NATURE-BASED SOLUTIONS IN CITIES:

Solutions and Examples for Municipalities and the Private Sector

GLOBAL PROGRAM ON NATURE-BASED SOLUTIONS FOR CLIMATE RESILIENCE

GFDRR
Global Facility for Disaster Reduction and Recovery

Administered by THE WORLD BANK
IBRD • IDA | WORLD BANK GROUP

IFC International Finance Corporation
WORLD BANK GROUP

In collaboration with: felixx

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CONTEXT

The purpose of this catalogue is to raise awareness in municipalities and the private sector of nature-based solutions (NBS) projects in urban settings that focus on scaling the resilience of cities to address the urban heat island effect, flooding, drought, water and air pollution, and more.

This catalogue is a summary of an extensive and in-depth technical Catalogue of Nature-based Solutions for Urban Resilience developed and financed by the Global Facility for Disaster Reduction and Recovery at the World Bank.[1] The aim of this abridged version is to raise general awareness of where nature-based solutions, which are still new in the market, can be integrated into urban settings. This catalogue targets municipalities and the private sector to help identify opportunities and possible projects for implementing urban nature-based solutions. The various solutions in this catalogue are illustrated with case studies from across the world, including those where cities were able to leverage private finance to scale urban projects integrating nature-based solutions.

This catalogue supplements IFC's Biodiversity Finance Reference Guide,[2] which includes nature-based solutions as accepted use of proceeds and is a companion resource to IFC's Catalogue of Nature-based Solutions for Infrastructure Projects for Water Utilities, Mining and Renewable Energy.

This catalogue will evolve over time as the market for nature-based solutions for urban resilience develops. To share additional case studies that demonstrate the role of the private sector in financing nature-based solutions for urban resilience, please email biodiversityfinance@ifc.org.

CONTEXT: WHAT IS BIODIVERSITY FINANCE?

This catalogue is a supplement to IFC's Biodiversity Finance Reference Guide,[2] which defines eligible investments and project activities that conserve, restore, or avoid negative impacts on biodiversity and ecosystem services and contribute to meeting the Global Biodiversity Framework targets.

IFC's Biodiversity Finance Reference Guide identifies eligible investment activities grouped under **three categories.**

This catalogue elaborates on investments in nature-based solutions in urban settings.

Investments that generate biodiversity co-benefits

Financing that seeks **to address the key drivers of biodiversity loss** (land/sea use change, pollution, overexploitation of resources, and invasive species) in economic activity.

Investments in biodiversity conservation and restoration

Financing to support **nature conservation or restoration** and related services as a primary objective of investment.

Investments in nature-based solutions

Financing to support the **integration of nature-based solutions into larger projects** to provide infrastructure services and displace or complement gray infrastructure.

To be considered biodiversity finance, eligible investments or project activities in nature-based solutions must:

- Provide infrastructure-type or other services that are material to a project's operation and/or core objectives
- Displace or complement gray infrastructure

CONTEXT: WHAT IS URBAN RESILIENCE?

A green corridor next to a railway in Vietnam *(photo by Hoach Le Dinh on Unsplash)*

Urban resilience is the capacity of a city's systems, businesses, institutions, communities, and individuals to survive, adapt, and thrive, no matter what chronic stresses and acute shocks they experience.[3]

Why act now?

- Over half the world's population lives in urban areas, with the number expected to climb to 70% by 2050.[4, 5]
- Climate change is increasingly causing more natural shocks to cities, particularly affecting areas with vulnerable populations, such as unplanned or informal urban settlements.
- Municipal governments can reach adaptation and resilience goals by setting up the right incentives to leverage private sector finance.

CONTEXT: WHAT ARE NATURE BASED SOLUTIONS?

An urban park in Nairobi, Kenya
(photo by Zac Wolff on Unsplash)

While there is no universally agreed on definition, this catalogue refers to NBS as:[6]

"actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits."

CONTEXT: NATURE-BASED SOLUTIONS

Benefits

Depending on the project and the setting, NBS offer many benefits when compared to gray infrastructure:[7]

1. **Business case:** Lower investment and operational/ maintenance costs for infrastructure services; lower replacement of capital expenditure
2. **Climate change mitigation:** Lower carbon footprint when compared to conventional alternatives; carbon sequestration services
3. **Climate change adaptation:** Disaster risk reduction; infrastructure resilience[8]
4. **Biodiversity benefits:** Higher plant and animal diversity; improved ecosystem services
5. **Economic:** Job creation and economic opportunities for local communities
6. **Social/human health:** Cultural, educational, and recreational opportunities and improvement of human health and wellness
7. **Food security:** Improved resilience to external shocks to support continued availability and accessibility of food (linked to climate change mitigation/adaptation)
8. **Water security:** Increased capacity of a population to safeguard sustainable access to adequate quantities of water (linked to climate change mitigation/adaptation)[9]

CONTEXT: NATURE-BASED SOLUTIONS

Barriers

Practitioners face challenges when planning for and implementing NBS:[7]

1. **Location specific:** Requires location-specific design, hindering the development of universal design guidelines and templates
2. **Specialized knowledge:** Requires specialized engineering expertise in designing and operating NBS
3. **Performance management:** Requires adaptive management and performance monitoring to complement long-term operations and maintenance
4. **Large footprint:** Some NBS require large land areas for implementation
5. **Knowledge gaps:** Proven frameworks, methodologies, case studies, and data needed for valuing ecosystem services are often lacking in emerging markets
6. **Permitting:** Lack of guidance from governments and institutional bodies on permitting for NBS given it is a nascent area in infrastructure
7. **Value for money:** Financing can be difficult to obtain given challenges in identifying and quantifying the commercial value of NBS
8. **Stakeholder consultation/involvement:** In urban contexts it can be difficult to consult with certain groups who may benefit from or experience adverse impacts of NBS (e.g. undocumented migrants)
9. **Long-term visibility of projects:** The impact of NBS may only be evident years after implementation

CONTEXT: NATURE-BASED SOLUTIONS IN CITIES

Five important principles to support the identification and integration of NBS investments in cities are listed below:[1]

1. Assess the **functions, benefits, costs,** and **suitability** considerations of NBS.

2. Apply an **integrated systems approach** (holistic) to NBS for resilience in urban landscapes.

3. Consider the principles of ecosystem conservation by adopting a hierarchy of ecosystem-based approaches, **prioritizing the protection and restoration of existing ecosystems** over the creation of a new NBS.

4. Consider the integration of NBS across a **range of spatial scales** (such as the river basin scale, the city scale, and the neighborhood scale).

5. Adopt a **multistakeholder and interdisciplinary** approach (such as resource users, nearby households and communities, and businesses existing around the NBS).

NATURE-BASED SOLUTIONS FOR **URBAN RESILIENCE**

CATALOGUE OF NATURE-BASED SOLUTIONS FOR URBAN RESILIENCE

The following section goes into further details on the below nature-based solutions.

Nature-based Solution	Infrastructure Service*	Performance	Scale	Key Driver of Biodiversity Loss Addressed**
Urban forests	Water supply; stormwater management; ground cover; temperature reduction	Reduce flooding; regulate water cycles; improve water and air quality; mitigate impacts of urban heat island effect; clean soil; carbon sequestration services	Neighborhood; city; river basin	Land use change; pollution
Terraces and slopes	Slope stabilization; stormwater management	Control and reduce erosion; capture and store stormwater; improve soil and water quality; promote food security	Neighborhood; city	Pollution; land use change
River and stream renaturation	Water supply; slope stabilization	Reduce flooding; reduce peak flow; stabilize water temperatures; improve air, water, and soil quality; reduce erosion	Neighborhood; city; river basin	Land use change; pollution
Building solutions	Stormwater management	Capture and store rainwater to reduce peak stormwater load; absorb solar radiation; reduce building temperature and air pollution	Neighborhood; city	Overexploitation of resources; pollution
Open green spaces	Stormwater management; ground cover; temperature reduction	Reduce flooding; increase water storage; reduce impacts of urban heat island effect; improve water, air, and soil quality	Neighborhood; city	Land use change; pollution

**Under the IFC Biodiversity Finance Reference Guide, an NBS investment must provide an infrastructure-type or other service that is material to a project's operation.*

***Under the IFC Biodiversity Finance Reference Guide, an activity must address a key driver of biodiversity loss to be considered biodiversity finance.*

CATALOGUE OF NATURE-BASED SOLUTIONS FOR URBAN RESILIENCE

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Nature-based Solution	Infrastructure Service*	Performance	Scale	Key Driver of Biodiversity Loss Addressed**
Green corridors	Stormwater management; ground cover; temperature reduction	Reduce flooding; increase water storage; improve water, air, and soil quality; reduce impacts of heat island effect	Neighborhood; city	Land use change; pollution
Urban farming	Ground cover; stormwater management; temperature reduction	Increase crop yield of local resource production; reduce flooding; increase water storage; improve water, air, and soil quality; reduce impacts of heat island effect	Neighborhood; city	Overexploitation of resources; land use change; pollution
Bioretention areas	Stormwater management; wastewater treatment; temperature reduction	Reduce flooding; increase water supply; mitigate peak loads on stormwater and sewerage systems; improve water and soil quality; reduce impacts of heat island effect	Neighborhood; city	Land use change; pollution
Natural inland wetlands	Stormwater management; wastewater treatment; temperature reduction	Reduce flooding; increase water supply; improve wastewater quality; erosion control; reduce impacts of heat island effect	City; river basin	Land use change; pollution; invasive species

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CATALOGUE OF NATURE-BASED SOLUTIONS FOR URBAN RESILIENCE

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Nature-based Solution	Infrastructure Service*	Performance	Scale	Key Driver of Biodiversity Loss Addressed**
Constructed inland wetlands	Wastewater treatment; stormwater management; temperature reduction	Improve wastewater quality; reduce flooding; increase water supply; reduce impacts of heat island effect	Neighborhood; city	Pollution; overexploitation of natural resources
River floodplains	Flood/stormwater management; wastewater treatment; temperature reduction	Reduce flooding; reduce peak flow; reduce environmental pollution to improve water quality; reduce impacts of heat island effect	City	Land use change; pollution
Mangrove forests	Protection of coastal assets	Reduce coastal flooding; mitigate wave action; carbon sequestration services; local resource production	City; river basin	Land use change; climate change
Salt marshes	Protection of coastal assets	Reduce coastal flooding; mitigate wave action; control erosion; carbon sequestration services	City; river basin	Land use change; climate change
Sandy shores	Protection of coastal assets	Reduce coastal flooding; control erosion; increase water supply	City; river basin	Land use change

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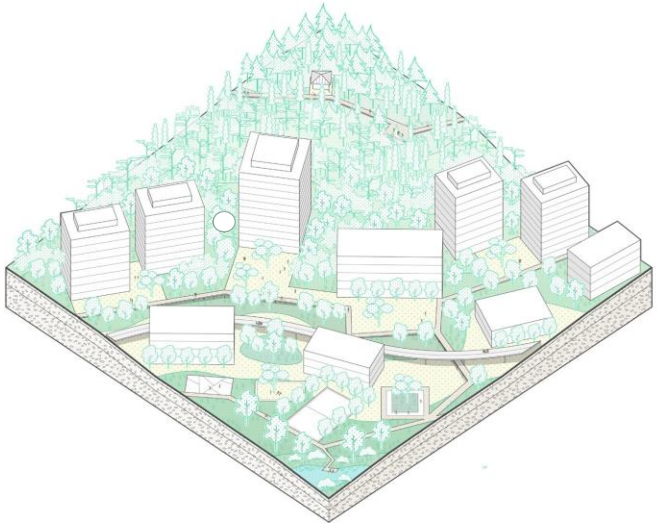
URBAN FORESTS

NATURE-BASED SOLUTIONS



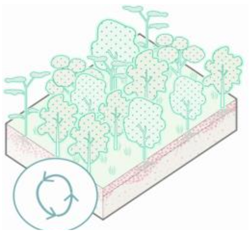
Visualization of forests in the urban context

Urban forests: Networks or systems comprising all woodlands, groups of trees, and individual trees located in urban and peri-urban areas, including forests, street trees, trees in parks and gardens, and trees in derelict corners.[10]

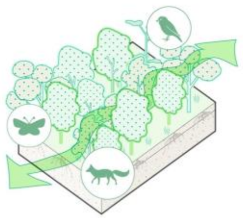
RATIONALE FOR NBS:

- Reduce flooding by increasing infiltration of stormwater.
- Regulate water cycles through retention, infiltration, and evapotranspiration.
- Improve water and air quality.
- Mitigate urban heat island effect.
- Control erosion and clean soil.
- Carbon sequestration services.

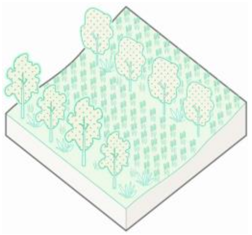
Special Techniques for Urban Forests



Phytoremediation forest: Consists of specific trees and shrubs with qualities that clean polluted soils (e.g. landfills). The roots remove, transfer, stabilize, and detoxify contaminants in the soil and groundwater.



Ecological forest corridors: Established lines of vegetation allowing the safe movement of species through the urban landscape, screened from light and noise.

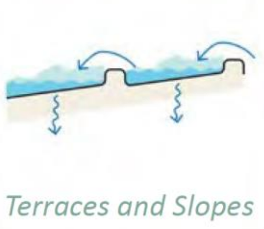


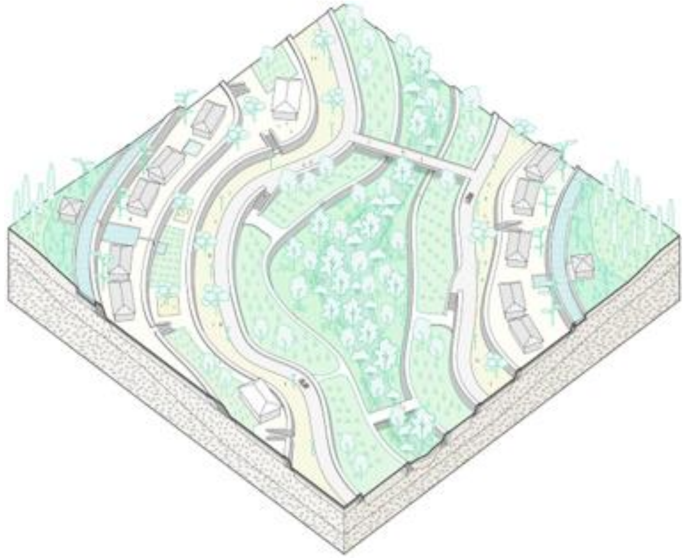
Agroforestry: A natural resource management system that integrates trees and wooded patches into farms and productive landscapes as well as diversifies and enhances agricultural production.[11]

*See case study on **Freetown the Tree Town Campaign in Sierra Leone** for a practical example.*

TERRACES AND SLOPES

NATURE-BASED SOLUTIONS





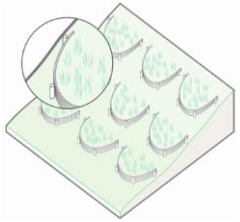
Visualization of terraces and slopes in the urban context

Terraces and slopes: Land-based structures that stabilize slopes and loose soil that are typically exposed to a variety of hazards, including floods, cyclones, droughts, landslides, and mudslides.

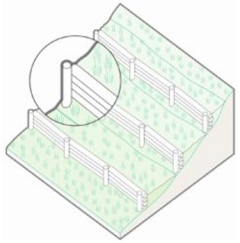
RATIONALE FOR NBS:

- Stabilize land and control erosion.
- Capture and store stormwater.
- Improve soil and water quality.
- Promote food security and increase crop yields by 2.5 times by conserving water and soil (*when used for food production).

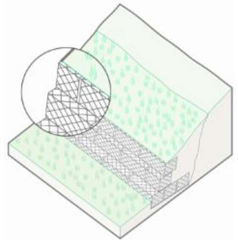
Special Techniques for Terraces and Slopes



Living smiles: A natural porous fence made of flexible plant cuttings installed to drain a terrace of excess water while capturing and retaining sediment, which is then incorporated into the existing soil.[12]



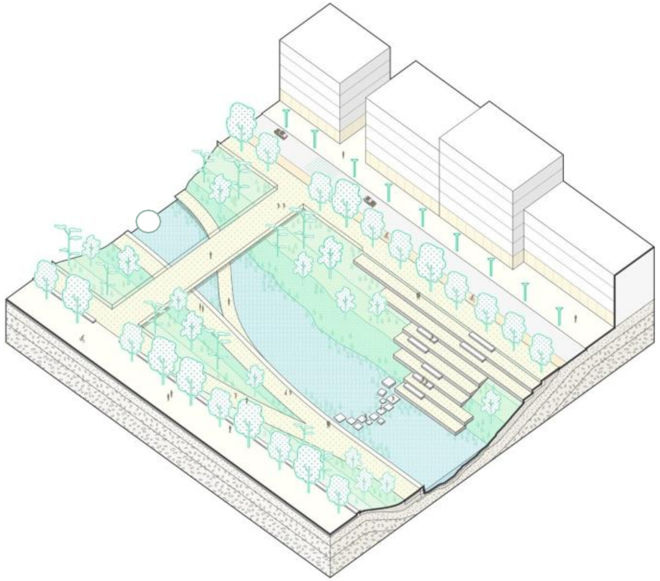
Wattle fence: Made of sturdy wooden posts driven vertically into the soil with willow shoots woven horizontally in between to act as a retaining wall to encourage vegetation growth while also reducing the impact of rolling materials during a storm.[12]



Vegetated gabions: Baskets made of galvanized steel filled with stones, often filled with earth and strengthened with geotextiles, used to reinforce and protect slopes from fast-moving stormwater.[12]

RIVER AND STREAM RENATURATION

NATURE-BASED SOLUTIONS



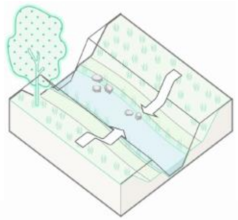
Visualization of river and stream renaturation in the urban context

River and stream renaturation: Removal of built structures, such as concrete embankments, and installation of natural measures, such as revegetation and riparian corridors, to encourage the water flow of a river or stream to return to its natural state.

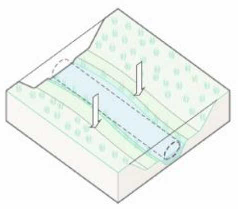
RATIONALE FOR NBS:

- Reduce flood risk by creating water retention and infiltration capacity in the river system.
- Reduce peak flow.
- Stabilize water temperature and reduce ambient temperatures in adjacent areas.
- Improve air, water, and soil quality.
- Reduce erosion and stabilize soils.

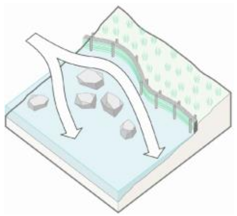
Special Techniques for River and Stream Renaturation



Bank and bed renaturation: Restore the natural dynamic of the river through various means, such as restoring the shape of the river, creating physical structures to direct the flow of water, and providing habitat for aquatic species.



Stream daylighting: A technique to remove layers of concrete and recreate the natural shape and dynamic of streams, resulting in better regulation of stormwater runoff and increased wildlife and aquatic habitat.[13]

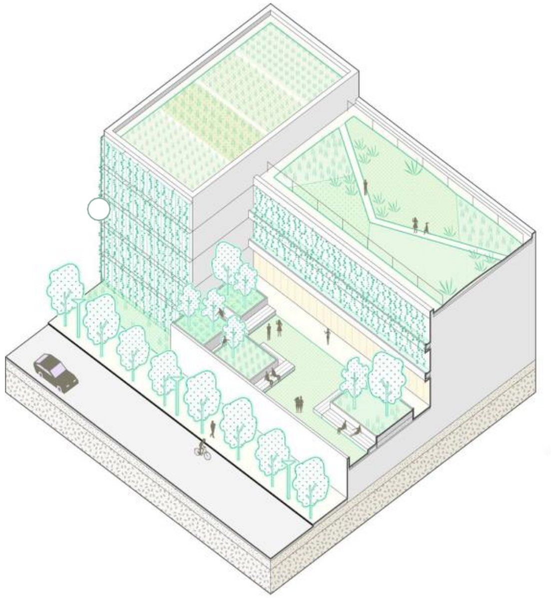


Bioengineering techniques: Use of plants, rocks, geotextiles, and membranes to recreate the natural course of a river and connect it to its landscape as part of floodplain revegetation, riverbank stabilization, and riverbed restoration.[13]

*See case study on **Bishan-Ang Mo Bio Park in Singapore** for a practical example.*

BUILDING SOLUTIONS

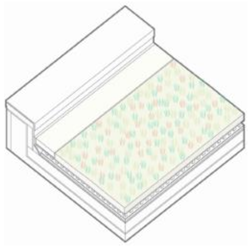
NATURE-BASED SOLUTIONS



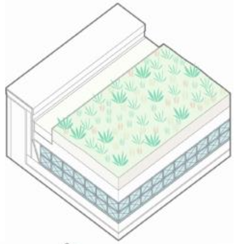
Visualization of building solutions in the urban context

Building solutions: Green construction methods that can be integrated into a new build or into a building's renovation that offer energy, economic, and carbon sequestration services.

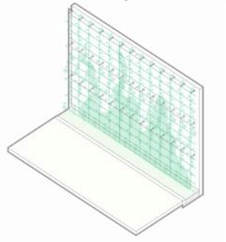
Special Techniques for Building Solutions



Extensive green roofs: A building technique that consists of horizontal layers (bioengineered growth medium, membranes to control plant roots, and buffers to collect, filter, store, reuse, or discharge water) to increase building performance in energy efficiency and stormwater management (not accessible to the public).[13]



Intensive green roofs: A building technique that has a thick substrate layer to support a higher variety of vegetation to support habitats and rooftop gardens to support urban farming (accessible to the public).[13, 14]



Ground-based green facades: A type of green wall with climbing plants rooted in ground planters that climb directly on the wall or on a special frame connected to the wall.[13]

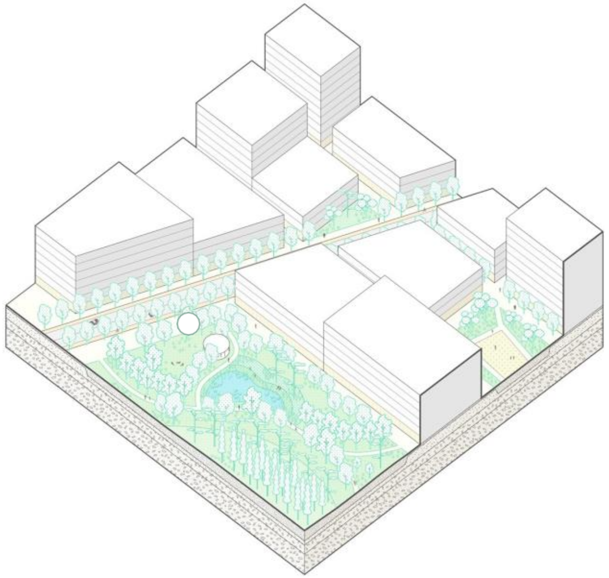
RATIONALE FOR NBS:

- Capture and store rainwater to reduce peak stormwater load on stormwater and sewerage systems.
- Absorb solar radiation through photosynthesis.
- Reduce building temperature and cool surrounding air.
- Reduce air pollution.

See case study on ***Private Property Retrofit Incentive Program in NYC, USA****,* ***Stormwater Retention Credit Trading Program in Washington, DC, USA****, and* ***Pay for Performance – Environmental Bond in Washington, DC, USA****, for practical examples.*

OPEN GREEN SPACES

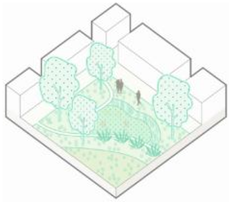
NATURE-BASED SOLUTIONS



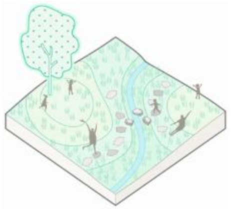
Visualization of open green spaces in the urban context

Open green spaces: An area of unpaved and biologically active private or public land such as gardens and city parks; these spaces can vary significantly in size and properties.

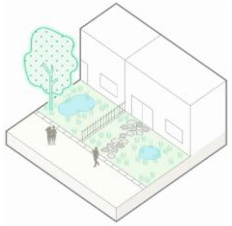
Special Techniques for Open Green Spaces



Pocket parks: Small, open spaces distributed throughout the urban landscape to serve the immediate population of a neighborhood and provide a variety of small-scale recreation possibilities.



Natural playgrounds: Playgrounds with native trees, flowers, rocks, and water to encourage social and physical activity for all ages.[15]



Climate-proof residential gardens: Vegetation adjacent to a residence that can manage stormwater, mitigate heat, and provide a habitat for local species.

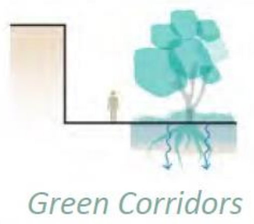
RATIONALE FOR NBS:

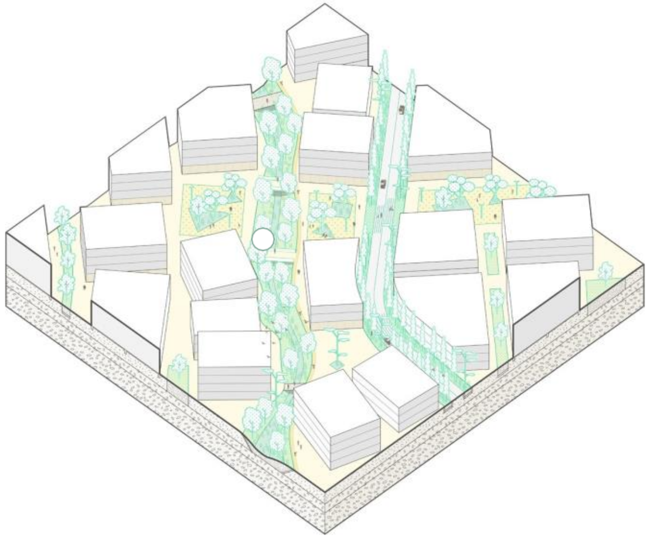
- Reduce flooding by managing stormwater and increasing water storage through infiltration.
- Reduce heat by providing shade and evaporative cooling.
- Improve water, air, and soil quality by removing pollutants.

See case study on ***Private Property Retrofit Incentive Program in NYC, USA****, and* ***Stormwater Retention Credit Trading Program in Washington, DC, USA****, for practical examples.*

GREEN CORRIDORS

NATURE-BASED SOLUTIONS





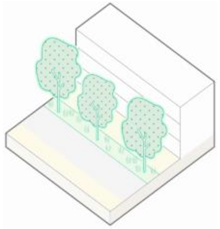
Visualization of green corridors in the urban context

Green corridors: Strips of trees, plants, or vegetation that connect green spaces in a city to foster a green urban infrastructure network (also known as linear natural infrastructure).

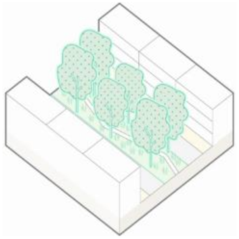
RATIONALE FOR NBS:

- Reduce flooding by managing stormwater and increasing water storage through infiltration.
- Reduce heat by providing shade and evaporative cooling (a 10% increase in the tree canopy cover reduces the maximum midday air temperature by about 1°C).
- Improve water, air, and soil quality by removing pollutants.

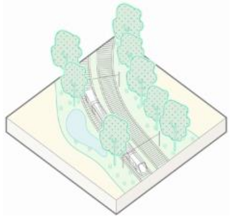
Special Techniques for Green Corridors



Street tree canopies: Planting of large native tree species to circulate rainwater, create a local microclimate, absorb pollution, provide shade, and attenuate heat, translating to lower cooling bills for buildings.



Green avenues: An unpaved, vegetated medium, with a continuous tree canopy, integrated into the green infrastructure network for climate adaptation and flood prevention.

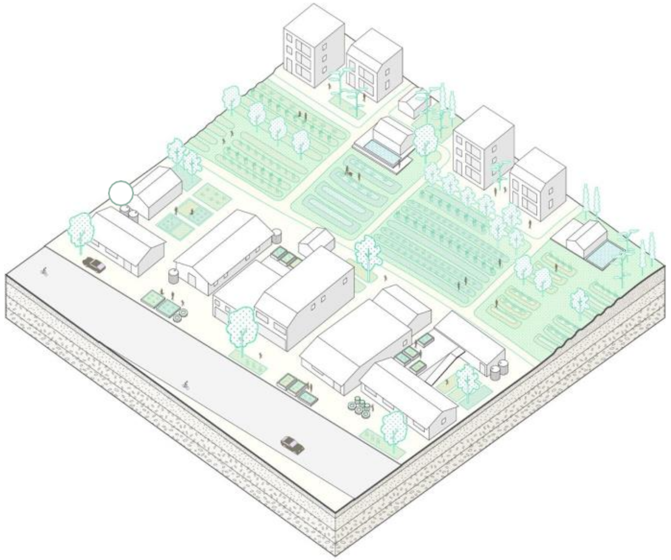


Urban green corridors: Planting of deciduous trees to create large canopies along streets, open train tracks, and other transportation and infrastructure corridors in open and derelict spaces.[16]

*See case study on **Rail Corridor Project in Singapore** for a practical example.*

URBAN FARMING

NATURE-BASED SOLUTIONS



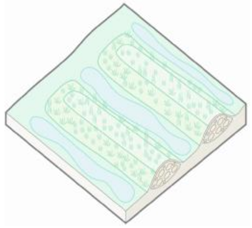
Visualization of farming in the urban context

Urban farming: Growing of plants or animals within and around cities and associated activities such as producing and delivering inputs as well as processing and marketing agricultural products.[17]

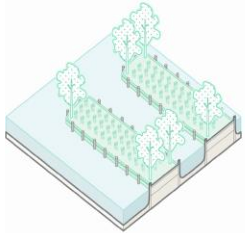
RATIONALE FOR NBS:

- Manage stormwater through the capture, storage, and infiltration of water by increasing impervious surfaces.
- Reduce urban heat by creating shade.
- Improve the quality of air, water, and soil.
- Provision of food, in particular vegetables, crops, fruit, spices, and poultry.
- Carbon sequestration services.

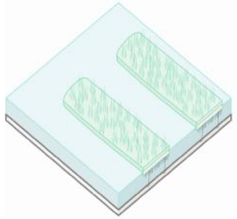
Special Techniques for Urban Farming



Raised beds: A low-cost technique of growing plants on an elevated surface built using noncorrosive materials, with good drainage, in urban areas where soil pollution is a threat.



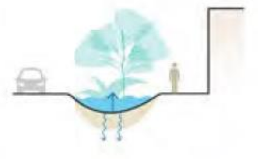
Amphibious farming: Uses artificial islands built on water, secured in place by driving wooden stakes into a lakebed, establishing a perimeter with woven reed fences, and filling with compost for a growing medium.

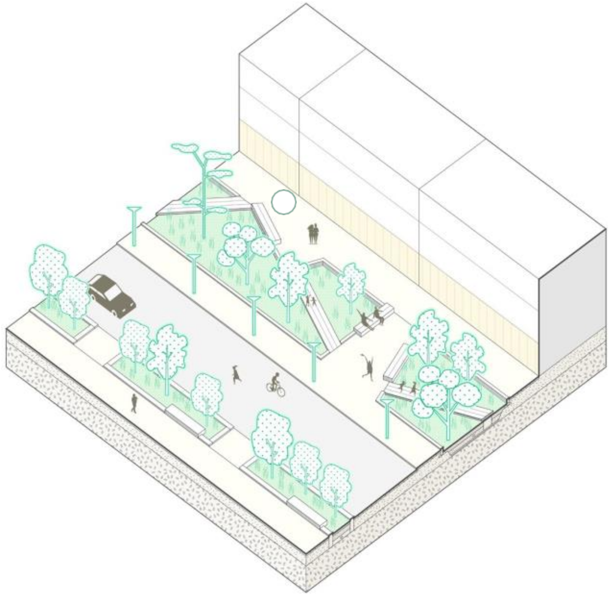


Floating farming: Suitable only for water bodies with low flow velocities, this method uses buoyant beds filled with compost of decomposing vegetation as the growing medium.[18, 19]

BIORETENTION

NATURE-BASED SOLUTIONS





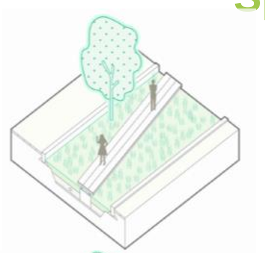
Visualization of bioretention in the urban context

Bioretention: Areas designed as shallow vegetated depressions that can intercept, infiltrate, divert, change the volume and velocity of, and treat stormwater flow. Typically used to augment gray stormwater and sewerage management.

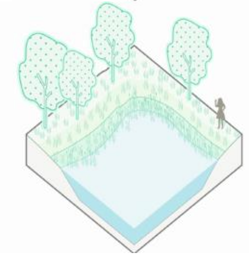
RATIONALE FOR NBS:

- Reduce flooding and mitigate peak water loads on stormwater and sewerage systems.
- Increase and stabilize water supply.
- Improve water and soil quality.
- Reduce heat by lowering surface and air temperatures.
- Carbon sequestration services.

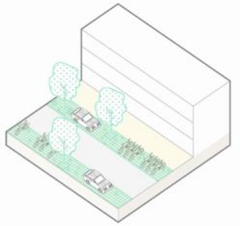
Special Techniques for Bioretention



Bioswales and rain gardens: Shallow, densely vegetated ground depressions with a variety of trees, shrubs, and grasses to collect stormwater from adjacent impervious surfaces. [20]



Detention and retention (pictured) ponds: Detention ponds are deeper than bioswales but perform the same service of temporarily capturing and storing stormwater. Retention ponds are permanent bodies of water that collect stormwater from the surrounding area to increase water supply for future use.[13, 21]

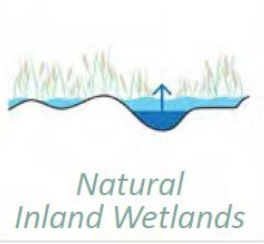


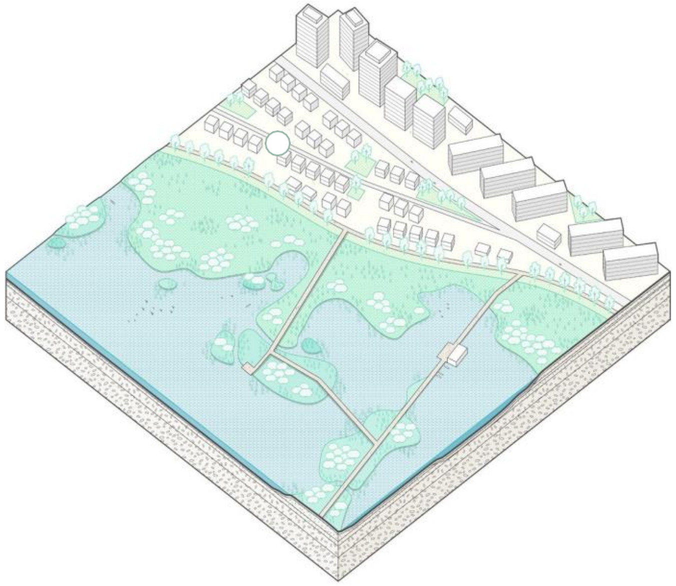
Permeable pavements: Alternatives to gray pavements that consist of a surface pavement layer, an underlying stone aggregate reservoir layer, and a filter layer to infiltrate, treat, and store rainwater and reduce runoff through seepage to underlying layers.[22]

*See case study on **Private Property Retrofit Incentive Program in NYC, USA**, **Stormwater Retention Credit Trading Program in Washington, DC, USA**, and **Pay for Performance – Environmental Bond in Washington, DC, USA**, for practical examples.*

NATURAL INLAND WETLANDS

NATURE-BASED SOLUTIONS

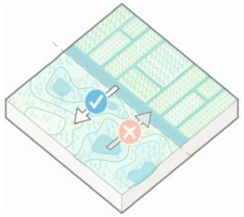




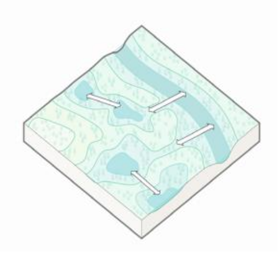
Visualization of natural inland wetlands in the urban context

Natural inland wetlands: Wetlands form an interface between land and water and are part of both aquatic and terrestrial ecosystems. They function as a two-way buffer, mitigating storms and assimilating pollutants.

Special Techniques for Natural Inland Wetlands



Drainage reduction: The transformation of wetlands to arable farmland by building an earthen wall to impound water and installing drainage systems to control the water table and provide stable irrigation for crops.



Improving lateral connectivity: Removal, reconnection, and rehabilitation of canals and artificial berms to natural wetlands and water bodies.

Maintenance and cleaning: Improving the performance of natural wetlands by removing and controlling invasive species and by reinstating lateral connections of water.

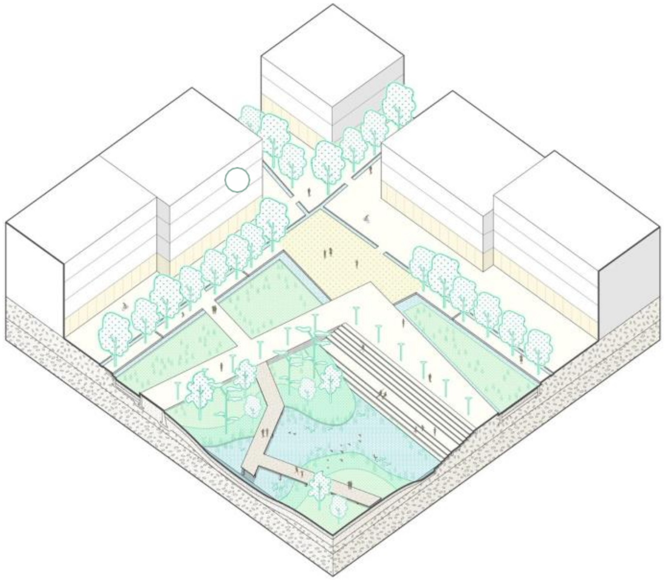
RATIONALE FOR NBS:

- Reduce flood risk through increased water supply storage and infiltration.
- Improve wastewater quality through water treatment.
- Plants’ roots offer natural sediment traps to control erosion.
- Reduce heat through wetland evapotranspiration.
- Substantial carbon sequestration services.

CONSTRUCTED INLAND WETLANDS

NATURE-BASED SOLUTIONS

Constructed Inland Wetlands



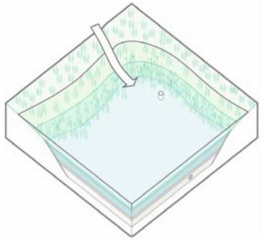
Visualization of constructed inland wetlands in the urban context

Constructed inland wetlands: Similar to natural wetlands in appearance, constructed inland wetlands are engineered systems designed to use the natural processes of wetland vegetation and soils to treat wastewater.

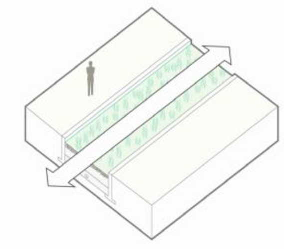
RATIONALE FOR NBS:

- Reduce flood risk by collecting and storing water.
- Absorb heat and regulate the rate of air temperature change.
- Improve water quality by removing various organic and nutrient pollutants.
- With proper maintenance (removal of built-up pollutants), can offer carbon sequestration services.

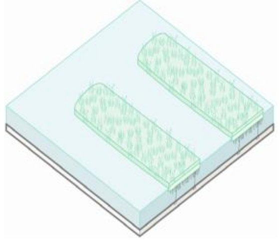
Special Techniques for Constructed Inland Wetlands



Surface constructed wetlands: Free water surface constructed wetlands that clean water through a series of planted marshes and engineered soils that remove contaminants.[23]



Subsurface gravel wetlands: Horizontal subsurface-flow constructed wetlands made of subsurface gravel beds and natural vegetation. They treat contaminated water by pumping it slowly through the subsurface gravel beds, where it gets filtered through the root zone and the soil. [23]



Floating wetlands: Constructed vegetated structures placed in existing water bodies to filter contaminants.[23]

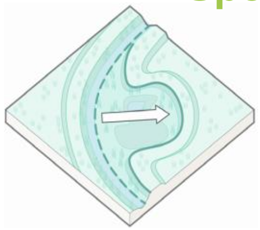
RIVER FLOODPLAINS

NATURE-BASED SOLUTIONS

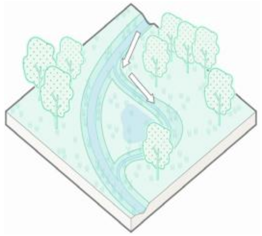
Visualization of river floodplains in the urban context

River floodplains: Practices that enhance the space available for rivers to be able to safely process higher water levels primarily to address flood risk, while also delivering additional environmental and social benefits.

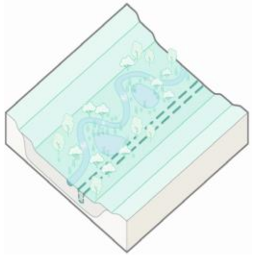
Special Techniques for River Floodplains



Setting levees back: The process of relocating a levee further back in the floodplain to provide extra space for the river to flood, resulting in lower flood elevation and increased habitat for wildlife.



River bypass or oxbow: A historical river meander that is cut off from the main channel during the natural process of channel migration or through manmade channelization. Water levels are maintained from flooding events overflowing into the oxbow.



Reactivating the floodplain: In an incised floodplain, a new meandering stream channel is excavated on the original floodplain by raising the streambed elevation. The former incised channel is filled and converted into a floodplain feature.

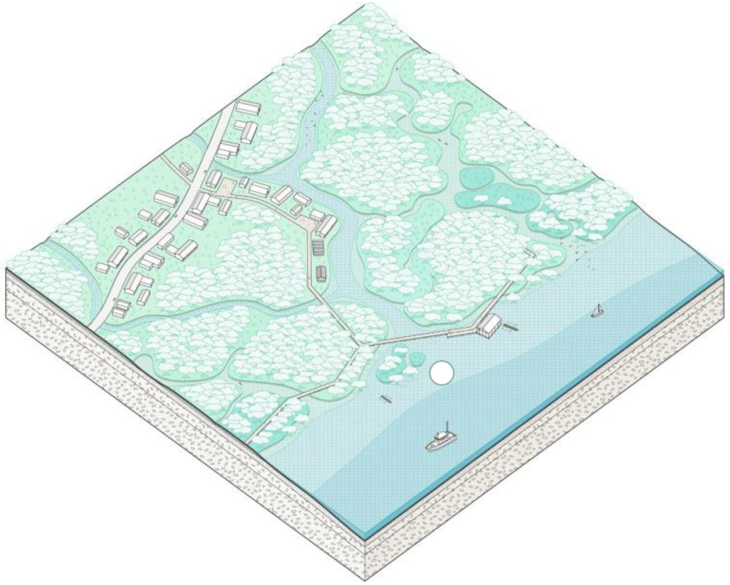
RATIONALE FOR NBS:

- Reduce peak flows and downstream flooding by storing and slowing water flow.
- Mitigate urban heat through controlling and lowering river temperature.
- Improve water quality and reduce environmental pollution.
- Carbon storage and sequestration.

See case study on the ***Rio Camboriu PWS Program in Santa Catarina, Brazil****, for a practical example.*

MANGROVE FORESTS

NATURE-BASED SOLUTIONS



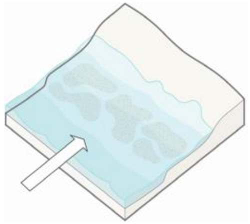
Visualization of mangrove forests in the urban context

Mangrove forests: A coastal ecosystem of halophytes – salt-tolerant trees and shrubs that live in the coastal intertidal zone. Over 80 different species of mangroves exist in tropical and subtropical zones.

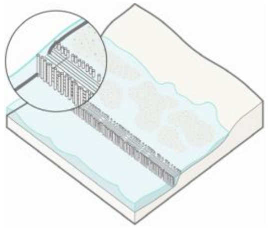
RATIONALE FOR NBS:

- Coastal flood regulation through mitigating wave action and reducing coastal flooding.
- Provide productive fishing grounds, supporting local resource production.
- Notable carbon sequestration services.
- Protect freshwater supplies from salination.

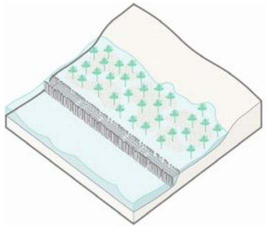
Special Techniques for Mangrove Forests



Restore hydrology: The strategic removal of certain water control devices to recover tidal influence and recreate the conditions for mangrove development, particularly in areas where human activities restricted tidal environments.



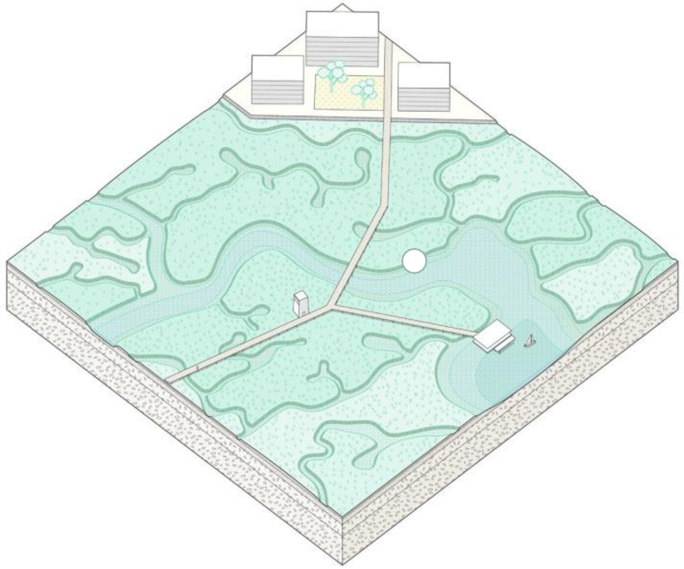
Permeable structures: Bamboo, twigs, and brushwood placed as a grid system facing the direction of the tidal current and erosive waves to capture sediment to provide substrate for mangroves to grow naturally.



Planting or sowing: Assist or enrich the natural regeneration process when natural supplies of seeds and propagules are limited due to lack of nearby parent trees or lack of hydrological connection to those trees.[24]

SALT MARSHES

NATURE-BASED SOLUTIONS



Visualization of salt marshes in the urban context

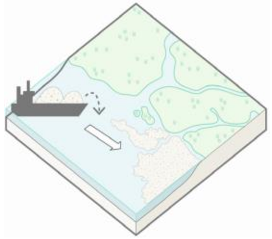
Salt marshes: Transitional coastal wetland ecosystems with high levels of biodiversity that occur along low wave energy coastlines as a result of fine sediment accumulation and colonization by halophytic, or salt-tolerant, plants.

RATIONALE FOR NBS:

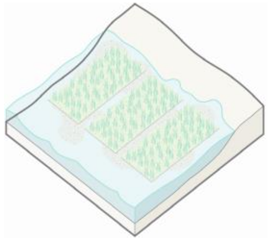
- Serve as a buffer from storms and floods by reducing waves and surges.
- Control erosion by stabilizing sediment.
- Notable carbon sequestration services.
- Improve water quality by filtering pollutants from land runoff.

Special Techniques for Salt Marshes

Restore hydrology: Removal of obstacles and restoration of the tidal influence and sediment flows to enable the conditions for salt marsh development in areas where human actions have disrupted the connection between waves/tides and marshland.



Mud motor: Locally sourced dredged mud is placed out in the open and close to the marsh, spread out so the tidal flow can slowly wash it off and deposit it in the salt marshes to gradually deliver additional growth to marshlands.[25]

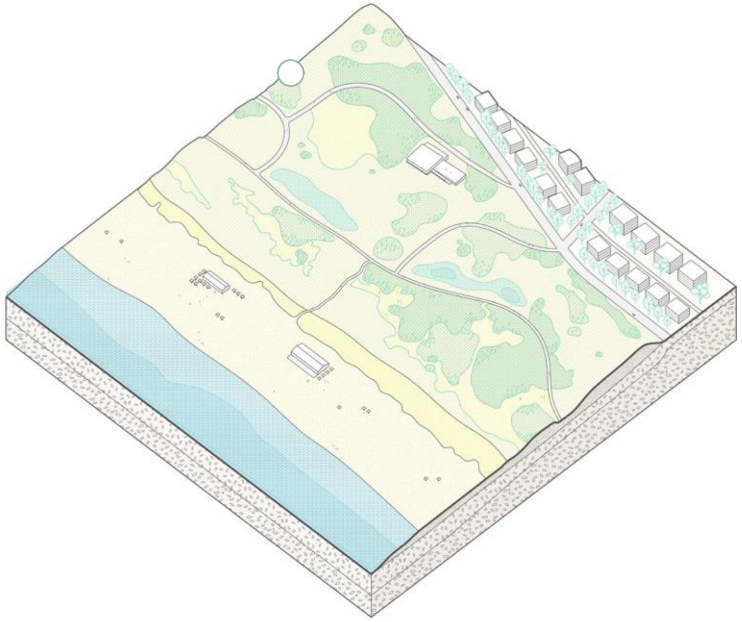


Planting mats: A bioengineered technique for salt marsh restoration that facilitates the reestablishment of salt marsh species. Plants are grown on dense coconut mats, which are then placed in the marsh to protect younger species during initial growth.[26]

See case study on ***Salt Marsh Restoration in San Diego, USA,*** *for a practical example.*

SANDY SHORES

NATURE-BASED SOLUTIONS



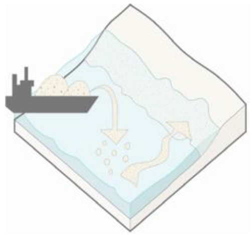
Visualization of sandy shores in the urban context

Sandy shores: Beaches are unconsolidated and non-cohesive sediment controlled by the slope of the inner shelf and coastal area, the abundance and type of sediments, tidal range, and wave energy. Dunes are accumulations of sand transported by wind to the backshore and stabilized by vegetation or other structures.[27]

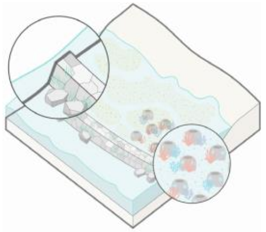
RATIONALE FOR NBS:

- Reduce flooding by dissipating wave energy.
- Prevent coastal erosion by containing and stabilizing sand.
- Increase infiltration to stabilize water supply.

Special Techniques for Sandy Shores



Beach nourishment and dune restoration: Feeding sand along or in front of a beach and allowing wave and tidal action to distribute it along the shore. Approaches to restore and manage beach systems include shoreface or beach nourishment (nearshore placement) and dune restoration and nourishment.[28, 29]



Artificial reefs and submerged structures: Hard substrate for coral or oysters that creates conditions to establish other ecosystems such as seagrass meadows, mangroves, and beach and dunes. Submerged structures create perched beaches, where the beach profile is raised or protected.[30]

URBAN NATURE-BASED SOLUTIONS

Case Studies: Public Municipality Projects

This section outlines practical case studies of nature-based solutions with commercial benefits that municipalities have implemented.

CASE STUDY: Bishan-Ang Mo Bio Park (Singapore)

INFRASTRUCTURE SERVICE	• Water supply.
CHALLENGE	• Singapore imports 40% of its water to meet demand. • Despite plentiful rainfall, Singapore has little land to capture and store water, resulting in urban flooding. • To reduce its reliance on water imports and reduce the risk of damage from flooding, Singapore undertook a project to increase available water catchment and storage areas.[31, 32]
NBS & FINANCING	• A 3-kilometer-long sinuous stream channel with bioengineered edges was restored in place of a 2.7-kilometer-long concrete-lined drainage channel. • Increasing the local water catchment reduces reliance on importing water from neighboring countries. Singapore currently pays Malaysia 0.01 Singapore dollars for 1,000 gallons of raw water from the Johor river in Malaysia (for a daily maximum of 250,000,000 gallons of water) [annual estimate ~S$1 mn].[33] • $56.3 million financed by the municipal government.[34]
IMPACT OF NBS	• Restoring the sinuous flow of the stream increased the water storage capacity of the local river and floodplain system by 40%, reducing the risk of flooding of nearby transport infrastructure. • The restored sinuous stream acts as a pollution filtration system, improving the water quality of the rivers flowing into the open sea. • Additional benefits of the NBS include a 30% increase in biodiversity and a 12% increase in recreational space.[7, 35]


Original concrete-lined canal

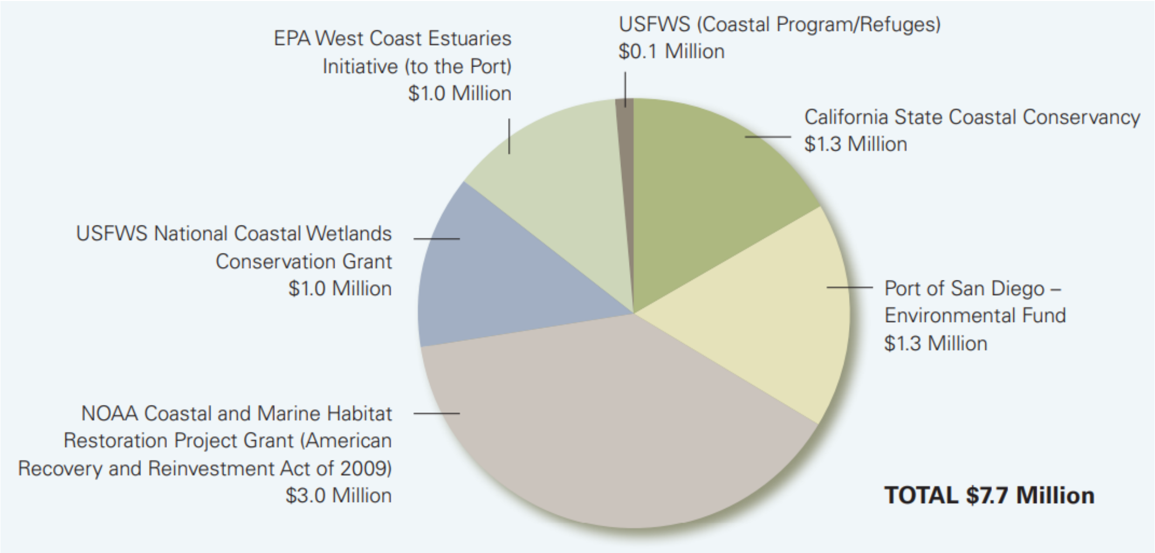

Restored sinuous stream channel (NBS)

*See **River and Stream Renaturation** for further technical information.*

CASE STUDY: Salt Marsh Restoration (San Diego, USA)

INFRASTRUCTURE SERVICE	• Protection of coastal assets.
CHALLENGE	• Over 70% of San Diego Bay's coastal salt marsh habitats were lost over the past 150 years from dredging and filling to accommodate maritime and urban development.[36] • The City of San Diego required cost-effective solutions to meet goals in its ambitious Climate Action Plan (Goal 5: Resilient Infrastructure and Healthy Ecosystems).[37]
NBS & FINANCING	• 200,000 cubic yards of sediment were redistributed within two salt ponds to restore hydrology to support coastal wetlands subject to the ebb and flow of the bay's tidal current. • Restoration of 257 acres of salt marshes (Western Salt Ponds) cost $5,631,666.[36]
IMPACT OF NBS	• Increased resilience to storm surges and rising water levels. • Improved water quality. • Increased carbon sequestration. • Restored habitat for marine invertebrates, fish, and birds.[38]

US Coastal Survey T-Sheets, 1851-1889, historic wetlands, South San Diego Bay[38]



*Funding sources for restoring coastal wetlands in and around the southern end of the bay, **including the western salt ponds project***[38]

*See **Salt Marshes** for further technical information.*

CASE STUDY: Odra River Basin Flood Protection Project (Wroclaw, Poland)

INFRASTRUCTURE SERVICE

- Flood/stormwater management.

CHALLENGE

- Wroclaw's stormwater management system was unable to manage the increased quantity of rainwater and snowmelt in the spring season.[39]
- The dense city center, the area most affected by historic floods, had limited area to expand to include additional flood management protection mechanisms.

NBS & FINANCING

- Dredged river and strengthened embankments to increase the flood carrying capacity of the Odra River in the channels through and around Wroclaw.[39]
- Increased storage for flood events by establishing a dry polder upstream of the town of Raciborz.[40]
- $489 million (World Bank and EU Cohesion Fund).

IMPACT OF NBS

- Increased the floodwater flow capacity from 2,200 m^3/s up to 3,600 m^3/s.
- Protects 2.5 million people and increases the resilience of property/infrastructure in several towns along the banks of the Odra River from flood damage.[41]
- Cost-effective solution as opposed to building and maintaining further gray infrastructure in and around Wroclaw to increase flood resilience.

Odra River in Poland (photo by Maxence Peniguet on Flickr)

Odra River in Poland

CASE STUDY: Rail Corridor Project (Singapore)

INFRASTRUCTURE SERVICE

- Temperature reduction.

CHALLENGE

- Singapore faces high temperatures, compounded by the urban heat island effect, where hard, heat-absorbing surfaces increase the temperature of a built-up urban area by several degrees.[42]

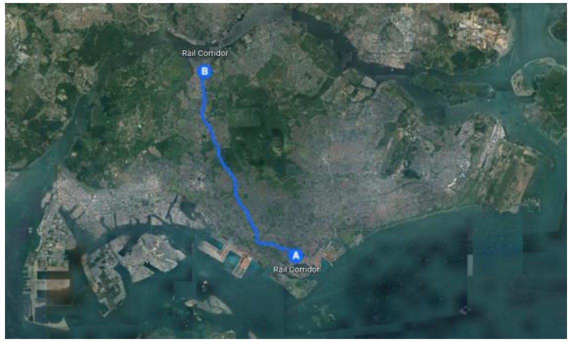
NBS & FINANCING

- Rewilded a 24 kilometer stretch of land (previously the Keratapi Tanah Melayu railway) and integrated it into the Clementi Nature Corridor as part of the Nature Ways project.[43, 44]
- Planted more than 52,000 native trees and shrubs along the railway corridor.
- Naturalized streams by restoring their shape to direct the flow of stormwater runoff and provide habitat for aquatic species.[45]
- Cost of project not disclosed. Financed by the municipal government.

IMPACT OF NBS

- Reduced air temperature and air pollution through natural evapotranspiration of plants in the increased coverage of a green canopy.
- Reduced flooding by managing stormwater through increased infiltration and stream naturalization.
- Increased habitat space for fauna, including endangered species (Sunda pangolin and straw-headed bulbul).

The nature trail in the Singapore Rail Corridor[46]



Aerial view of the Rail Corridor crossing Singapore[47]

*See **Green Corridors** for further technical information.*

CASE STUDY: Freetown the Tree Town Campaign (Sierra Leone)

INFRASTRUCTURE SERVICE	• Stormwater management; ground cover.
CHALLENGE	• Natural forest cover in Freetown's Western Area Peninsula has declined by about 70% in the last 50 years due to a growing population and climate change.[48] • This has led to increased risk of flooding and landslides.[48]
NBS & FINANCING	• Plant and grow 1 million trees within the city (a 50% increase in the city's vegetation cover) through funding tree seedlings, tree-planting and growing, and canopy tree mapping. • Innovative digital tracker to enhance community ownership and measure the tree survival rate. • Undisclosed portion of the $50 million World Bank funding to the Resilient Urban Sierra Leone Project.
IMPACT OF NBS	• Reduced flood and landslide risks through stabilizing slopes with roots from increased canopy cover.[49] • Reduced heat stress. • Improved air and water quality. • Recovered degraded habitat to increase biodiversity.

Participants in the Freetown the Tree Town Campaign[50]

*See **Urban Forests** for further technical information.*

URBAN NATURE-BASED SOLUTIONS
Case Studies: Municipality Projects with Private Sector Involvement

This section outlines practical case studies of nature-based solutions with commercial benefits that municipalities have implemented.

Globally, there are limited NBS projects in municipalities with direct private sector involvement. Given that these kinds of projects are at a nascent stage of development, the case studies illustrated in the following section primarily reflect a developed market context. Emerging markets can leverage lessons learned from these cases to pilot the approaches in new settings.

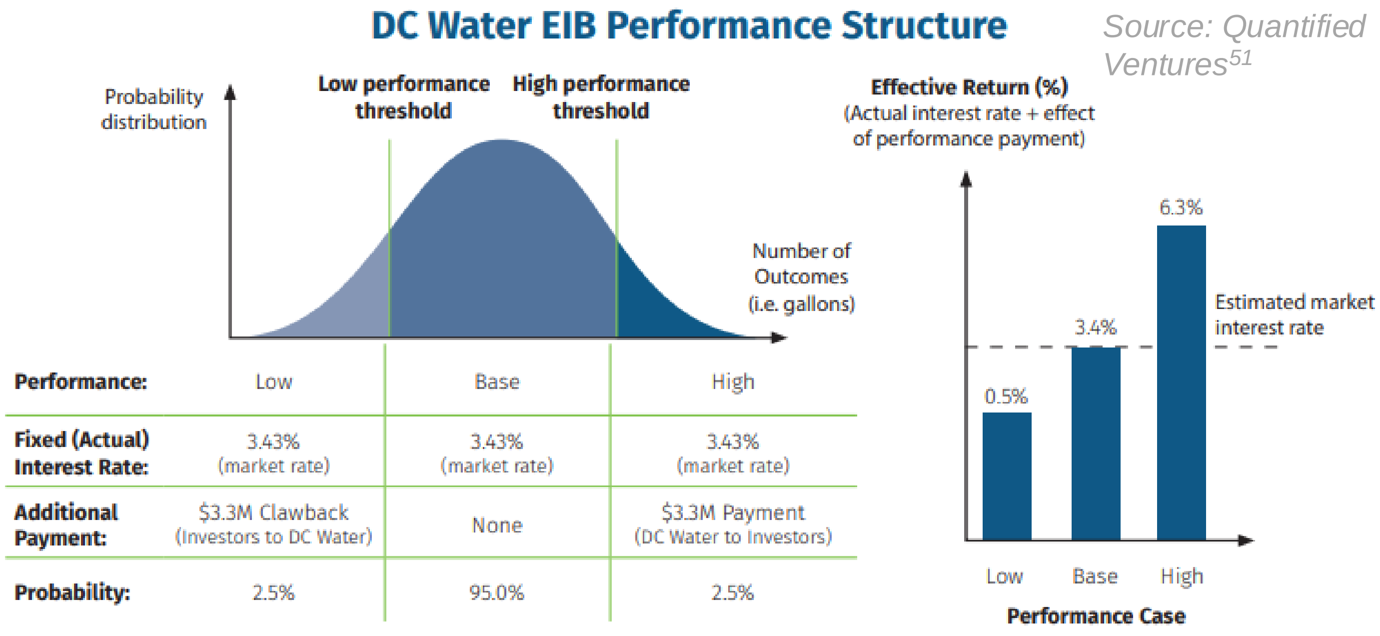
CASE STUDY: Pay for Performance – Environmental Bond (Washington, DC, USA)

INFRASTRUCTURE SERVICE

- Stormwater management.

CHALLENGE

- Old combined sewer system for sanitation and stormwater, leading to sewer overflow into rivers after rains.



Source: Quantified Ventures[51]

NBS & FINANCING

- Pilot to create 20 acres of NBS (permeable pavement, green roofs, and landscaped retention facilities).
- $25 million Environmental Impact Bond privately placed with Goldman Sachs & Calvert Impact Capital.
- Interest payment is linked to performance of NBS (see graph for performance structure).[51]

IMPACT OF NBS

- Approximately 650,000 gallons of water captured annually.
- Potential to expand from the pilot 20 acres to 345 acres.

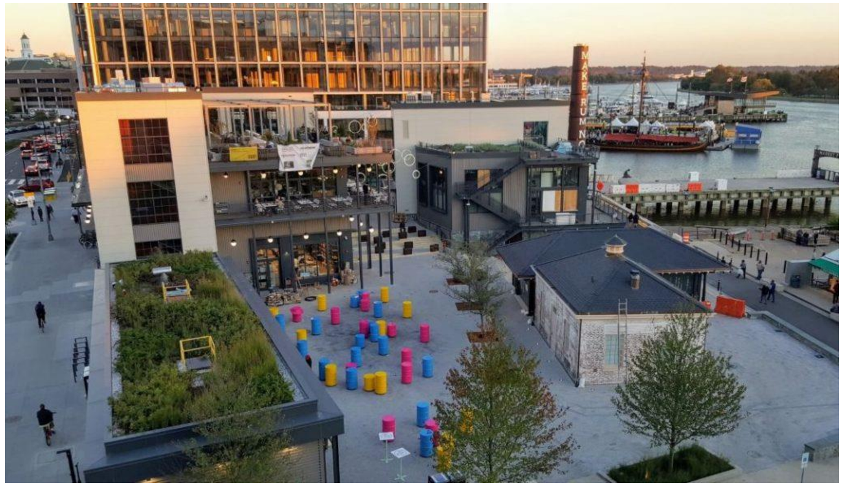
*See **Building Solutions** and **Bioretention** for further technical information.*

CASE STUDY: Stormwater Retention Credit Trading Program (Washington, DC, USA)

INFRASTRUCTURE SERVICE	• Stormwater management.
CHALLENGE	• Old combined sewer system for sanitation and stormwater, leading to sewer overflow into rivers after rains; a leading cause of pollution of the Chesapeake Bay.[54]

NBS & FINANCING	• Stormwater Retention Credit Trading Program to promote uptake of green infrastructure for stormwater management and to leverage private capital.
	  ◦ Required level of stormwater retention on site as part of building/development permitting process.
	  ◦ Developers can meet requirements on site or purchase stormwater retention credits.
	  ◦ Credits traded in voluntary market or through the municipal government at a guaranteed price.[53]
	• Cost of establishing the program not disclosed.

IMPACT	• Stormwater management system captures 3.2 inches of rainwater on site (versus required 1.2 inches) through various NBS.[53]



The Wharf's stormwater management system comprises the following NBS:

- Green infrastructure and landscape features
- Green roofs
- Native plants and trees
- Permeable pavement
- Rain gardens
- Rainwater cisterns
- Tree boxes[53]

*See **Building Solutions**, **Open Green Spaces**, and **Bioretention** for further technical information.*

CASE STUDY: Private Property Retrofit Incentive Program (NYC, USA)

INFRASTRUCTURE SERVICE

- Stormwater management.

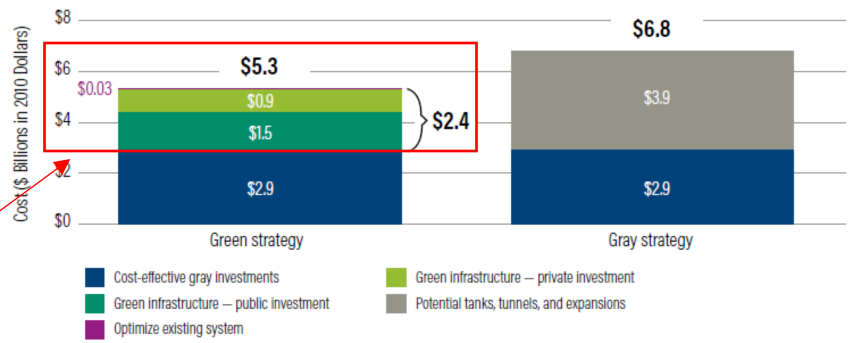
CHALLENGE

- Lack of publicly owned space for green infrastructure for stormwater management.

NBS & FINANCING

- Private Property Retrofit Incentive Program to install green infrastructure on private property through leveraging private capital.[56]
- Nature-based solutions included rain gardens, filtration basins, and permeable pavements.
- Total project cost: $5.3 billion. Green infrastructure elements cost a combined $2.4 billion in public ($1.5 billion) and private ($0.9 billion) funding.
- Additional tax abatement to property owners who install green roofs.[55]

Figure 4.2 | Reducing Cost by Mixing Green and Gray Infrastructure*, New York City



Note: *Combining green and gray infrastructure cost 22 percent less than gray alone.
Source: Bloomberg and Holloway 2018.

IMPACT OF NBS

- Green infrastructure that captures 10% of the impervious area of combined sewer watersheds would cost approximately $1.5 billion in public funds compared to $3.9 billion in public funds for comparable gray investments.
- Additional benefits are estimated to be $139 million to $418 million in reduced energy bills, increased property values, and health benefits.
- Attracted nearly $1 billion in private finance.[55]

*See **Building Solutions**, **Open Green Spaces**, and **Bioretention** for further technical information.*

CASE STUDY: River Catchment Restoration (Greater Cape Town, South Africa)

INFRASTRUCTURE SERVICE

- Water supply; stormwater management.

CHALLENGE

- Severe water shortage with sustained periods of drought.
- High cost of investing in deep aquifer drilling, desalination, water reuse, and increased surface water storage ($540 million).

NBS & FINANCING

- Removal of water-intensive alien vegetation (invasive species), including acacia, pine, and eucalyptus, that consume 20% more water than native vegetation in 7 priority river catchment areas.[57]
- $25.5 million financed by The Nature Conservancy Public/Private Water Fund (private contributors included Pepsi, Coca-Cola, Levi's, and Caterpillar).

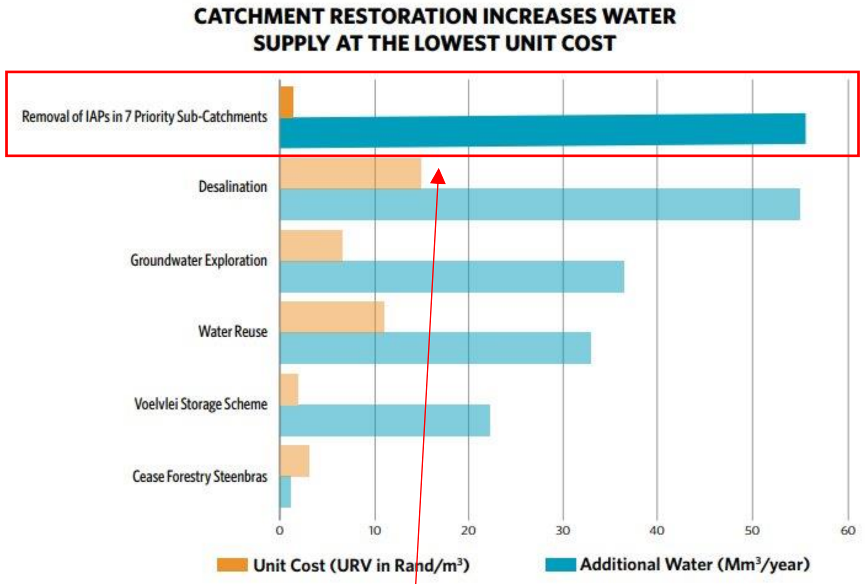


Figure E 1. Water supply gain and unit cost (URV) comparison between different catchment restoration and other supply options (costs include raw water treatment cost where applicable).

Source: The Nature Conservancy[21]

IMPACT OF NBS

- Removing invasive species will recover:
  - 55 billion liters of water per year within 6 years (equal to 2 months of water supply for Cape Town).
  - 100 billion liters of water within 30 years.[58]
- Restoring the water catchment area supplies water at 1/10 the unit cost when compared to alternative water augmentation solutions such as desalination (see graph for cost comparison).[58]

CASE STUDY: Rio Camboriu PWS Program (Santa Catarina, Brazil)

INFRASTRUCTURE SERVICE

- Wastewater treatment; flood management.

CHALLENGE

- Camboriu River lacks capacity to serve as a reliable source of drinking water supply to meet demands of an increased city population, particularly in summer:
  - Lack of water storage infrastructure in the ill-suited topography in the watershed.
  - High sediment load at the water plant's intake point leading to large water losses in the treatment of stream water.[59]


Regenerating forest in riparian areas through fencing for cattle exclusion

Photo by Andre Targa Cavassani, TNC

NBS & FINANCING

- The Balneario Comboriu Water Company (EMASA), the water supplier for both municipalities, invested in protecting remaining natural forests and restoring degraded areas with high sediment load to reduce treatment water losses and cost.
- To implement the watershed conservation strategy, EMASA created the Camboriu Payments for Watershed Service (PWS) project, which implements several NBS interventions:
  - Restoring and conserving degraded riparian and headwater areas and upland forest on steep slopes through fencing for cattle exclusion and planting of native trees.
- Landowners receive payments as compensation for maintaining interventions on their property.[59]

IMPACT OF NBS

- Reduced the risk of municipal water supply shortages during the tourist high season.
- Reduced flooding risk due to increased water storage areas.
- NBS implementation is substantially cheaper than gray infrastructure alternatives.
- From 2015 to 2045, the PWS program will produce average annual sediment reduction-related benefits of about $194,000.[59]

*See **River Floodplains** for further technical information.*

REFERENCES

[1] World Bank. 2021. A Catalogue of Nature-based Solutions for Urban Resilience. World Bank Group. https://openknowledge.worldbank.org/handle/10986/36507.
[2] IFC. 2023. Biodiversity Finance Reference Guide. https://www.ifc.org/wps/wcm/connect/publications_ext_content/ifc_external_publication_site/publications_listing_page/biodiversity-finance-reference-guide.
[3] Resilient Cities Network. 2023. What Is Urban Resilience? https://resilientcitiesnetwork.org/what-is-urban-resilience/.
[4] Wijesiri, B., Liu, A., and Goonetilleke, A. 2020. Impact of Global Warming on Urban Stormwater Quality: From the Perspective of an Alternative Water Resource. Journal of Cleaner Production.
[5] Nerini, F.F., Tomei, J., To, L.S., Bisaga, I., Parikh, P., Black, M., Borrion, A., Spataru, C., Broto, V.C., Anandarajah, G., and Milligan, B. 2018. Mapping Synergies and Trade-offs between Energy and the Sustainable Development Goals. Nature Energy.
[6] Cohen-Shacham, E., Walters, G., Janzen, C., and Maginnis, S, eds. 2016. Nature-based Solutions to Address Global Societal Challenges. Gland, Switzerland: International Union for Conservation of Nature (IUCN). https://portals.iucn.org/library/sites/library/files/documents/2016-036.pdf.
[7] Green-Gray Community of Practice. 2020. Practical Guide to Implementing Green-Gray Infrastructure. https://www.conservation.org/docs/default-source/publication-pdfs/ci-green-gray-practical-guide-v08.pdf?sfvrsn=62ed4b48_2.
[8] AECOM. 2022. Practical User's Guide for the NNBF Guidelines. https://qrcgcustomers.s3-eu-west-1.amazonaws.com/account569877/32337810_2.pdf?0.08791332031073118.
[9] IUCN. 2020. Guidance for Using the IUCN Global Standard for Nature-based Solutions. A User-friendly Framework for the Verification, Design and Scaling Up of Nature-based Solutions. First edition. Gland, Switzerland: IUCN.
[10] FAO. 2016. Guidelines on Urban and Peri-urban Forestry. Salbitano, F., Borelli, S., Conigliaro, M., and Chen, Y. FAO Forestry Paper No. 178. Rome, Food and Agriculture Organization of the United Nations.
[11] FAO. 2021. Agroforestry. http://www.fao.org/forestry/agroforestry/en/.
[12] Polster, D.F. 2008. Soil Bioengineering for Land Restoration and Slope Stabilization. Course material for training professional and technical staff. Duncan, British Columbia, Polster Environmental Services.
[13] Eisenberg, B., and Polcher, V. 2020. Nature-based Solutions Technical Handbook. UNaLab Horizon. https://unalab.eu/system/files/2020-02/unalab-technical-handbook-nature-based-solutions2020-02-17.pdf.
[14] Dakdokters. n.d. Water Collection on Roofs. Online article. https://dakdokters.nl/en/polder-roofs/.
[15] Kahn Jr, P.H., and Kellert, S.R., eds. 2002. Children and Nature: Psychological, Sociocultural, and Evolutionary Investigations. MIT Press.
[16] Natural Walking Cities. 2019. Creating and Promoting Walkable and Natural Infrastructure for Sustainable Cities. http://naturalwalkingcities.com/.
[17] FAO. 2011. The State of the World's Land and Water Resources for Food and Agriculture: Managing Systems at Risk. London, UK: Earthscan.
[18] Climate Technology Centre & Network. n.d. Floating Agricultural Systems. https://www.ctc-n.org/technologies/floatingagricultural-Systems.
[19] Haq, A.H.M.R., Ghosal, T.K., and Ghosh, P. 2004. Cultivating Wetlands in Bangladesh. Leisa Magazine 20 (4): 18–20.
[20] Department of Environmental Protection. 2006. Stormwater Best Management Practices (BMP) Manual. Pennsylvania. Water 5 (1): 13–28. https://pecpa.org/wp-content/uploads/Stormwater-BMP-Manual.pdf.
[21] Iwaszuk, E., Rudik, G., Duin, L., Mederake, L., Davis, M., Naumann, S., and Wagner, I. 2019. Addressing Climate Change in Cities. Catalogue of Urban Nature-based Solutions. Berlin, Krakow: Ecologic Institute and Sendzimir Foundation. https://www.ecologic.eu/sites/files/publication/2020/addressing-climate-change-in-cities-nbs_catalogue.pdf.
[22] Low Impact Development Center. 2007. Low Impact Development Center (LIDC) Urban Design Tools. https://www.lid-stormwater.net/.

REFERENCES

[23] Kennen, K., and Kirkwood, N. 2015. Phyto: Principles and Resources for Site Remediation and Landscape Design. Routledge.
[24] Deltares. n.d. Mangrove Restoration: To Plant or Not to Plant? https://www.deltares.nl/app/uploads/2016/07/Mangrove-restoration_to-plant-or-not-to-plant.pdf.
[25] Baptist, M.J., Gerkema, T., Van Prooijen, B.C., Van Maren, D.S., Van Regteren, M., Schulz, K., Colosimo, I., Vroom, J., Van Kessel, T., Grasmeijer, B., and Willemsen, P. 2019. Beneficial Use of Dredged Sediment to Enhance Salt Marsh Development by Applying a 'Mud Motor.' Ecological Engineering 127: 312–323.
[26] EcoShape. https://www.ecoshape.org/en/cases/pioneer-salt-marsh-restoration-for-coastal-protection-eastern-scheldt-nl/construction-phase/; https://www.ecoshape.org/en/concepts/growing-salt-marshes/biosphere/; https://www.ecoshape.org/en/concepts/growing-salt-marshes/hydrosphere-salt-marshes/.
[27] Wright, D.L., and Short, A. 1984. Morphodynamic Variability of Beaches and Surf Zones, a Synthesis. Marine Geology 56: 92–118.
[28] USACE. 2021. International Guidelines on Natural and Nature-based Features for Flood Risk Management. https://ewn.erdc.dren.mil/?page_id=4351.
[29] Scottish Natural Heritage. 2000. A Guide to Managing Coastal Erosion in Beach/Dune Systems. https://www.nature.scot/sites/default/files/2017-07/Publication%202000%20-%20Beach%20Dunes%20-%20a%20guide%20to%20managing%20coastal%20erosion%20in%20beach%20dune%20systems.pdf.
[30] Jacobsen, E.E. 1982. Perched Beach. In: Beaches and Coastal Geology. Encyclopedia of Earth Sciences Series. New York, NY: Springer. https://doi.org/10.1007/0-387-30843-1_320.
[31] Atelier Dreiseitl. 2012. Bishan-Ang Mo Kio Park and Kallang River. https://www.c40.org/wp-content/static/other_uploads/images/1963_AD-Ref_Singapore_Bishan-Park.original.pdf?1538133801.
[32] Shafer, C. 2014. Bishan-Ang Mo Kio Park and Kallang River: From Concrete Canal to Natural Wonderland. Ecological Urbanism. https://web.mit.edu/nature/projects_14/pdfs/2014-Bishan-Ang-Mo-Kia-Park-Schaefer.pdf.
[33] Singapore Ministry for Foreign Affairs. 2023. Water Agreements. https://www.mfa.gov.sg/SINGAPORES-FOREIGN-POLICY/Key-Issues/Water-Agreements.
[34] C40. 2018. Singapore: Bio-engineering Works at Bishan-Ang Mo Kio Park to Prevent Urban Flooding. https://www.c40.org/case-studies/singapore-bio-engineering-works-at-bishan-ang-mo-kio-park-to-prevent-urban-flooding/.
[35] NSW Government. 2024. Bishan-Ang Mo Kio Park, Singapore. https://www.planning.nsw.gov.au/government-architect-nsw/case-studies/bishan-ang-mo-kio-park-Singapore.
[36] Southern California Wetlands Recovery Project. 2024. South San Diego Bay Restoration. https://scwrp.org/projects/south-san-diego-bay-restoration/#:~:text=The%20restoration%20of%20coastal%20salt,levees%20to%20restore%20tidal%20circulation.
[37] City of San Diego. 2022. Climate Action Plan. https://www.sandiego.gov/sites/default/files/san_diegos_2022_climate_action_plan_0.pdf.
[38] Southwest Wetlands Interpretive Association. 2021. South San Diego Bay Coastal Wetland Restoration and Enhancement Project. https://scc.ca.gov/webmaster/ftp/pdf/sccbb/2021/2101/20210121Board05D_Restoration%20Success.pdf.
[39] World Bank. 2015. Improving Poland's Odra River for Safety. https://www.worldbank.org/en/results/2015/02/05/improving-odra-river-for-safety-poland.
[40] World Bank. 2007. Odra River Basin Flood Protection. https://projects.worldbank.org/en/projects-operations/project-detail/P086768.
[41] World Bank. 2021. Odra River Basin Flood Protection Project. https://documents1.worldbank.org/curated/en/272151612535424724/pdf/Poland-Odra-River-Basin-Flood-Protection-Project.pdf.
[42] Bloomberg. 2020. This Is How Singapore Keeps Its Cool as the City Heats Up. https://www.bloomberg.com/news/features/2020-12-01/singapore-climate-change-reducing-heat-takes-trees-and-technology.
[43] WEF. 2024. Cities Are Using Nature to Cut Urban Temperatures – by 2C in One Case. https://www.weforum.org/agenda/2024/01/nature-positive-cities-tackle-extreme-heat/.
[44] National Parks. 2024. About Our Parks, Nature Reserves and Park Connectors. https://beta.nparks.gov.sg/visit/when-visiting-parks/about-parks-nature-reserves-pcns/nature-corridors-ways.
[45] The Rail Explorers. 2023. The Rail Corridor Guide Sheet. https://www.nparks.gov.sg/-/media/rail-corridor/rc-resources/trifold-guidesheet.ashx.
[46] Singapore National Parks. 2023. Biodiversity & Greenery. https://railcorridor.nparks.gov.sg/biodiversity/.

REFERENCES

[47] Xu, S. 2023. An Old Railway Running through Singapore Is Now a Thriving Nature Reserve. https://www.bloomberg.com/news/articles/2023-02-17/singapore-transforms-rail-line-into-nature-reserve-instead-of-development.
[48] Catholic Relief Services and The Nature Conservancy. 2022. Western Area Peninsula Water Fund – Assessing the Return on Investment for Nature-based Solutions for the Western Area Peninsula and Freetown, Sierra Leone.
[49] World Bank. 2021. A Catalogue of Nature-based Solutions for Urban Resilience. Washington, DC: World Bank Group.
[50] Fisseha, T., Toya, A., Cowan, N.M., and Duma, L. 2021. #FreetownTheTreeTown Campaign: Using Digital Tools to Encourage Tree Cultivation in Cities. https://blogs.worldbank.org/sustainablecities/freetownthetreetown-campaign-using-digital-tools-encourage-tree-cultivation.
[51] Quantified Ventures. n.d. Case Study: DC Water. https://static1.squarespace.com/static/5d5b210885b4ce0001663c25/t/5e136b61f2afef61e95e7472/1578331001269/DC+Water+Case+Study_Quantified+Ventures.
[52] Quantified Ventures. n.d. Hampton, VA: An Environmental Impact Bond to Fight Flooding. https://www.quantifiedventures.com/hampton-eib.
[53] Metropolitan Planning Council. 2019. Stormwater Credit Trading: Lessons from Washington D.C. https://www.metroplanning.org/news/8671/Stormwater-Credit-Trading-Lessons-from-Washington-D-C.
[54] Department of Energy and Environment. n.d. Stormwater Retention Credit Trading Program. https://doee.dc.gov/src.
[55] City of New York. n.d. NYC Green Infrastructure Plan: A Sustainable Strategy for Clean Waterways. https://www1.nyc.gov/assets/dep/downloads/pdf/water/stormwater/green-infrastructure/nyc-green-infrastructure-plan-2010.pdf.
[56] NACWA. 2021. New York City Reaches Out to Its Customers to Propel Green Infrastructure Investment. https://www.nacwa.org/news-publications/news-detail/2021/06/28/new-york-city-reaches-out-to-its-customers-to-propel-green-infrastructure-investment.
[57] The Nature Conservancy. 2023. Nature-based Solutions Are Protecting Cape Town's Water Supply. https://www.nature.org/en-us/about-us/where-we-work/africa/stories-in-africa/nature-based-solutions-could-protect-cape-town-s-water-supply/.
[58] The Nature Conservancy. 2019. Greater Cape Town Water Fund: Business Case – Assessing the Return on Investment for Ecological Infrastructure Restoration. https://www.nature.org/content/dam/tnc/nature/en/documents/GCTWF-Business-Case-April-2019.pdf.
[59] Kroeger, T., Klemz, C., Shemie, D., Boucher, T., Fisher, J.R.B., Acosta, E., Dennedy-Frank, P.J., Targa Cavassani, A., Garbossa, L., Blainski, E., Comparim Santos, R., Petry, P., Giberti, S., and Dacol, K. 2017. Assessing the Return on Investment in Watershed Conservation: Best Practices Approach and Case Study for the Rio Camboriú PWS Program, Santa Catarina, Brazil. The Nature Conservancy, Arlington, VA.

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