of salt-tolerant crops, rice and aquaculture integrated into rotation systems.
Northern Uplands, Laos: Shifting cultivation and deforestation contexts.
Central Dry Zone, Myanmar: Polyculture with drought-resistant crops to address low rainfall and soil erosion.

NbS-46: WASTEWATER-FED AQUACULTURE & TREATMENT PONDS



Wastewater-fed aquaculture, wastewater stabilization ponds (WSPs), and anaerobic treatment ponds support waste management, water depollution, and regenerative agriculture by harnessing natural processes for nutrient recycling, pollution control, and resource recovery. They can be considered as a sub-category of wastewater-related NbS. Wastewater-fed aquaculture utilizes treated or partially treated wastewater to cultivate fish, plants, and other aquatic organisms, integrating waste reuse with food production, as seen in Bangladesh and Vietnam's rice-fish farming systems. WSPs, including anaerobic, facultative, and aerobic ponds, treat blackwater, greywater, or faecal sludge through sunlight, wind, microorganisms, and algae, effectively removing biochemical oxygen demand (BOD) and pathogens. Anaerobic treatment ponds specifically focus on breaking down organic material and producing biogas, which can be used as an energy source for heating, cooking, or small-scale electricity generation. These systems offer technical benefits, such as low-cost operation, high nutrient recovery for agricultural reuse, and significant BOD reduction (up to 85%), while addressing water pollution. They also provide landscape-level co-benefits, including reduced nutrient runoff, improved soil fertility, and a circular economy approach to wastewater reuse. Social and economic advantages include lower sanitation costs for rural and peri-urban areas, food security and opportunities for local energy production.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| NUTRIENT RECYCLING AND RECOVERY | NATURAL WASTEWATER TREATMENT | CIRCULAR ECONOMY

| BIODIVERSITY SUPPORT | COMMUNITY-BASED WATER MANAGEMENT | POLLUTION CONTROL

MAIN PROBLEMS ADDRESSED

SOIL EROSION
BIODIVERSITY LOSS
FLOOD CONTROL
DISASTER RISK REDUCTION
CARBON SEQUESTRATION
FOOD SECURITY

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Soil and nutrient cycling**: Wastewater provides nutrients (e.g., nitrogen and phosphorus) to support aquaculture and agriculture, promoting soil fertility and sustainable food production.

REGULATING

- **Water purification**: Natural processes in stabilization ponds and anaerobic treatment reduce organic pollutants and pathogens, improving water quality and protecting aquatic ecosystems.

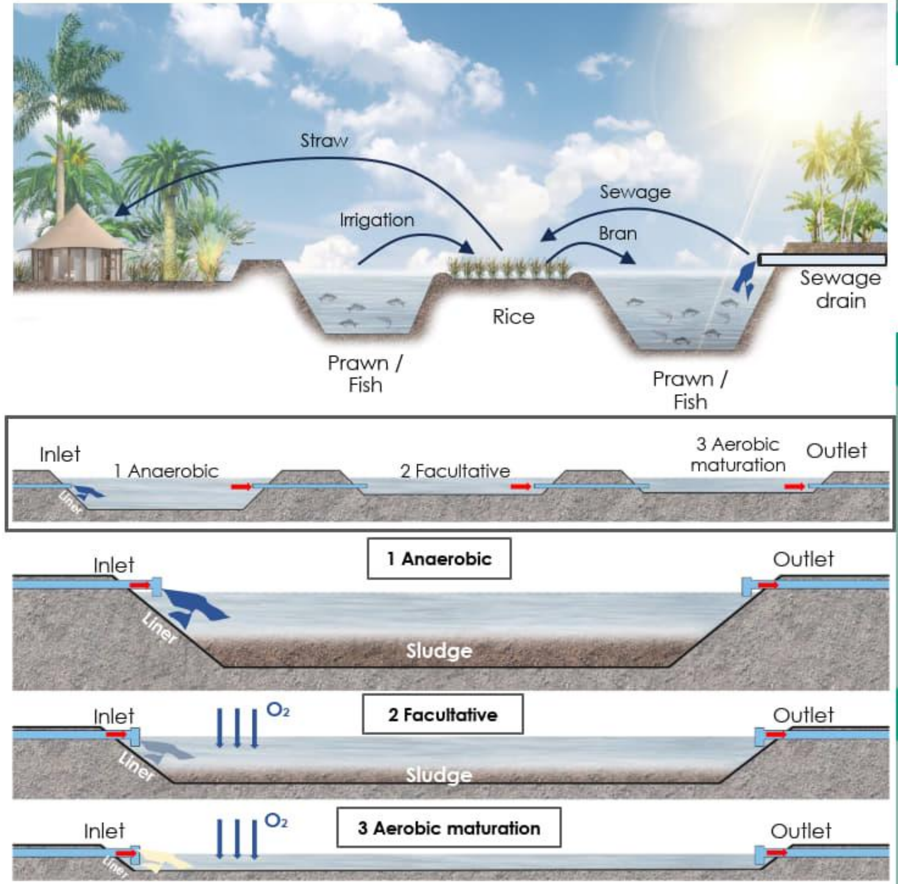
PROVISIONING

- **Food production**: Aquaculture systems using treated wastewater produce fish and other aquatic organisms for local consumption and markets.

SOCIAL BENEFITS

- **Livelihood opportunities**: Wastewater-fed aquaculture and biogas recovery generate income and job opportunities for local communities while improving sanitation infrastructure.

NbS-46: WASTEWATER-FED AQUACULTURE & TREATMENT PONDS



Wastewater Stabilization Ponds (WSPs) function individually or in series, with three types: anaerobic, facultative, and aerobic (maturation), each with specific roles. WSPs are low-cost with high BOD and pathogen removal but require large areas and expert design. The nutrient-rich effluent (e.g., nitrogen and phosphorus) is suitable for agricultural reuse but not for direct discharge into surface waters.

Source: https://sswm.info/factsheet/waste-stabilisation-ponds

PROJECT'S CHALLENGES & RISKS

- **Health Risks**: Inadequate treatment or monitoring of wastewater can result in harmful pathogen exposure, posing risks to public health and aquaculture safety.
- **Land Use Conflicts**: Large surface areas required for stabilization ponds may compete with land needed for agriculture or urban development.
- **Community Acceptance**: Negative perceptions of using treated wastewater for aquaculture or agriculture can hinder local adoption and scalability.
- **Maintenance and Expertise**: Effective operation requires skilled personnel for design, maintenance, and monitoring, which may be challenging in remote or resource-limited areas.

NbS co-BENEFITS AND THEIR INDICATORS

- **Nutrient Recycling for Agriculture**
  Treated wastewater provides nutrients (e.g., nitrogen, phosphorus) for agriculture
- **Renewable Energy Generation**
  Anaerobic ponds can produce biogas, with potential outputs of 30–50 m³/day for small-scale energy needs.
- **Increased Aquaculture Productivity**
  Integrated wastewater-fed systems can increase fish yields by 20–50%, supporting local food security.
- **Carbon Emission Reduction**
  Biogas recovery offsets fossil fuel use, reducing greenhouse gas emissions by up to 1 ton CO_2 equivalent per 10,000 m³ of treated wastewater.
- **Improved Water Quality**
  BOD reduction rates in stabilization ponds can reach 40–85%, enhancing downstream water ecosystems.
- **Livelihood Enhancement**
  Farmers and fishers benefit from diversified income streams.

COST ANALYSIS

- **Direct Costs**
  Construction and installation range from $3–$10 per m³ of wastewater treated.
- **Indirect Costs**
  Land acquisition and training costs average $2k–$5k/ha, influenced by local land values and workforce needs.
- **Time Horizon**
  Typical lifespan of systems is 15–20 years, with a discount rate of 5–8% for financial feasibility studies.
- **Direct Benefits**
  Savings on fertilizer and energy production can generate significant benefits.
- **Indirect Benefits**
  Enhanced agricultural yields and aquaculture income.
- **Risk Assessment**
  Risks such as contamination or maintenance failures could result in unexpected costs for repairs and mitigation.

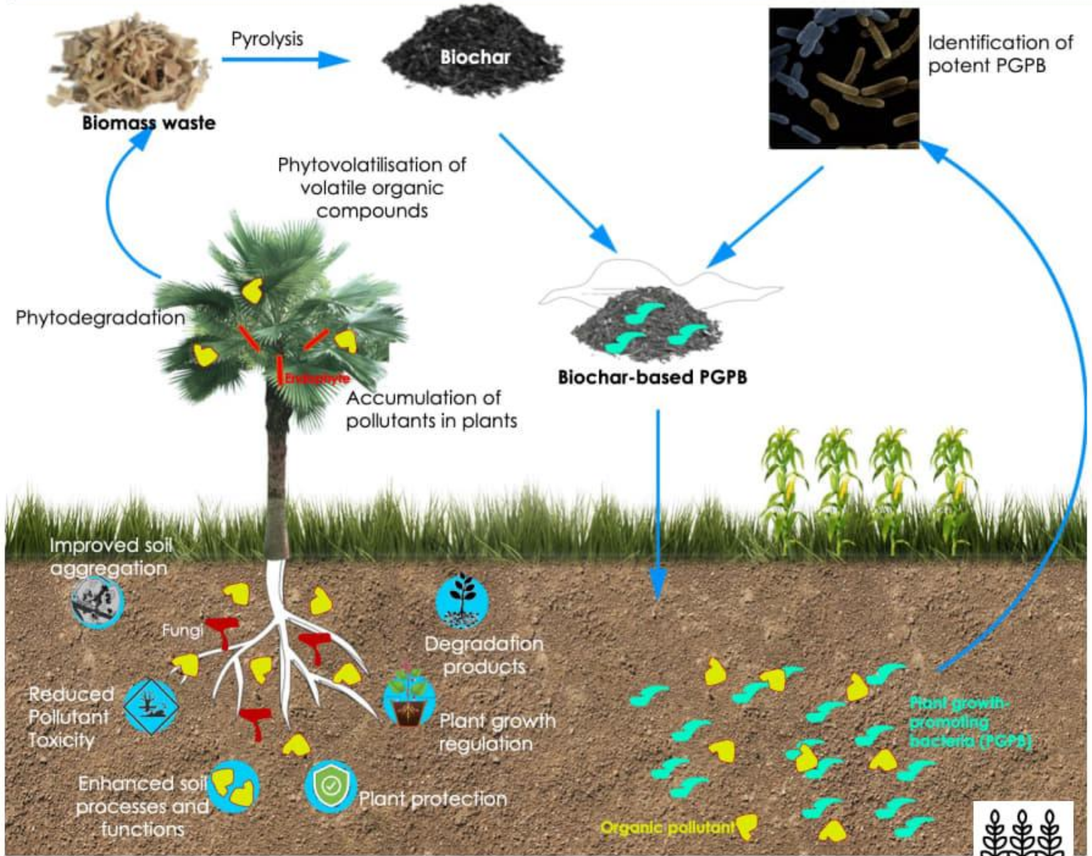
REFERENCES:

Community-based anaerobic ponds integrated into palm oil mill wastewater treatment systems, **Trang Province, Thailand**
Pilot wastewater stabilisation ponds, **Kampong Chhnang, Cambodia**
980 million litres of wastewater treated daily and supporting fish farming, **East Kolkata Wetlands**

IMPLEMENTATION OPPORTUNITIES:

Mekong Delta, Vietnam: to support integrated rice-fish farming systems.
Central Luzon, Philippines: Wastewater from livestock and poultry farming could be treated in anaerobic ponds and reused for aquaculture
Northern Sumatra, Indonesia: Palm oil plantations' wastewater can be treated in anaerobic ponds.

NbS-47: BIOCHAR AND CROP NUTRIENT MANAGEMENT



Landscapes supported: Regenerative Agriculture

EbA (ECOSYSTEM-BASED APPROACHES)

| SOIL FERTILITY ENHANCEMENT | WATER RESOURCE MANAGEMENT | NUTRIENT CYCLING |
| CLIMATE RESILIENCE | BIODIVERSITY SUPPORT | POLLUTION REDUCTION |

MAIN PROBLEMS ADDRESSED

SOIL EROSION | BIODIVERSITY LOSS | CARBON SEQUESTRATION

Biochar is a stable, carbon-rich material produced by heating organic biomass (such as crop residues, wood, or manure) in a low-oxygen environment (a process called pyrolysis). In the context of regenerative agriculture, biochar serves multiple purposes: improving soil health, enhancing crop productivity, sequestering carbon, and promoting circular nutrient use.

In Southeast Asia, where agriculture is central to livelihoods and the environment faces challenges like soil degradation, nutrient loss, and greenhouse gas emissions, biochar offers a promising solution. By combining biochar with crop nutrient management, farmers can improve soil fertility and water retention, reduce dependence on chemical fertilizers, and restore degraded lands. Biochar aligns with the principles of Nature-based Solutions (NbS) by supporting Soil Health Improvement, Climate Change Mitigation, Circular Economy and Waste Management

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Soil Health Improvement**: Enhances soil structure, organic matter, and microbial activity, promoting long-term agricultural productivity.

REGULATING

- **Carbon Sequestration**: Stores carbon in soil, reducing greenhouse gas emissions and contributing to climate change mitigation.

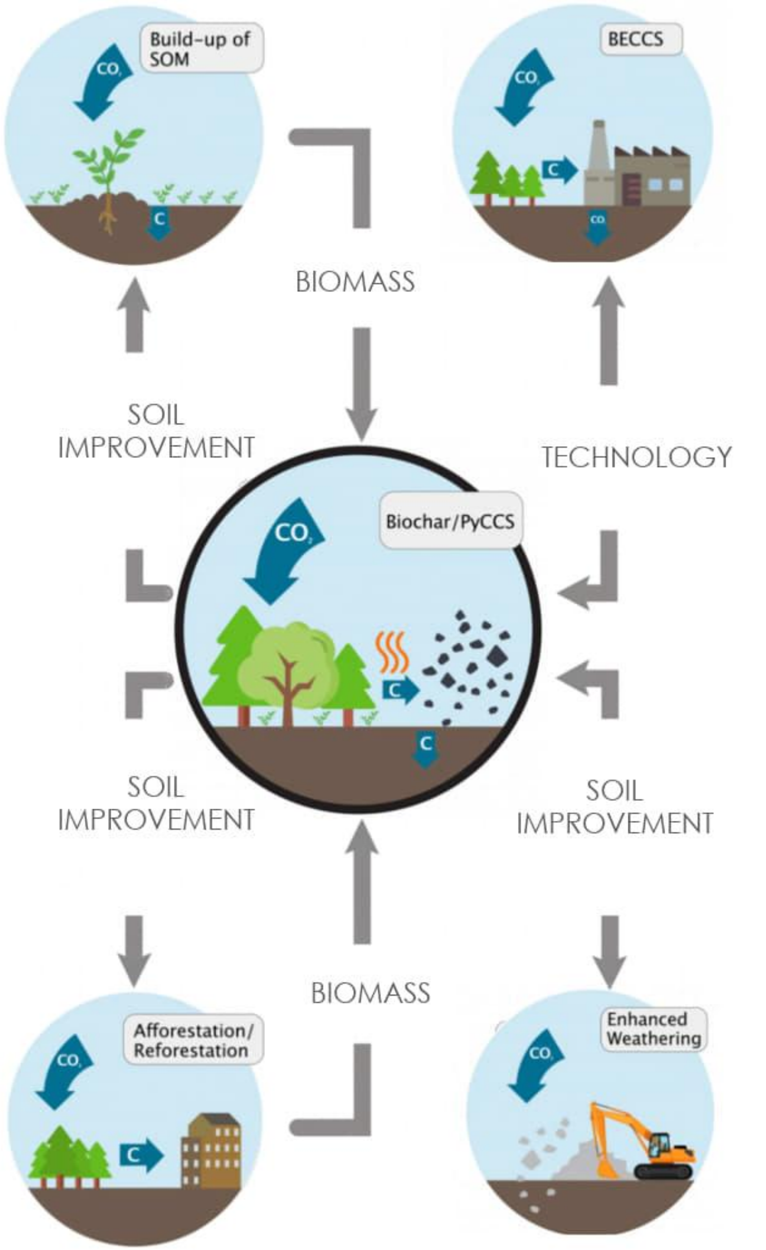
PROVISIONING

- **Improved Crop Yields**: Increases agricultural output through enhanced nutrient availability and soil fertility.

SOCIAL BENEFITS

- **Farmer Livelihoods**: Reduces input costs and improves yields, enhancing economic stability for smallholder farmers.

NbS-47: BIOCHAR AND CROP NUTRIENT MANAGEMENT



PROJECT'S CHALLENGES & RISKS

- **High Initial Costs**: The production and application of biochar can be expensive for smallholder farmers, limiting widespread adoption.
- **Limited Technical Knowledge**: Farmers may lack awareness or training on proper biochar production methods and application techniques, reducing its effectiveness.
- **Feedstock Availability**: Ensuring a sustainable and adequate supply of biomass for biochar production can be challenging, particularly in regions with high competition for organic materials.
- **Soil-Type Variability**: Biochar effectiveness depends on soil type and local conditions, making its benefits inconsistent across diverse landscapes in Southeast Asia.

NbS co-BENEFITS AND THEIR INDICATORS

- **Enhanced Soil Fertility**
  Increase in soil organic carbon and nutrient levels after biochar application.
- **Improved Water Retention**
  Higher soil moisture content during dry seasons compared to untreated soils.
- **Carbon Sequestration**
  Measurable amount of carbon stored in the soil, tracked through biochar application rates and soil carbon analysis.
- **Reduced Greenhouse Gas Emissions**
  Lower emissions of nitrous oxide and methane from treated agricultural fields compared to usual practices
- **Improved Crop Yields**
  Increased productivity (e.g., kg/ha) for key crops grown in treated fields.
- **Farmer Economic Resilience**
  Reduced fertilizer costs and increased net income per hectare for smallholder farmers using biochar.

COST ANALYSIS

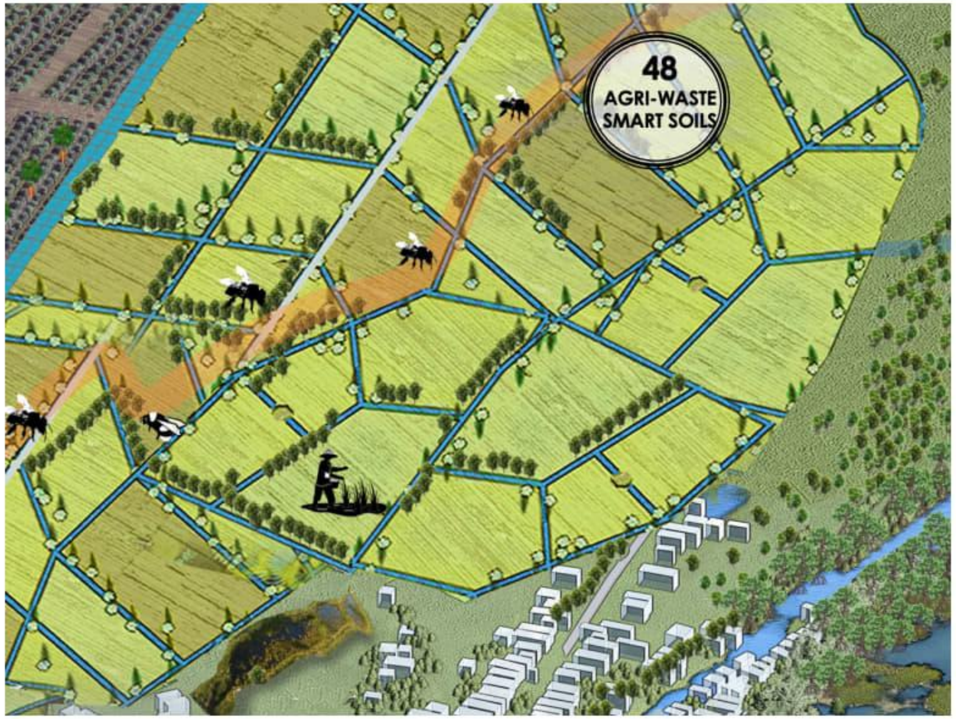
- **Direct Costs**
  Production and application costs range from $300 to $600 per ha annually, depending on feedstock and labor costs.
- **Indirect Costs**
  Training, capacity building, and monitoring costs are typically $50 to $150 per ha annually, varying with program scale.
- **Time Horizon and Discount Rate**
  10–20 years with a discount rate of 5–10%, reflecting long-term soil health and carbon storage benefits.
- **Direct Benefits**
  Direct revenue gains of $100 to $400 per ha annually, depending on crop type and market prices.
- **Indirect Benefits**
  Long-term soil health improvements can save $50 to $200 per ha annually in input expenses.
- **Risk Assessment**
  Inconsistent biochar quality or soil compatibility could require mitigation costs of $50 to $100 per ha annually for adjustments

REFERENCES AND IMPLEMENTATION OPPORTUNITIES

Biochar for Sustainable Agriculture Project
Central Kalimantan, Indonesia
This project focuses on using biochar derived from agricultural residues to improve soil fertility in degraded peatlands, reducing greenhouse gas emissions and enhancing crop yields.

Mekong Delta
Chao Phraya
Citarum River Basin
Irrawaddy Delta

NbS-48: AGRI-WASTE SMART SOILS



Agri-waste smart soils transform agricultural by-products, such as crop residues, animal manure, and agro-industrial waste, into soil amendments like compost, biochar, and organic mulches. These amendments enrich soil organic matter, enhance water retention, and improve nutrient availability, fostering long-term soil fertility and resilience. In Southeast Asia, this approach offers a circular economy model that minimizes waste while addressing soil degradation and nutrient depletion.

By recycling organic waste back into farmlands, agri-waste smart soils reduce dependence on chemical fertilizers and mitigate environmental pollution, contributing to sustainable farming practices that support local livelihoods and ecosystem health.

In the region's diverse agricultural landscapes—ranging from rice paddies in the Mekong Delta to plantation systems in Indonesia—agri-waste smart soils address pressing challenges like declining soil quality, water scarcity, and climate vulnerability. The addition of biochar or compost not only improves soil structure but also sequesters carbon, making it a viable climate mitigation strategy. Furthermore, by enhancing soil's ability to retain nutrients and water, this NbS helps farmers adapt to erratic rainfall patterns and droughts exacerbated by climate change. The approach aligns with the goals of regenerative agriculture by rebuilding soil fertility, enhancing biodiversity, and promoting sustainable crop productivity, making it a crucial tool for resilient food systems in Southeast Asia.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

NUTRIENT EFFICIENCY | EROSION CONTROL | SOIL FERTILITY IMPROVEMENT | FOOD SECURITY | WASTE RETENTION & CIRCULAR ECONOMY | WATER RETENTION AND SOIL STRUCTURE

MAIN PROBLEMS ADDRESSED

SOIL EROSION
BIODIVERSITY LOSS
FLOOD CONTROL
DISASTER RISK REDUCTION
CARBON SEQUESTRATION
FOOD SECURITY

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Soil Fertility Enhancement**: Improving soil organic matter and microbial diversity, supporting nutrient cycling and maintaining soil health.

REGULATING

- **Carbon Sequestration**: The use of biochar and compost helps capture and store carbon in the soil, contributing to climate change mitigation.

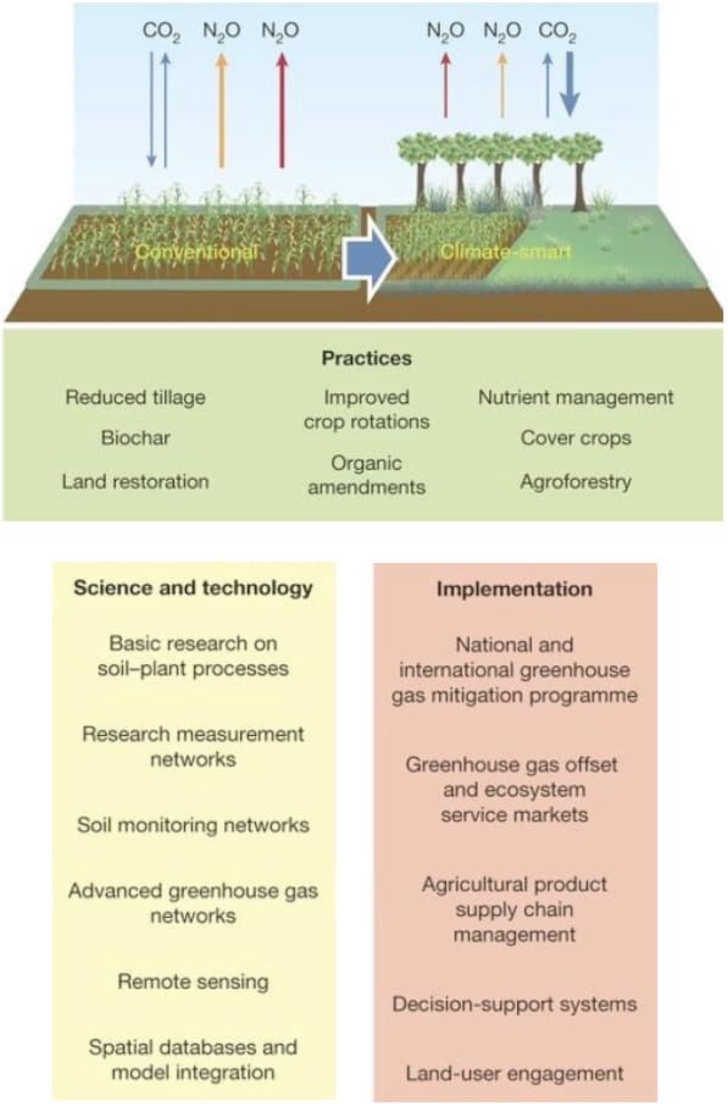
PROVISIONING

- **Improved Crop Productivity**: By enhancing soil fertility and water retention, agri-waste smart soils can increase agricultural yields, supporting food security.

SOCIAL BENEFITS

- **Waste Reduction** : By recycling agricultural by-products, this NbS reduces environmental pollution and promotes sustainable farming practices.

NbS-48: AGRI-WASTE SMART SOILS



Components of Clean Growth Agriculture. Source: Tulay Yildirim

PROJECT'S CHALLENGES & RISKS

- **Lack of Infrastructure for Waste Collection**: Insufficient infrastructure for collecting and processing agri-waste limits the availability of raw materials for soil amendments.
- **Limited Knowledge**: Farmers may lack knowledge or training on the benefits and proper application of agri-waste smart soils, hindering widespread adoption.
- **Contamination Risks**: Improperly processed or contaminated agri-waste can introduce pathogens or toxins into the soil, potentially affecting crop safety and soil health.
- **Cost of Production**: The cost of producing or sourcing quality agri-waste amendments like biochar and compost may be a barrier for smallholder farmers.

NbS co-BENEFITS AND THEIR INDICATORS

- **Improved Soil Health**
  Enhanced soil fertility and microbial diversity, measured by increased soil organic matter content and microbial activity.
- **Waste Reduction**
  Decreased agricultural waste going to landfills, measured by the volume of agri-waste repurposed for soil amendments.
- **Climate Change Mitigation**
  Increased carbon sequestration, indicated by higher levels of soil organic carbon and biochar content in the soil.
- **Water Retention and Efficiency**
  Improved soil moisture retention, indicated by reduced irrigation requirements and better crop growth during dry periods.
- **Enhanced Agricultural Productivity**
  Increased crop yields, indicated by higher output per hectare due to improved soil fertility
- **Reduced Environmental Pollution**
  Decreased nutrient runoff and water pollution, measured by improved water quality and reduced chemical fertilizer use.

COST ANALYSIS

- **Direct Costs**
  Costs include waste collection, processing, and application, ranging from $50 to $200 /ha/year, depending on local infrastructure and scale.
- **Indirect Costs**
  Potential loss in productivity during the transition period.
- **Time Horizon**
  Typically 5–10 years, with a discount rate of 5–7% for long-term investments in soil improvement practices.
- **Direct Benefits**
  Direct benefits from increased crop yields and improved soil quality could range from $100 to $500 per hectare annually.
- **Indirect Benefits**
  Enhanced water retention and reduced need for synthetic fertilizers
- **Risk Assessment**
  Risk of failure due to poor application or contamination can result in medium-range losses if not properly managed.

REFERENCES:

Indian Council of Agricultural Research (ICAR) Agri-Waste Management Project: **Convert agricultural waste** into compost, biochar, and organic amendments to enhance soil fertility, reduce pollution, and improve crop productivity.

IMPLEMENTATION OPPORTUNITIES:

Mekong Delta: Agri-waste smart soils could enhance fertility and help mitigate salinity issues.
Java Island: Large-scale plantations can benefit from it through biochar or compost production
Mindanao Region: Agri-waste from coconut and banana plantations can be used for composting or biochar production.

NbS-49: ANTI-SALT BUNDS

Anti-salt bunds are natural or man-made structures designed to prevent saltwater intrusion and protect agricultural lands, particularly rice paddies, from tidal flooding in coastal regions. In Southeast Asia, these bunds are critical in areas where rising tides and salinization threaten local food security, as they act as barriers against the encroachment of seawater during high tides, preserving freshwater resources for irrigation. Technically, they help maintain soil quality by preventing salinity buildup that can damage crops, particularly rice, which is sensitive to salt stress.

The bunds can also enhance water retention, regulate water flow, and help maintain soil fertility. The landscape benefits include reducing coastal erosion, protecting habitats, and enabling farmers to continue cultivating land in saline-prone areas. Socially, these systems foster community involvement in environmental management and agriculture, ensuring sustainable livelihoods for local farmers who rely on healthy ecosystems for food production. Similar to successful projects like the anti-salt bunds in Senegal, Southeast Asian adaptations can integrate local knowledge, support resilience to climate change, and enhance agricultural productivity while contributing to coastal ecosystem protection.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| INTEGRATED COASTAL ZONE MANAGEMENT | AGROECOLOGICAL APPROACHES

| COMMUNITY-BASED RESOURCE MANAGEMENT | FLOOD RISK REDUCTION | ECOSYSTEM RESTORATION

MAIN PROBLEMS ADDRESSED

SOIL EROSION

FLOOD CONTROL

DISASTER RISK REDUCTION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Soil formation and nutrient cycling**: Anti-salt bunds help maintain soil health by preventing salinization.
- **Biodiversity support**: By protecting coastal and wetland ecosystems, they support local biodiversity in rice paddies and adjacent ecosystems.

REGULATING

- **Saltwater intrusion control**: They regulate the intrusion of saltwater into agricultural areas, protecting crops from salinity stress.
- **Flood and erosion control**: The bunds help reduce the impacts of tidal floods, preventing coastal erosion and protecting agricultural fields from flood damage.

PROVISIONING

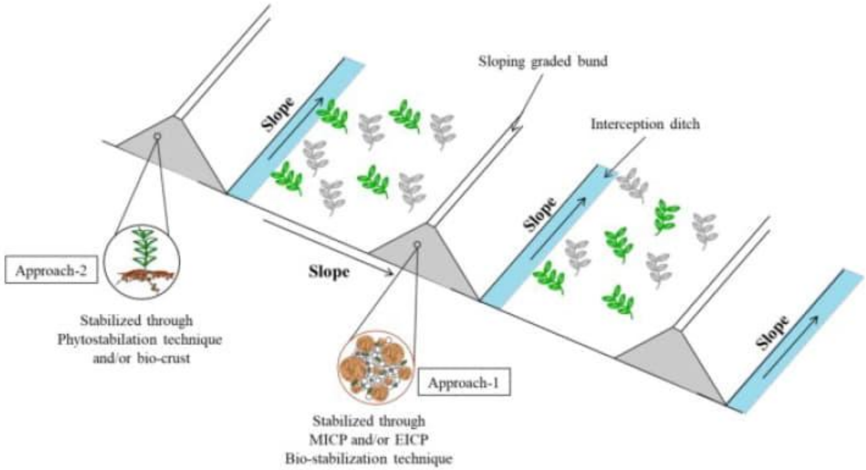
- **Water quality regulation**: They help maintain freshwater quality by reducing the mixing of saline and freshwater.
- **Agricultural productivity**: By protecting farmland from saltwater damage, they support sustained agricultural yields.

SOCIAL BENEFITS

- **Community resilience and empowerment**: The involvement of local communities in the construction and maintenance of anti-salt bunds fosters collaboration and enhances their adaptive capacity to climate change.

NbS-49: ANTI-SALT BUNDS

Planting pits and upward ties may further increase the success of bunds. Drawing inspired by OUESSAR et al. (2012)



Source: Biostabilisation of soils as sustainable pathway for anti-desertification, Mahi Patil

PROJECT'S CHALLENGES & RISKS

- **High construction and maintenance costs**: The initial investment and ongoing maintenance of anti-salt bunds can be financially burdensome for local communities or governments, especially in low-income regions.
- **Extreme weather vulnerability**: Anti-salt bunds may be damaged during extreme weather events like typhoons.
- **Land and space limitations**: In densely populated coastal areas, there may be limited space available for constructing bunds without displacing agricultural land or compromising other land uses.
- **Governance challenges**: Coordination among stakeholders can be difficult, leading to conflicts over land and resources.

NbS co-BENEFITS AND THEIR INDICATORS

- **Improved Agriculture Productivity**
  Increased rice and crop yields due to reduced saltwater intrusion, leading to higher productivity and more reliable harvests in affected regions.
- **Increased Biodiversity**
  Restoration of habitats for both aquatic and terrestrial species.
- **Water Quality Improvement**
  Improved freshwater quality in surrounding agricultural areas, measured by a decrease in salinity levels in groundwater and surface water.
- **Enhanced Coastal Resilience**
  Reduced coastal erosion and protection against tidal surges, demonstrated by the prevention of saltwater flooding in agricultural zones.
- **Community Empowerment**
  Active local community participation in the construction, monitoring, and maintenance of the bunds.
- **Climate Change Adaptation**
  Reduced vulnerability of farming areas to saline soil conditions caused by sea-level rise, tracked by improved soil health.

COST ANALYSIS

- **Direct Costs**
  Estimated direct costs from $10,000 to $50,000 per km, including materials, labor, and equipment.
- **Indirect Costs**
  Indirect costs include maintenance costs for bunds, potentially around $1,000 to $3,000 annually per km for monitoring and repairs.
- **Time Horizon**
  Time horizon is 10-20 years, with a discount rate from 3% to 7% depending on project scale and local financial conditions.
- **Direct Benefits**
  Increased crop yields estimated at $500 to $2,000 /ha annually due to reduced saltwater intrusion and improved soil conditions.
- **Indirect Benefits**
  Improved water quality and coastal resilience, with long-term savings from avoided flood damage and water purification
- **Risk Assessment**
  Risks include potential failure due to poor construction or extreme weather events.

REFERENCES:

Large scale anti-salt bund project in Mekong River Delta
Sundarbans anti-salt bunds in India and Bangladesh
Sine Saloum Delta anti-salt bunds in Senegal

IMPLEMENTATION OPPORTUNITIES:

Western Timor, Indonesia
Tonle Sap Lake region, Cambodia
Songkhla Province, Thailand
Mekong Delta, Vietnam

NbS-50: RAINFORESTATION FARMING

Rainforestation Farming is an innovative NbS that integrates reforestation with agroforestry to address landslides, soil erosion, and slope stabilization while enhancing biodiversity and supporting local livelihoods in Southeast Asia. Unlike conventional reforestation, it prioritizes the use of native tropical tree species to restore ecological balance while incorporating shade-tolerant crops for economic benefits, making it highly adaptable to sloped and degraded landscapes. Rainforestation farming systems replicate natural forest structures, with multiple canopy layers that stabilize slopes, enhance soil water retention, and reduce surface runoff, thereby mitigating the risk of landslides and flash floods. In the Philippines, where the approach was pioneered, species such as *Narra* (*Pterocarpus indicus*), *Dao* (*Dracontomelon dao*), and *Rattan* have proven effective in combining ecological restoration with economic outputs.

The system not only promotes reforestation but also ensures sustainable agricultural productivity, fostering food security, and reducing the dependency of communities on monoculture farming. Technically and socially, it delivers a triple win: ecological resilience, economic opportunity, and disaster risk reduction, making it a holistic solution for the challenges faced in Southeast Asia's forested and agricultural landscapes.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOSYSTEM RESTORATION
- BIODIVERSITY CONSERVATION
- CLIMATE CHANGE MITIGATION
- SUSTAINABLE LIVELIHOODS
- WATER & SOIL REGULATION

MAIN PROBLEMS ADDRESSED

- SOIL EROSION
- DISASTER RISK REDUCTION
- BIODIVERSITY LOSS
- FOOD SECURITY

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Soil health improvement**: Facilitates nutrient cycling and soil aeration through enhanced water infiltration.

REGULATING

- **Flood mitigation**: Reduces stormwater runoff and prevents urban flooding by increasing water infiltration.
- **Urban cooling**: Lowers ambient temperatures by reducing heat island effects through greenery and water retention.

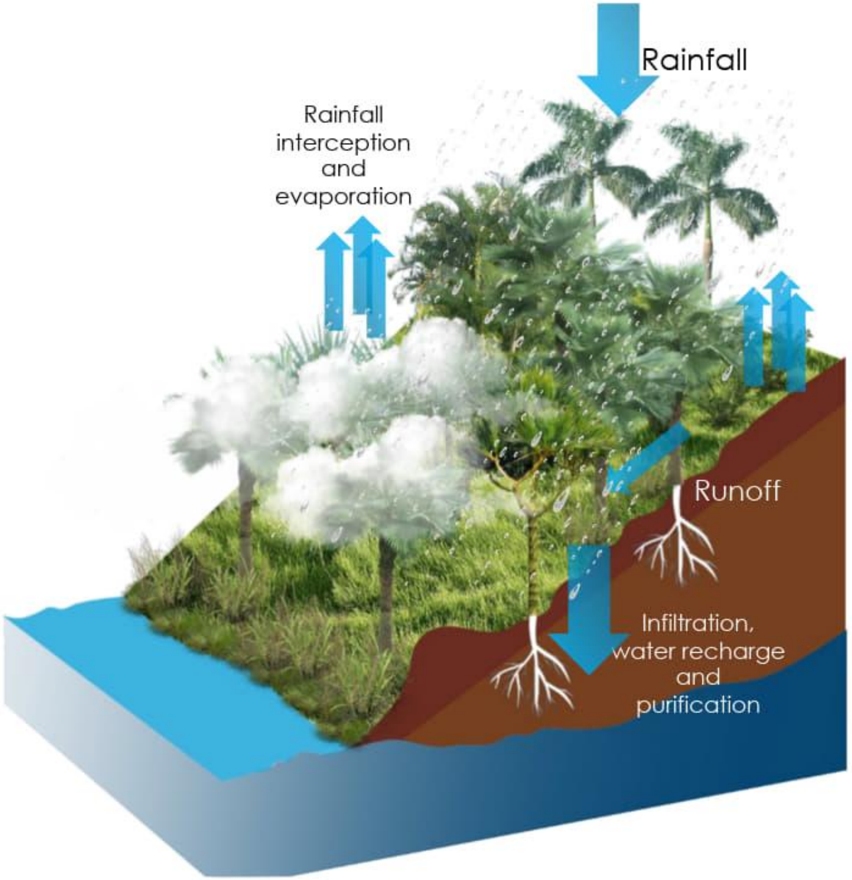
PROVISIONING

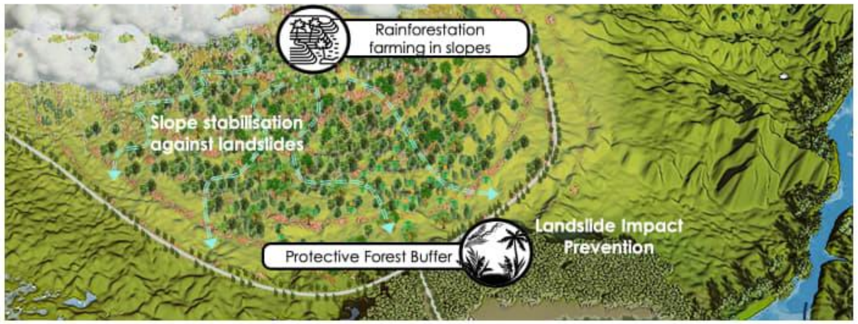
- **Groundwater recharge**: Replenishes local aquifers by allowing rainwater to percolate into the ground.

SOCIAL BENEFITS

- **Improved walkability and livability**: Enhances urban aesthetics and encourages pedestrian-friendly environments.
- **Disaster resilience**: Builds community resilience against climate impacts like floods and heatwaves.

NbS-50: RAINFORESTATION FARMING





PROJECT'S CHALLENGES & RISKS

- **Initial Costs and Maintenance:** Establishing rainforestation sites can be costly due to the need for native seedlings, technical training, and labor for site preparation.
- **Timeframe for Benefits:** Unlike fast-growing monocultures, native trees take longer to grow and produce economic returns, which may deter smallholder farmers who need short-term income.
- **Complexity of Implementation:** Successful implementation requires expertise in native species selection, site-specific ecosystem restoration, and sustainable farming practices.
- **Competition for Land:** Competition with other land uses like monoculture plantations or housing, especially in areas with high population pressure.

NbS co-BENEFITS AND THEIR INDICATORS

Biodiversity Restoration
Increase in native tree species richness per hectare by 50%-70% within 5 years.

Soil stabilisation and erosion control
Reduction in soil erosion rates by up to 60% on reforested slopes within 3 years.

Carbon Sequestration
Annual sequestration of 5-10 tons of CO_2 equivalent per hectare in mixed agroforestry systems.

Food Security Enhancement
Annual yield of agroforestry crops (e.g., coffee, cacao, or root crops) contributing to 20%-30% of household income within 3 years.

Improved Watershed Protection
Reduction in peak runoff volume by up to 40% during heavy rains, improving downstream water quality.

Community Resilience and Livelihood Support
30%-50% increase in income diversification among participating households due to tree products and agroforestry crops.

COST ANALYSIS

Direct Costs
Establishment costs of $1,500–$3,000 per hectare, including planting materials, labor, and training.

Indirect Costs
$500–$1,000/ha annually for maintenance, monitoring, and opportunity costs of initial land-use changes.

Time Horizon
20–30 years with a discount rate of 5%–7%, considering long-term ecological and livelihood benefits.

Direct Benefits
$2,000–$4,000 per hectare annually from agroforestry yields like fruits, timber, and crops after 3–5 years.

Indirect Benefits
Ecosystem services valued at $5,000–$7,000/ha annually, including carbon sequestration, water regulation, and biodiversity conservation.

Risk Assessment
Medium risk due to potential challenges like invasive species, market access, and community buy-in.

REFERENCES:

the Philippines, Mount Pangasugan, Leyte Rainforestation Initiative.
Indonesia, Java, Gunung Kidul Regency Forest Landscape Restoration.
Thailand, Mae Chaem Watershed Agroforestry.

IMPLEMENTATION OPPORTUNITIES:

Timor, Leste, Maubisse Highlands.
Cambodia, Cardamom Mountains, agroforestry crops like durian and rambutan.

NbS-51: FLOATING TREATMENT WETLANDS (FTW) & PHYTOFILTRATION

Rotorua large-scale Floating Treatment Wetland, New Zealand

Riverside floating treatment wetlands in Chicago

Floating Treatment Wetlands (FTWs) are a versatile NbS that excels in phytofiltration, providing effective water depollution, wastewater treatment, and ecosystem regeneration. These systems feature buoyant platforms that support aquatic plants like reeds and vetiver grass, whose roots extend into the water to perform phytoremediation by absorbing excess nutrients, heavy metals, and organic pollutants.

In addition to their phytofiltration capabilities, FTWs enhance water quality by promoting biofilm activity, which breaks down contaminants, and by physically filtering suspended solids, improving water clarity. Their application is particularly effective in post-mining landscapes, where they treat metal-laden wastewater and stabilize degraded aquatic ecosystems. FTWs also address agricultural runoff, mitigate eutrophication in urban waterways, and support regenerative aquaculture practices.

Beyond water treatment, FTWs contribute to the regeneration of soil and water systems, foster biodiversity, and provide sustainable uses for waste biomass in bioenergy or compost, promoting a circular economy. Their low cost, adaptability to various environments, and potential for community participation make FTWs an attractive solution for restoring ecological balance, enhancing aesthetic value, and supporting livelihoods. This holistic approach underscores their value as a Nature-based Solution for addressing Southeast Asia's environmental and socio-economic challenges.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| PHYTOREMEDIATION & ECOSYSTEM RESTORATION | WATER QUALITY MANAGEMENT

| NUTRIENT CYCLING | SEDIMENTATION MANAGEMENT | INTEGRATED WASTEWATER TREATMENT

MAIN PROBLEMS ADDRESSED

SOIL EROSION · BIODIVERSITY LOSS · FLOOD CONTROL · DISASTER RISK REDUCTION · CARBON SEQUESTRATION · FOOD SECURITY

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Enhance biodiversity** by creating habitats for aquatic species, birds, and beneficial insects.
- **Support nutrient cycling** through biofilm activity and plant-microbe interactions.

REGULATING

- **Improve water quality** by removing nutrients (nitrogen, phosphorus), heavy metals, and pollutants through phytoremediation.
- **Reduce turbidity and sedimentation** by trapping suspended solids and particulate matter in dense root networks.

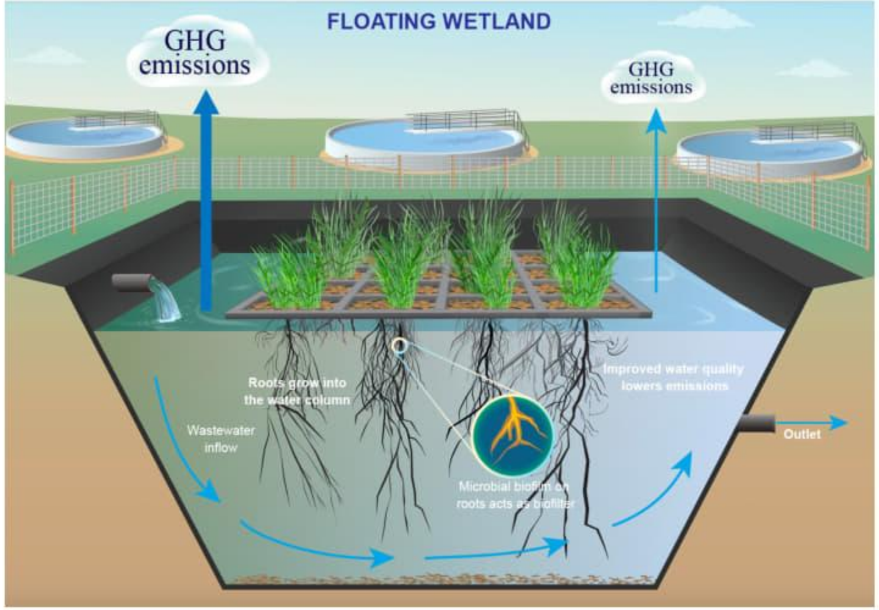
PROVISIONING

- **Provide harvested biomass for use in bioenergy**, compost, or sustainable agricultural practices.
- Offer cleaner water for downstream agricultural, aquacultural, and industrial applications.

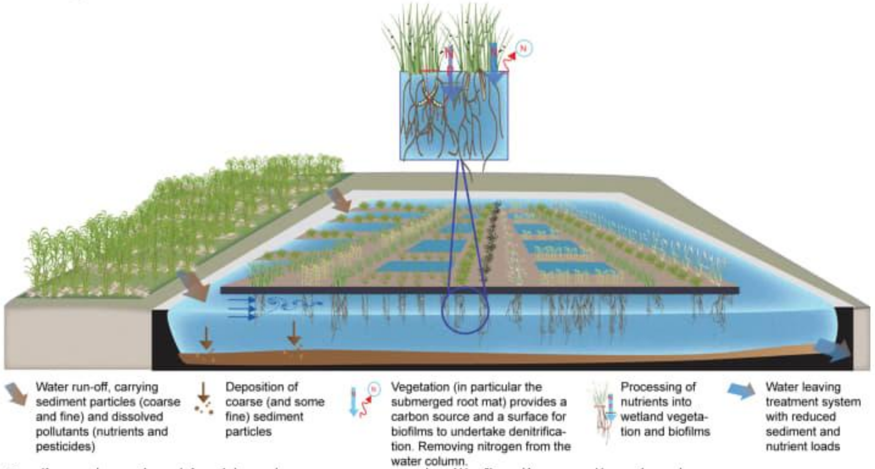
SOCIAL BENEFITS

- **Enhance landscape aesthetics**, contributing to urban and rural beautification and increased recreational value.
- **Promote community involvement** in water quality management and ecosystem restoration, fostering environmental stewardship.

NbS-51: FLOATING TREATMENT WETLANDS (FTW) & PHYTOFILTRATION



Floating wetland technical section. *Source: Blue Carbon Lab*



Sediment and nutrient loads management with floating wetland systems

PROJECT'S CHALLENGES & RISKS

- **Climate Vulnerability**: Extreme weather events such as typhoons and heavy rains can damage floating platforms and disrupt their functionality.
- **Heavy Metal Accumulation**: Harvested biomass from phytoremediation may contain concentrated toxins, requiring careful disposal or reuse strategies to avoid secondary contamination.
- **Maintenance and Monitoring**: Ensuring long-term performance requires consistent maintenance, monitoring, and community engagement, which may be resource-intensive in some regions.
- **Site Suitability**: Inappropriate site selection, such as areas with strong currents or unstable water levels, can limit the effectiveness and stability of FTWs.

NbS co-BENEFITS AND THEIR INDICATORS

- **Biodiversity Enhancement**
  Increased species richness and abundance of aquatic organisms, birds, and insects in areas with FTWs.
- **Water Quality Improvement**
  Reduction in nutrient concentrations (e.g., nitrogen and phosphorus) and suspended solids in treated water.
- **Climate Resilience**
  Improved water quality and ecosystem stability during extreme weather events like floods and droughts.
- **Waste Recovery & Circular Economy**
  Amount of biomass harvested from FTWs repurposed for compost, bioenergy, or sustainable agriculture.
- **Aesthetic & Recreational Value**
  Increased community use and positive perceptions of water bodies enhanced with FTWs.
- **Community Engagement and Awareness**
  Number of local stakeholders participating in FTW installation, maintenance, or environmental education programs.

COST ANALYSIS

- **Direct Costs**
  Typically ranges from $40 to $100/m2, depending on materials, plant species, and site conditions.
- **Indirect Costs**
  Maintenance and monitoring costs can add $10 to $20/m2/year, including labor, biomass harvesting, and periodic repairs.
- **Time Horizon**
  FTWs could have a lifespan of 10–15 years with a typical discount rate of 5–10%
- **Direct Benefits**
  Water treatment cost savings can be valuable, especially in areas with high nutrient loads.
- **Indirect Benefits**
  Enhanced ecosystem services and biodiversity can lead to economic gains through tourism, fisheries, and improved agricultural productivity.
- **Risk Assessment**
  Possible damage from extreme weather events.

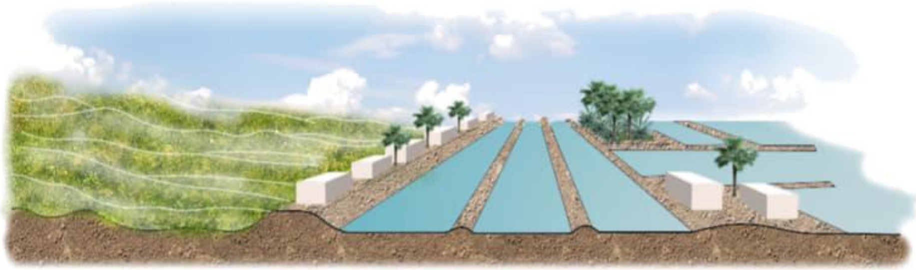
REFERENCES:

FTWs in Bishan-Ang Mo Kio Park, **Singapore**
Pond Restoration in Kunshan, **China**
Large-scale FTWs deployed to mitigate eutrophication, effectively reducing nutrient loads, Lake Rotorua, **New Zealand**

IMPLEMENTATION OPPORTUNITIES:

Citarum River, **Indonesia** (highly polluted river system)
Tonle Sap Lake, **Cambodia**: FTWs can address water quality degradation caused by agricultural runoff.
Mekong Delta, **Vietnam**: FTWs can improve water quality in aquaculture ponds and mitigate pollution from agricultural activities.

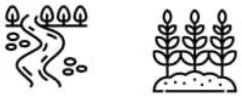
NbS-52: DRAINAGE REDUCTION IN RICE PADDY FIELDS



Drainage channels along rice paddy fields of the Mekong River Delta
Source: WWF, RoyalHaskoning

Polyculture through drainage management in channels along rice paddy fields.
Source: WWF, RoyalHaskoning

LANDSCAPES SUPPORTED



EbA (ECOSYSTEM-BASED APPROACHES)

- SOIL FERTILITY ENHANCEMENT
- FLOOD REGULATION
- INTEGRATED WATER RESOURCES MANAGEMENT
- BIODIVERSITY CONSERVATION
- CLIMATE RESILIENCE

MAIN PROBLEMS ADDRESSED

FOOD SECURITY

FLOOD CONTROL

DISASTER RISK REDUCTION

CARBON SEQUESTRATION

Drainage reduction in rice paddy fields addresses climate resilience and food security by optimizing water management through controlled irrigation and reduced water drainage.

In regions like the Mekong River Delta, where rice cultivation is crucial, this approach involves maintaining higher water levels during the rice growing season, reducing the need for frequent drainage.

Technically, it enhances soil moisture retention, reduces water consumption, and minimizes the release of methane, a potent greenhouse gas, by creating anaerobic conditions. This method can also help mitigate the risks of saltwater intrusion, a growing concern in coastal areas. On the landscape level, it supports floodplain ecosystems and maintains natural hydrological cycles, while promoting sustainable land use practices.

Socially, drainage reduction ensures stable crop yields, improves farmers' resilience to climate-related extremes like droughts and floods, and strengthens food security in vulnerable rural communities. It can be applied in other Southeast Asian regions, such as the Chao Phraya Basin in Thailand and parts of South Kalimantan in Indonesia, where similar climatic challenges are faced.

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Soil Fertility Enhancement**: Maintains higher water levels, which promotes anaerobic conditions that enrich soil organic matter and support nutrient cycling.

REGULATING

- **Flood Regulation**: By maintaining controlled water levels, drainage reduction helps manage floodwaters, reducing the risk of flooding downstream.

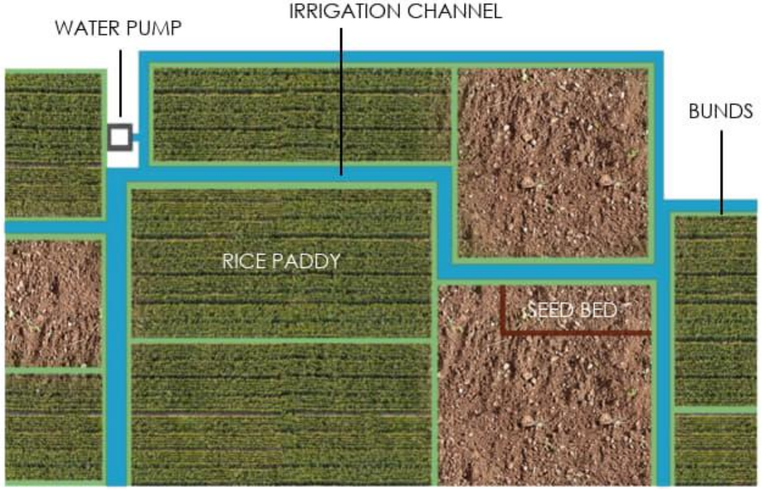
PROVISIONING

- **Improved Crop Yields**: Enhanced soil fertility and water availability lead to more stable and productive rice cultivation, supporting food security.

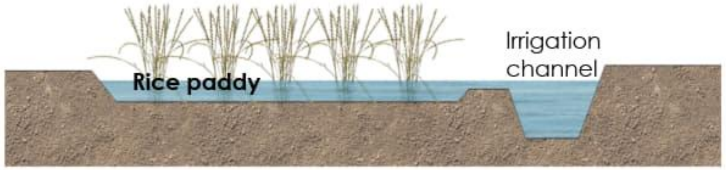
SOCIAL BENEFITS

- **Resilient Livelihoods**: Helps farmers adapt to climate-related changes such as droughts and floods, improving community resilience and long-term food security.

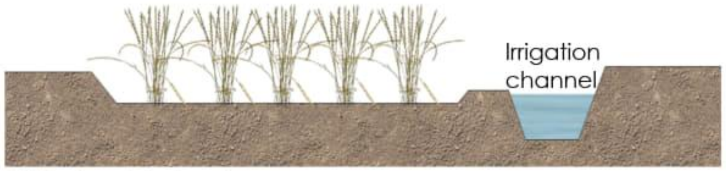
NbS-52: DRAINAGE REDUCTION IN RICE PADDY FIELDS



Reduction of drainage in rice paddy fields



Water level during flood season



Water level during dry season

PROJECT'S CHALLENGES & RISKS

- **Land Use Conflicts :** Moving levees away from rivers often requires land acquisition or repurposing
- **High initial costs:** The upfront costs of planning, acquiring land, and constructing levee setbacks are substantial.
- **Displacement :** The creation of setback areas may displace people, wildlife, or existing ecosystems.
- **Maintenance and Monitoring Needs :** Although levee setbacks offer long-term benefits, they may require ongoing monitoring and maintenance to ensure they continue functioning as intended.

NbS co-BENEFITS AND THEIR INDICATORS

Increased Soil Fertility
Higher soil organic matter content and improved nutrient levels measured after maintaining water levels..

Reduced Greenhouse Gas Emissions
Decrease in methane emissions, monitored through periodic soil gas sampling during the rice-growing season.

Enhanced Water Retention
Improved water retention in the soil, measured by soil moisture content during dry periods.

Improved Biodiversity
Increased presence of aquatic species and wetland flora, tracked through biodiversity surveys in the rice fields.

Flood risk Mitigation
Lower incidence of downstream flooding, monitored through water flow data and flood event records in nearby areas.

Increased Resilience to Climate Change
Stable crop yields and reduced vulnerability to climate extremes assessed through yield data and climate stress reports.

COST ANALYSIS

Direct Costs
Costs for water management infrastructure range from $100 to $300 per ha annually.

Indirect Costs
Displacement, legal costs and uncertainty in flood protection.

Time Horizon
50–100 years for ecosystem recovery and long-term flood mitigation.

Direct Benefits
Flood risk reduction, biodiversity restoration, carbon sequestration, water quality improvement.

Indirect Benefits
Groundwater recharge, recreation, reduced urban heat, and climate resilience..

Risk Assessment
Environmental, social, financial, and climate-related risks that could affect project success.

REFERENCES:

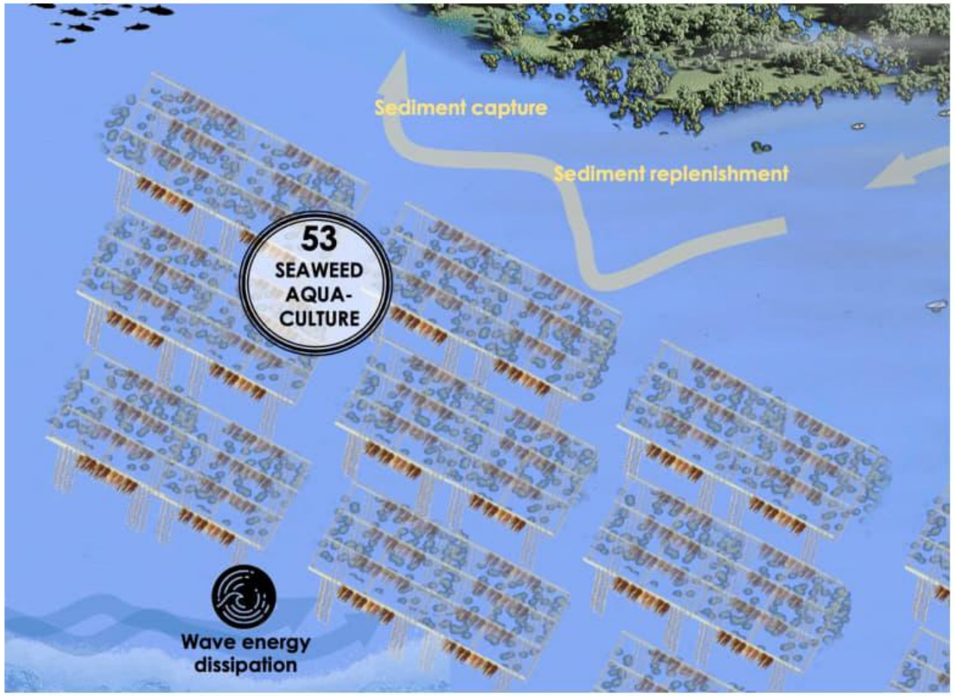
The Netherlands, Nijmegen, Room for the river project.
US, Reconnecting the Missouri River Floodplain.

IMPLEMENTATION OPPORTUNITIES:

Thailand, Chao Phraya River basin, Upper and central floodplain areas outside of urbanized zones.

Indonesia, Jakarta, Ciliwung River, Upstream and midstream areas.

NbS-53 SEAWEED AQUACULTURE



Seaweed aquaculture can contribute significantly to carbon sequestration and marine ecosystem protection, as it naturally absorbs CO2 during photosynthesis, helping mitigate the impacts of climate change by sequestering carbon in their biomass and the surrounding waters. Additionally, seaweed cultivation promotes the remineralisation of nutrients by bacteria, enhancing nutrient cycling and water quality in coastal zones. As a biodegradable product, seaweed can be used in various industries, including food, biofuels, and pharmaceuticals, creating sustainable economic opportunities for local communities. Seaweed aquaculture also provides habitat for marine life, supporting biodiversity, while helping to protect coastal areas from erosion by stabilizing sediments.

However, the size and scale of seaweed farming are crucial to ensure it remains a beneficial NbS. If managed poorly or cultivated at too large a scale, seaweed farms could alter local ecosystems, cause shading that reduces light penetration, and potentially interfere with native species. Optimizing the density and location of seaweed cultivation is essential to avoid negative impacts on marine wildlife, including fish and coral reefs. Ideal locations are sheltered coastal zones with high nutrient availability but low risk of excess eutrophication, and farms should be carefully monitored to ensure sustainable productivity without disrupting the balance of marine ecosystems.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- CARBON SEQUESTRATION
- WATER QUALITY IMPROVEMENT
- BIODIVERSITY ENHANCEMENT
- ECOSYSTEM RESTORATION
- NUTRIENT CYCLING

MAIN PROBLEMS ADDRESSED

- BIODIVERSITY LOSS
- FLOOD CONTROL
- SOIL EROSION
- CARBON SEQUESTRATION
- FOOD SECURITY

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Biodiversity Enhancement**: Seaweed aquaculture provides habitat and food for various marine species.

REGULATING

- **Carbon Sequestration**: Seaweed absorbs CO2 from the atmosphere, contributing to carbon storage and climate change mitigation.
- **Water Quality Improvement**: Seaweed helps improving water quality and reducing eutrophication risks.

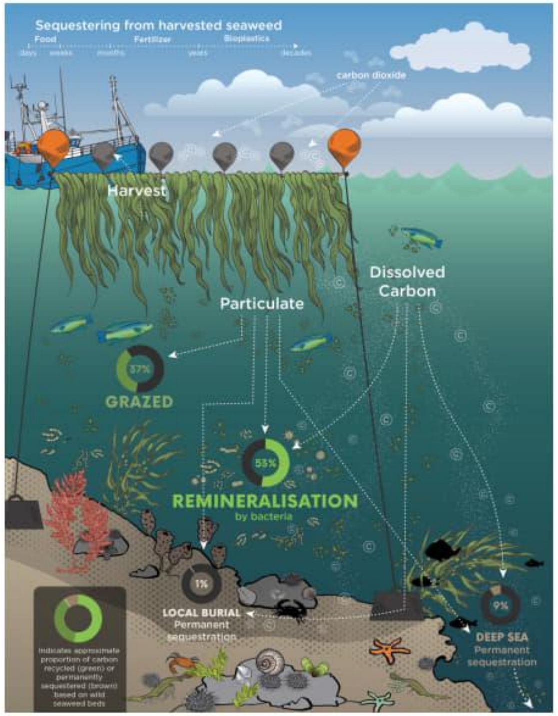
PROVISIONING

- **Sustainable Seafood Production**: Seaweed farming provides a renewable source of food, fuel, and other products with minimal environmental impact.

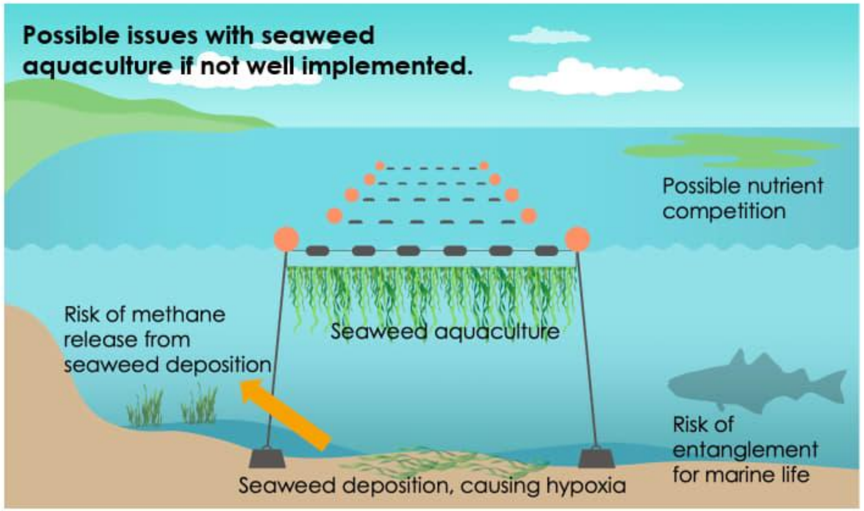
SOCIAL BENEFITS

- **Livelihood Support**: Seaweed aquaculture creates jobs and income opportunities for local communities.

NbS-53 SEAWEED AQUACULTURE



Processes of seaweed aquaculture.
Source : sustainableseachallenge.co.nz



PROJECT'S CHALLENGES & RISKS

- **Environmental Stress**: Seaweed farms can be vulnerable to environmental stressors like temperature fluctuations, ocean acidification, and pollution.
- **Coastal Habitat Degradation**: Improper placement or large-scale seaweed farming could lead to the degradation of sensitive coastal ecosystems.
- **Overexploitation and Monoculture**: Intensive seaweed farming can lead to overexploitation of coastal areas and the establishment of monocultures.
- **Market Volatility**: Seaweed aquaculture markets can be unstable, with fluctuating prices driven by global demand, impacting the economic viability of local farmers.

NbS co-BENEFITS AND THEIR INDICATORS

Carbon Sequestration
Reduced atmospheric CO_2 levels due to seaweed biomass growth, measured in tons of CO_2 sequestered per year.

Water Quality Improvement
Decrease in nitrogen and phosphorus concentrations in farmed areas.

Biodiversity Enhancement
Increase in species diversity around seaweed farm sites, measured by the number of species observed.

Coastal Erosion Prevention
Reduction in coastal erosion rates near seaweed farm installations.

Livelihood Support
Increase in income and employment rates in coastal communities involved in seaweed aquaculture.

Sustainable Food Source
Volume of seaweed harvested and sold as food or other products, measured in tons per year.

COST ANALYSIS

Direct Costs
Seaweed farms costs are between \$2k-\$5k/ha, including materials like ropes, buoys, and labor.

Indirect Costs
Capacity-building, research, and monitoring costs range from \$500 to \$1,500/ha/year.

Time Horizon
10–20 years, with a discount rate of 5–10% for long-term cost-benefit analysis.

Direct Benefits
Annual revenue from seaweed harvest can reach \$3,000 to \$10,000 per hectare.

Indirect Benefits
Benefits from ecosystem services like carbon sequestration, nutrient cycling, and coastal protection.

Risk Assessment
Risks like disease, storm damage, or market fluctuations could result in losses of \$1,000 to \$3,000 per hectare in affected years.

REFERENCES:

Philippines, Farmers' Development in Tawi-Tawi.
Indonesia, Seaweed Aquaculture for Blue Carbon.
Tanzania , Blue Economy and Seaweed Farming in Zanzibar.

IMPLEMENTATION OPPORTUNITIES:

Vietnam, Mekong Delta.
Thailand, Andaman Coast.
Philippines, Central Visayas.
Malaysia, Eastern Sabah.
Indonesia, Sunda Strait.

NbS-54: VETIVER GRASS SYSTEMS (VGS)

Vetiver Grass Systems (VGS) addresses landslide prevention, slope stabilization, post-mining soil recovery, and soil enrichment near agricultural areas in Southeast Asia. Vetiver grass (*Chrysopogon zizanioides*), known for its deep, dense, and vertical root system, binds soil effectively, reducing erosion and improving slope stability, even on steep terrains and degraded landscapes. Its adaptability to diverse climatic conditions, from tropical to sub-tropical environments, makes it ideal for the region's diverse ecosystems. VGS is often combined with agroforestry practices, integrating native tree species such as teak (*Tectona grandis*), bamboo, and fruit-bearing trees to create multi-functional landscapes that provide additional ecological and economic benefits, such as wildlife habitat restoration, carbon sequestration, and livelihood support for local communities. By rehabilitating degraded lands, particularly in post-mining areas, VGS enhances soil fertility, water retention, and agricultural productivity, fostering climate resilience in flood- and drought-prone areas. Its affordability, minimal maintenance requirements, and compatibility with traditional farming systems make VGS socially and economically viable for smallholder farmers and local governments. Existing lessons from Southeast Asia emphasize the importance of participatory approaches in implementing VGS, where community engagement ensures sustained maintenance and integration with local land-use practices. As such, VGS supports not only physical resilience to climate events like floods and landslides but also strengthens rural livelihoods and promotes sustainable land management across the region.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| EROSION CONTROL & SOIL CONSERVATION | AGROECOSYSTEM RESILIENCE | BIODIVERSITY ENHANCEMENT

| FLOOD & WATER MANAGEMENT | SOIL FERTILITY & ENRICHMENT | CARBON SEQUESTRATION

MAIN PROBLEMS ADDRESSED

SOIL EROSION

FLOOD CONTROL

DISASTER RISK REDUCTION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Biodiversity enhancement**: VGS support species by providing ground cover and stabilizing soil.

REGULATING

- **Water filtration**: VGS dense root system reduces sediment and contaminants in water runoff, improving water quality in nearby water bodies.

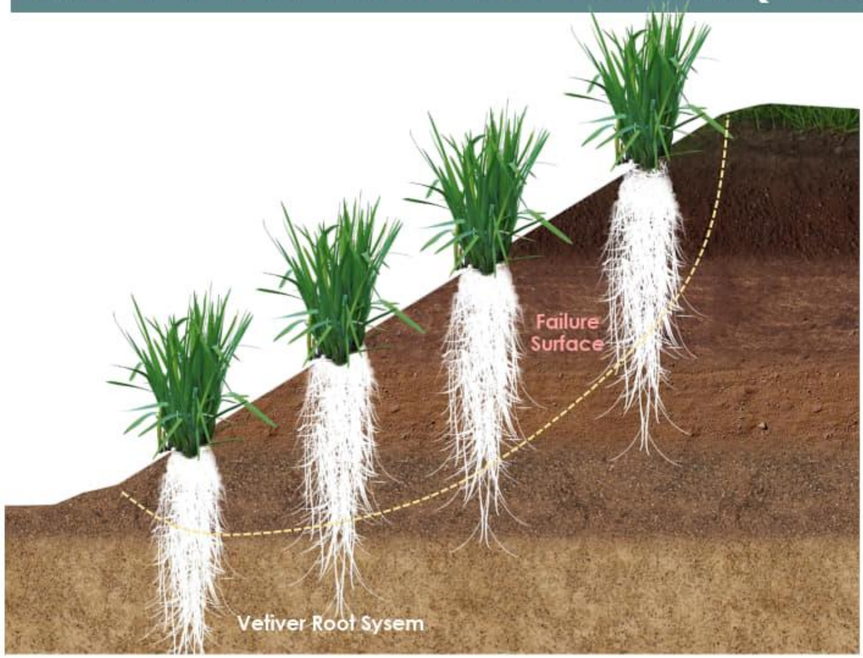
PROVISIONING

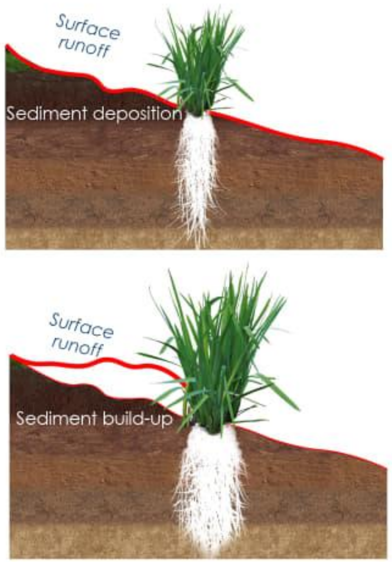
- **Soil fertility enhancement**: The root structure of vetiver enhances soil structure and helps retain moisture, improving soil quality and fertility.

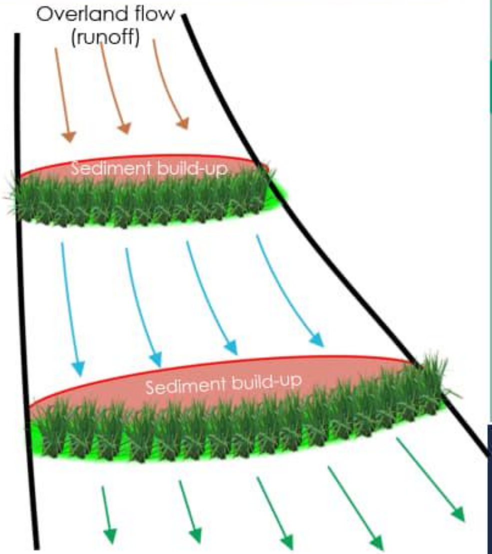
SOCIAL BENEFITS

- **Livelihood support**: Vetiver grass can be harvested and processed into mats, baskets, and ropes, providing income for local communities.

NbS-54: VETIVER GRASS SYSTEMS (VGS)







PROJECT'S CHALLENGES & RISKS

- **Invasive Potential**: Vetiver grass, if not properly managed, may become invasive and outcompete local vegetation, leading to a loss of biodiversity in some ecosystems.
- **Site-Specific Suitability**: VGS may not be effective in areas with extreme soil salinity or poor drainage, limiting its application in certain coastal regions.
- **Initial Investment and Maintenance**: While VGS is cost-effective in the long term, initial establishment costs and ongoing maintenance efforts can be a barrier for smallholder farmers.
- **Climate Sensitivity**: Vetiver grass may not perform optimally in extreme climate conditions, such as prolonged droughts or high heat.

NbS co-BENEFITS AND THEIR INDICATORS

- **Soil Erosion Control**
  Reduced soil erosion rates, measured through sediment deposition and soil loss assessments.
- **Flood Mitigation**
  Decreased surface runoff, evaluated by water retention capacity and reduced flood frequency in adjacent areas.
- **Soil Fertility Restoration**
  Increased organic matter content and nutrient levels in the soil, measured by soil quality tests.
- **Carbon Sequestration**
  Amount of carbon stored in vetiver biomass and soil, quantified through carbon sequestration assessments.
- **Biodiversity Enhancement**
  Increased species diversity, tracked by monitoring the presence of native flora and fauna in areas integrated with VGS.
- **Livelihood Improvement**
  Increase in local income, measured by sales of vetiver-based products or improved agricultural yields.

COST ANALYSIS

- **Direct Costs**
  Vetiver grass system establishment costs (e.g., seedlings, planting, irrigation) range from \$500 to \$2,000 per ha.
- **Indirect Costs**
  Costs related to monitoring, maintenance, and capacity building for local communities can amount to \$200 to \$500 annually per ha.
- **Time Horizon**
  10–20 years time horizon with a discount rate of 5–10% to account for long-term benefits and costs.
- **Direct Benefits**
  Increased agricultural productivity or reduced erosion
- **Indirect Benefits**
  Indirect benefits, such as carbon sequestration, improved water quality, and biodiversity enhancement, can yield estimated savings or gains of \$200 to \$1,000 per hectare annually.
- **Risk Assessment**
  Risks include initial establishment failure, invasion by non-native species, or underperformance due to poor site selection

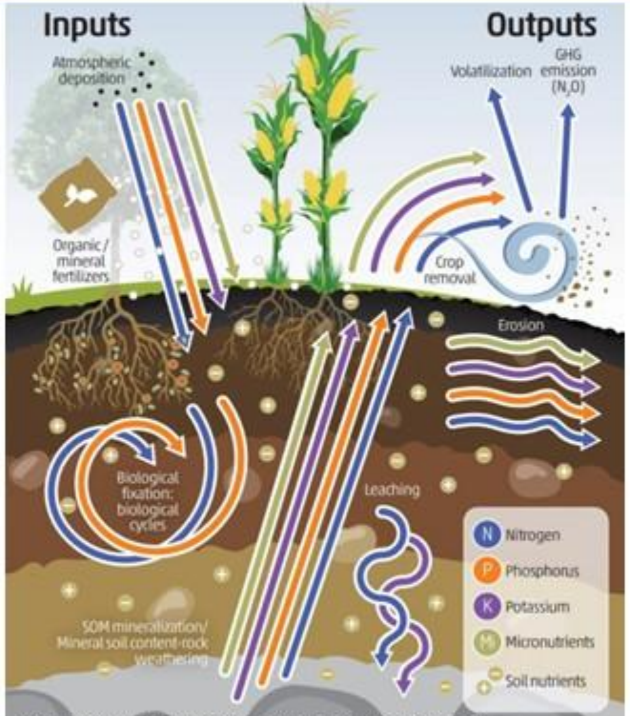
REFERENCES:

Mindanao Post-mining Rehabilitation Project, the Philippines
Post-Coal mining rehabilitation, Quang Ninh Province, Vietnam
VGS applications in Northern Highlands, Thailand

IMPLEMENTATION OPPORTUNITIES:

Riau Province post-mining recovery, Sumatra, Indonesia
Bolaven Plateau Soil recovery in agriculture, Laos
Slope stabilisation in Benguet Province, Phil.

NbS-55: SOIL MICROORGRANISMS AND BIOFERTILIZERS



Source : UN, Food and agriculture organization

Soil microorganisms reduce reliance on synthetic fertilizers, improving soil fertility, and enhancing nutrient cycling. These microorganisms, including nitrogen-fixing bacteria, phosphate-solubilizing fungi, and mycorrhizal fungi, support sustainable farming by mimicking and enhancing natural ecosystem processes. By fixing atmospheric nitrogen and solubilizing non-bioavailable phosphorus, they make essential nutrients accessible to crops while reducing the environmental impact of excessive fertilizer use. Biofertilizers containing these microorganisms improve soil structure, suppress plant pathogens, and boost crop resilience, ensuring long-term agricultural productivity. This NbS restores soil health and biodiversity while addressing critical challenges such as soil degradation, finite phosphorus reserves, and greenhouse gas emissions from chemical fertilizer production. In Southeast Asia, soil microorganisms can be game-changers for farmers facing environmental and socioeconomic pressures. The region's high agricultural intensity has led to declining soil health, nutrient depletion, and water pollution from fertilizer runoff. Leveraging microbial biofertilizers tailored to Southeast Asia's diverse soils and climates can help reverse these trends. For example, integrating biofertilizers with traditional farming practices such as agroforestry can boost yields while preserving soil organic matter and mitigating erosion in upland areas. Additionally, biofertilizers are cost-effective alternatives to synthetic fertilizers, which are increasingly unaffordable for smallholder farmers due to rising global prices.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| POLLUTION REDUCTION | WATER RESOURCE PROTECTION | IMPROVING NUTRIENT CYCLING

| FOOD SECURITY | DRYLAND ADAPTATION | AGROFORESTRY & SUSTAINABLE LAND MANAGEMENT

MAIN PROBLEMS ADDRESSED

SOIL EROSION

BIODIVERSITY LOSS

FLOOD CONTROL

CARBON SEQUESTRATION

FOOD SECURITY

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Nutrient cycling:** Enhance nitrogen and phosphorus availability through biological nitrogen fixation (BNF) and phosphate solubilization, maintaining ecosystem productivity.

REGULATING

- **Climate regulation:** Reduce greenhouse gas emissions by lowering synthetic fertilizer use and enhancing soil carbon sequestration.

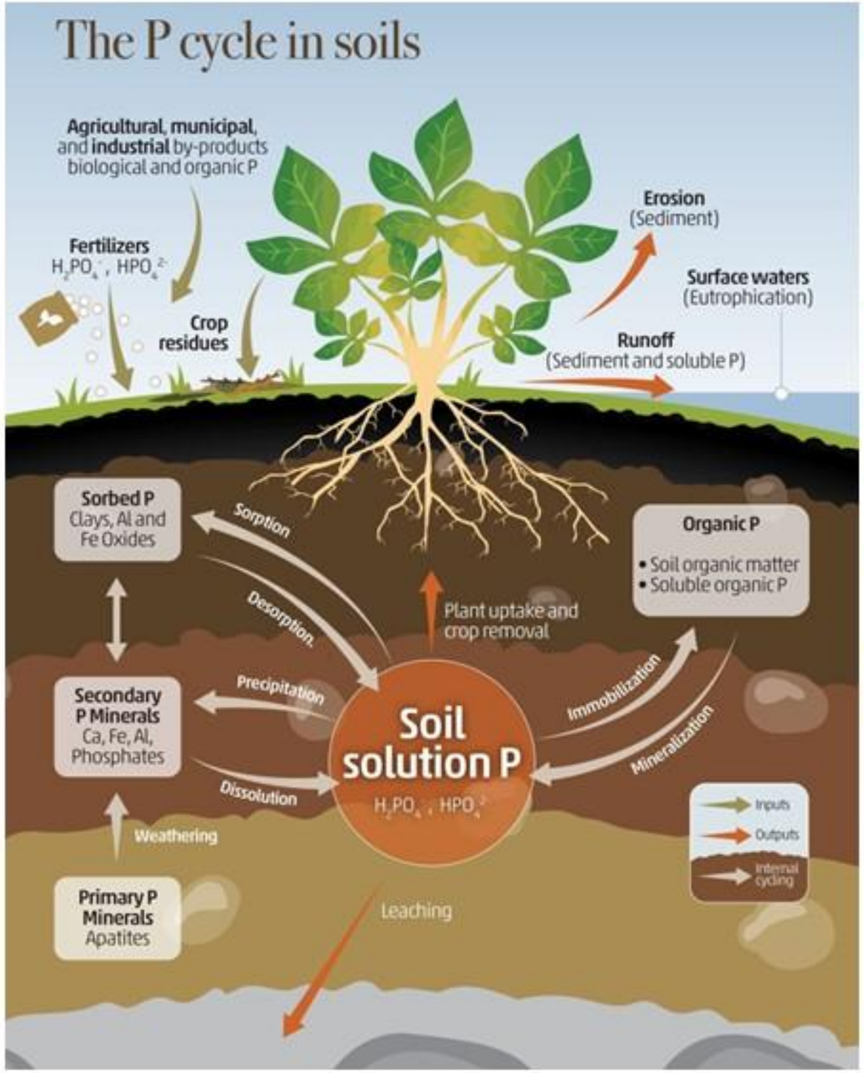
PROVISIONING

- **Food production:** Increase crop yields by improving nutrient uptake efficiency, ensuring sustainable agricultural productivity.

SOCIAL BENEFITS

- **Livelihood support:** Reduce dependency on expensive chemical inputs, increasing profitability for smallholder farmers and fostering inclusive rural economies.

NbS-55: SOIL MICROORGANISMS AND BIOFERTILIZERS



The phosphorus cycle
Source : www.sustainabilitynz.co.nz

PROJECT'S CHALLENGES & RISKS

- **Competition with native microbiomes:** Introduced biofertilizers may face challenges from existing soil microbial communities
- **Variable soil conditions:** High variability in soil pH, organic matter, and nutrient content can limit the performance and adaptability of biofertilizers.
- **Interaction with agricultural practices:** Pesticides and herbicides can disrupt microbial activity and reduce biofertilizer efficacy.
- **Market and scalability issues:** Limited availability of affordable, high-quality biofertilizers and undeveloped distribution networks hinder widespread adoption by smallholder farmers.

NbS co-BENEFITS AND THEIR INDICATORS

Improved Soil Fertility
Increase in soil organic matter content and nutrient levels (e.g., nitrogen and phosphorus).

Enhanced Crop Productivity
Measurable rise in crop yield per hectare compared to fields using synthetic fertilizers alone.

Climate Change Mitigation
Reduction in greenhouse gas emissions, such as nitrous oxide, from decreased chemical fertilizer use.

Water Quality Protection
Reduction in nutrient runoff and eutrophication levels in nearby water bodies.

Biodiversity Conservation
Increase in microbial and plant diversity in agricultural soils.

Economic Savings for Farmers
Decrease in fertilizer costs per growing season for smallholder farmers.

COST ANALYSIS

Direct Costs
Production and application of biofertilizers range from \$50 to \$200 /ha depending on the type and formulation.

Indirect Costs
Capacity building, training, and distribution infrastructure add \$20 to \$50 per hectare annually.

Time Horizon
Benefits typically materialize over a 5-10 year period with a discount rate of 5-7% applied to long-term investments.

Direct Benefits
Increased crop yields generating additional revenues.

Indirect Benefits
Improved soil health.

Risk Assessment
Potential variability in effectiveness.

REFERENCES:

Vietnam: Enhancing Rice Production with Biofertilizers in the Mekong Delta.
India: Biofertilizer promotion in Maharashtra and Uttar Pradesh.
Africa: Mycorrhizal Biofertilizer (arbuscular mycorrhizal fungi) Application in Kenya.

IMPLEMENTATION OPPORTUNITIES:

Philippines, Central Luzon: Intense rice and maize cultures.
Thailand, Isan Region : Poor, sandy soils and reliance on chemical fertilizers present an opportunity for nitrogen-fixing and phosphate-solubilizing biofertilizers to boost productivity sustainably.

NbS-56: BIOENGINEERING REMEDIATION OF CONTAMINATED SOILS (BRCS)

Bioengineering Remediation of Contaminated Soils involves the use of biological methods, such as plants, microbes, and soil organisms, to remediate soils contaminated by industrial waste, agrochemical overuse, mining activities, or urban runoff. Techniques like phytoremediation (using hyperaccumulator plants to extract heavy metals), microbial bioremediation (utilizing soil microbes to degrade pollutants), and mycoremediation (using fungi to break down organic contaminants) are employed to restore soil health.

These approaches are particularly relevant in Southeast Asia, where rapid industrialization, agricultural intensification, and poor waste management have led to widespread soil contamination. Technically, bioengineering remediation improves soil fertility and enhances ecosystem services, while also preventing pollutants from entering water systems. At the landscape level, it promotes the restoration of degraded lands for agriculture or forestry, contributing to adaptive land management in the face of climate change.

Economically and socially, it provides cost-effective alternatives to conventional chemical remediation, engages local communities in restoration efforts, and creates opportunities for green jobs. By reducing greenhouse gas emissions from degraded lands and enabling carbon sequestration, this NbS supports both climate mitigation and adaptation, fostering sustainable and resilient landscapes across the region.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| PHYTOREMEDIATION | BIOREMEDIATION | MYCOREMEDIATION | SOIL RESTORATION

| AGROFORESTRY-BASED REMEDIATION | WATER INFILTRATION | INTEGRATED LANDSCAPE MANAGEMENT

MAIN PROBLEMS ADDRESSED

- BIODIVERSITY LOSS
- AIR QUALITY IMPROVEMENT
- CARBON SEQUESTRATION
- FOOD SECURITY

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Soil Formation and Fertility Restoration:** Enhances nutrient cycling and microbial activity, rebuilding soil structure and fertility.

REGULATING

- **Pollution Control:** Removes heavy metals, pesticides, and persistent organic pollutants (POPs) from soils, reducing environmental contamination.

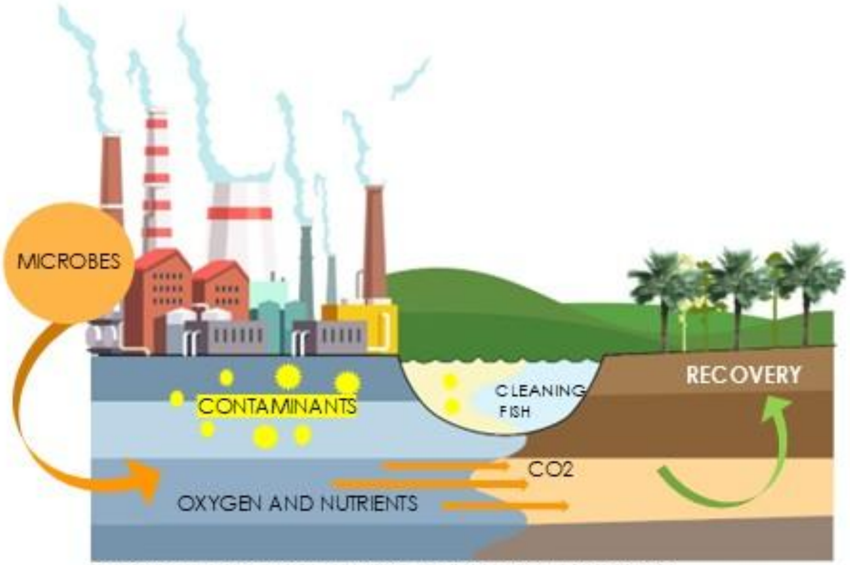
PROVISIONING

- **Sustainable Agricultural Productivity:** Rehabilitated soils enable safe cultivation of crops, ensuring a reliable food supply.

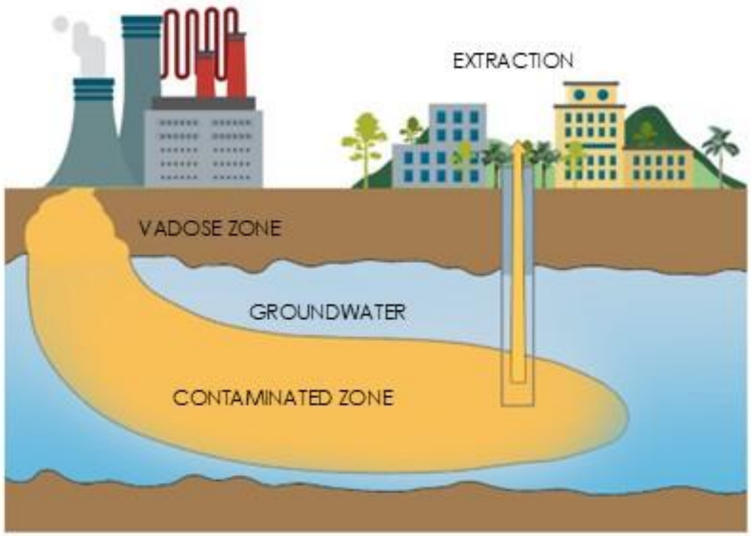
SOCIAL BENEFITS

- **Livelihood Improvement:** Provides opportunities for local communities through eco-friendly soil restoration practices and agricultural recovery.

NbS-56: BIOENGINEERING REMEDIATION OF CONTAMINATED SOILS (BRCS)



BIOENGINEERING REMEDIATION FOR CONTAMINATED SOILS



PROJECT'S CHALLENGES & RISKS

- **High Initial Costs**: BRCS methods require substantial investments in technology, infrastructure, and expertise, which can be a barrier for some regions.
- **Variable Soil Contamination Profiles**: The heterogeneity of soil contaminants across sites makes it challenging to standardize remediation techniques and achieve consistent results.
- **Climatic and Environmental Sensitivity**: Extreme weather events can disrupt bioremediation processes and re-mobilize contaminants.
- **Community Engagement** : Limited understanding of bioengineering solutions among local stakeholders may hinder adoption and long-term maintenance of the restored sites.

NbS co-BENEFITS AND THEIR INDICATORS

- **Improved Soil Health**
  Increase in soil organic matter content by at least 20% post-remediation.
- **Enhanced Biodiversity**
  25% rise in plant and microbial diversity in remediated sites within three years.
- **Carbon Sequestration**
  Annual sequestration of 2–5 metric tons of CO_2 per hectare in rehabilitated soils.
- **Water Quality Improvement**
  Reduction of contaminant leaching into groundwater by over 50% within two years.
- **Increased Agricultural Productivity**
  15–30% yield improvement in crops grown on remediated soils compared to pre-remediation levels.
- **Community Livelihood Support**
  10% increase in local income opportunities through involvement in remediation projects and subsequent land use.

COST ANALYSIS

- **Direct Costs**
  Implementation costs range from \$5k to \$15k/ha, depending on the level of contamination and techniques used.
- **Indirect Costs**
  Monitoring, stakeholder engagement, and opportunity costs are estimated at \$2 to \$5k/ha.
- **Time Horizon**
  5–10 years with a recommended discount rate of 5% to 10% for long-term benefits.
- **Direct Benefits**
  Improved land value and agricultural productivity.
- **Indirect Benefits**
  Ecosystem service enhancements, such as improved water quality and carbon sequestration.
- **Risk Assessment**
  Potential project delays or failure due to site complexity or stakeholder challenges could result in 10–30% cost overruns.

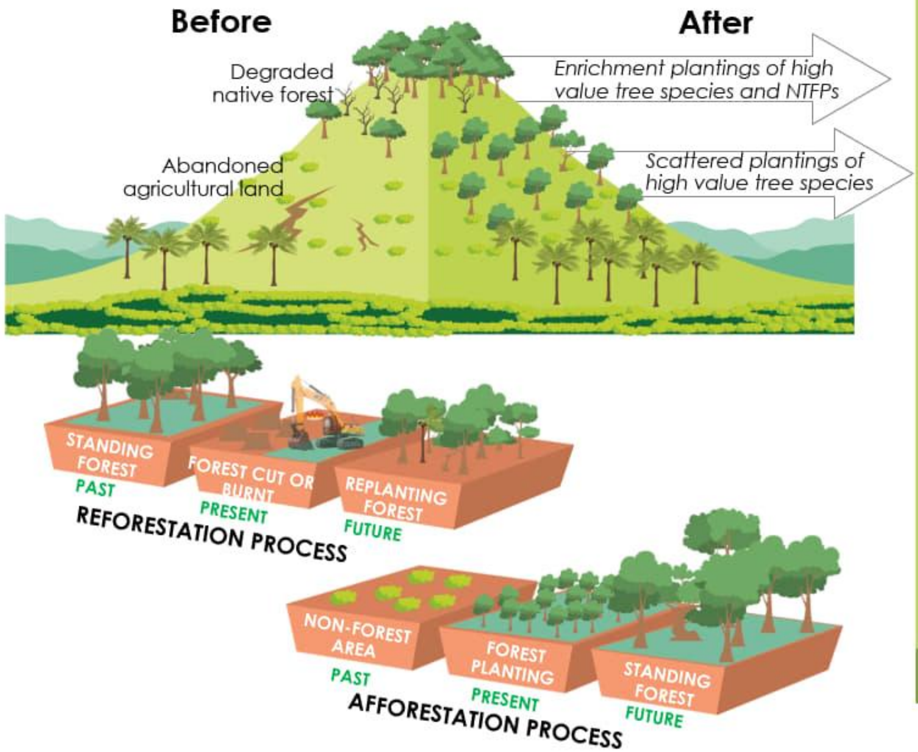
REFERENCES:

India, Jharia Coalfield Phytoremediation Project: Phytoremediation techniques to rehabilitate heavily polluted mining areas using hyperaccumulator plants like vetiver grass and Indian mustard.

IMPLEMENTATION OPPORTUNITIES:

Thailand, Thamaka District: Contaminated rice fields affected by industrial wastewater discharge.
Philippines, Boac River Basin, Marinduque: An area impacted by the Marcopper mining disaster, where heavy metal contamination persists in soils and water bodies.

NbS-57: UPLAND REFORESTATION, AFFORESTATION AND AGROFORESTRY

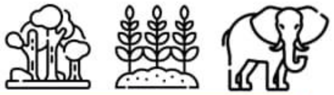


Upland reforestation, afforestation, and agroforestry are vital nature-based solutions (NbS) for addressing reforestation needs in the slopes, valleys, and upland areas of Southeast Asia, where rapid deforestation, land degradation, and extreme weather events threaten ecosystems and local livelihoods. These approaches focus on restoring degraded forests, establishing new forested areas (afforestation), and integrating trees with agricultural practices (agroforestry) to stabilize slopes, reduce soil erosion, mitigate landslides, and enhance water retention.

By blending native species with fruit or timber-yielding trees, agroforestry systems balance biodiversity conservation with sustainable resource use, benefiting local communities economically and ecologically. Reforestation efforts in montane tropical rainforests, dry deciduous forests, and mangroves also enhance carbon sequestration, provide critical wildlife habitats, and regulate hydrological cycles, reducing the risks of floods and sedimentation in valleys.

These NbS approaches foster community engagement, create livelihood opportunities, and restore ecological integrity, making them indispensable for building resilient landscapes and promoting sustainable development in Southeast Asia.

LANDSCAPES SUPPORTED



EbA (ECOSYSTEM-BASED APPROACHES)

| FOREST LANDSCAPE RESTORATION | AGROECOLOGICAL PRACTICES | WATERSHED MANAGEMENT | SUSTAINABLE RESOURCE MANAGEMENT | WILDLIFE HABITAT CREATION | CLIMATE CHANGE MITIGATION

MAIN PROBLEMS ADDRESSED

SOIL EROSION | FLOOD CONTROL | BIODIVERSITY LOSS | DISASTER RISK REDUCTION | CARBON SEQUESTRATION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Soil Formation and Fertility**: Trees improve soil structure, prevent erosion, and enhance nutrient cycling for long-term agricultural productivity.

REGULATING

- **Water Regulation**: Forests stabilize water cycles by reducing runoff, improving infiltration, and maintaining groundwater recharge.
- **Climate Regulation**: Tree cover sequesters carbon, reduces heat islands, and mitigates local and global climate impacts.

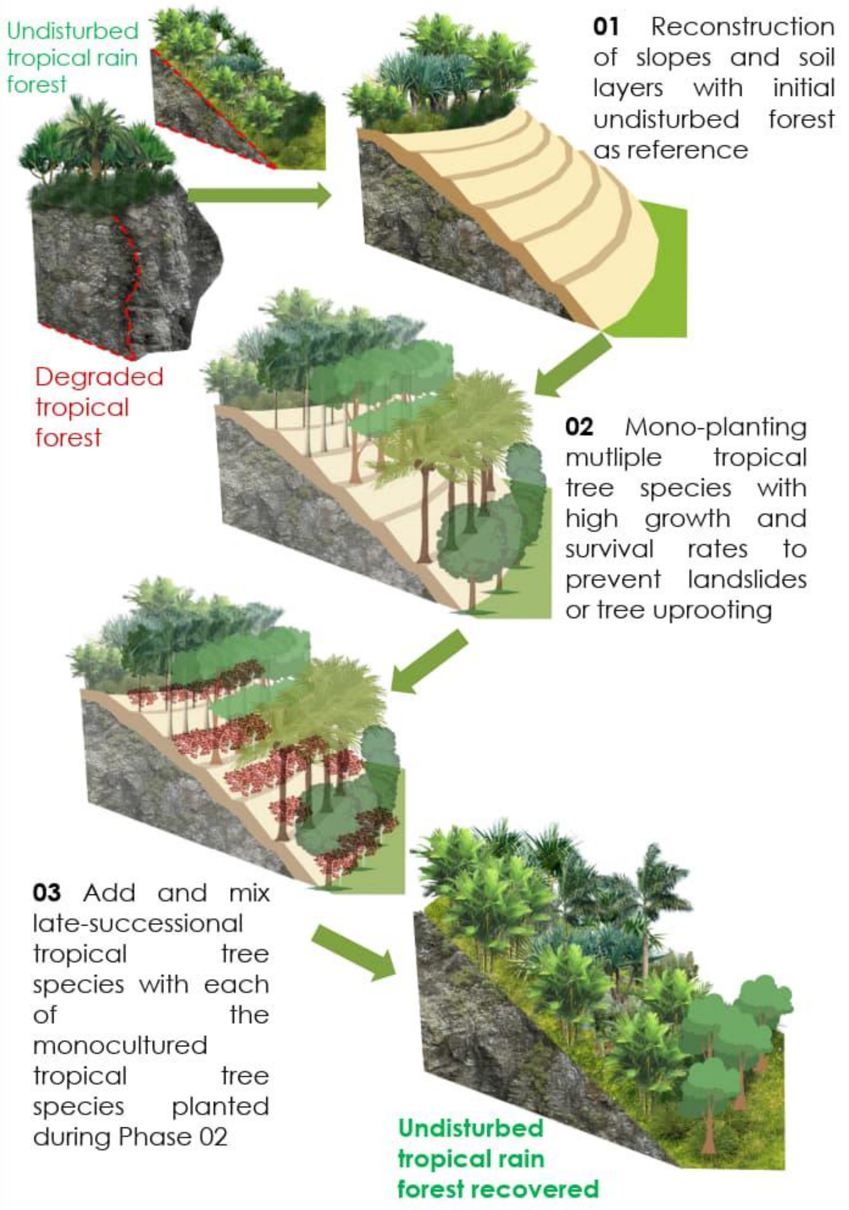
PROVISIONING

- **Timber and Non-Timber Products**: Sustainable harvesting of wood, fruits, and medicinal plants for economic and subsistence use.

SOCIAL BENEFITS

- **Livelihood Enhancement**: Agroforestry systems create diverse income sources for rural communities.
- **Disaster Resilience**: Trees reduce landslide risks and buffer communities from floods, protecting lives and assets.

NbS-57: UPLAND REFORESTATION, AFFORESTATION AND AGROFORESTRY



PROJECT'S CHALLENGES & RISKS

- **Inappropriate Species Selection**: Choosing non-native or poorly adapted species can disrupt local ecosystems and fail to achieve ecological restoration goals.
- **Community Engagement Challenges**: Insufficient involvement of local communities can lead to conflicts over land use and undermine the long-term success of projects.
- **Climate Vulnerability**: Changing climate conditions, such as prolonged droughts or extreme rainfall, can hinder tree survival and growth in upland areas.
- **Land Tenure Issues**: Unclear or disputed land ownership can delay project implementation and create challenges in maintaining reforested or afforested areas.

NbS co-BENEFITS AND THEIR INDICATORS

- **Erosion Control**
  Reduces soil erosion on upland slopes, measurable by a 30–50% decrease in annual sediment loss within reforested areas.
- **Carbon Sequestration**
  Enhances carbon storage, with an estimated 5–10 tons of CO_2 absorbed per hectare annually in mature forests.
- **Water Regulation**
  Improves watershed health, indicated by a 20–40% increase in groundwater recharge and reduced surface runoff during rainy seasons.
- **Biodiversity Conservation**
  Supports wildlife habitats, with a measurable increase of 15–25% in species richness in project areas over 5 years.
- **Livelihood Support**
  Provides sustainable income through agroforestry crops like coffee or spices.
- **Disaster Risk Reduction**
  Mitigates landslide risks, shown by a 60–80% reduction in landslide frequency in reforested regions over a decade.

COST ANALYSIS

- **Direct Costs**
  Average costs of $800–$2,500 per ha, including sapling purchase, labour, and maintenance.
- **Indirect Costs**
  Opportunity costs of land use change and capacity-building activities range from $200–$800 per ha over the project duration.
- **Time Horizon**
  Project benefits over 20–50 years, with a discount rate of 5–7% applied for long-term valuation of ecosystem services.
- **Direct Benefits**
  Carbon credits and agroforestry yields generate $300–$1,000 annually per hectare after 5–7 years.
- **Indirect Benefits**
  Ecosystem service improvements, such as reduced disaster recovery costs and water regulation.
- **Risk Assessment**
  Implementation risks are estimated at a 10–20% loss of investment.

REFERENCES:

Indonesia, Harapan Rainforest Project (100,000 ha.
Philippines Upland Reforestation Initiative, Northern Luzon.
Thailand, Chiang Mai Highland Reforestation Project.

IMPLEMENTATION OPPORTUNITIES:

Vietnam, Central Highlands.
Indonesia, Dry zones of Timor-Leste and West Timor.
Mekong River Basin.

NbS-58: FOREST FIRE MANAGEMENT

Preventive forest fire and post-fire management as a Nature-based Solution (NbS) aims to integrate technical, landscape, and community-driven approaches to reduce fire risks, restore ecosystems, and enhance resilience to climate change.

Techniques include the establishment of firebreaks using native vegetation, controlled burning to reduce fuel loads, and the use of soil moisture-enhancing measures, such as rewetting degraded peatlands to prevent ignition. Socially, engaging local communities through participatory fire monitoring, traditional fire knowledge, and alternative livelihood programs reduces slash-and-burn practices.

Contextually, such strategies are vital for fire-prone regions like Indonesia's peatlands and Myanmar's dry forests, where forest fires exacerbate biodiversity loss and greenhouse gas emissions. Economically, preventive fire management reduces disaster response costs and enhances ecosystem services like carbon sequestration, water regulation, and agroforestry productivity, while post-fire actions focus on soil stabilization, reforestation with fire-resistant species, and biodiversity recovery. By addressing both mitigation and adaptation, forest fire management as an NbS contributes to sustainable landscapes, improved livelihoods, and long-term climate resilience in the region.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| FIRE-RESILIENT ECOSYSTEM RESTORATION | AGROFORESTRY PRACTICES | LANDSCAPE CONNECTIVITY | COMMUNITY-BASED FIRE MONITORING | SUSTAINABLE WATERSHED MANAGEMENT

MAIN PROBLEMS ADDRESSED

SOIL EROSION

BIODIVERSITY LOSS

DISASTER RISK REDUCTION

CARBON SEQUESTRATION

AIR QUALITY IMPROVEMENT

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Biodiversity support:** Enhancing habitat quality and connectivity by restoring fire-damaged ecosystems with native species.

REGULATING

- **Carbon sequestration:** Preventing forest fires reduces GHG, while post-fire reforestation captures carbon over time.
- **Microclimate regulation:** Maintaining forest cover stabilizes local temperatures and humidity, reducing the risk of fire-prone conditions.

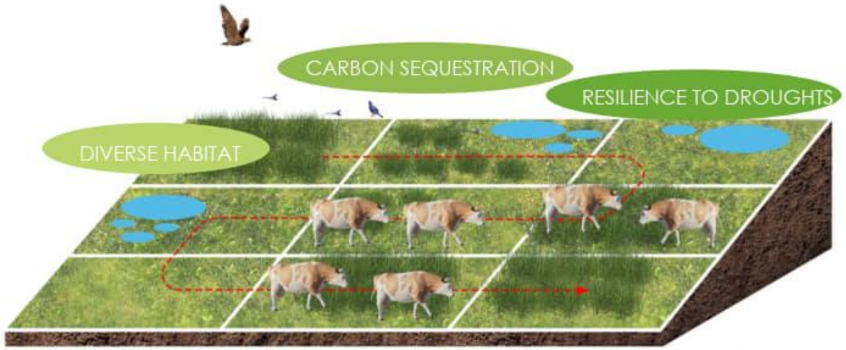
PROVISIONING

- **Sustainable timber and non-timber products:** Promoting fire-resilient forest management ensures long-term availability of forest resources such as wood, resin, and medicinal plants.

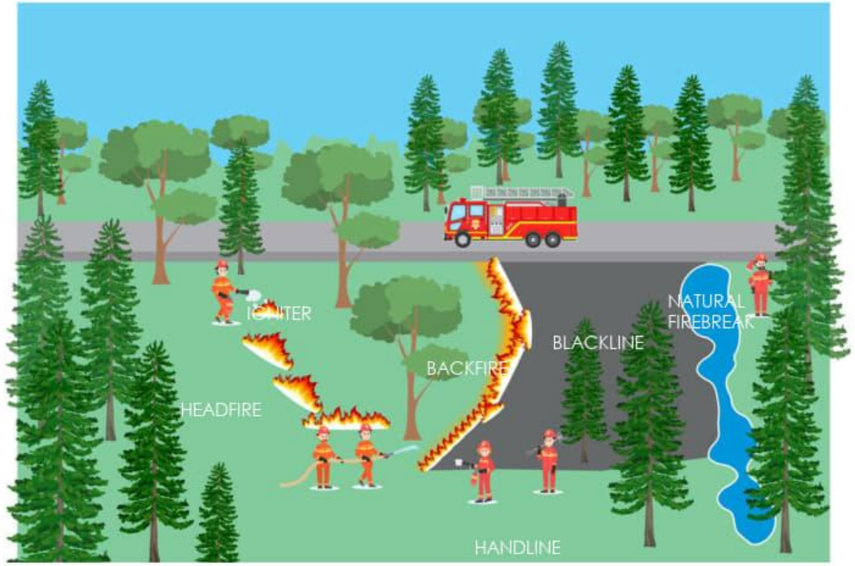
SOCIAL BENEFITS

- **Disaster risk reduction for communities:** Reducing fire incidents protects livelihoods, settlements, and agricultural lands from destruction.

NbS-58: FOREST FIRE MANAGEMENT



Regenerative grazing : Cattle graze in one area and move on to the next for full regrowth.



Controlled burn : Burn managers try to find a natural firebreak (creek) from which they set a down wind backfire. This creates the blackline (buffer zone) at which the spot headfires will stop. Crew members patrol a handline to contain the burn.

PROJECT'S CHALLENGES & RISKS

- **Limited Community Capacity**: Many local communities lack the training and resources for effective fire prevention, monitoring, and management.
- **Illegal Land Clearing Practices**: Unregulated slash-and-burn agriculture often undermines fire management efforts and increases fire risks.
- **Climate Variability**: Prolonged droughts and extreme weather events intensify fire risks and challenge long-term management strategies.
- **Cross-Border Fire Spread**: Transboundary haze pollution from uncontrolled fires in neighbouring regions complicates coordinated fire management efforts across Southeast Asia.

NbS co-BENEFITS AND THEIR INDICATORS

Biodiversity Conservation
Reduced fire incidences help protect habitats for endangered species, measured by stable or increasing wildlife populations.

Carbon Sequestration
Lower fire activity maintains forest carbon stocks, indicated by reduced carbon emissions in affected areas.

Improved Air Quality
Effective fire control reduces haze and particulate matter, reflected in lower PM2.5 levels in regional air quality indices.

Enhanced Water Regulation
Forests preserved from fires improve watershed health, measured by stable water flow and reduced sedimentation in rivers.

Community Livelihoods
Reduced fire damage protects agroforestry and forest-based economies, indicated by stable income levels for forest-dependent communities.

Disaster Risk Reduction
Fire management lowers risks of soil erosion and land degradation, measured by reduced post-fire landslide occurrences.

COST ANALYSIS

Direct Costs
Implementation costs include equipment, personnel, and training, typically ranging from \$150–\$500/ha/year

Indirect Costs
Opportunity costs of restricted land use or reduced logging can range from \$50–\$200/ha.

Time Horizon
Long-term benefits accrue over 10–20 years, with a discount rate of 5–8%

Direct Benefits
Avoided losses in timber, biodiversity, and ecosystem services

Indirect Benefits
Improved air quality and public health

Risk Assessment
Potential risks include funding gaps and community non-compliance

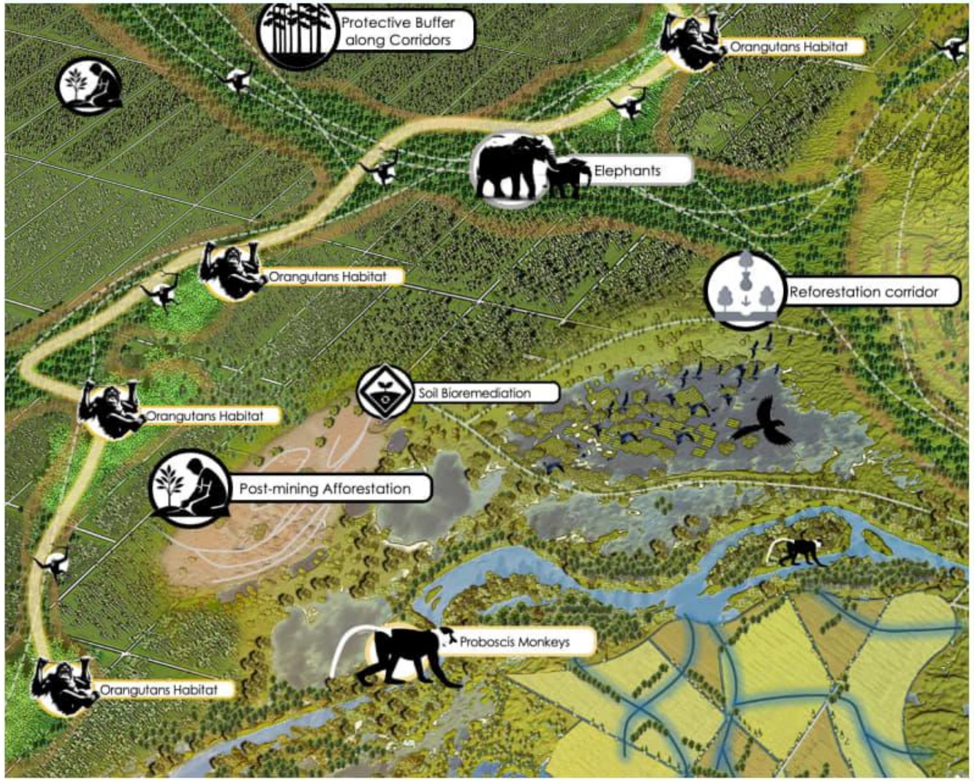
REFERENCES:

The Heart of Borneo Initiative, forest management through community engagement and creating firebreaks, **Indonesia.**
Peatland Restoration Project, Sarawak, **Malaysia**
Forest Fire Prevention and Control Program, Northern **Thailand**

IMPLEMENTATION OPPORTUNITIES:

Sumatra and Kalimantan forests, **Indonesia**
Chiang Mai Province, **Thailand**
Central HighVlands, **ietnam**

NbS-59: WILDLIFE MOBILITY LINKAGES



Wildlife mobility corridors serve as nature-based solutions (NbS) that ensure the safe passage and survival of migrating animal species in Southeast Asia, e.g. elephants, tigers, gibbons, proboscis monkeys, orangutans, birds, pollinators, small mammals, and insects, whose habitats are fragmented by roads, railways, mining, agriculture, and urbanization.

These corridors integrate forested pathways, restored landscapes, and green infrastructure like wildlife overpasses, underpasses, and canopy bridges tailored to the needs of various species. Technological innovations such as GPS tracking, camera traps, and bioacoustic monitoring enable the identification and protection of key movement routes.

Synergies between insects and mammals, like pollinators guiding animals to food-rich habitats, are leveraged to enhance ecosystem connectivity. By blending ecological restoration with sustainable land use planning, wildlife corridors maintain biodiversity, prevent human-wildlife conflict, and secure critical habitats, ensuring that species can migrate, forage, and reproduce while adapting to environmental changes. Successful examples include the Kinabatangan Wildlife Corridor in Malaysia and the wildlife-friendly design of railway projects in Thailand, showcasing how technology and nature can harmonize for conservation.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOSYSTEM RESTORATION
- BIODIVERSITY CONSERVATION
- CLIMATE CHANGE MITIGATION
- SUSTAINABLE LIVELIHOODS
- WATER & SOIL REGULATION

MAIN PROBLEMS ADDRESSED

- SOIL EROSION
- FLOOD CONTROL
- DISASTER RISK REDUCTION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Soil health improvement**: Facilitates nutrient cycling and soil aeration through enhanced water infiltration.

REGULATING

- **Flood mitigation**: Reduces stormwater runoff and prevents urban flooding by increasing water infiltration.
- **Urban cooling**: Lowers ambient temperatures by reducing heat island effects through greenery and water retention.

PROVISIONING

- **Groundwater recharge**: Replenishes local aquifers by allowing rainwater to percolate into the ground.

SOCIAL BENEFITS

- **Improved walkability and livability**: Enhances urban aesthetics and encourages pedestrian-friendly environments.
- **Disaster resilience**: Builds community resilience against climate impacts like floods and heatwaves.

NbS-59: WILDLIFE MOBILITY LINKAGES

Mobility patterns of male orangutans in corridors passing across oil palm cultures

Overpasses for gibons (India, Thailand)

PROJECT'S CHALLENGES & RISKS

- **Initial Costs and Maintenance:** Establishing rainforestation sites can be costly due to the need for native seedlings, technical training, and labour for site preparation.
- **Timeframe for Benefits:** Unlike fast-growing monocultures, native trees take longer to grow and produce economic returns, which may deter smallholder farmers who need short-term income.
- **Complexity of Implementation:** Successful implementation requires expertise in native species selection, site-specific ecosystem restoration, and sustainable farming practices.
- **Competition for Land:** Competition with other land uses like monoculture plantations or housing, especially in areas with high population pressure.

NbS co-BENEFITS AND THEIR INDICATORS

Biodiversity Restoration
Increase in native tree species richness per hectare by 50%-70% within 5 years.

Soil stabilisation and erosion control
Reduction in soil erosion rates by up to 60% on reforested slopes within 3 years.

Carbon Sequestration
Annual sequestration of 5-10 tons of CO_2 equivalent per hectare in mixed agroforestry systems.

- **Food Security Enhancement**
  Annual yield of agroforestry crops (e.g., coffee, cacao, or root crops) contributing to 20%-30% of household income within 3 years.
- **Improved Watershed Protection**
  Reduction in peak runoff volume by up to 40% during heavy rains, improving downstream water quality.
- **Community Resilience and Livelihood Support**
  30%-50% increase in income diversification among participating households due to tree products and agroforestry crops.

COST ANALYSIS

- **Direct Costs**
  Establishment costs of $1,500–$3,000 per hectare, including planting materials, labour, and training.
- **Indirect Costs**
  $500–$1,000/ha annually for maintenance, monitoring, and opportunity costs of initial land-use changes.
- **Time Horizon**
  20–30 years with a discount rate of 5%–7%, considering long-term ecological and livelihood benefits.
- **Direct Benefits**
  $2,000–$4,000 per hectare annually from agroforestry yields like fruits, timber, and crops after 3–5 years.
- **Indirect Benefits**
  Ecosystem services valued at $5,000–$7,000/ha annually, including carbon sequestration, water regulation, and biodiversity conservation.
- **Risk Assessment**
  Medium risk due to potential challenges like invasive species, market access, and community buy-in.

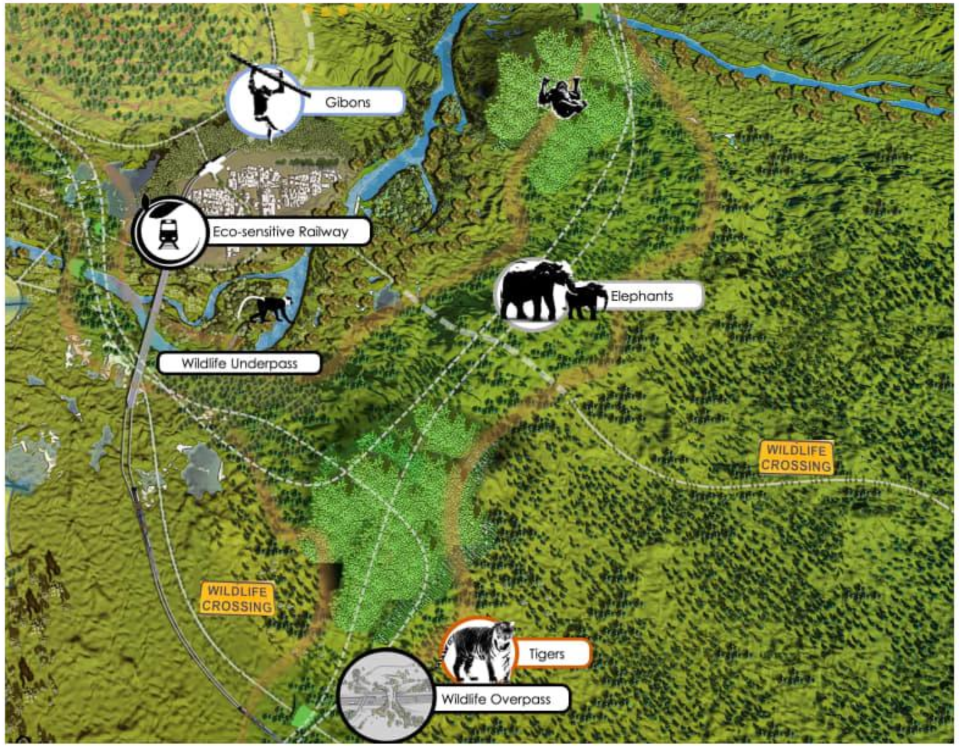
REFERENCES:

Mount Pangasugan, Leyte Rainforestation Initiative, the Philippines
Gunung Kidul Regency Forest Landscape Restoration, Java, Indonesia
Mae Chaem Watershed Agroforestry, Thailand

IMPLEMENTATION OPPORTUNITIES:

Timor Leste: Maubisse Highlands
Hilly areas of Quang Nam Province, Vietnam
Cardamom Mountains in Cambodia: agroforestry crops like durian and rambutan

NbS-60: ECOLOGICAL BRIDGES AND UNDERPASSES



Ecological bridges and underpasses help address the fragmentation of habitats caused by roads, railways, canals, and urban areas, which hinder the mobility of wildlife species such as tigers, elephants, orangutans, and gibbons. These green infrastructures facilitate safe wildlife movement across human-made barriers, ensuring connectivity between critical habitats, reducing roadkill incidents, and supporting the survival of endangered species.

Ecological bridges, often elevated or with green vegetation, allow animals to cross above roads, while underpasses or tunnels provide safe passage beneath highways and railways, ensuring uninterrupted movement for a variety of species. These solutions are crucial in regions where rapid urbanization and infrastructure development threaten biodiversity.

The primary function of ecological bridges and underpasses is to restore habitat connectivity, enabling wildlife to access food, breeding, and migration routes. These structures enhance biodiversity conservation, mitigate human-wildlife conflicts, and support ecosystem health by promoting genetic diversity through safe species movement. Additionally, they provide social and economic benefits by improving wildlife conservation, which boosts ecotourism and local livelihoods, while reducing the costs associated with road accidents involving animals.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

ECOSYSTEM CONNECTIVITY | WILDLIFE CONSERVATION | HABITAT RESTORATION

BIODIVERSITY ENHANCEMENT | ECOSYSTEM HEALTH | HUMAN-WILDLIFE CONFLICT MITIGATION

MAIN PROBLEMS ADDRESSED

BIODIVERSITY LOSS

AIR QUALITY IMPROVEMENT

CARBON SEQUESTRATION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Habitat connectivity:** Facilitate safe passage for wildlife across fragmented landscapes.
- **Biodiversity preservation** by enabling migration and genetic exchange.

REGULATING

- **Mitigating roadkill** by preventing animals from crossing roads and highways.
- **Climate resilience**: Help maintain the movement of species necessary for adapting to changing climate conditions and ecosystems.

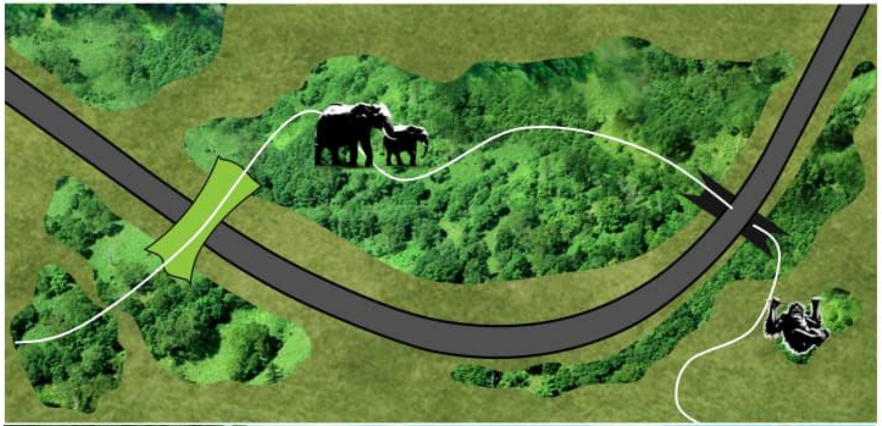
PROVISIONING

- By **maintaining habitat connectivity**, they ensure the continued availability of ecosystem services like pollination and seed dispersal.
- **Access to resources** and breeding areas without crossing dangerous human-made barriers.

SOCIAL BENEFITS

- **Reduced human-wildlife conflict**: Lower the risks to human life
- **Ecotourism opportunities:** Promote wildlife viewing and education by highlighting successful conservation efforts.

NbS-60: ECOLOGICAL BRIDGES AND UNDERPASSES



PROJECT'S CHALLENGES & RISKS

- **High construction costs**: Significant investment required in infrastructure and design tailored to local wildlife needs.
- **Maintenance challenges**: Regular upkeep and monitoring of these structures can be resource-intensive, particularly in remote or forested areas with limited access.
- **Limited effectiveness in highly urbanized** or fragmented environments: ecological bridges and underpasses may not be as effective in connecting wildlife habitats.
- **Risk of insufficient public and political support**: Securing long-term funding and policy commitment for the construction and operation of these structures can be difficult without support from governments.

NbS co-BENEFITS AND THEIR INDICATORS

- **Biodiversity Enhancement**
Monitoring animal movement and population recovery in areas adjacent to ecological bridges.
- **Reduced Wildlife Mortality**
A reduction in reported wildlife roadkill incidents along connected corridors.
- **Habitat Restoration**
Improvement in vegetation cover and species diversity in restored areas around the bridges.
- **Climate Resilience**
Increased resilience of wildlife populations to climate-induced habitat shifts.
- **Cultural and Ecological Awareness**
Community engagement programs and increased local participation in wildlife monitoring and conservation activities.
- **Eco-tourism**
Growth in wildlife tourism and eco-tourism activities in regions with ecological bridge projects.

COST ANALYSIS

- **Direct Costs**
Construction, materials, and labour usually range from \$500k to \$5M per structure.
- **Indirect Costs**
Land acquisition, environmental assessments, and regulatory compliance costs could add 10-20% to the total project budget.
- **Time Horizon**
Typically 30-50 years, with a discount rate of around 3-5% to account for long-term maintenance and benefits.
- **Direct Benefits**
Reduced wildlife mortality and enhanced connectivity, generate savings due to fewer roadkill incidents and improved ecosystem services.
- **Indirect Benefits**
Ecological bridges can significantly increase tourism revenue.
- **Risk Assessment**
Risks include potential delays due to regulatory approvals, unforeseen environmental impacts, or construction challenges.

REFERENCES:

Malaysia, Sunda Pangolin Ecological Bridge (Taman Negara National Park): Connecting fragmented habitats for endangered species.
India, Kerala, The Elephant Crossing, Western Ghats.

IMPLEMENTATION OPPORTUNITIES:

Thailand, Khao Yai National Park.
Indonesia, Taman Nasional Bukit Barisan Selatan (Sumatra).
Cambodia, Cardamom Mountains.

NbS-61: ECO-SENSITIVE RAILWAY INFRASTRUCTURE

Eco-sensitive railway infrastructure is a design approach integrating transportation networks with biodiversity conservation, wildlife mobility, and ecosystem preservation. In Southeast Asia, where railways often cut through biodiverse landscapes, this approach involves designing railway embankments and passages that allow wildlife corridors to remain intact, ensuring safe passage for species such as elephants, tigers, and deer.

Eco-sensitive designs include grassways protecting pollinators, vegetated overpasses, culverts, and tunnel crossings that accommodate both large mammals and smaller fauna like amphibians and reptiles. These features can be combined with native plant species, such as bamboo, mangroves, and grasses, to restore soil composition, enhance carbon sequestration, and improve local biodiversity along the tracks.

Such infrastructure also minimizes soil erosion, reduces flooding by maintaining natural water flow, and stabilizes embankments during heavy rains, enhancing climate resilience.

Beyond ecological benefits, it improves human safety by reducing wildlife-vehicle collisions and supports community livelihoods by preserving the natural resources surrounding railway corridors. Existing lessons from projects in India's Western Ghats and Thailand's Khao Yai National Park highlight the importance of participatory planning with local communities and conservation experts to balance infrastructure development with ecological integrity.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| FLOOD AND WATER FLOW MANAGEMENT | ECOSYSTEM RESTORATION | SOIL STABILISATION

| BIODIVERSITY CONSERVATION | EROSION CONTROL | HUMAN-WILDLIFE CONFLICT MITIGATION

MAIN PROBLEMS ADDRESSED

SOIL EROSION

BIODIVERSITY LOSS

CARBON SEQUESTRATION

DISASTER RISK REDUCTION

FLOOD CONTROL

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Habitat Connectivity**: Maintains wildlife corridors to support species migration and ecosystem functioning.

REGULATING

- **Flood and Climate Regulation**: Maintains natural water flow and reduces flood risks. Sequesters carbon through reforestation and native vegetation along railway corridors.

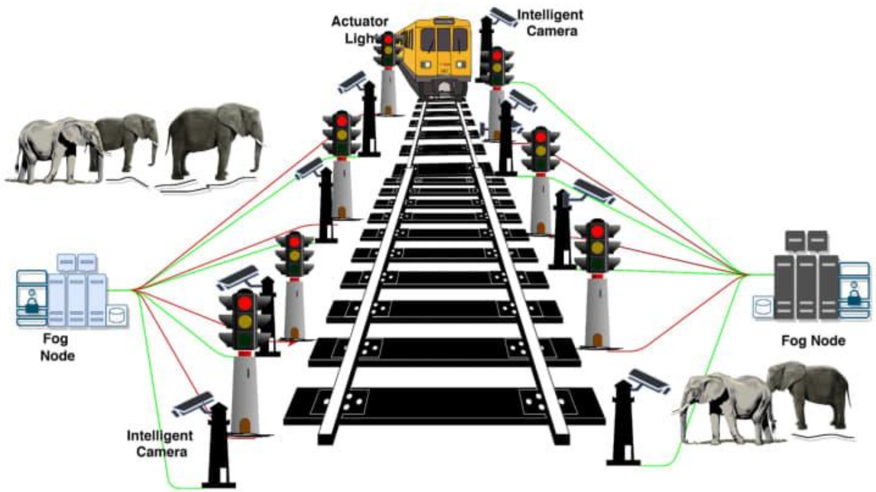
PROVISIONING

- **Biodiversity Resources**: Supports local flora and fauna, providing ecosystems for pollinators, seed dispersers, and other wildlife.

SOCIAL BENEFITS

- **Safety Enhancement**: Reduces wildlife-vehicle collisions, improving safety for both humans and animals.

NbS-61: ECO-SENSITIVE RAILWAY INFRASTRUCTURE



Design and Development of a Fog-Assisted Elephant Corridor over a Railway Track. *Source: Manash Kumar Mondal, Riman Mandal, Sourav Banerjee*

PROJECT'S CHALLENGES & RISKS

- **High Initial Costs**: Significant upfront investment for wildlife crossings, drainage systems, and vegetation restoration, which can strain project budgets.
- **Land Use Conflicts**: Acquiring land for eco-friendly designs, such as wildlife corridors, may face opposition from local communities or compete with agricultural and development needs.
- **Maintenance Complexity**: Ensuring long-term functionality of crossings, culverts requires regular monitoring and maintenance, which can be resource-intensive.
- **Wildlife Adaptation Challenges**: Some species may not immediately use the provided crossings due to poor placement or design choices.

NbS co-BENEFITS AND THEIR INDICATORS

Soil Erosion Control
Reduced soil erosion rates, measured through sediment deposition and soil loss assessments.

Flood Mitigation
Decreased surface runoff, evaluated by water retention capacity and reduced flood frequency in adjacent areas.

Soil Fertility Restoration
Increased organic matter content and nutrient levels in the soil, measured by soil quality tests.

Carbon Sequestration
Amount of carbon stored in vetiver biomass and soil, quantified through carbon sequestration assessments.

Biodiversity Enhancement
Increased species diversity, tracked by monitoring the presence of native flora and fauna in areas integrated with VGS.

Livelihood Improvement
Increase in local income, measured by sales of vetiver-based products or improved agricultural yields.

COST ANALYSIS

Direct Costs
Vetiver grass system establishment costs (e.g., seedlings, planting, irrigation) range from $500 to $2,000 per ha.

Indirect Costs
Costs related to monitoring, maintenance, and capacity building for local communities can amount to $200 to $500 annually per ha.

Time Horizon
10–20 years time horizon with a discount rate of 5–10% to account for long-term benefits and costs.

Direct Benefits
Increased agricultural productivity or reduced erosion.

Indirect Benefits
Indirect benefits, such as carbon sequestration, improved water quality, and biodiversity enhancement, can yield estimated savings or gains of $200 to $1,000 per hectare annually.

Risk Assessment
Risks include initial establishment failure, invasion by non-native species, or underperformance due to poor site selection.

REFERENCES:

Sixiao-Xiaomengyang Expressway, Yunnan, **China**
Dohazari-Cox's Bazar Railway, **Bangladesh**
Northeast Frontier Railway, **India**

IMPLEMENTATION OPPORTUNITIES:

East Coast Rail Link (ECRL), **Malaysia**
Kanchanaburi "Death Railway", **Thailand**
Bukit Barisan Selatan National Park, **Indonesia (Sumatra)**

NbS-62: PHYTOREMEDIATION FOREST CORRIDORS

Phytoremediation forest corridors use plants and trees to remove, stabilize, or degrade contaminants in soil, water, and air, aiding in ecosystem restoration. Hyperaccumulator plants play a key role through processes like phytoextraction (absorbing contaminants), phytostabilization (immobilizing pollutants), phytodegradation (breaking down toxins), and rhizofiltration (filtering water contaminants). Mangrove forests, especially along coastlines and estuaries, are highly effective in trapping sediments, reducing soil toxicity, and enriching landscapes with nutrients.

These corridors not only address pollution but also promote biodiversity, carbon sequestration, and soil health. They provide essential ecosystem services like flood control, coastal protection, and the restoration of degraded lands (e.g., post-mining areas or agricultural soils). Additionally, they enhance local livelihoods by supporting sustainable resource use, making them valuable for both environmental and community resilience.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- POLLUTION CONTROL & REMEDIATOIN
- SOIL & WATER QUALITY IMPROVEMENT
- EROSION & SEDIMENT CONTROL
- BIODIVERSITY CONSERVATION
- CLIMATE RESILIENCE
- COMMUNMITY BASED CO-BENEFITS

MAIN PROBLEMS ADDRESSED

- SOIL EROSION
- BIODIVERSITY LOSS
- FLOOD CONTROL
- DISASTER RISK REDUCTION
- CARBON SEQUESTRATION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Enhance soil formation and microbial activity** by fostering nutrient cycling and organic matter buildup through phytostimulation and litter decomposition.

REGULATING

- **Filter pollutants and improve water quality** through rhizofiltration and phytostabilization, reducing sediment toxicity in wetlands and coastal areas.

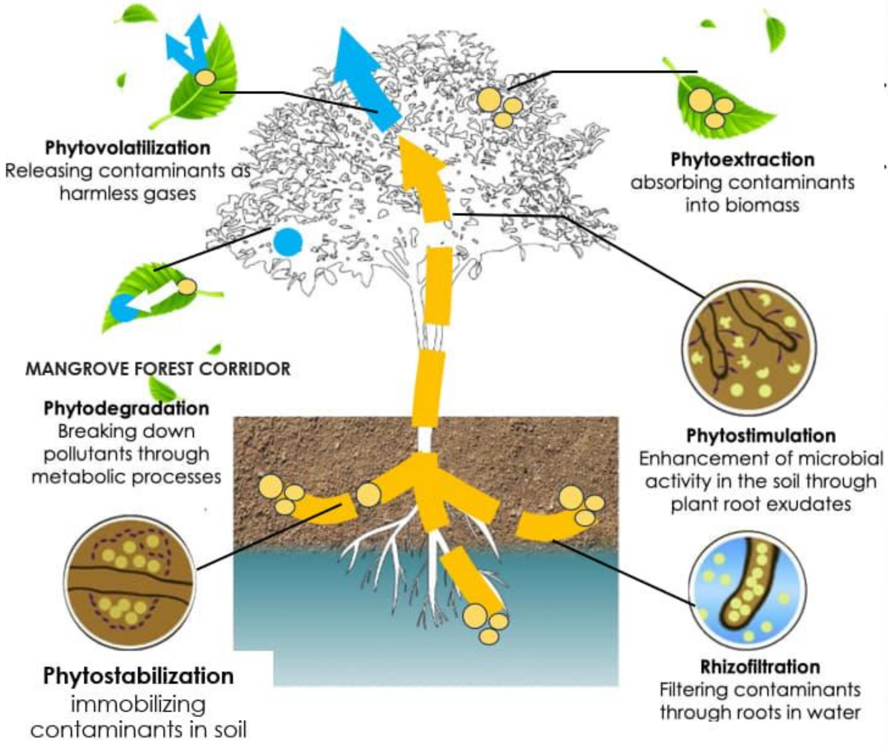
PROVISIONING

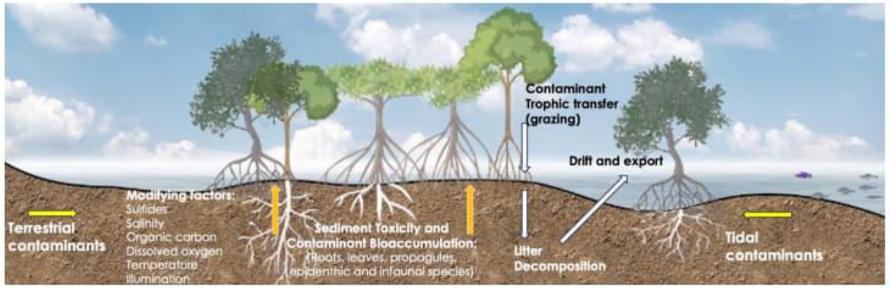
- **Provide biomass resources**, including wood, fodder, and non-timber forest products from phytoremediative vegetation.

SOCIAL BENEFITS

- **Improve community health** by mitigating soil and water contamination and creating green spaces for recreation and cultural value.

NbS-62: PHYTOREMEDIATION FOREST CORRIDORS





PROJECT'S CHALLENGES & RISKS

- **Limited species adaptability**: Selecting the right hyperaccumulator plants for local soil, climate, and pollution conditions.
- **Long-term effectiveness**: Phytoremediation processes, such as phytoextraction and stabilization, often require extended timeframes to significantly reduce contaminants, delaying visible ecosystem benefits.
- **Contaminant re-release risks**: Improper management of harvested biomass from hyperaccumulators can lead to the re-release of toxic elements back into the environment.
- **Socioeconomic conflicts**: Balancing land use for phytoremediation corridors with community needs for agriculture, infrastructure, or resource extraction can cause disputes and hinder project implementation.

NbS co-BENEFITS AND THEIR INDICATORS

Enhanced Soil Health
Phytoextraction reduces toxic heavy metals, indicated by a measurable 20-50% decrease in soil contamination levels over 5 years.

Erosion Control
Stabilized soil reduces sediment loss, indicated by a 30-50% reduction in annual soil erosion rates in treated areas.

Biodiversity Conservation
Restored habitats support native species, indicated by a 15-30% increase in flora and fauna diversity within 3 years.

Carbon Sequestration
Forest corridors absorb atmospheric CO_2, indicated by 5-10 tons of carbon stored per hectare annually.

Improved Water Quality
Rhizofiltration reduces pollutants in runoff, demonstrated by a 30-60% decline in waterborne heavy metals and nitrates near project sites.

Community Livelihood Support
Agroforestry or forest-based products generate income, indicated by a 10-20% increase in household earnings from sustainable forest resources.

COST ANALYSIS

Direct Costs
Establishment costs for phytoremediation species and planting range from $1,500–2,500/ha depending on site conditions.

Indirect Costs
Monitoring, maintenance, and capacity-building programs can cost an additional $500–800/ha/year.

Time Horizon
10–20 years, using a 4–7% discount rate to account for long-term environmental benefits.

Direct Benefits
Saving of $2,000–5,000/ha in future land rehabilitation and clean-up costs.

Indirect Benefits
Enhanced biodiversity, carbon sequestration, and community livelihoods provide ecosystem service values of $5,000–8,000/ha/year.

Risk Assessment
Costs related to potential plant failure, pest outbreaks, or stakeholder disputes are estimated at $200–500/ha/year as contingency planning.

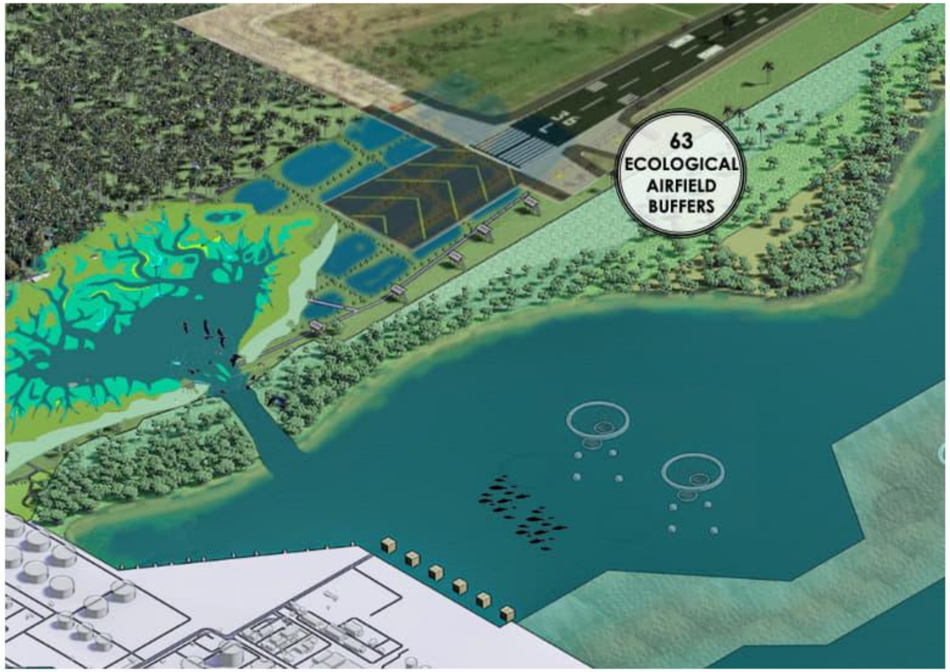
REFERENCES:

Indonesia, East Kalimantan mining sites reclamation using hyperaccumulator plants for nickel, lead, and mercury detoxification.
Philippines, Palawan Forest and Coastal Restoration Phytoremediation corridors.

IMPLEMENTATION OPPORTUNITIES:

Indonesia, Sumatra Palm Oil plantations.
Laos, Bolaven Plateau post-mining region.
Malaysia, Sarawak degraded peatland forests from mining.

NbS-63 ECOLOGICAL AIRFIELD BUFFER, HABITAT ENHANCEMENT & CARBON COMPENSATION SYSTEM



The Ecological Airfield Buffer, Habitat Enhancement, and Carbon Compensation System is a comprehensive NbS concept designed to address critical environmental challenges at airports, including soil restoration, water management, bird safety, and biodiversity conservation, while compensating for the ecological footprint and GHG emissions of airport activities.
This approach integrates phytoremediation zones to restore and depollute airport grounds, biofiltration wetlands for stormwater management and pollutant filtration, and vegetated buffers to provide habitat connectivity while minimizing bird strikes near runways. The creation of ecological habitat islands and reforestation zones nearby compensates for habitat loss and sequesters carbon, aligning with regional climate goals. Technically, the system employs solutions like biochar, native plantings, and gabion walls for resilience, while landscape strategies focus on integrating green corridors and multifunctional spaces that enhance biodiversity and serve as carbon sinks. This NbS fosters resilience to climate challenges such as monsoons and heatwaves, ensuring airports operate safely and sustainably while reducing impacts on the broader ecological health of Southeast Asia's urban and peri-urban landscapes.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| ECOSYSTEM RESTORATION | ECOSYSTEM-BASED DISASTER RISK REDUCTION
| ECOLOGICAL ENGINEERING | HABITAT CONNECTIVITY | WILDLIFE-FRIENDLY DESIGN

MAIN PROBLEMS ADDRESSED

BIODIVERSITY LOSS
FLOOD CONTROL
URBAN HEAT ISLAND
CARBON SEQUESTRATION
AIR QUALITY IMPROVEMENT

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Provides habitat islands and connectivity corridors to support local flora and fauna.
- Restores degraded soils through biochar application and native vegetation.

PROVISIONING

- Vegetated buffers and green infrastructure enhance water storage and availability.
- Planting fast-growing species for agroforestry can provide biomass or non-timber forest products.

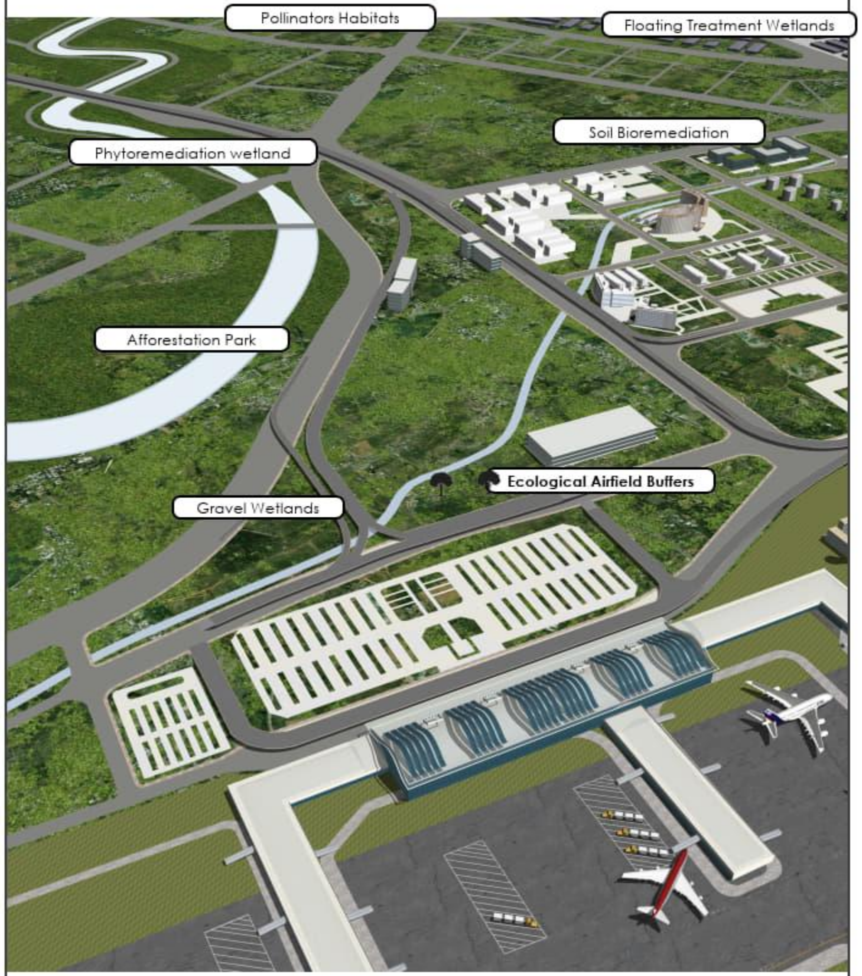
REGULATING

- Wetlands and biofiltration systems remove pollutants from stormwater runoff.
- Forested buffers and agroforestry systems reduce GHG emissions by capturing carbon.

SOCIAL BENEFITS

- Habitat-enhanced areas near airports offer green spaces for local communities and travelers.
- Involves local stakeholders in afforestation, habitat creation, and maintenance projects.

NbS-63 ECOLOGICAL AIRFIELD BUFFER, HABITAT ENHANCEMENT & CARBON COMPENSATION SYSTEM



PROJECT'S CHALLENGES & RISKS

- **Land Use Conflicts**: Limited availability of surrounding land for ecological buffers and compensation systems due to urbanization and competing development priorities.
- **Bird-Aircraft Collisions**: Balancing habitat creation with the risk of attracting birds near flight paths, requiring careful species and site selection.
- **Maintenance Costs**: High financial and technical resources are needed to maintain ecological buffers, wetlands, and vegetation in tropical climates prone to invasive species and rapid plant growth.

NbS co-BENEFITS AND THEIR INDICATORS

GHG Emission Reduction
Reduction in net carbon emissions measured by the amount of CO_2 sequestered annually through vegetation and reforested areas.

Biodiversity Enhancement
Increase in local wildlife populations and species diversity.

Improved Water Quality
Decrease in pollutants such as nitrates and phosphates in runoff, assessed through water quality testing.

Economic Efficiency
Cost savings from reduced stormwater infrastructure needs.

Community Benefits
Increased public access to green spaces and natural areas.

Climate Resilience
Enhanced flood protection and heat mitigation, measured by reduced surface temperatures and improved drainage capacity in and around the airport grounds.

COST ANALYSIS

Direct Costs
Establishment costs for vegetation, wetlands, and habitat creation range between $500k and $1.5 million /100 ha.

Indirect Costs
Long-term maintenance and monitoring costs (ecological surveys, vegetation upkeep), at around $50k–$100k annually per site.

Time Horizon
Investment recouped over a 20–30 year horizon with a 3–5% discount rate.

Direct Benefits
Carbon sequestration valued at $30–$60/ton of CO_2 annually, potentially offsetting $100k–$500k of carbon taxes or credits per airport site.

Indirect Benefits
Flood mitigation, water filtration, recreational spaces provide significant economic benefits.

Risk Assessment
Risk mitigation measures for ecological failure may require significant investments in adaptive management over 5 years.

REFERENCES:

Singapore, Changi Airport : eco-friendly initiatives and ecological buffer zones.
Thailand, Suvarnabhumi Airport: constructed wetlands for wastewater treatment and flood management.
India, Kempegowda International Airport: 250-acre green zone with native plants.

IMPLEMENTATION OPPORTUNITIES:

Philippines, Manila, Ninoy Aquino International Airport.
Indonesia, Bali, Ngurah Rai International Airport.
Rebana Economic Corridor.
Vietnam, Hanoi, Noi Bai International Airport.

NbS-64: ROADSIDE BIOENGINEERING & SLOPE MANAGEMENT

Ecosystem-based roadside bioengineering and slope management address flood control, slope stabilization against landslides, and road infrastructure protection by integrating vegetation, geotextiles, and natural materials into engineered slopes. This approach reduces erosion, enhances soil stability, and mitigates landslide risks in areas prone to cloudbursts and heavy rainfall. It incorporates soil bioengineering techniques such as live staking, vegetative wattles, and green retaining walls, which not only provide structural support but also promote natural water infiltration and reduce surface runoff. For instance, vegetation cover stabilizes slopes while serving as a barrier against sediment flow into water bodies, contributing to improved water quality and reduced downstream flooding risks.
Benefits include cost-effective and sustainable alternatives to hard engineering for managing steep slopes and reducing landslide hazards. Vegetation used in bioengineering enhances soil structure, increases root cohesion, and improves slope drainage. By integrating well with low-impact road design, preserving natural landscapes and reducing construction-related ecological disturbances, it safeguards communities residing in landslide-prone regions, enhances road safety, and creates employment opportunities in planting, maintaining vegetation, and reduces costs of repairs and maintenance compared to traditional retaining walls highlight its value.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

SOIL & SLOPE STABILISATION | INTEGRATED WATER MANAGEMENT | GREEN INFRASTRUCTURE | WILDLIFE CORRIDOR ENHANCEMENT | CLIMATE RESILIENCE | ECOSYSTEM RESTORATION

MAIN PROBLEMS ADDRESSED

SOIL EROSION | DISASTER RISK REDUCTION | FLOOD CONTROL

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Soil formation and stabilization** through vegetative root systems that bind soil, preventing erosion and enhancing slope stability.

REGULATING

- **Mitigation of landslide risks and regulation of water flow** by controlling runoff, reducing sedimentation, and enhancing natural water infiltration.

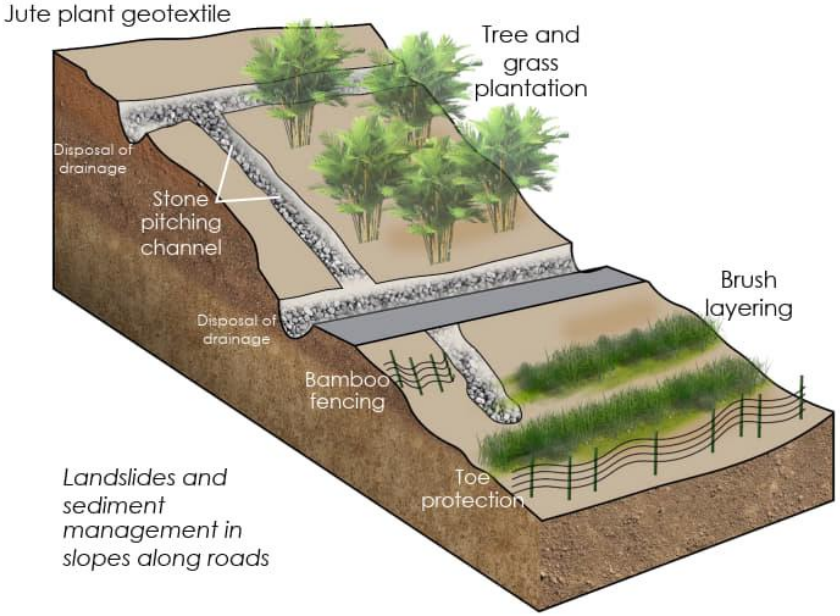
PROVISIONING

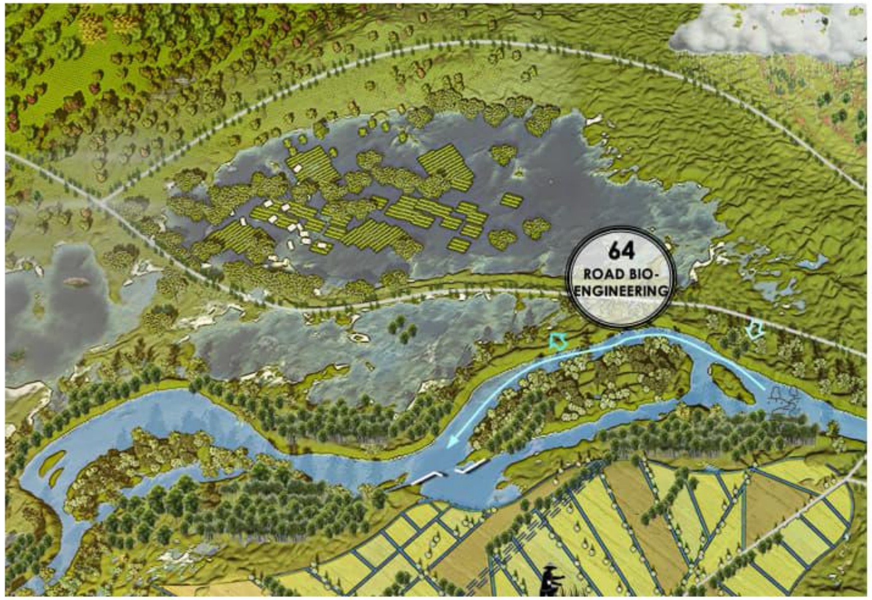
- **Provision of local resources**, such as bamboo and native plants, used for bioengineering, supporting sustainable material sourcing.

SOCIAL BENEFITS

- **Improved road safety and reduced infrastructure maintenance costs**, benefiting local communities and enabling safer access to markets, schools, and healthcare facilities.

NbS-64: ROADSIDE BIOENGINEERING & SLOPE MANAGEMENT





PROJECT'S CHALLENGES & RISKS

- **Limited Plant Suitability**: Identifying native and fast-growing species that thrive in Southeast Asia's diverse climates and soil conditions can be challenging.
- **High Initial Maintenance Needs**: Newly established vegetation requires regular monitoring, irrigation, and protection from pests or grazing to ensure proper growth and slope stabilization.
- **Technical Expertise Gaps**: A lack of trained professionals in bioengineering techniques may lead to improper implementation or failure of stabilization projects.
- **Climate Change Impacts**: Increased frequency of extreme rainfall events may overwhelm bioengineered systems, causing erosion or landslides.

NbS co-BENEFITS AND THEIR INDICATORS

- **Erosion Control**
  Reduction in soil loss rates, measurable through decreased sediment deposition in nearby water bodies.
- **Biodiversity Support**
  Increase in native vegetation cover and habitat availability for local wildlife, tracked by species diversity surveys.
- **Carbon Sequestration**
  Enhanced carbon storage in vegetation and soils, quantifiable through biomass assessments.
- **Water Quality Improvement**
  Decrease in sediment and nutrient runoff into rivers, monitored by water quality testing.
- **Community Livelihood Support**
  Enhanced access to natural resources like fodder and medicinal plants, measured through community resource usage surveys.
- **Cost-effective Road Safety**
  Reduction in road maintenance and landslide repair costs, evaluated through annual infrastructure expenditure reports.

COST ANALYSIS

- **Direct Costs**
  Implementation costs range from \$10k to \$50k/km depending on slope complexity.
- **Indirect Costs**
  Maintenance and monitoring costs around \$1k to \$5k/km/year, covering vegetation upkeep and erosion checks.
- **Time Horizon**
  Typically evaluated over a 20–30 year period with a discount rate of 4–8%.
- **Direct Benefits**
  Prevented road damage and landslide repairs save significant investments in vulnerable site.
- **Indirect Benefits**
  Improved water retention, biodiversity, and community benefits, based on ecosystem services.
- **Risk Assessment**
  Potential failures, such as improper vegetation establishment, could lead to remedial costs to restore slope stability.

REFERENCES:

Nepal, Highway Slope Stabilization.
Philippines, Slope Management along the Pan-Philippine Highway.
Malaysia, Slope Stabilization at Cameron Highlands.

IMPLEMENTATION OPPORTUNITIES:

Vietnam, Ho Chi Minh Road, mountainous area.
Northern Thailand (Chiang Mai to Chiang Rai Roads).
Indonesia, Sumatra Trans Roads.

NbS-65: ELECTRO-WETLANDS

Electrowetlands are a combination of constructed wetlands with bioelectrochemical systems to support energy production, stormwater filtering, water depollution, and regenerative agriculture in Southeast Asia. By harnessing microbial fuel cells, electrowetlands generate electricity from organic waste decomposition while simultaneously removing pollutants like nitrogen, phosphorus, and heavy metals from stormwater and wastewater. These systems enhance agricultural productivity by recycling nutrient-rich treated water for irrigation and reducing chemical input reliance. Technically, they offer efficient pollutant breakdown and renewable energy generation.

Socially and economically, they improve rural livelihoods through decentralized energy access, lower water treatment costs, and enhanced food security. The Bioelectrochemical Wetland System (BEWS) in Kunming, China integrates constructed wetlands with microbial fuel cells to treat wastewater and generate electricity. This system effectively removes over 85% of nitrogen and phosphorus and up to 95% of organic pollutants, while producing electricity (up to 0.5 watts per square meter) through microbial activity. The treated water is reused in agriculture, reducing fertilizer costs and improving water quality, making it a sustainable and low-maintenance solution for water pollution, energy production, and agricultural support, particularly suitable for rural areas in Southeast Asia.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- WATER QUALITY IMPROVEMENT
- ENERGY PRODUCTION
- WASTEWATER TREATMENT
- ECOSYSTEM RESTORATION
- CLIMATE RESILIENCE
- AGRICULTURE SUPPORT

MAIN PROBLEMS ADDRESSED

BIODIVERSITY LOSS

CARBON SEQUESTRATION

FOOD SECURITY

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Enhances habitat for various species by restoring wetland ecosystems.
- Facilitates the cycling of nutrients through electrochemical and microbial processes.

REGULATING

- Improves water quality by removing pollutants from wastewater.
- Mitigate the impacts of water pollution and nutrient overloads in aquatic ecosystems.

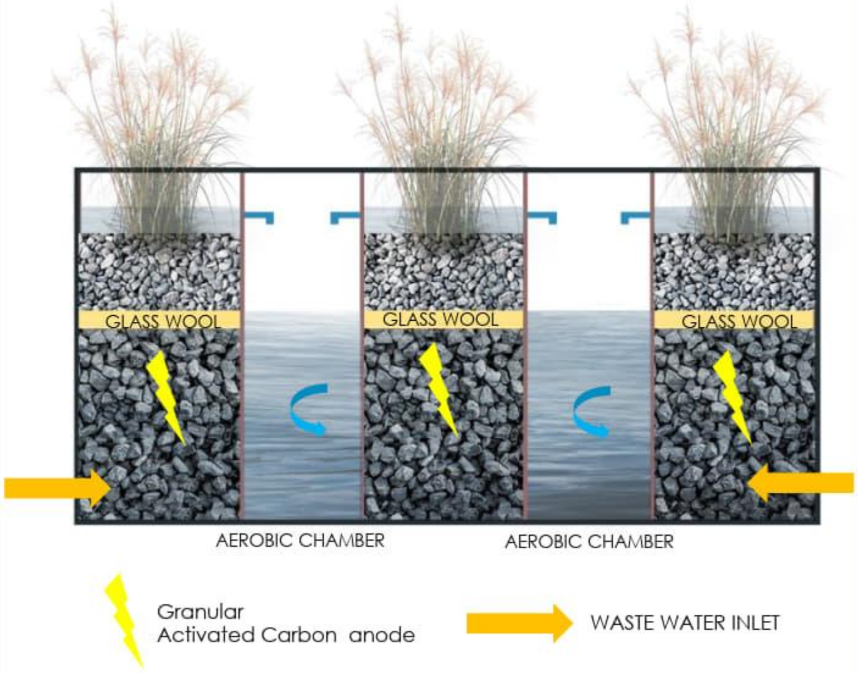
PROVISIONING

- Generates renewable energy through microbial fuel cells, providing sustainable electricity.
- Offers a low-cost, effective way to treat wastewater and recycle it for use in agriculture or other applications.

SOCIAL BENEFITS

- Reduces waterborne diseases by improving water quality in surrounding communities.

NbS-65: ELECTRO-WETLANDS



CONSTRUCTED WETLAND MICROBIAL FUEL CELL SYSTEM
SOURCE : https://doi.org/10.1016/j.cej.2023.141686

PROJECT'S CHALLENGES & RISKS

- **Technical Complexity**: The design and operation of electrowetlands require specialized knowledge and expertise, which may be lacking in some regions.
- **High Initial Costs**: Setting up electrowetlands systems involves significant upfront investment in infrastructure and technology.
- **Limited Scalability**: Due to the high space requirements, it may be challenging to scale electrowetlands for large urban areas.
- **Environmental Sensitivity**: Changes in local environmental conditions (e.g., water temperature, pH levels) can affect the efficiency and stability of electrowetland systems.

NbS co-BENEFITS AND THEIR INDICATORS

Water Quality Improvement
Removing pollutants, with an indicator being reduced levels of nitrogen and phosphorus in treated water.

Carbon Sequestration
The vegetation in electrowetlands helps sequester carbon.

Biodiversity Support
They provide habitat for various species.

Energy Production
Contribute to renewable energy, with an indicator being the amount of electricity generated from the electrochemical process.

Flood Mitigation
By regulating water flow, they can help reduce flooding risks.

Community Health Improvement
By improving water quality and managing wastewater, electrowetlands can reduce waterborne diseases.

COST ANALYSIS

Direct Costs
Setup costs including materials and labor can range from $200k to $500k per hectare.

Indirect Costs
Ongoing maintenance costs, including monitoring, cleaning, and energy, can amount to $10k to $50k/year per site.

Time Horizon
The expected time horizon for electrowetlands to show tangible results is 5 to 10 years.

Direct Benefits
Direct benefits include the reduction of wastewater treatment costs.

Indirect Benefits
Indirect benefits include ecosystem services like improved biodiversity and carbon sequestration.

Risk Assessment
Key risks include the potential failure of the electrochemical process or operational issues, which can result in repair costs.

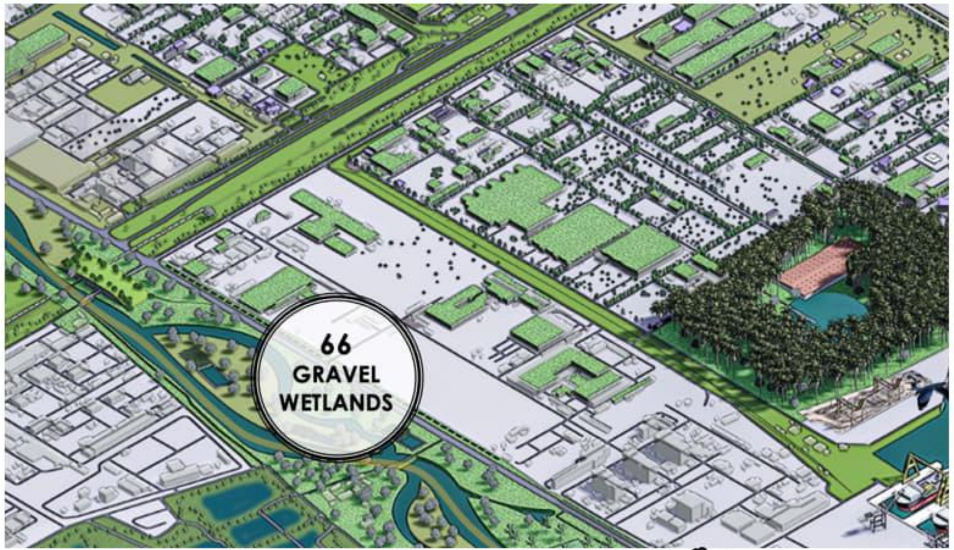
REFERENCES:

China, Kunming, The Bioelectrochemical Wetland System (BEWS) integrates constructed wetlands with microbial fuel cells to treat wastewater and generate electricity.

IMPLEMENTATION OPPORTUNITIES:

Indonesia, Jakarta: Electrowetlands could treat polluted water while providing better water quality.
Vietnam, Ho Chi Minh City: Addressing wastewater management in areas with rapid industrial growth.

NbS-66: GRAVEL WETLANDS



Gravel wetlands are engineered systems designed to mimic the functions of natural wetlands by using gravel substrates, vegetation, and microbial activity to manage stormwater, treat wastewater, and enhance biodiversity. These systems are particularly suited for implementation along roadsides in urban, industrial, and rural areas of Southeast Asia, where rapid urbanization and industrial expansion have increased water pollution and flood risks. Technically, gravel wetlands filter pollutants, trap sediments, and remove nutrients such as nitrogen and phosphorus, making them effective for water quality improvement. They enhance urban and rural aesthetics, create green buffers along roads, and stabilize soils to prevent erosion. Socially, gravel wetlands provide co-benefits such as recreational spaces, educational opportunities, and improved resilience against climate impacts like flooding and heat stress. By combining ecological functionality with landscape and community benefits, gravel wetlands offer a sustainable, low-maintenance solution that supports the region's environmental and social priorities.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

| FLOOD MANAGEMENT | EROSION CONTROL | WATER QUALITY IMPROVEMENT
| BIODIVERSITY CONSERVATION | CLIMATE RESILIENCE | HABITAT CONNECTIVITY

MAIN PROBLEMS ADDRESSED

- BIODIVERSITY LOSS
- SOIL EROSION
- AIR QUALITY IMPROVEMENT
- FLOOD CONTROL

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- **Habitat Creation**: Provide habitats for aquatic and semi-aquatic species, enhancing biodiversity.

REGULATING

- **Water Quality Improvement**: Remove pollutants such as nutrients, sediments, and heavy metals from stormwater and wastewater.

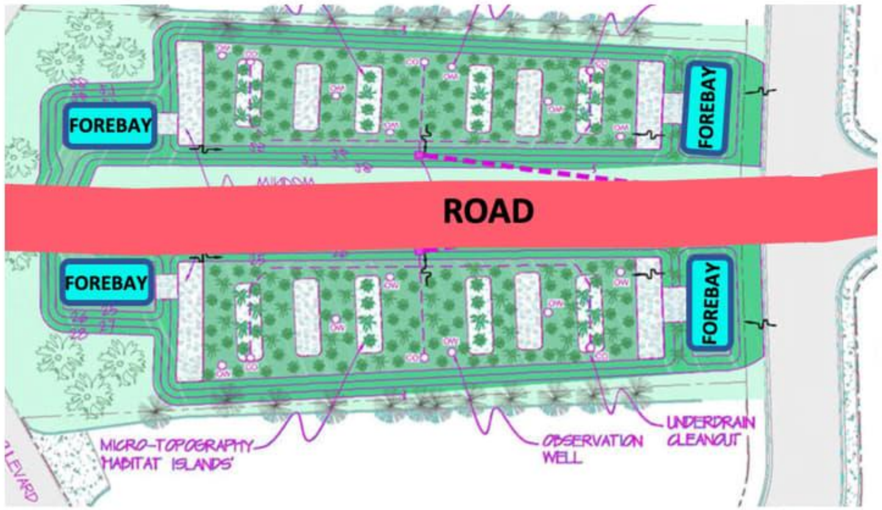
PROVISIONING

- **Water Resource Management**: Store and slowly release treated water for potential reuse in irrigation or other non-potable applications.

SOCIAL BENEFITS

- **Aesthetic and Recreational Value**: Enhance landscapes along roads and offer opportunities for community engagement and education.

NbS-66: GRAVEL WETLANDS



PROJECT'S CHALLENGES & RISKS

- **High Initial Costs**: Gravel wetlands require significant upfront investment, which may be challenging for local governments with limited budgets.
- **Maintenance Needs**: Regular sediment removal, vegetation management, and monitoring are necessary, but lack of funding or technical capacity can hinder long-term functionality.
- **Land Availability**: Securing suitable land in densely populated urban areas or along busy roads can be difficult due to competing land uses.
- **Climatic Extremes**: Heavy rainfall, prolonged droughts, or flooding in Southeast Asia can impact the performance and structural stability of gravel wetlands.

NbS co-BENEFITS AND THEIR INDICATORS

Improved Water Quality
Reduction in nutrient and pollutant concentrations in outflow water.

Flood Risk Mitigation
Volume of stormwater retained and peak flow reduction during heavy rainfall events (m3).

Biodiversity Enhancement
Increase in the number and diversity of aquatic and terrestrial species within the wetland.

Urban Cooling
Measurable reduction in temperature in areas around the gravel wetland compared to grey surfaces.

Aesthetic and Recreational Value
Community satisfaction surveys and increased use of wetland-adjacent spaces for recreational activities.

Erosion Control
Reduction in sediment deposition downstream or along adjacent land areas.

COST ANALYSIS

Direct Costs
Initial construction costs : from $100k to $200k per ha (excavation, gravel, plants, and labor).

Indirect Costs
Annual maintenance costs: from $5k to $10k per ha, covering sediment removal and monitoring.

Time Horizon and Discount Rate
Project life expectancy is around 20–25 years, with a discount rate of 3–7% for cost-benefit analysis.

Direct Benefits
Water treatment savings around $50k to $80k /ha/year, depending on pollutant loads and water quality.

Indirect Benefits
Urban cooling and biodiversity enhancement can provide $10k to $20k/ha/year in non-market benefits.

Risk Assessment
Potential risks (e.g. flooding or structural failure) might incur $5 to $15k per ha for periodic repairs or adaptive measures.

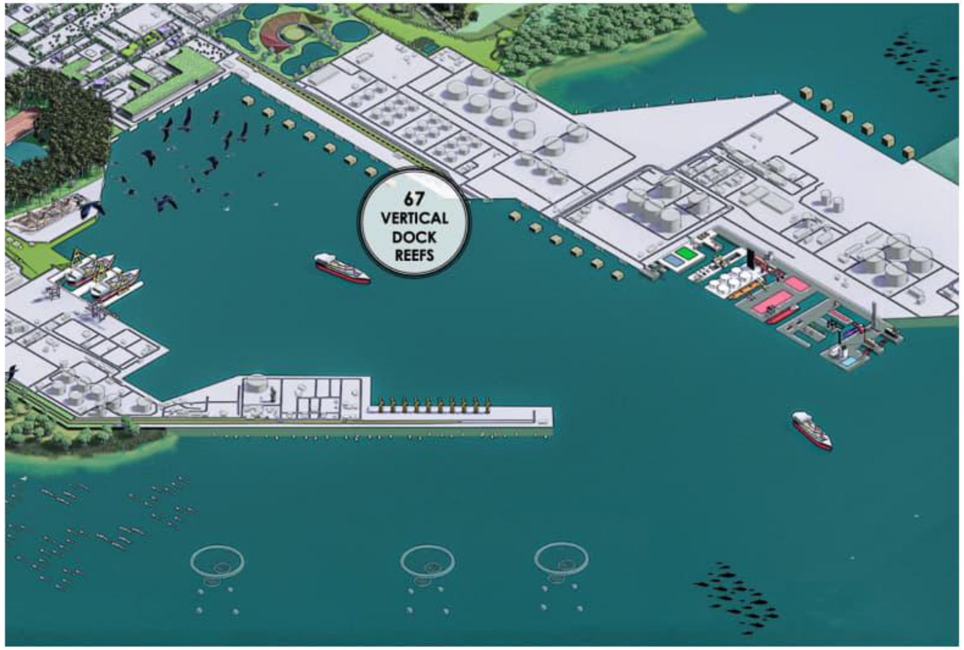
REFERENCES:

Singapore, Changi Airport Gravel Wetland.
Thailand, Bangkok, Suan Luang Rama IX Park.
Malaysia, Johor Bahru,UTM Campus Wetland.
Indonesia, Yogyakarta Urban Wetland Project.

IMPLEMENTATION OPPORTUNITIES:

Indonesia, Jakarta's riverbanks and low-lying urban zones.
Vietnam, HCMC and Hanoi's road corridors and urban green spaces.
Greater Manila agglomeration.

NbS-67 VERTICAL DOCK REEFS



Vertical dock reefs enhance marine biodiversity and ecosystem functions along artificial coastlines, particularly in urbanized and industrial port areas. These structures are typically retrofitted onto vertical seawalls, docks, and other hard, smooth underwater surfaces that provide limited ecological value.

By incorporating eco-engineered materials, such as textured tiles or modular reef structures, vertical dock reefs create habitat complexity that promotes the settlement of marine organisms, such as algae, oysters, and mussels, while offering refuge and nursery areas for small fish, crabs, and other marine species.

The design mimics natural reef ecosystems, improving the ecological function of otherwise artificial and sterile environments.

Vertical dock reefs contribute to sediment stabilization, water filtration, and biodiversity restoration. By enhancing sessile communities of filter feeders, such as mussels and oysters, these structures improve water quality by removing excess nutrients and particles.

They also support fisheries by providing habitats for commercially important species, thus offering economic co-benefits for local communities. Socially, they raise awareness about urban marine conservation and promote sustainable practices in coastal infrastructure.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ECOLOGICAL ENGINEERING
- MARINE HABITAT RESTORATION
- SUSTAINABLE FISHERIES MANAGEMENT
- URBAN MARINE BIODIVERSITY CONSERVATION
- INTEGRATED COASTAL ZONE MANAGEMENT

MAIN PROBLEMS ADDRESSED

BIODIVERSITY LOSS

FLOOD CONTROL

SOIL EROSION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Vertical dock reefs provide essential habitats for marine organisms.
- Promoting diverse marine life by offering new surfaces for colonization, contributing to a more complex ecosystem.

REGULATING

- Through biofiltration by mussels, oysters, and other filter feeders, it improves water clarity and reduce pollutants.
- The structures contribute to stabilizing sediments and protecting shorelines from erosion caused by wave action and storms.

PROVISIONING

- Providing breeding grounds and feeding habitats for various marine species.
- Enhancing aquaculture by creating additional environments for shellfish.

SOCIAL BENEFITS

- Enhancing the resilience of coastal areas to flooding, erosion, and sea-level rise.
- Promoting environmental awareness and eco-tourism by creating visually appealing and biodiverse marine environments.

NbS-67 VERTICAL DOCK REEFS

Eco-engineered Tiles Enhance Marine Biodiversity on Seawalls, Hong Kong.
Source: ADB

Eco-engineered Tiles Affect the Structure of Sessile Communities, Malaysia.
Source: ADB

PROJECT'S CHALLENGES & RISKS

- **Environmental pollution:** High levels of industrial and port-related pollution in Southeast Asia may hinder the establishment of healthy marine ecosystems on vertical dock reefs.
- **Biofouling competition:** Invasive species may outcompete native organisms on vertical dock reefs, disrupting biodiversity and ecosystem stability.
- **Structural degradation:** Harsh marine conditions, such as strong currents and storms, could cause physical damage to the vertical dock reef structures over time.
- **High maintenance costs:** The need for periodic cleaning and repairs to maintain reef functionality can increase operational costs and require long-term investment.

NbS co-BENEFITS AND THEIR INDICATORS

Biodiversity Enhancement
Increase in species richness and abundance, with measurable growth in the populations of fish, mollusks, and other marine organisms.

Water Filtration
Improvement in water quality due to filter-feeding organisms, contributing to reduced sediment and nutrient levels.

Coastal Erosion Control
Reduction in wave energy impacting nearby shorelines, evidenced by decreased erosion.

Carbon Sequestration
Uptake of CO2 by marine organisms like corals and mussels, with measurable reductions in carbon levels in the water.

Economic Opportunities
Boost in local economies through sustainable fisheries and eco-tourism.

Education and Awareness
Increased public and community engagement in marine conservation.

COST ANALYSIS

Direct Costs
The installation of vertical dock reefs can range from USD 50k to 100k/project depending on the scale and location.

Indirect Costs
Monitoring, maintenance, and community outreach can range from USD 10k to 20k/year.

Time Horizon
Project lifespan of 20 years, discount rate of 3%.

Direct Benefits
The direct benefits include biodiversity restoration, with economic returns from fisheries and eco-tourism.

Indirect Benefits
Improvements in water quality and reduced erosion can lead to savings in port maintenance costs and improved local fisheries.

Risk Assessment
Risks include installation failures or environmental conditions that may hinder habitat growth.

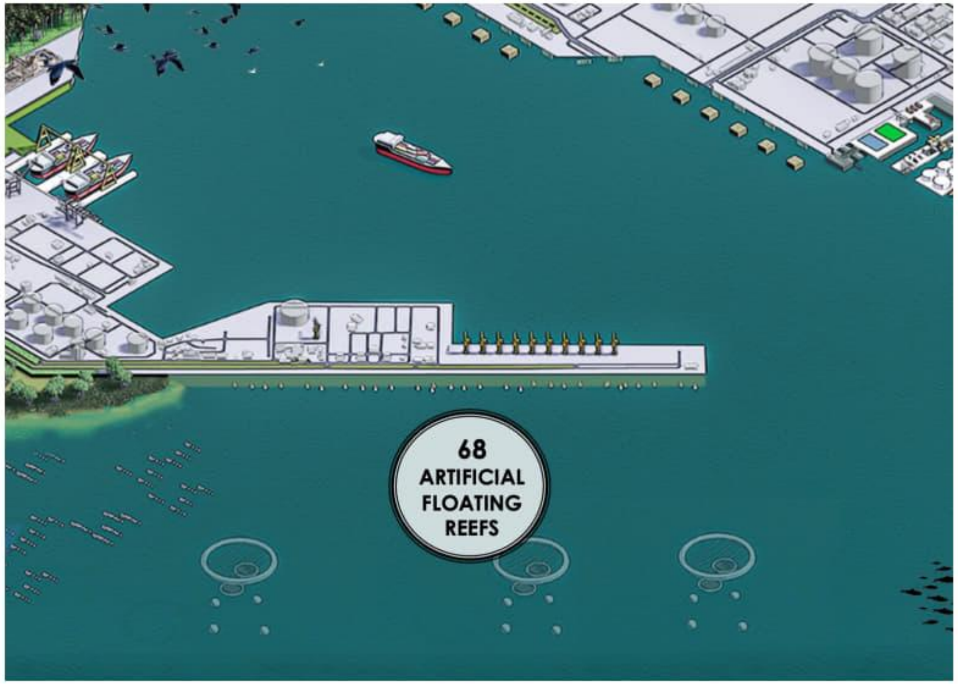
REFERENCES:

Netherlands, Port of Rotterdam Vertical Dock Reefs.
China, Hong Kong's Eco-engineered Seawalls.
Singapore, Marina Bay Floating Wetlands.

IMPLEMENTATION OPPORTUNITIES:

Indonesia, Jakarta Bay, Urban waterfront areas and industrial ports.
Vietnam, Ho Chi Minh City and Haiphong.
Philippines, Ports, Manila Bay.

NbS-68 ARTIFICIAL FLOATING REEFS



Artificial floating reefs and pontoon-based structures are created to enhance marine biodiversity and ecosystem services by providing settling substrates for various organisms, including algae, mussels, sponges, and oysters.

These structures mimic natural reef functions by creating habitat complexity in otherwise smooth and artificial underwater environments, such as port areas, industrial coastlines, and urban waterfronts. By fostering the growth of filter-feeding organisms, floating reefs contribute to water purification, nutrient cycling, and the creation of fish habitats, ultimately supporting marine biodiversity in degraded or highly engineered coastal zones.

In port and coastal industry settings, artificial floating reefs offer multiple benefits. They enhance water quality by reducing suspended particulates and excess nutrients through filter feeders, making them particularly relevant for polluted or eutrophic waters. Additionally, they provide refuge and breeding grounds for fish, improving local fisheries and contributing to ecosystem restoration.

Over time, the accumulation of marine life on these structures can also offer wave attenuation benefits, reducing coastal erosion and improving shoreline resilience. However, challenges such as maintenance, biofouling management, and integration with port operations must be carefully addressed to maximize long-term benefits.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- HABITAT RESTORATION & CREATION
- WATER QUALITY IMPROVEMENT
- COASTAL & MARINE ECOSYSTEM CONNECTIVITY
- CLIMATE ADAPTATION & RESILIENCE
- SUSTAINABLE BLUE ECONOMY

MAIN PROBLEMS ADDRESSED

- BIODIVERSITY LOSS
- FLOOD CONTROL

ECOSYSTEM SERVICES AND ACTIONS

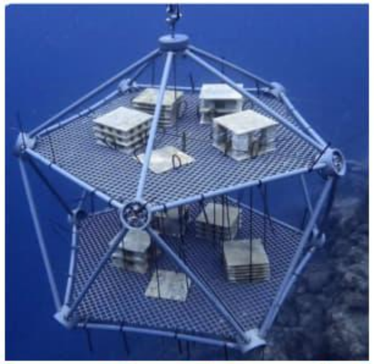
SUPPORTING
- Provide artificial substrates for marine biodiversity, fostering settlement of algae, mussels, oysters, and fish nurseries.

REGULATING
- Improve water quality by promoting filter-feeders (e.g., mussels, oysters, sponges) that remove excess nutrients and pollutants.

PROVISIONING
- Enhance local fisheries by creating habitats that support fish stocks and shellfish populations.

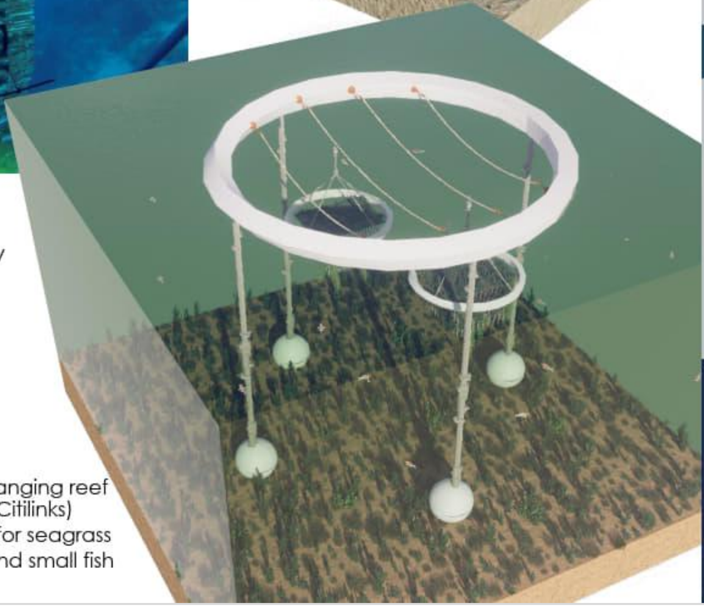
SOCIAL BENEFITS
- Promote eco-tourism and recreational fishing opportunities in urbanized port environments.

NbS-68 ARTIFICIAL FLOATING REEFS



Coral Arks floating reef structures built by Sand Diego University

Floating hanging reef structure designed for oysters and small fish nurseries in port areas



Floating hanging reef structure (Citilinks) designed for seagrass capture and small fish nurseries

PROJECT'S CHALLENGES & RISKS

- **Biofouling and Maintenance:** Excessive accumulation of marine organisms can lead to structural degradation.
- **Water Pollution and Contaminants** – Ports often have high levels of pollutants, which may hinder the growth of beneficial marine species on the reefs.
- **Structural Stability and Storm Resilience:** Floating and hanging reef structures must withstand extreme weather events, strong currents, and typhoons.
- **Stakeholder Conflicts and Navigation Safety:** Balancing ecological benefits with port operations, shipping routes, and industrial activities can create regulatory and spatial planning challenges.

NbS co-BENEFITS AND THEIR INDICATORS

- **Marine Biodiversity Enhancement**
  Increase in fish and invertebrate species observed per square meter of artificial reef surface.
- **Improved Water Quality**
  Reduction in suspended particulate matter and nutrient pollution through filtration by mussels, oysters, and sponges.
- **Wave Attenuation, Coastal Protection**
  Reduction in wave energy by a measurable percentage due to reef structures.
- **Support for Small-scale Fisheries**
  Increased local fish stocks, with higher catch rates reported by nearby fishers.
- **Carbon Sequestration**
  Biomass growth and calcium carbonate deposition contributing to measurable carbon capture in marine sediments.
- **Educational and Recreational Value**
  Number of awareness programs, diving activities, or eco-tourism initiatives linked to the artificial reef sites.

COST ANALYSIS

- **Direct Costs**
  Installation costs range from $50k to $500k/ha, depending on materials, design complexity, and deployment scale.
- **Indirect Costs**
  Monitoring, maintenance, and regulatory compliance can add $5,000 to $20k/year/site.
- **Time Horizon**
  Effective over a 15-30 year lifespan with discount rate of 5-7% for ecosystem service valuation.
- **Direct Benefits**
  Enhanced fisheries productivity and eco-tourism can generate $10k to $100k/year/reef, depending on location and biomass accumulation..
- **Indirect Benefits**
  Improved water quality, shoreline protection, and carbon sequestration
- **Risk Assessment**
  Risks include biofouling, structural degradation, and storm damage

REFERENCES:

ECOCEAN's Biohut Reef system consists of artificial reef modules suspended from docks and piers to act as nurseries for marine life, **France and Asia.**
Floating Reef Balls Project **(Florida, USA & Thailand)**

IMPLEMENTATION OPPORTUNITIES:

Port of **Singapore**
Manila Bay, **Philippines**
Jakarta Bay, **Indonesia**
Chonburi & Rayong Ports, **Thailand**
Tanjung Priok Port, **Indonesia**

NbS-69 MARINE SEDIMENTATION BASINS FOR BIOTURBATION

Marine Sedimentation Basins for Bioturbation play a crucial role in enhancing ecosystem health by promoting and supporting bioturbation, the process of sediment mixing and redistribution by benthic organisms. These basins are strategically located to create low-energy environments where fine sediments accumulate, fostering the settlement of burrowing organisms such as worms, mollusks, crustaceans, and certain fish species. By stabilizing the substrate and preventing erosion, these basins create conditions suitable for the colonization of bioturbators, facilitating habitat restoration and long-term stability.

As organisms burrow and move through sediment layers, they introduce oxygen from the water column into deeper layers, enhancing nutrient recycling and increasing the availability of critical nutrients like nitrogen and phosphorus. This process supports primary productivity in surrounding ecosystems and promotes biodiversity by providing sheltered, food-rich habitats for benthic fauna. In addition, bioturbation helps reduce the build-up of toxic compounds such as hydrogen sulfide, contributing to the detoxification and improvement of sediment quality. Furthermore, as these organisms feed and burrow, they redistribute sediment particles, which enhances sediment porosity and permeability, improving sediment-water interactions and overall ecosystem health.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- SEDIMENT MANAGEMENT
- HABITAT RESTORATION AND PROTECTION
- NUTRIENT CYCLING
- BIODIVERSITY ENHANCEMENT
- WATER QUALITY ENHANCEMENT

MAIN PROBLEMS ADDRESSED

- BIODIVERSITY LOSS
- FLOOD CONTROL

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Provides a stable habitat for benthic organisms, fostering species diversity and promoting ecological balance.

REGULATING

- Traps fine sediments and prevents erosion, helping to stabilize the substrate and reduce sedimentation.
- Facilitates the breakdown of toxic compounds (hydrogen sulphide) enhancing water quality.

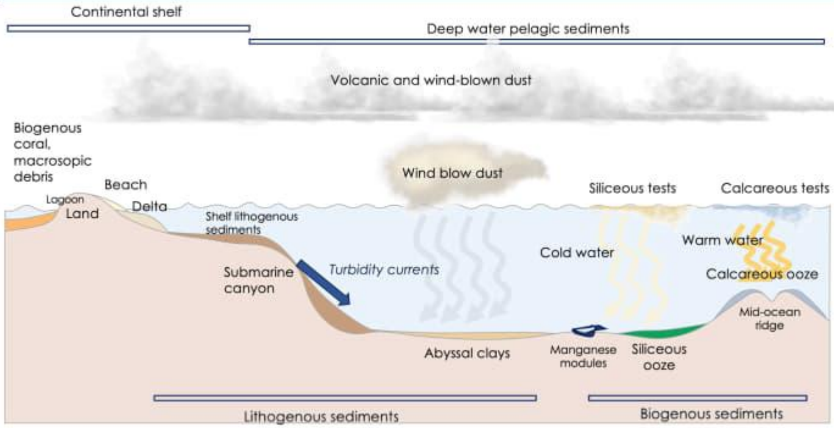
PROVISIONING

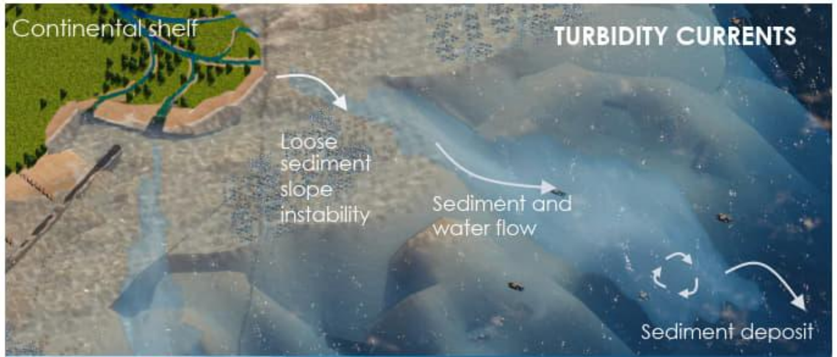
- Enhances nutrient cycling in coastal ecosystems, enriching nutrient availability for primary productivity and supporting marine food webs.

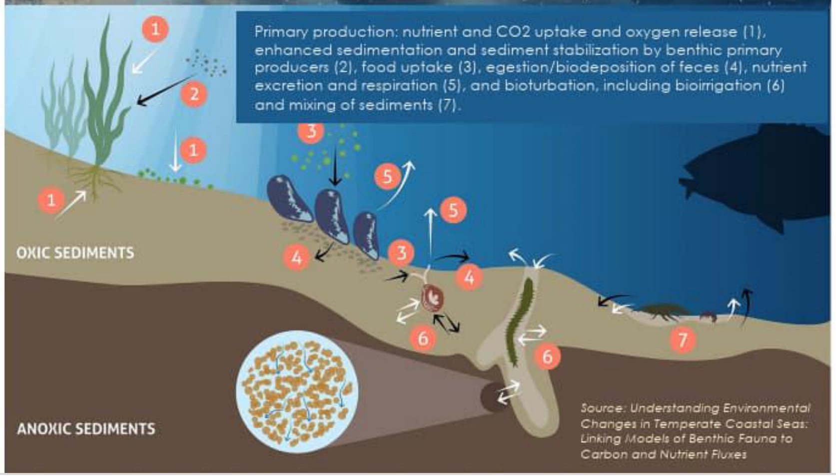
SOCIAL BENEFITS

- Supports sustainable marine and fisheries management by enhancing habitat quality and maintaining ecosystem services, which can contribute to local livelihoods and food security.

NbS-69 MARINE SEDIMENTATION BASINS FOR BIOTURBATION







PROJECT'S CHALLENGES & RISKS

- **Sediment Contamination**: High levels of pollutants in fine sediments may negatively impact bioturbation processes and disrupt ecosystem functions.
- **Climate Change Impact**: Rising sea levels and increased storm intensity may alter sediment dynamics, affecting the stability and effectiveness of sedimentation basins.
- **Benthic Species Vulnerability**: Overfishing and habitat degradation may reduce populations of benthic organisms essential for bioturbation.
- **Design and Maintenance Challenges**: Incorrectly designed basins or poor maintenance can lead to insufficient sediment trapping or siltation.

NbS co-BENEFITS AND THEIR INDICATORS

Improved Water Quality

Reduction in turbidity levels and improved oxygenation, measured by lower levels of suspended solids and higher dissolved oxygen.

Enhanced Biodiversity

Increased species richness and diversity of benthic organisms, indicated by higher numbers of burrowing species and other bioturbators within the sediment.

Nutrient Cycling

Improved nutrient availability for marine habitats.

Coastal Erosion Mitigation

Stabilization of coastal sediments, with a decrease in erosion rates as measured by sediment retention in the basin.

Sediment Detoxification

Reduction in toxic substances such as hydrogen sulphide, with improvements in sediment quality.

Resilience to Climate Change

Increased resilience to extreme weather events, with improved sediment health and stability.

COST ANALYSIS

Direct Costs

Construction including dredging, materials, and labor, could range from USD 500k to USD 2 M

Indirect Costs

Monitoring, environmental assessments, and additional infrastructure for ecosystem monitoring to be estimated.

Time Horizon

Returns on investment could be 10-20 years, with a discount rate typically ranging from 5% to 8% for long-term projects.

Direct Benefits

Improved water quality, fisheries, and tourism

Indirect Benefits

Enhanced ecosystem resilience, biodiversity improvements, and reduced maintenance dredging

Risk Assessment

Potential risks involve system failure due to poor design or maintenance, which could lead to additional costs for remediation and damage control..

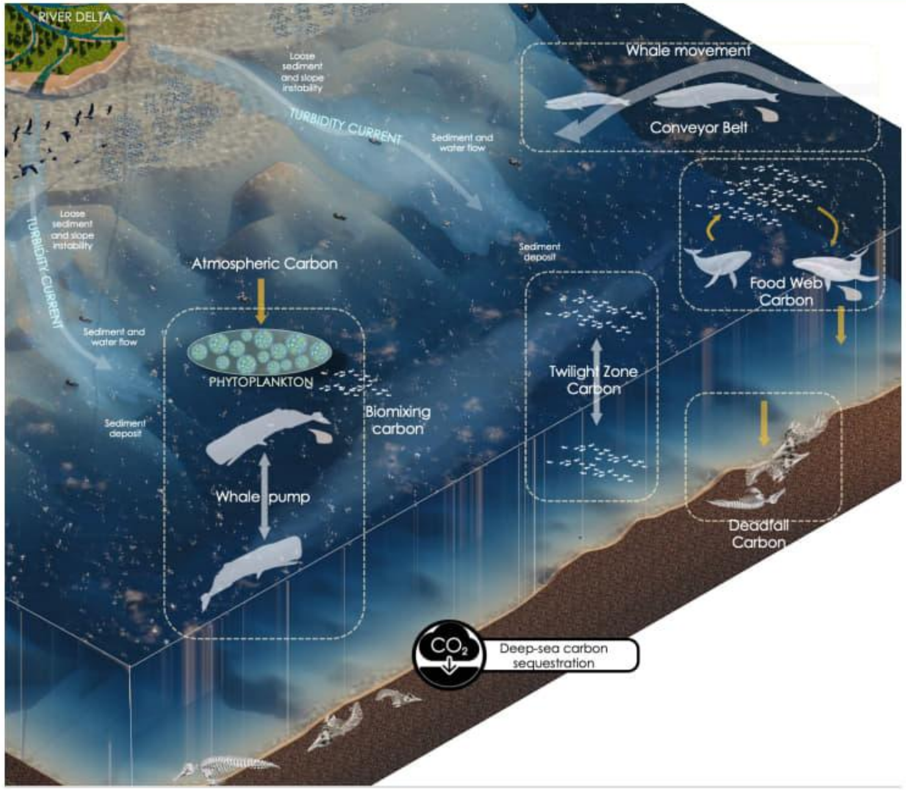
REFERENCES:

Australia, Queensland, Great Barrier Reef Marine Park, Sediment load management from agricultural runoff, reduction of the sedimentation pressure on the reefs.
Vietnam, Mekong Delta Sediment Management Program.

IMPLEMENTATION OPPORTUNITIES:

Vietnam, Da Nang, Haiphong, Ports and estuaries.
Indonesia, Surabaya and Medan Port Areas to address port dredging and river sedimentation.

NbS-70 DEEP-SEA SEQUESTRATION OF MESOPELAGIC FAUNA



Deep-sea sequestration of mesopelagic fauna presents an emerging NbS for marine ecosystems, by leveraging natural processes to enhance carbon capture and ecosystem resilience. It involves six key actions: Enhancing the Biological Pump, which strengthens the ocean's ability to transport carbon to the deep-sea via the food web; Promoting Bioluminescent Behaviour, where mesopelagic organisms contribute to light-driven carbon cycling; Sustainable Management of Fisheries, ensuring mesopelagic species thrive without overfishing, thus maintaining their role in carbon sequestration; Artificial Upwelling Systems, which stimulate phytoplankton growth, supporting the food chain and increasing carbon storage; Marine Protected Areas (MPAs) and Conservation, creating sanctuaries to protect mesopelagic habitats and enhance biodiversity; and Monitoring and Research of Deep-sea Ecosystems, to understand carbon cycling and the ecological value of these species. In Southeast Asia, it can boost regenerative seascapes by stabilizing marine ecosystems, fostering biodiversity, and reducing sedimentation rates. It also contributes to climate change mitigation by enhancing carbon storage in deep-sea sediments. Technically, the integration of deep-sea sequestration with sustainable fisheries and MPAs will support the region's coastal economies, while research and monitoring can refine conservation practices. These approaches not only offer long-term environmental and climate benefits but also enhance the social and economic resilience of coastal communities dependent on healthy marine ecosystems.

LANDSCAPES SUPPORTED

EbA (ECOSYSTEM-BASED APPROACHES)

- ENHANCED BIOLOGICAL CARBON PUMP
- SUPPORT FOR MARINE BIODIVERSITY
- NUTRIENT RECYCLING AND UPWELLING
- CLIMATE CHANGE MITIGATION
- IMPROVED ECOSYSTEM MONITORING
- REDUCTION OF OCEAN ACIFIDIFICATION

MAIN PROBLEMS ADDRESSED

- BIODIVERSITY LOSS
- CARBON SEQUESTRATION
- DISASTER RISK REDUCTION

ECOSYSTEM SERVICES AND ACTIONS

SUPPORTING

- Enhancing Marine Biodiversity and marine life in mesopelagic zones.
- Facilitates the cycling of nutrients and organic matter in deep-sea ecosystems.

REGULATING

- Contributes to long-term carbon storage.
- Bioturbation and nutrient recycling processes help buffer the effects of ocean acidification.

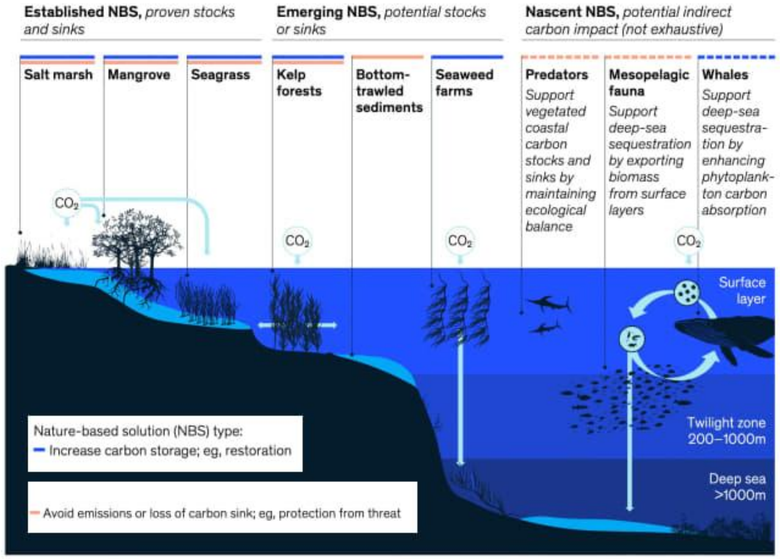
PROVISIONING

- Promotes sustainable management of mesopelagic species, ensuring their role in marine food webs.
- Provides opportunities for scientific research on deep-sea ecosystems.

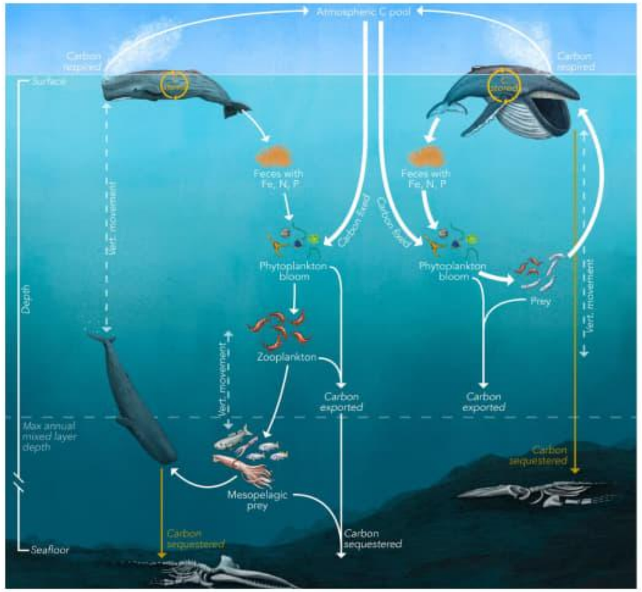
SOCIAL BENEFITS

- Sustainable fisheries and effective marine conservation can provide long-term benefits to coastal communities.

NbS-70 DEEP-SEA SEQUESTRATION OF MESOPELAGIC FAUNA



Blue Carbon : The potential of coastal and oceanic climate action
Source : McKinsey



Great whales direct and indirect nutrient and carbon cycling pathways
Source : University of Hawai News, Photo credit : Pearson, et al.2022)

PROJECT'S CHALLENGES & RISKS

- **Uncertainty in Ecosystem Dynamics**: Poor understanding of the complex interactions in deep sea ecosystems. The biological pump makes it challenging to predict the effectiveness of deep-sea sequestration efforts.
- **Overfishing and Unsustainable Practices**: Unsustainable fishing practices undermine conservation efforts, disrupting the mesopelagic food web.
- **Technological and Monitoring Gaps**: The lack of advanced monitoring to assess deep-sea ecosystems hinders the ability to track artificial upwelling or bioluminescent behaviour promotion.
- **Limited Funding and Policy Support**: Insufficient financial resources and lack of clear policies for marine conservation and sustainable fisheries.

NbS co-BENEFITS AND THEIR INDICATORS

- **Enhancement of Carbon Sequestration**
  Increased rate of carbon storage in deep-sea sediments.
- **Improved Biodiversity Conservation**
  Increased species diversity and abundance in Marine Protected Areas (MPAs).
- **Resilience of Marine Ecosystems**
  Reduced vulnerability of marine ecosystems to climate change impacts, as evidenced by the stabilization of deep-sea habitats and food webs.
- **Promotion of Ocean Health and Water Quality**
  Enhanced water quality and reduced ocean acidification due to balanced nutrient cycling and sedimentation processes.
- **Sustainable Fisheries Management**
  Recovery of mesopelagic fish populations and improved fisheries yield through reduced overfishing.
- **Advancement in Scientific Knowledge &Research**
  Increased number of research publications, data collection, and policy recommendations for deep-sea ecosystems and their conservation.

COST ANALYSIS

- **Direct Costs**
  USD 5-10M per year for establishing and maintaining research, marine protected areas, artificial upwelling systems, and fisheries management programs.
- **Indirect Costs**
  USD 2-4 million per year for policy development, community engagement, and monitoring of impacts on marine ecosystems.
- **Time Horizon**
  Typically 10-30 years for this kind of project.
- **Direct Benefits**
  Carbon sequestration, biodiversity enhancement, and increased fisheries productivity.
- **Indirect Benefits**
  Enhanced climate resilience and improved coastal protection.
- **Risk Assessment**
  Potential failure of artificial upwelling systems or lack of enforcement in MPAs.

REFERENCES:

The **Southern Ocean Carbon and Climate Observations and Modeling** (SOCCOM) Project explores the impact of mesopelagic fauna and the biological pump on carbon sequestration.
Sulu-Celebes Sea Marine Ecosystem-Based Management (MEbM) Program includes strategies for creating marine protected areas (MPAs) to enhance nutrient cycling and biodiversity.

IMPLEMENTATION OPPORTUNITIES:

Philippines, Sulu Sea could benefit from MPAs and biological pump research.
Indonesia, Bali Strait, is an ideal location for artificial upwelling systems.
Gulf of Thailand (Cambodia, Vietnam, Thailand) could implement research on mesopelagic fauna.

Conclusion

This catalogue of 70 nature-based solutions aims to offer a comprehensive framework for tackling Southeast Asia's diverse environmental and socio-economic challenges.

Through a strategic categorisation of NbS practices, we have demonstrated how these solutions can be implemented across a range of landscapes to foster climate resilience, sustainable development, and ecosystem health. The NbS outlined here are not just isolated interventions but are designed to work synergistically within their respective landscapes, enhancing the natural environment, supporting local communities, and contributing to regional and global climate goals.

The nine landscape categories provide a structured approach for scaling up NbS to address pressing challenges in riverine systems, coastal zones, urban environments, agriculture, and marine ecosystems. Whether it is restoring mangrove forests, improving urban water management, supporting climate-smart cities, or promoting regenerative agriculture, each practice plays a critical role in improving the resilience of ecosystems and human settlements to climate events and environmental degradation.

The diversity of practices presented—ranging from river restoration and coastal reforestation to sustainable farming techniques and marine habitat protection—underscores the adaptability and versatility of NbS in meeting local needs while aligning with global sustainability frameworks, such as the IUCN's societal challenges.

This catalogue highlights the technical feasibility and environmental benefits of these solutions and offers financial insights, emphasising their potential for cost-effective implementation and long-term sustainability.

However, successful implementation of these solutions requires more than just technical know-how. It calls for strong policy support, cross-border collaboration, and community engagement.

By embedding NbS into national policies, regional climate agendas, and local development strategies, Southeast Asia can harness the full potential of these nature-inspired solutions to build climate-resilient, ecologically sustainable, and inclusive communities.

Moreover, the scaling up of NbS across diverse landscapes, combined with a strong focus on community-based approaches, will help ensure that these solutions are not only effective but also accessible and equitable. Local engagement, capacity building, and the integration of traditional knowledge will be crucial in driving the success of these NbS initiatives, ensuring they are both contextually relevant and socially acceptable.

This catalogue has been designed to serve as both a tool and a call to action for policymakers, planners, and practitioners in Southeast Asia and beyond. It demonstrates the potential for NbS to address multiple societal challenges, from biodiversity conservation and disaster risk reduction to economic development and climate adaptation.