BLUE CITIES

NATURE-BASED SOLUTIONS FOR COASTAL CLIMATE RESILIENCE

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UNIFESP · Maré de Ciência · 2021 2030 Década das Nações Unidas da Ciência Oceânica para o Desenvolvimento Sustentável · Ministério da Ciência, Tecnologia e Inovação · Governo Federal Brasil União e Reconstrução · Em cooperação unesco · Fundação Grupo Boticário

BLUE CITIES: NATURE-BASED SOLUTIONS FOR COASTAL CLIMATE RESILIENCE

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Blue Cities : Nature-based Solutions for Coastal Climate Resilience / Coordenação de Aline Sbizera Martinez. -- 1ª ed. -- Santos : Universidade Federal de São Paulo (UNIFESP), 2025. -- 110 p.

ISBN: 978-65-85919-60-9 (on line)

1. Sustainability. 2. Coastal cities. 3. Climate resilience. 4. Urban adaptation. 5. Nature-based Solutions. I. Martinez, Aline Sbizera (coord.) II. Título.

CDD 338.927

Bibliotecária Daianny Seoni de Oliveira - CRB 8/7469

Preamble

We live in a constantly changing world where climate and biodiversity crises impact thousands of people daily, demanding urgent actions for adaptation and resilience. Although various documents and action plans at different governance levels emphasize the importance of ecosystem restoration and climate resilience, highlighting Nature-based Solutions (NbS) as strategic pathways, many professionals responsible for adaptation initiatives and urban planning still face challenges in implementing NbS projects in their local contexts.

Focused on coastal cities, this document provides an overview of NbS that can be applied in Brazil to enhance climate resilience. Although this guide was prepared within a more regional perspective, it offers solutions that can be applied to cities worldwide. We aim to support decision-makers, public managers, legislators, investors, and the general public by compiling information to facilitate the identification of NbS strategies for promoting urban sustainability and preparing cities to cope with extreme weather events that are intensifying due to climate change.

This work was produced by the Brazilian Ocean Literacy Alliance, coordinated by the Maré de Ciência Program/Federal University of São Paulo (UNIFESP), the Ministry of Science, Technology, and Innovation of Brazil (MCTI), and UNESCO, in collaboration with the Boticário Group Foundation for Nature Protection, to strengthen the science-policy interface. The information shared here is based on globally implemented examples and rigorous scientific curation, reinforcing the opportunity for science-based decision-making rooted in successful experiences.

Acknowledgments

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SUPPORT
São Paulo Research Foundation (FAPESP 2019/24416-8) and National Council for Scientific and Technological Development through the Biodiversity Research Program (CNPq 441230/2023-7).

SUGGESTED CITATION
Blue Cities: Nature-based Solutions for Coastal Climate Resilience (2024). Technical-scientific guide. Brazilian Ocean Literacy Alliance (UNIFESP-UNESCO-MCTI)/FGB. Santos-SP, Brazil, 110 pp. ISBN:

ILLUSTRATIVE IMAGES
All graphical representations of Nature-based Solutions presented in this document were generated by OpenAI's ChatGPT language model. Illustrations of the front cover and chapters were generated by Adobe Firefly's generative AI model.

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1. Glossary

Adaptive management – An environmental management approach that recognizes the inherent uncertainty in managing ecological systems and uses continuous scientific-based monitoring to assess the effectiveness of interventions. In the context of NbS (Nature-based Solutions), it involves tracking environmental, social, and economic indicators at the intervention site throughout the process (before, during, and after implementation). Based on results, strategies are dynamically adjusted to enhance conservation and minimize undesirable impacts. This practice emphasizes the need for continuous learning, promoting more effective and sustainable solutions.

Atlantic Forest – A tropical and subtropical biome characterized by dense, biodiverse forest with tall trees, shrubs, and a rich variety of epiphytes, such as bromeliads and orchids. Originally, it extended along the Brazilian coast from Rio Grande do Norte to Rio Grande do Sul, covering hillsides and plains. Despite being highly fragmented due to urbanization and deforestation, the Atlantic Forest still provides essential ecosystem services, such as climate regulation, protection of watersheds and slopes, and provision of habitat for numerous endemic species of fauna and flora, many of which are threatened with extinction.

Bioretention system – Interventions designed as shallow, vegetated depressions that can intercept, infiltrate, divert, modify, and treat the volume and flow rate of stormwater runoff.

Blue spaces – Aquatic environments like rivers, lakes, seas, wetlands, and other bodies of water. They play a crucial role in regulating the hydrological cycle, purifying water, mitigating floods, and promoting aquatic biodiversity, as well as offering recreational and aesthetic benefits.

Climate adaptation – The process of adjusting ecological, social, and economic systems in response to current or expected climatic events to minimize harm, reduce vulnerabilities, and take advantage of opportunities associated with climate change.

Climate change – Significant and lasting alteration in patterns of temperature, precipitation, and other climate variables on the global scale due to both human and natural factors.

Climate resilience – The social, economic, and ecological capacity of ecosystems to adapt to, withstand, and recover from the impacts of climate events, especially as a result of climate change.

Coastal hardening – The construction of rigid structures at the land-sea interface to protect urban areas and meet societal needs. This process often replaces unconsolidated natural environments, such as sandy beaches and muddy bottoms, with artificial surfaces, altering the natural dynamics of the coast and compromising the provision of ecosystem services.

Coastal zone – The interface region between terrestrial and marine environments, including coastal environments and their adjacent areas. This region is characterized by both direct and indirect influences from the sea. Currently, 443 municipalities officially belong to the coastal zone in Brazil. Of these, 279 municipalities have territories directly in contact with the ocean.

Coral reefs – Hard substrate formations composed primarily of calcareous structures built by corals, calcareous algae, and other marine organisms. In Brazil, shallow coral reefs are mainly found in the Northeast region. These ecosystems host a high biodiversity of fish and invertebrates and are essential for sustainable fishing and tourism. Coral reefs also provide many other ecosystem services, such as coastal protection against erosion and wave force.

Dunes – Formations created by the accumulation of sand shaped by wind, which can move and change shape but are often stabilized by vegetation. Dunes are common along the Brazilian coast, especially in the Northeast and South regions, where they play important ecological roles, such as natural protection against coastal erosion and storm surges, and supporting vegetation adapted to dry and sandy environments.

Ecosystem services – The essential benefits that nature provides, on which humans depend to survive. Examples include the provision of food (e.g., fish, crustaceans, vegetables), raw materials (e.g., wood, gas, minerals), and drinking water; air and water purification, climate regulation, coastal protection, pollination, and opportunities/conditions for recreation, tourism, and spiritual well-being.

Extreme weather event – A severe meteorological or climatic event, such as torrential rains, intense heat waves, severe swells, major floods, or prolonged droughts, which represents significant deviations from the average climatic patterns of a region. These events used to be rarer but are becoming more frequent due to climate change.

Flood – Accumulation of water in urban areas caused by heavy rainfall or drainage issues, resulting in streets or other areas temporarily covered with water.

Grey infrastructure – Physical structures built by humans on land or sea, designed exclusively to support and facilitate human activities. These structures are typically constructed using materials like concrete, steel, or other artificial components and have a significant impact on transforming the natural environment. Common examples include breakwaters, paved streets, parks with impermeable surfaces, seawalls, groynes, buildings, houses, avenues, bridges, and wharves.

Green spaces – Areas covered by natural or planted vegetation, such as gardens, parks, and forests, within or near urban settings. These spaces provide ecological benefits, such as climate regulation, air purification, biodiversity conservation, and leisure and wellness opportunities for people.

Inundation – The overflow of water bodies, such as rivers and seas, caused by heavy rainfall, swells, or storm surges, raising water levels above normal. This phenomenon covers usually dry areas and can affect large regions, causing extensive damage.

IPCC – The Intergovernmental Panel on Climate Change is formed by a group of scientists established by the United Nations with the purpose of assessing and reviewing scientific research related to climate change to inform and guide global climate policies.

Mangrove – A coastal ecosystem formed at the transition between terrestrial and marine environments, characterized by floodable soils and vegetation adapted to changing salinity and low oxygen levels. In Brazil, mangroves are found from the state of Amapá to Santa Catarina, being more abundant in the North and Northeast regions. This ecosystem provides vital ecosystem functions, such as coastal protection, carbon storage, sediment retention, and pollutant filtering. Mangroves support a rich biodiversity, including various commercially important species like fish, mollusks, and crustaceans.

Marine macroalgae – Photosynthetic organisms that grow on rocky or floating substrates in coastal environments. In Brazil, macroalgae occur across various coastal regions and play important ecological roles, such as absorbing excess nutrients, improving water quality, and supporting marine biodiversity. They are also a valuable source of commercial products, used in food, fertilizer production, and in the manufacturing of cosmetics and pharmaceuticals.

Nature-based Solutions (NbS) – Actions that use natural processes and ecosystems to address the most urgent challenges of society, such as water scarcity risks and the impacts of extreme weather events, including floods and landslides. This is a natural resource management approach that benefits biodiversity and human well-being, while also promoting solutions for socioeconomic development.

Nutrient cycling – The movement and transformation of nutrients within soil, water, and plants and other organisms, ensuring that essential elements for life remain available in the environment.

Oyster reefs – Aggregations of oysters attached to hard substrates, such as rocks, mangrove roots and other solid materials in shallow coastal waters. Oyster reefs are primarily found in estuarine areas.

Pollination – The process by which wind, insects, birds, and other animals transfer pollen among plants, enabling their reproduction and the production of fruits and seeds.

Primary productivity – The process in which plants and algae, through photosynthesis, convert sunlight into energy, producing oxygen and biomass. This process is fundamental for providing energy and supporting the entire food web.

Restinga forest – A coastal ecosystem formed on sandy, nutrient-poor soils, characterized by diverse vegetation ranging from low grasses to shrubs and small trees adapted to saline conditions and strong winds. In Brazil, restingas are distributed along the entire coast, where they perform essential ecological functions such as coastal erosion protection, dune stabilization, and providing habitat for various species of flora and fauna.

Salt marsh – A coastal ecosystem of low-lying, floodable areas characterized by salt-tolerant grasses and sedges adapted to brackish water. In Brazil, salt marshes occur primarily in the South region, in estuarine areas and coastal lagoons, playing a crucial role in pollutant filtering, flood protection, and supporting local biodiversity.

Seagrasses – Vascular plants that grow submerged in shallow coastal environments. These plants provide essential ecosystem services, such as carbon sequestration, coastal erosion protection, pollutant filtering, and habitat for numerous marine species. In Brazil, seagrasses extend from the Northeast to the South region.

Secondary productivity – The amount of energy or biomass generated by animals when consuming plants or other animals, contributing to the growth and reproduction of species.

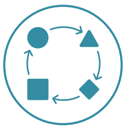
Sustainability – The responsible use of natural resources without compromising the well-being and development of future generations. Sustainability depends on balancing economic, social, and environmental aspects, aiming to conserve nature and promote a lifestyle that does not deplete natural resources.

Urbanization – The process of city growth and development, characterized by an increase in urban space and population within urban areas, expansion of infrastructure, and the social, economic, and cultural transformations associated with urban life.

2. Dictionary of Icons

Benefits of Nature-based Solutions

2.1 FUNCTIONAL benefits



Adaptability
Subject to adjustment and expansion over time to respond to changes in environmental conditions and sea level rise.

Air purification
Grasses, shrubs, and trees act as natural filters, removing pollutants from the air, such as carbon dioxide, particles, and other toxic gases.

Coastal protection
Blue parks and natural ecosystems, such as restingas, coral reefs, mangroves, salt marshes, and dunes, act as natural barriers. They absorb wave energy, tidal forces, and strong winds, buffer the impacts of storms, and help mitigate sea level rise. As a result, they protect coastal areas and enhance their resilience against extreme weather events.

Durability
The combination of structures designed based on ecological principles with the resilience of natural systems extends the lifespan of coastal defense structures.

Erosion control
Vegetation on slopes, estuarine areas, and other natural coastal ecosystems stabilize the soil by controlling surface runoff and water flow, which reduces erosion. These systems protect coastal areas, river banks, and steep terrains, restoring the natural sediment dynamics and ensuring the protection of infrastructure and communities.

Flood mitigation
Green parks and healthy natural systems, such as wetlands and forests, absorb and retain excess rainwater, slowing down runoff and reducing the severity and frequency of floods. Coastal ecosystems also act as natural barriers, minimizing the intrusion of saline waters and reducing the impact of tides and storms.

Groundwater recharge
Natural vegetation and permeable surfaces facilitate water infiltration into the soil, replenishing groundwater reserves.

Local production
It provides fresh, locally grown food, reducing the need for long-distance food transportation.

Thermal comfort
Vegetation provides natural thermal insulation to buildings and maintains milder temperatures around green and blue spaces.

Waste reduction
Recycling organic waste through composting.

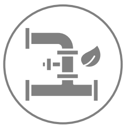
Water flow reduction
Capture, absorption, or dissipation of rainwater, slowing down runoff and reducing peak volumes, alleviating flow in urban drainage systems.

Water purification
Plants, soils, and sediments filter pollutants from water, reducing contamination of water bodies, aquifers, and drainage systems.

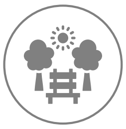
Water supply
Through rainwater harvesting and efficient irrigation systems to conserve water, it provides an alternative source for non-potable uses, such as irrigation, toilet flushing, and laundry.

2.2 URBAN benefits

Civil protection
Green and blue spaces protect the urban population by minimizing risks related to flooding, inundations, landslides, and diseases from air and water contamination. Additionally, well-designed greenways enhance pedestrian and cyclist safety by reducing vehicle speeds and keeping people away from traffic.

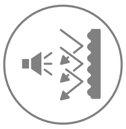


Drainage
Efficient management of rainwater capture, absorption, and redirection relieves pressure on drainage systems.



Enhanced public spaces
Green and blue spaces enhance urban public areas by providing recreational and accessible spaces, such as parks, trails, and social zones, promoting social interaction, leisure, public well-being, and opportunities for closeness to nature.

Infrastructure protection
Green and blue spaces, as well as natural habitats, minimize losses and damage to urban infrastructure caused by extreme weather events (rain, storms, storm surges, heatwaves).

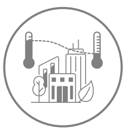


Noise reduction
Green areas act as natural sound barriers, reducing noise pollution by creating an acoustic buffer zone between residential areas and busier streets.

Space optimization
Green and blue infrastructures represent a strategic use of urban territory, serving both utilitarian and recreational functions, thus maximizing the limited urban space.

Sustainable urban design and planning
Integrating green and blue infrastructures into urban planning balances urban development with environmental conservation. This practice creates more sustainable and resilient cities, promoting a more livable urban environment in the long term.

Urban aesthetics
Green infrastructures and natural areas integrated into urban design improve the aesthetics of cities, making them more pleasant and attractive for residents and visitors.

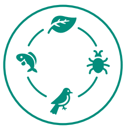


Urban cooling
Vegetation provides shade and releases moisture, cooling urban areas, increasing thermal comfort, and potentially reducing the energy needed to cool buildings. Additionally, permeable surfaces reduce heat absorption.

Urban mobility
Greenways provide safe routes for cyclists and pedestrians, connecting different areas of the city, improving access to public transportation, and creating more pleasant and safe environments for walking.

2.3 ENVIRONMENTAL benefits

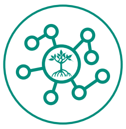
Air quality
Vegetation absorbs air pollutants and releases oxygen, helping to purify the atmosphere and reduce greenhouse gases. By improving air quality, natural areas contribute to ecological balance, promote ecosystem health, and mitigate the impacts of climate change.



Biodiversity
Green and blue spaces provide habitats for a wide variety of plant and animal species, promoting local biodiversity. The creation of green infrastructure, restoration of degraded natural areas, and preservation of pristine natural areas contribute to increasing biodiversity and conserving species.

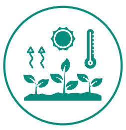
Carbon sequestration and storage
Terrestrial and aquatic vegetation, including algae, captures carbon dioxide from air and water and stores carbon in its tissues. This process is crucial for mitigating climate change and promoting urban sustainability.

Enhancement of ecological functions
Green and blue spaces integrate natural elements that support biodiversity and essential ecological processes, including pollination, nutrient cycling, water and air purification, as well as primary and secondary productivity.



Habitat connectivity
Strategic spatial planning for the conservation, restoration, or creation of green or blue spaces in urban environments facilitates the movement and dispersal of native biota, enhances genetic diversity, and provides essential resources and buffer zones within fragmented urban landscapes.

Healthy soils
Organic farming practices and the use of native plants in green infrastructure improve soil structure and fertility, promoting healthier soils in urban areas.



Thermal stress reduction
Cooling temperature in urban environments conserves moisture and decreases local thermal stress, creating more stable and favorable conditions for the survival and reproduction of flora and fauna.

Water quality
Terrestrial and aquatic vegetation, soil, and filter-feeding animals (e.g., oysters and mussels) filter pollutants from water, enhancing water quality in rivers, lakes, ponds, estuaries and seas. Additionally, vegetation helps stabilize the soil, reducing erosion and sedimentation in water bodies, thereby protecting and promoting water quality in aquatic ecosystems.

2.4 SOCIAL benefits

Community engagement
Green and blue spaces can serve as community areas that promote collaboration and community engagement in sustainable practices through environmental education and volunteer activities. These spaces also encourage community involvement in the planning, monitoring, and maintenance of ecological projects.

Community resilience
Empowering communities to be more self-sufficient and resilient to climate change.

Cultural value
Conserving and restoring natural environments preserves and strengthens the cultural and historical connections of communities with coastal areas.

Education
Green and blue spaces in cities expose residents to natural environments, encouraging environmental stewardship and sustainable practices. By providing outdoor spaces for social gathering and community engagement, these areas create educational opportunities around ecology, resource management, and sustainability, fostering a culture of environmental conservation.

Food security
Natural areas, such as mangroves, and oyster and coral reefs, enhance food security in cities by providing habitats for various commercially valuable species (e.g., fish, molluscs and crustaceans), ensuring sustainable fishing and protecting coastal resources. Additionally, urban gardens promote the local production of fresh food, reducing dependence on supply chains and strengthening community resilience.

Health
Access to green and blue spaces in cities provides opportunities for relaxation, recreation, and physical activities, which reduce stress and improve physical and mental health, benefiting the population's quality of life. Moreover, these natural spaces filter pollutants from the air and water, contributing to the prevention of respiratory and waterborne diseases.

Recreation
Green or blue public spaces provide recreation and leisure opportunities for the population by creating areas for relaxation, socialization, physical activities, or hosting events.

Sense of security
People trust and feel confident in the ability of mitigation policies to protect their communities from environmental disasters.

2.5 ECONOMIC benefits

Attractiveness for investments

Cities with green and blue spaces become more attractive to businesses and investors who value sustainability and quality of life. Furthermore, solutions that reduce the risk of natural disasters provide safe zones for sustainable urban development, attracting new investments and promoting economic growth.

Boost in local economy

Green and blue spaces attract visitors and tourists, boosting the local economy through increased spending on recreation, food, and other services. Businesses located near greenways also benefit from higher customer traffic in the area.

Fisheries productivity

The revitalization and protection of terrestrial and aquatic ecosystems in urban areas improve water quality and provide critical spawning and nursery habitats, collectively supporting the growth and sustainability of fishery stocks, including species consumed by local communities and those of economic importance.

Food cost savings

Local food production, especially in urban centers, strengthens food security by providing fresh products and diversifying supply. Furthermore, proximity to the end consumer reduces transportation costs and fees, positively impacting prices and fostering a more just and sustainable supply chain.

Healthcare savings

Improved air and water quality, combined with the encouragement of physical activity and recreation in green and blue spaces, contributes to public health by reducing the costs of treating respiratory diseases, waterborne diseases, and chronic illnesses related to urban environments (stress, anxiety, and sedentary lifestyles).

Increased property value

Properties with or near green and blue spaces tend to increase in value due to their sustainable functionality, aesthetic appeal, and the recreational and safety opportunities they offer.

Infrastructure cost savings

By managing stormwater runoff, urban green spaces reduce the need for extensive underground drainage systems, lowering the costs of construction and maintenance of these infrastructures.

Job creation

The design, construction, and maintenance of green and blue infrastructures, as well as the management of natural areas in cities, create jobs in fields such as landscaping (landscape architect, arborist), engineering (civil, materials, agricultural, forestry), urban operations (bioconstruction technician, equipment operator, plumber), urban agriculture (horticulturist, irrigation technician), environmental management (environmental technician, public area caretaker, biologist, chemist, geographer, oceanographer, physicist), and ecotourism (tourism specialist, environmental instructors, and guides).

Reduced damage costs

Mitigating the risks of flooding, storm surges, landslides, and strong winds reduces costs associated with damage to public infrastructure, residential properties, and businesses. It also lowers expenses related to repairs of drainage and electrical systems, and water contamination remediation.

Reduced insurance premiums

Mitigating risks from flooding, inundation, and landslides caused by rain, storm surges, and sea level rise can reduce insurance premiums for properties in safe areas, offering significant savings for property owners and businesses.

Transportation cost savings

Greenways provide economic alternatives to car use, saving money on fuel and vehicle maintenance, while also reducing road wear and the need for expensive infrastructure expansions.

3. CLIMATE CHANGE AND THE VULNERABILITY OF COASTAL CITIES

Cities around the world are facing increasingly urgent challenges related to climate change. The intensification of risks, combined with accelerated urbanization and loss of biodiversity and ecosystem services, exacerbates poverty and socio-economic inequalities. Extreme events such as storms, floods, heatwaves, and droughts, which are becoming more intense and frequent, threaten the well-being and lives of populations, causing significant economic losses and social instability, particularly among those living in coastal areas.

In Brazil, about a quarter of the population lives in the coastal zone[1], where cities are rapidly expanding. If we consider people living up to 150 km from the coast, this number surpasses half of the Brazilian population, according to the 2022 demographic census (54.8%[1-2]). Historically, the growth of cities in Brazil, and many developing countries, has occurred in a disorganized manner, with large concentrations of people in vulnerable areas[3]. These regions face exacerbated climate impacts, as they are often located in high-risk areas, such as low-lying zones or steep slopes[4]. The lack of maintenance in essential infrastructure, such as drainage systems and impermeable surfaces, intensifies natural risks, including flooding and the effects of urban heat islands.

In the face of the threats posed by climate change, the need for adaptation policies and urban resilience becomes increasingly urgent, aiming to mitigate future risks and ensure the sustainability of these critical areas.

The majority of the Brazilian population lives on or near the coast.

3.1 Challenges

3.1.1 Climate projections

Extreme events associated with recent climate anomalies in the ocean and atmosphere are already causing severe damage in several countries, including Brazil. This reality poses challenges that require integrated and well-planned actions to minimize negative impacts and protect coastal cities. Future projections indicate that the frequency and intensity of these events may increase, making the implementation of effective adaptation and mitigation strategies even more urgent.

Global temperature rise

Data from the IPCC (2021)[5] revealed a significant increase in the global average air temperature (1.09 °C) and ocean surface temperature (0.88 °C) between 2011 and 2020, compared to pre-industrial levels (1850-1900). The rate of ocean warming has doubled in the last 20 years[6], accelerating the impacts of climate change.

Sea level rise

The global mean sea level has risen about 10 cm since 1993[5]. Projections suggest that by 2100, the mean sea level could increase by at least 43 cm in a low-carbon emission optimistic scenario, possibly reaching 82 cm in a pessimistic scenario[5].

Changes in rainfall patterns

Climate projections for Brazil by 2100 indicate an increase in rainfall in the South and Southeast regions, while the Northeast and parts of the Amazon will face a reduced rainfall regime[4,7].

Examples of significant extreme events in Brazil in the last decade

2014

Severe drought in the state of São Paulo

Cantareira system reservoir completely dry.

Photos SABESP

Ocean-atmosphere conditions

In January 2014, a persistent and intense atmospheric blocking formed over the South Atlantic and Southeast Brazil. This phenomenon lasted 45 days (the usual duration is about one week), disrupting the transport of moisture from the Amazon and hindering the passage and development of major rainfall systems in parts of the Southeast region, especially in the state of São Paulo. During this period, positive anomalies in air and sea temperatures in the South Atlantic were also recorded.

Extreme event

The low rainfall recorded at the end of 2013 and in the first half of 2014 led to the worst water crisis ever registered in the state of São Paulo. The Cantareira system, which supplies water to the São Paulo Metropolitan Area, reached its historical lowest level. Other reservoirs in the states of São Paulo and Rio de Janeiro also reached critical low levels.

Damage

The population in several cities experienced long periods of water rationing, with frequent cuts in water supply. Many relied on water deliveries via tanker trucks. The prolonged drought also impacted the economy, causing price increases in food and electricity rates, along with massive losses for industrial activity. At the time, the estimated financial loss was in the billions of reais. There was also an increase in wildfires and tons of fish died in some rivers.

2020

Bomb cyclone in the South region

Trees and light poles felled in Florianópolis, Santa Catarina.
Photo: Santa Catarina Military Fire Department.

Warehouses in Muitos Capões, in the state of Rio Grande do Sul, destroyed by strong winds.
Photo: Civil Defense of Rio Grande do Sul.

Warehouse destroyed by a 'bomb cyclone' in the municipality of Palmitos, in the state of Santa Catarina.
Photo: Civil Defense of Santa Catarina.

Ocean-atmosphere conditions

In March and April 2020, the average air temperature was lower than usual, with values up to 1.5 °C cooler for southern Brazil. The surface temperature of the South Atlantic Ocean was warmer, ranging on average from 1 to 3 °C above normal values during May and June 2020.

Extreme event

On June 29-30th, 2020, a bomb cyclone formed when a low-pressure center moved from northern Argentina to Uruguay and Rio Grande do Sul. This phenomenon, which generated strong winds and big waves along the coast, was caused by a rapid drop in atmospheric pressure and produced winds up to 60% stronger than traditional cyclones. It was the most severe wind event ever recorded in southern Brazil, causing more damage than cyclone Catarina in 2004.

Damage

Thirteen deaths were confirmed, with nearly 1 million people affected. There were disruptions in power supply and port activities, along with damage to urban infrastructure. Over 20,000 homes were damaged or destroyed, with economic losses totaling around R$250 million.

2021

Heavy rainfall in the state of Bahia

Flood in the State of Bahia.
Photo: Record TV

Resident helping to rescue people on the streets of the local community in Itabuna.
Photo: Guthierry Andrade

Damage caused by flooding in the Nova Alegria district after heavy rains.
Photo: Eduardo Anizelli/Folhapress

Ocean-atmosphere conditions

In December 2021, the air temperature in the Southern region of Bahia was 0.5 to 1 °C colder than usual. During the same period, the surface temperature of the South Atlantic Ocean showed positive anomalies, with temperatures 0.5 to 2 °C warmer than normal.

Extreme event

Between December 22 and 29th, 2021, the formation of the South Atlantic Convergence Zone (SACZ) caused heavy rains in the Central-West and Southeast regions of Brazil. This natural phenomenon, which extends from the Amazon to the Atlantic, generated abnormal rainfall due to the convergence of moisture with opposing winds. A subtropical depression, a low-pressure area, contributed to the formation of clouds, winds, and storms. The interaction of the SACZ with this low-pressure zone intensified the rain in the Eastern and Southern Bahia.

Damage

More than 160 municipalities declared a state of emergency in Bahia, 26 people died and over 100,000 people were affected. Also, the heavy rains caused landslides, floodings, and interruptions in water and power supply. Economic losses were estimated in the billions of reais.

2022

Heavy rainfall in the states of Alagoas and Pernambuco

Damage to the streets of vulnerable communities in the state of Pernambuco caused by heavy rain and landslides.
Photo: Diego Nigro/AFP/MetSul Metereologia

Homeless people walking on the flooded street in São Miguel dos Campos in the state of Alagoas.
Photo: Ailton Cruz

Damage caused by a landslide in the community of Jardim Monte Verde in Recife, Pernambuco.
Photo: Brenda Alcantara/AFP/MetSul Metereologia

Ocean-atmosphere conditions

In May 2022, the air temperature in the Northwestern part of Northeast Brazil was 0.5 to 1 °C warmer than normal. The surface temperature of the ocean was also warmer, about 1 °C above the usual levels.

Extreme event

In Northeast Brazil, heavy rains are often caused by a phenomenon called Easterly Waves, which form from atmospheric disturbances in Africa that move to the Atlantic. These waves produce massive rainfall over Brazil, particularly during autumn and winter. When they reach the Brazilian coast, they cause intense rainfall, mainly in the Zona da Mata (within the coastal area between the states of Bahia and Rio Grande do Norte) and sometimes in Southern Bahia and the coast of Ceará. In this event, the aggravating factor was the ocean temperature, which was warmer and increased the intensity of the rainfall.

Damage

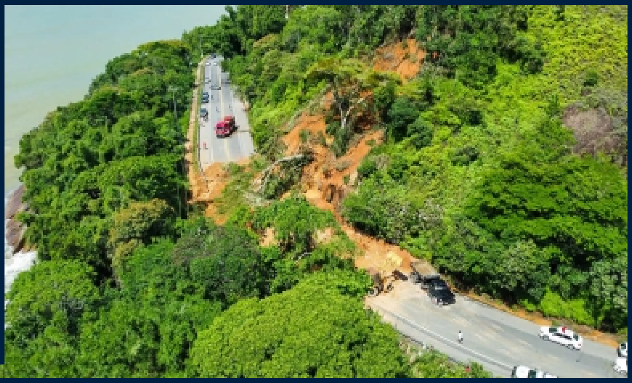
Extreme rainfalls hit mainly the coast of the state of Alagoas and the Metropolitan Region of Recife (the area around the capital of the state of Pernambuco). Around 130,000 people were displaced or left homeless by the disaster, with more than 2 million affected. Cities were flooded, and there were interruptions in water supply. Tens of thousands of homes and hundreds of urban infrastructure were damaged or destroyed. Economic losses were estimated in the hundreds of millions of reais.

2023

Heavy rainfall on the coast of São Paulo

Landslide in Vila Sahy, São Sebastião.
Photo: Amanda Perobelli/Reuters

Civil defense and rescue team searching for people in Vila Sahy, São Sebastião.
Photo: Tiago Queiroz/Estadão



Roadblock.
Photo: Government of the State of São Paulo - SP 55 near Lagoinha

Ocean-atmosphere Conditions

In 2023, historical record highs for air temperature were reached, with anomalies of +0.69 °C compared to historical data from 1991-2020. In February 2023, the average air temperature on the central and northern coasts of São Paulo was 1 °C above normal. The surface temperature of the South Atlantic was also above reference values in January and February, with monthly averages ranging from 0.5 to 3 °C warmer than usual.

Extreme event

The convergence of a cold front with an area of intense heat, combined with the formation of a low-pressure region between the states of Minas Gerais, Rio de Janeiro, and São Paulo, caused heavy rainfall, particularly along the coast of São Paulo. The high sea level, driven by the cold front, hindered the drainage of rainwater into the ocean. The extreme rainfall resulted in a record amount of precipitation — 683 mm in 24 hours in the municipality of Bertioga/SP. Intense rains led to flooding and landslides, mainly in the northern municipalities of São Paulo coast.

Damage

Over 60 deaths were confirmed, most in São Sebastião/SP, with more than 60,000 people affected. Flooding and landslides obstructed and destroyed roads and damaged other urban infrastructure. Water supply was interrupted and some populated areas became isolated for days. Economic losses were estimated in the hundreds of millions of reais.

2023

Historic drought in the Amazon river basin

Communities isolated by drought.
Photo: Rafa Neddermeyer/Agência Brasil

Completely dry rivers in the Amazon.
Photo: Divulgação/Observatório do Clima

Food transportation compromised by droughts.
Photo: Defesa Civil/Envira/Divulgação

Ocean-atmosphere conditions

Sea surface temperatures in the Pacific and North Atlantic Oceans rose by 2 to 4 °C above historical averages due to the combined effects of the El Niño phenomenon and record-breaking air temperatures. These conditions led to a rainfall deficit and intense heat waves from June to November 2023.

Extreme event

Some rivers reached their lowest levels in 120 years, completely drying up in some sections and impacting tributary rivers. Millions of hectares of water surface area were lost, with lakes experiencing a reduction of 75 to 90% of their volume. The lack of rainfall contributed to an increase in wildfire occurrences.

Damage

Communities were isolated, lacking access to healthcare services and facing difficulties in transporting essential supplies. Navigation difficulties on rivers resulted in significant economic impacts due to the inability to move goods, driving up food prices. The drought also affected electricity generation, leading to power outages and higher tariffs. Dozens of municipalities declared a state of emergency. The extreme reduction in lake water volume and subsequent warming resulted in fish and dolphin mortality, including endangered species.

2024

Heat waves and heavy rainfall in the state of Rio Grande do Sul

Rescue of a resident isolated by water in Rio Grande do Sul.
Photo: @deisefalci

Porto Alegre flooded by the flooding of the Guaíba River.
Photo: Renan Mattos/Reuters

Taquari River during heavy rains in the city of Encantado, Rio Grande do Sul.
Photo: REUTERS/Diego Vara

Ocean-atmosphere conditions

Since late 2023 and continuing into the summer of 2024, record-breaking air temperatures have been recorded, with several heat waves occurring. The surface temperature of the South Atlantic Ocean has been approximately 0.7 °C above the historical average (1971-2000) during the same periods in 2024, with both 2023 and 2024 recording the highest temperatures ever observed since that baseline period.

Extreme event

Cold fronts from Antarctica were blocked by a high-pressure system stationed in central Brazil. Combined with moisture from the Amazon region, which was directed toward Rio Grande do Sul due to atmospheric blocking, extreme rainfall caused severe flooding, particularly in the Taquari Valley.

Damage

Hundreds of deaths were confirmed, dozens of cities were flooded or inundated, thousands of people were displaced or homeless, and millions were affected. Water and electricity supplies were interrupted. The state's main airport remained closed for months due to the damage. Economic losses were estimated in the billions of reais. The recovery of the affected cities, and of the state as a whole, will take years.

2024

Wildfires in Brazil

Carbonized alligator in the Pantanal of Mato Grosso do Sul.
Photo: Gustavo Figueirôa/SOS Pantanal - CREDITO: CAMPO GRANDE NEWS

Burning between the southwest of Amazonas and the north of Rondônia.
Photo: Marizilda Cruppe / Greenpeace

Amazon in flames.
Photo: Christian Braga/Greenpeace

Ocean-atmosphere conditions

Brazil experienced another period of intense drought and high air temperatures, particularly during the winter of 2024. Analyses conducted by **CEMADEN** (National Center for Monitoring and Early Warning of Natural Disasters) indicated that, in 2024, the country experienced its most severe drought since 1951. Compared to other severe drought events in the past two decades, the 2023-2024 drought was the most extensive, affecting over 5 million km² of the country. Contributing factors include the occurrence of El Niño, global climate change, and increasing deforestation.

Extreme event

Atmospheric conditions conducive to wildfire proliferation, in association with widespread criminal actions, led to unprecedented increases in the number of wildfires across the country. According to MapBiomas[8], the area burned in Brazil in the first half of 2024 was 529% higher than historical averages for that period. Between January and September 2024, more than 22 million hectares were burned, an area roughly equivalent to the state of Roraima. The Amazon and Pantanal were the most affected biomes.

Damage

Over 70% of the burned area was native vegetation, resulting in severe environmental damage that is hard to quantify. Additionally, highways and airports were closed during fire events. Hundreds of cities declared a state of emergency, affecting millions of people. Direct deaths were reported, and indirect deaths and health impacts on millions of individuals are highly probable but difficult to measure. The fires led to increased food prices and electricity rates. Economic losses were estimated in the billions of reais.

3.1.2 Vulnerabilities and Impacts of Climate Change

The intensification of these extreme events increases the risks of:

Flooding and inundations: With sea level rise and more frequent storms, urban areas near the coast are exposed to flooding, where water temporarily accumulates, and inundations, which are more severe situations of overflow and prolonged water retention. These events cause significant damage to public and private infrastructure, hinder access to essential services, and put citizens' lives and well-being at risk. According to the IPCC Report (2022)[12], by 2050, one billion people will face the risk of coastal flooding due to sea level rise. In Brazil, over 2 million people are at risk along the coastline[13].

Spread of diseases: Contaminated water from sea level rise and flooding facilitates the spread of waterborne diseases, posing a serious threat to public health.

Coastal erosion: Sea level rise and the force of storm surges aggravate the loss of soil and sediments along the coastline, putting urban areas at risk and increasing vulnerability to flooding.

Landslides: Intense rains associated with storms and flooding saturate soil on sloped areas, increasing the risk of landslides. This process can result in the collapse of land and rocks, causing destruction of homes, blocking roads, and threatening the lives of people living on steep slopes.

Unequal social impacts: The effects of natural disasters are felt unevenly, primarily affecting communities in more vulnerable areas, such as steep slopes and flood-prone regions (e.g., settlements in mangrove and marsh areas). Groups such as women, children, the elderly, indigenous communities, and low-income populations face disproportionate risks due to greater exposure and lower capacity for adaptation. These groups can suffer an average mortality rate up to 15 times higher, as evidenced in highly vulnerable countries in the past decade[12].

Just like coastal cities, although less exposed to the direct impacts of sea level rise, inland cities share significant climate challenges, such as more intense and frequent heat waves and cold spells, wildfires, heavy rainfalls, and gales, affecting:

Population health and well-being: Extreme events can intensify respiratory problems and those related to water contamination, cardiovascular diseases, and mental health issues in the population, increasing the demand for medical care and overwhelming healthcare systems in cities.

Food Security: Agricultural activities, essential for supplying cities, suffer from extreme climatic fluctuations, compromising production and food security.

Coastal cities are particularly vulnerable to sea level rise, ocean storms, strong winds, storm surges, and processes associated with coastal erosion[9-11].

3.1.3 Urban Infrastructure and Traditional Approaches

Cities, by prioritizing conventional and rigid infrastructure models, often neglect integration with the natural environment, limiting their ability to respond to the impacts of climate change.

Lack of integration with the natural environment: Urban infrastructure traditionally prioritizes standardized and rigid constructions, with little consideration of their environmental impacts or for integration with the natural environment and sustainability.

Urban density and lack of green spaces: Many cities have dense and uniform constructions, with disproportionate ratios between the built environment and open spaces, which intensifies the impacts of climate change.

Limitations of traditional built-protection solutions: Interventions aimed at reducing disaster risks in coastal cities have been based on grey infrastructures (e.g., seawalls, breakwalls), which may often prove ineffective or even harmful in the long run.

Need for Innovative Solutions: The complexity of climate change requires innovative and integrated solutions that take into account the dynamics of the coastal environment and the need for long-term adaptation.

Urbanization and Coastal Hardening

Urban growth has increasingly concentrated in coastal areas, especially in developing countries like Brazil. This growth accelerates coastal hardening, which involves the construction of grey infrastructure in aquatic environments to protect urban areas and meet societal needs. In the São Paulo coast, a recent study[14] mapped 244 km of coastline occupied by artificial structures such as seawalls, wharves, and piers. Additionally, over 400 km of urbanized areas were located in low-lying land near beaches and mangroves, increasing the vulnerability of cities to storm surges and flooding. This growing process highlights the urgency of integrating climate adaptation solutions and more sustainable coastal planning.

Access the scientific communication document of this study here

3.1.4 Demands for Sustainable and Multifunctional Solutions

Given the current scenario, it is urgent to implement innovative and scientifically-based actions to address the challenges of coastal cities in an integrated and effective manner, benefiting both society and the environment. In contrast to the rigid nature of grey infrastructure, green-blue solutions — such as the restoration of mangroves and dunes, creation of linear parks, and green roofs — promote a more harmonious adaptation to the urban and coastal environment, enhancing resilience to extreme climate events and creating healthier and more sustainable cities.

With the increase in extreme events along the Brazilian coast, it is essential that strategies aimed at strengthening the physical, social, and economic security of coastal cities shall go beyond reactive measures. More than ensuring the emergency supply of energy, water, and food following a climate-related disaster, it is crucial to invest in preventive and long-term adaptation actions. To strengthen the resilience of coastal cities, it is necessary to focus on robust investments in the following areas:

Protection of coastal zones: This includes the restoration and protection of ecosystems such as mangroves, dunes, and restinga forests, the construction of resilient coastal defense infrastructure, and the implementation of strategic setback policies in high-risk areas.

Improvement of water treatment and supply systems: Expanding the capacity of existing systems, investing in advanced treatment technologies, and promoting efficient use and reuse of water.

Urban spatial planning and adaptation: Integrating spatial planning, land use and occupancy management, and the development of green-blue urban areas to reduce vulnerability to extreme climate events and promote more resilient, healthy, and sustainable cities.

Ensuring the health of the environment is also ensuring human health and well-being

4. NATURE-BASED SOLUTIONS (NbS)

Currently, there is a growing shift in ideas aimed at developing and applying ecological construction techniques that use renewable local materials and design principles to better harmonize urban environments with nature, preparing cities to cope with climate change. Thus, the crucial role of NbS in enhancing urban resilience is increasingly recognized. **NbS are based on the use of ecological systems and natural processes to address and solve environmental, social, and economic challenges in an integrated manner.**

NbS translate into actions such as the implementation of green infrastructure, the restoration of coastal ecosystems, the creation of parks and ecological corridors, among other initiatives aimed at harmonizing urban environments with nature. In Brazil, the Innovation Observatory for Sustainable Cities (**Observatório de Inovação para Cidades Sustentáveis** - OICS, in Portuguese) has already mapped 40 NbS initiatives, with 11 located in coastal cities.

Validated Resilience

A review conducted by Brazilian researchers, based on global studies, revealed that the adoption of NbS can double the resilience of cities to multiple climate risks[15].

Check the full study

These approaches are aligned with various international agreements and initiatives, such as the Sendai Framework for Disaster Risk Reduction, the Sustainable Development Goals (SDGs), the UN Decades of the Ocean Science for Sustainable Development and on Ecosystem Restoration, the Paris Agreement, and the New Urban Agenda. These commitments promote the integration of environmental goals with risk management to address emerging needs in climate risk mitigation and combat environmental degradation. They also aim to enhance the protection and adaptive capacity of vulnerable communities, while encouraging public and private investments in disaster risk prevention and reduction.

NbS represent a paradigm shift in the way society plans and builds cities, paving the way for a more sustainable and resilient future. In Brazil, these solutions could play a crucial role in reducing carbon emissions. According to a recent **study**, NbS — especially the protection of natural ecosystems and reforestation — have the potential to mitigate up to 78% of carbon emissions needed for Brazil to achieve its net-zero emissions targets, making a significant contribution to the country's climate commitments. Such initiatives not only promote carbon capture but also strengthen biodiversity and ecosystem services, benefiting local communities.

Nature-based Solutions (NbS) are actions that utilize natural processes and ecosystems to address the most urgent challenges of our time. It is a natural resource management approach that generates benefits for biodiversity while promoting solutions for socioeconomic development and human well-being[16]. The implementation of NbS addresses challenges such as water and food scarcity, as well as the impacts of extreme weather events, which can cause disasters like flooding, inundation, landslides, erosion, and urban heat islands. These solutions involve the restoration or simulation of natural ecosystems to provide essential services, such as water purification, protection against natural disasters, climate regulation, and the improvement of air quality.

4.1 NbS for Coastal Urban Areas

NbS integrate a range of approaches including protection of natural systems, sustainable management, restoration, and the creation of green, blue, or natural infrastructure[17]. These approaches can be organized in a hierarchy, prioritizing the protection of existing ecosystems over improved management, rehabilitation and restoration, or the creation of new NbS. It is important to highlight that NbS go beyond just biodiversity conservation in cases of environmental protection and recovery interventions. They are considered as such when aiming to solve socio-environmental problems in a multifunctional way, benefiting both the environment and socioeconomic demands. The hierarchy of these approaches is particularly relevant for identifying and prioritizing NbS opportunities at a strategic level, such as in screening investment opportunities in a city. However, these hierarchical approaches are complementary, and the development of an NbS strategy should consider all of these elements.

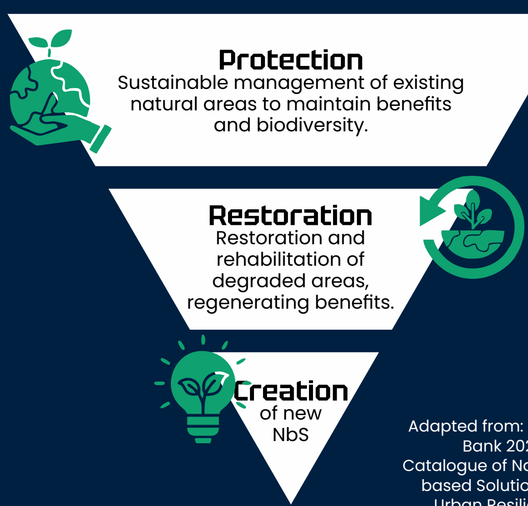
1. Protection: Adopting this hierarchy promotes a strategic approach to planning, emphasizing the need to strengthen the protection of urban natural areas to preserve their functional and biodiversity values. Examples of ecosystems that can be protected include dunes, coastal plains, floodplains, urban forests, oyster reefs and mangroves. While protection is crucial, many natural areas within urban zones are degraded, subject to various impacts that compromise their ability to provide ecosystem services.

2. Recovery: The second hierarchical layer focuses on the restoration and rehabilitation of ecosystems to improve their performance and benefits. Initiatives such as reforestation, wetland restoration, riverbank rehabilitation, and coastal ecosystem restoration (e.g., mangroves, marshes, and beaches) are practical examples of these actions.

3. Creation: The third hierarchical layer involves the creation of new NbS, used to mitigate impacts and increase urban resilience. This includes interventions such as green roofs, vegetated facades, artificial wetlands, and bioretention areas, which can also generate additional benefits for communities.

These strategies can be applied to projects ranging from residential homes, buildings, and neighborhoods to larger scales that extend beyond municipal boundaries, such as watersheds and estuaries. The following examples of NbS will illustrate different approaches in various urban contexts, demonstrating how these strategies can enhance urban sustainability and resilience in coastal cities.

Hierarchy of Strategies Within the Concept of Nature-Based Solutions



Adapted from: World Bank 2021 – "A Catalogue of Nature-based Solutions for Urban Resilience."

Spatial scales of NbS

Scale: Local

Spatial Range: Houses, buildings, streets, squares

Solutions applied at smaller scales, such as buildings, streets, or blocks. These interventions can mitigate localized flooding, improve the microclimate, increase biodiversity, and create spaces for leisure and social interaction, addressing specific local problems. Practical examples include green roofs, rain gardens, and bioswales.

Scale: City

Spatial Range: Municipalities, large municipal spaces

Solutions that encompass the planning and implementation of strategies across a large part of the municipal territory. They aim to broadly transform urban infrastructure and integrate natural systems into city management, improving environmental quality, and enhancing resilience to climatic events, and the well-being of the population. These solutions involve projects that affect the planning of green and blue zones, mobility systems and stormwater management. Examples include linear parks, the creation or restoration of green areas along rivers, and ecological corridors that connect different parts of the city. Coordination between sectors and municipal policies is essential to ensure that these interventions benefit multiple neighborhoods and promote urban resilience.

Scale: Region

Spatial Range: Intermunicipal areas

Solutions involving interventions that cover large geographical areas and require an integrated and collaborative approach between municipalities. These interventions aim to manage interconnected natural systems, such as watersheds, water springs, coastal areas, estuaries, and delta systems. Typical examples include ecological corridors, integrated water resources management, and the restoration of degraded areas, ensuring environmental resilience, human well-being, and economic benefits.

Sources: **UNEP**, **OICS**

Since the focus of this document is on coastal cities, we initially present examples of NbS aimed at coastal areas: the restoration and protection of natural coastal habitats, marine eco-engineering, and coastline realignment. Next, we present other NbS with broader applications that also bring benefits to inland cities, such as green walls and roofs, rain gardens, constructed wetlands, bioretention swales, parks and green streets, floodable parks, and terraces and slopes. The types of NbS were listed based on the hierarchy of NbS strategies, highlighting their main characteristics, the climate or environmental risks typically targeted by the intervention, their multiple benefits, and examples of implementation in coastal cities.

4.1.1 Restoration and Protection of Natural Habitats

Scale:
City and Regional

Approach Hierarchy:
Protection and Recovery

Targeted risks – Loss of ecosystem services, flooding, erosion, landslides.

Solution – Revitalization of degraded natural habitats to restore their natural functions and protection of natural areas, enhancing local biodiversity, safeguarding coastal cities from extreme climate events, and ensuring healthy ecosystems for future generations.

Design – Restoration uses natural processes and native species to improve the health and stability of soil, water quality, and provide habitats and favorable conditions for terrestrial and marine life. Restoration initiatives may include reforestation of native trees and plants, reintroduction of native fauna, and replanting of mangroves. Interventions to ameliorate environmental conditions, such as local hydrodynamics and morphodynamics (e.g., marine eco-engineering), can also be used to facilitate the restoration process.

Protected areas are designated through the identification and conservation of regions with ecological, cultural, or historical importance, aimed at conserving biodiversity and natural resources. They typically involve spatial zoning to control human activities, establishing legal and management structures, and implementing conservation strategies to maintain and restore ecosystems while allowing sustainable use and recreational activities.

Application – Ecological restoration in urban coastal areas should be strategically applied to protect against flooding, coastal erosion, and landslides. These areas include river margins, estuaries, and seafront areas, where the restoration of salt marshes, mangroves, oyster reefs and coral reefs can buffer wave impacts and reduce flooding from storm surges. Restored beaches and dunes can act as natural storm barriers, minimizing coastal erosion. Steep slopes in urban areas, prone to landslides and soil erosion, are critical points for implementing vegetated slopes.

The protection of relatively undisturbed green and blue spaces in cities should be prioritized as critical areas for maintaining terrestrial and marine biodiversity, promoting habitat connectivity (e.g., ecological corridors, urban forests, and reefs). Focusing on strategic areas is essential to safeguard the population, maintain cultural values and minimize damage to public infrastructure, assets, and properties.

Benefits:

FUNCTIONAL

- Erosion control
- Flood mitigation
- Water purification
- Air purification
- Water flow reduction

URBAN

- Sustainable urban design and planning
- Drainage
- Urban aesthetics
- Enhanced public spaces
- Civil protection
- Infrastructure protection
- Urban cooling

ENVIRONMENTAL

- Biodiversity
- Habitat connectivity
- Water quality
- Enhancement of ecological functions
- Air quality
- Carbon sequestration and storage
- Healthy soils

SOCIAL

- Education
- Community engagement
- Recreation
- Health
- Food security
- Cultural value

ECONOMIC

- Attractiveness for investments
- Infrastructure cost savings
- Boost in local economy
- Job creation
- Reduced insurance premiums
- Fisheries productivity
- Healthcare savings
- Reduced damage costs
- Increased property value

4.1.1.1 Beaches and Dunes

Beaches are coastal areas formed by the deposition of sediments, such as sand, shells, and rocks, while dunes are sand elevations shaped by the wind. Together, they play a vital role in naturally protecting coastal cities against erosion and storm impacts, acting as natural barriers that absorb wave energy and prevent coastal inundation. Ecologically, beaches and dunes are essential habitats for a diverse range of species, including seabirds, crabs, and sea turtles, which rely on these environments for feeding, breeding, and shelter. Dunes, with their adapted vegetation, also help stabilize sediments, prevent erosion, and contribute to coastal equilibrium.

Beaches and dunes hold significant social and economic value for coastal cities. They attract tourism, generating income through recreational and sport practices, provide natural resources like sand, and create opportunities for other economic activities such as fishing and local trade. Beaches also play a crucial role in the leisure and well-being of local communities and tourists, promoting quality of life and providing outdoor areas for diverse cultural uses.

Interventions

Various techniques are employed to restore beaches and dunes, aiming to reestablish their natural roles as protective barriers against erosion and storms. Common approaches include:

Planting of native vegetation: Planting native grasses and shrubs that stabilize the soil with their roots, reducing erosion caused by wind and water.

Installation of fences and barriers: Fences are installed around dunes, preferably using sustainable materials, such as untreated wood from local or reforested sources, and plant-based materials, like coconut fiber mats or straw. These fences help restrict pedestrian and vehicle access, allowing dunes to regenerate naturally and facilitating the capture of wind-transported sand.

Besides these techniques, it is common to remove invasive species and create drainage systems to help maintain the integrity of these formations.

NbS in action

Photos: Biovert; Diário do Rio

Restoration of the dunes of Ipanema and Leblon

Location: Rio de Janeiro/RJ, Brazil

Objective: Environmental restoration and coastal protection

Description: The dune restoration project on the beaches of Ipanema and Leblon, developed by the partnership between the Instituto E and the Rio de Janeiro City Hall, was implemented in 2009 to reinforce coastal defenses in the city and promote urban sustainability. The restoration involved planting 38000 seedlings of 8 native species, essential for dune stabilization, reducing coastal erosion, and encouraging the return of native wildlife. Covering more than 10000 m² of replanted area and with 28 sandbanks, the restored dunes now attract various bird species seeking food and safe nesting sites, enhancing local ecosystem conservation. This project exemplifies the efforts to integrate environment and urban protection, valuing the coastline as an ecological and sustainable leisure space for locals and visitors while boosting the climate resilience.

Find out more: **Instituto E**; **Diário do Rio**; **Biovert**

Photos: Apremavi; SECOM

Restaura Restinga Project

Location: Florianópolis/SC, Brazil

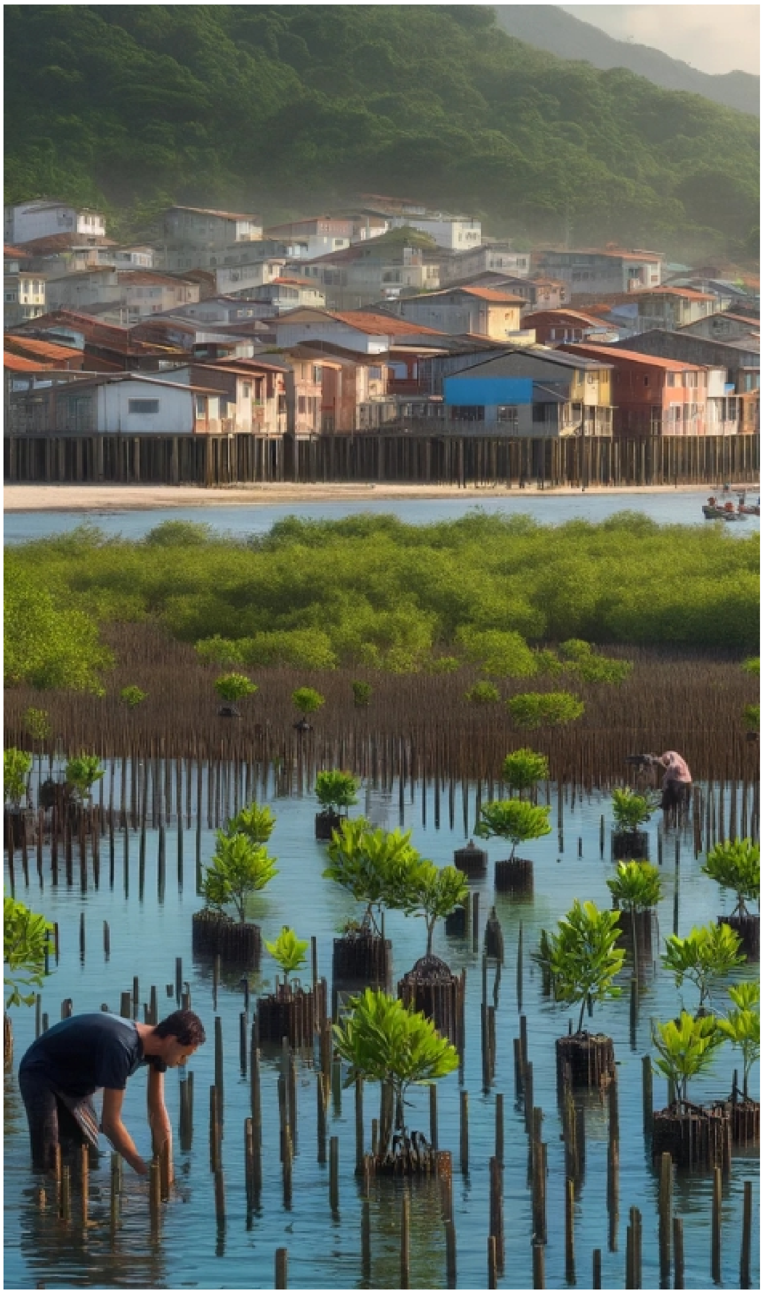
Objective: Restore restinga vegetation, promote dune conservation, and enhance climate resilience in Florianópolis city

Description: The Restaura Restinga project was launched in the Lagoa da Conceição Natural Park, Florianópolis, as an initiative targeting the restoration of degraded restinga areas and protection of coastal dunes. Focused on restoring native vegetation and combating erosion, the project engages volunteers and the local community in planting typical restinga species and monitoring their growth. Initiated in 2022, the ecological restoration process includes seed collection from conserved areas, native seedling production, and planting along the beach and sand dune margins. This initiative promotes biodiversity and mitigates erosion. Through partnerships with the Federal University of Santa Catarina and the Association for Environmental and Life Preservation (Apremavi), the project not only restores local vegetation but also raises awareness about the importance of restingas for environmental balance and coastal protection. This project exemplifies how collaboration among science, society and government can create lasting positive impacts, safeguarding fragile ecosystems and valuing the city's natural heritage.

Find out more: **Instituto E**; **Diário do Rio**

4.1.1.2 Mangroves and Salt marshes

Mangroves and salt marshes are ecosystems adapted to flooded and brackish areas, playing a crucial role in the protection of coastal cities. These environments act as natural barriers that stabilize soil, retain sediments, and buffer the impact of waves and storms, preventing erosion and flooding. Ecologically, these ecosystems provide habitats for various species of fish, crustaceans, mollusks, and birds, many of which have significant commercial and ecological importance. Mangroves and salt marshes also contribute to pollutant filtration, improving water quality. These ecosystems play a key role in carbon sequestration and storage, helping to mitigate global warming.



Socioeconomically mangrove and salt marsh areas are vital for coastal communities, providing resources such as fish and shellfish and offering areas for activities like recreational fishing and ecotourism. The conservation of these ecosystems, therefore, promotes food security and the sustainability of local economies, while protecting urban infrastructure from damage caused by extreme weather events.

Did you know?

There is an online tool dedicated to registering and monitoring mangrove restoration projects worldwide! The Mangrove Restoration Tracker is an app that allows users to record and track the outcomes of these initiatives in real-time.

Check out here

A recent study indicates that Brazilian mangroves store 1.9 billion tons of carbon dioxide (CO_2), which could potentially yield at least R$48.9 billion in carbon credits, based on current rates in the Brazilian voluntary market[18].

Access the study here

Interventions

Mangrove and salt marsh restoration involves multiple steps and techniques aimed at reestablishing their functionality. The initial focus is on restoring natural hydrological conditions, as these environments rely on adequate water flow, quality, and sedimentation to thrive.

Restoring drainage

Removing barriers that block tidal flow and sediment accumulation. Reactivating natural drainage channels and managing elevation levels, allowing native vegetation to recolonize the area.

Planting native species

In severely degraded areas, planting native species may be essential.

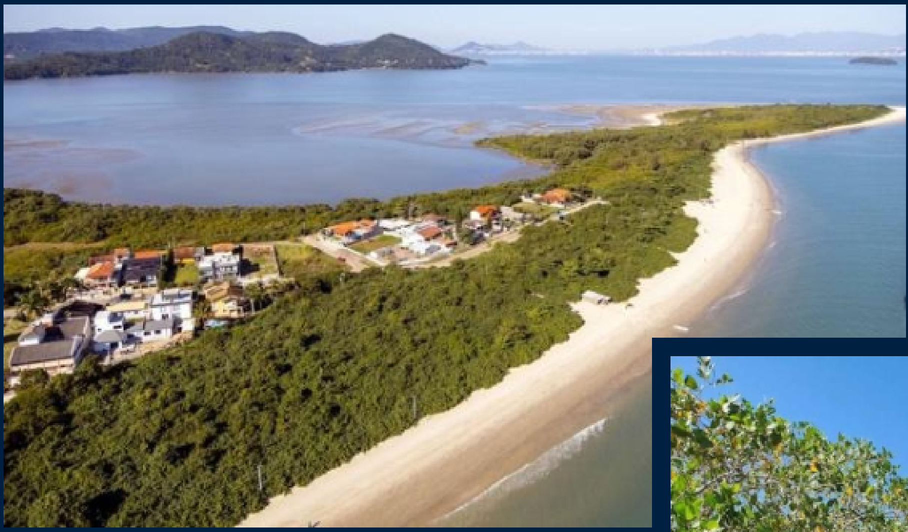
Passive restoration

Allowing nature to regenerate itself. This strategy is often more efficient than seedling planting, provided that proper environmental conditions are restored.

Marine eco-engineering

In cases where replanting is necessary or water flow initially needs to be reduced, marine eco-engineering — through the use of temporary rigid structures or the creation of natural habitats, such as oyster reefs — can assist in facilitating the restoration process.

NbS in action



Photos: Dilton Castro

RAÍZES da Cooperação Project

Location: Florianópolis/SC, Brazil

Objective: Restore mangroves to enhance climate resilience

Description: The RAÍZES da Cooperação project is an ecological restoration initiative aimed at recovering degraded mangrove areas and enhancing the climate resilience. The action involves planting native mangrove species (Rhizophora mangle, Laguncularia racemosa, Avicennia schaueriana), which are essential for regenerating local biodiversity. Simultaneously, the project promotes the removal of invasive exotic species which negatively impact native biodiversity and ecosystem functioning. With an integrated approach, the project combines environmental restoration with community awareness, involving local organizations, public schools, universities, conservation units, and traditional communities in activities such as education, planting, sustainable management, and monitoring of restored areas. The initiative also contributes to the prevention of extreme weather events, such as storm surges and flooding, by strengthening the ecosystem services provided by mangroves and aiding in carbon sequestration.

Find out more: **RAÍZES da Cooperação**

Photos: NEMA

Restoration and Protection of Lagoa Verde

Location: Rio Grande/RS, Brazil

Objective: Restore and conserve salt marshes to strengthen sustainability and climate resilience

Description: The restoration and protection of the salt marshes in the Lagoa Verde Environmental Protection Area (APA) is an initiative aimed at preserving this ecosystem, which occupies part of the urban area of Rio Grande city, and promoting climate resilience. In 2002, the Lagoa Verde APA project conducted a comprehensive diagnosis of the natural environment and human activities in the surrounding area, identifying the ecological potential of the region and proposing sustainable uses such as contemplative ecotourism, and other cultural and educational practices. As part of the project actions, 2.000 native seedlings were planted to restore vegetation and the local ecosystem. The initiative promotes biodiversity recovery and protection against extreme weather events, while encouraging community involvement and the development of sustainable activities in the area.

Find out more: **NEMA**; **SEMA**

4.1.1.3 Seagrasses and Macroalgae

Seagrasses and macroalgae are similar because they live in the sea and perform photosynthesis, but they are quite different from each other. Seagrasses are vascular plants that grow in shallow coastal areas, forming underwater meadows. They have roots, stems, and leaves, just like the plants we see on land. On the other hand, macroalgae, such as sargassum, are simpler organisms without roots or a vascular system, and they attach to rocks or float in the sea. Although they are not plants, macroalgae also produce energy through sunlight. Aquatic communities formed by seagrasses and macroalgae play a fundamental role in marine life and the sustainability of coastal zones. They provide shelter and food for numerous marine species, such as fish, mollusks, turtles, and manatees, and serve as nurseries for species of economic importance. These ecosystems also absorb nutrients and pollutants, helping to maintain water quality. They also reduce coastal erosion by stabilizing sediments and play a role in carbon sequestration, helping to mitigate climate change. Socioeconomically, seagrasses and macroalgae support many species essential for fishing and underwater tourism. Macroalgae, in particular, are used in food (such as nori leaves, widely used in oriental cuisine), fertilizer production, medicine, and as raw materials for cosmetics and pharmaceuticals. The sustainable harvesting and cultivation of macroalgae create jobs and promote the development of local economies.

Interventions

Seagrasses

Transplanting seedlings or seeds to suitable areas where environmental conditions such as water quality, temperature, light, and sediments are favorable for growth.

Reducing local stressors, such as pollution and destructive fishing and navigation practices, is essential.

Macroalgae

Transplanting individuals or reproductive material to previously selected areas where environmental conditions have been restored. Choosing suitable native species and continuous monitoring are key to ensuring restoration success.

Reducing local stress factors, such as pollution and high turbidity.

Eco-engineering techniques, such as structures to anchor macroalgae, can be used to facilitate growth.

NbS in action

Photo: Ana Paula Correa do Carmo

Photos: Fernando Morais/APA Costa das Algas

Costa das Algas EPA

Location: Espírito Santo, Brazil

Description: The Costa das Algas Environmental Protection Area (APA), created in 2010, extends over 115.002 hectares and includes reefs, rocky shorelines, rhodolith banks, and seagrass areas, holding one of the largest diversities of marine algae in Brazil. These ecosystems provide a variety of habitats and growth areas for several commercial and endangered fish species, as well as support traditional small-scale fishing activities essential for the subsistence of local communities. The maintenance of this APA is crucial for both the sustainability of traditional communities and the protection of coastal cities in the region, strengthening climate resilience and marine biodiversity conservation.

Find out more: **ICMBio**, **Rede De Gestores de Ucs**, **Catálogo de Plantas das Ucs do Brasil**, **Websérie Costa das Algas**

4.1.1.4 Coral Reefs

Coral reefs are underwater formations created by the deposition of coral skeletons, marine organisms that form compact colonies in warm, shallow waters. This ecosystem plays a vital role in protecting coastal cities by acting as natural barriers that reduce wave energy, preventing coastal erosion and protecting urban infrastructure from storms. Ecologically, coral reefs harbor a great diversity of marine species, including fish, mollusks, and crustaceans, serving as nurseries and feeding areas for many species. They contribute to maintaining biodiversity and play an important role in nutrient cycling, promoting the health of marine ecosystems. Socioeconomically, coral reefs are crucial for fishing, providing habitats for commercially valuable species and supporting the local fishing economy. These environments also attract thousands of tourists interested in activities such as snorkeling and scuba diving. The conservation of coral reefs is critical for the sustainability of coastal cities, as they not only protect the coastline but also foster local economic development and support cultural values of many coastal communities in Brazil.

Natural barriers: Economic value

According to a study conducted in Brazil, coral reefs, sandstones, and rocky shores covering about 170 km² between Bahia and Maranhão states in the Northeast region, are estimated to generate R$160 billion in benefits related to coastal protection. Each square kilometer of reef prevents R$941 million in damage[19].

Access the study here

Interventions

Coral reef restoration involves various techniques to rehabilitate these fragile ecosystems and improve their resilience. The most common methods include:

Coral propagation

Fragments of coral are collected, cultivated in underwater nurseries or terrestrial tanks, and then replanted on degraded reefs. This increases the coverage of live corals and improves diversity.

Artificial structures

Structures such as concrete blocks or rock molds are deployed to provide suitable surfaces for coral growth and stabilize the reef.

Coral Fixation

Damaged corals or coral fragments can be directly fixed to the reef with materials like cement or ties to promote their recovery.

Larval propagation

This technique involves collecting coral gametes during spawning, fertilizing them in the laboratory, and reintroducing the larvae to the reef.

NbS in action

Photos: Biofábrica de corais

Biofábrica de Corais (Coral Biofactory)

Location: Ipojuca/PE, Brazil

Objective: Coral reef conservation through biotechnology.

Description: The Biofábrica de Corais, launched in 2017 in Pernambuco, aims to restore degraded coral reefs, particularly those affected by bleaching and pollution. Using biotechnology, the project cultivates corals in a lab where damaged fragments are treated and then reintroduced to the marine environment. The initiative also innovated with the use of 3D-printed bases, which provide support for coral growth during their recovery. So far, over a thousand coral fragments have been treated, promoting the recovery of species such as Millepora alcicornis and Mussismilia harttii. The biofactory has shown positive impacts both in ecological restoration and in engaging the local community in reef monitoring. They also conduct environmental education activities, raising awareness of the importance of reefs and sustainable tourism in the region.

Find out more: **Biofábrica de corais**

4.1.1.5 Oyster Reefs

Oyster reefs are underwater structures formed by aggregations of oysters that attach to hard substrates in shallow coastal waters. These reefs provide essential ecological functions, such as filtering large volumes of water, which helps improve water quality. Oyster reefs are biodiversity-rich habitats, supporting various marine species. They also play an important role in coastal protection, stabilizing sediments and attenuating wave energy. Oyster reefs are vital for coastal communities, supporting fishing and aquaculture activities that generate jobs and contribute to local economic development and human well-being.

Science and sustainability

In Brazil, oyster harvesting is a traditional practice carried out by traditional communities through artisanal fishing, such as in Guaratuba Bay, in the state of Paraná[20]. Although it is a common activity, there are still scientific gaps regarding the extent and historical distribution of oyster reefs in the country. Identifying their location and conservation status is essential to promote the sustainability of artisanal fishing and leverage the ecological benefits of these reefs, such as coastal protection, benefiting both cities and local communities.

Intervention

Oyster reef restoration generally involves creating artificial reefs and cultivating oyster larvae in nurseries, which are then transplanted to restoring reef areas. These sites are selected based on water quality and the presence of suitable substrates for oyster growth. Materials such as shells and rocks are used to create a base for oysters to attach to. The cultivation of juvenile oysters in controlled nurseries increases the oyster population, which is later transferred to the reefs to help with water filtration and sediment stabilization. Eco-engineering can be used to optimize this process, constructing structures that facilitate oyster growth and accelerate reef recovery.

NbS in action

Photo: NSW government

Photo: Francisco Martinez Baena

Restoration of Oyster Reefs in NSW Australia

Location: New South Wales, Australia

Objective: Restore oyster reefs to enhance ecosystem services

Description: The restoration of oyster reefs in New South Wales aims to recover native oyster reefs, which have historically played a crucial role in water filtration and supporting marine biodiversity. These reefs were severely degraded by decades of exploitation and environmental changes. The first large-scale project began in 2015, reintroducing native oysters onto submerged structures designed to facilitate colonization and growth. In addition to planting juvenile oysters, the initiative conducts continuous monitoring of water quality and ecosystem health and promotes educational campaigns to raise local community awareness about the importance of these reefs. Since its implementation, the project has shown promising results: restored areas demonstrate increased natural oyster colonization, greater marine biodiversity, and significant improvements in coastal water quality. The restored reefs not only provide habitat for fish and invertebrates but also help protect the coast from erosion and boost resilience to climate change.

Find out more: **NSW government**, **The Nature Conservancy**

4.1.1.6 Estuarine River Floodplains

Estuarine river floodplains are flood-prone areas along river margins that flow into estuaries. These ecosystems play a vital role in providing natural protection for coastal cities against flooding, acting as buffer zones that absorb excess water. Ecologically, floodplains are biodiversity-rich habitats, home to various species of fish, birds, and mammals. These environments serve as nursery and feeding areas for many aquatic and terrestrial species, while also aiding in water purification by filtering sediments and pollutants before they reach the sea. Socioeconomically, floodplains support activities such as artisanal fishing and ecotourism, and they also provide fertile land for agriculture.

Interventions

Restoration interventions in estuarine river floodplains typically involve removing artificial barriers to restore natural water flow in flood-prone areas, reestablishing ideal hydrological conditions. This can include reopening drainage channels, which allows native vegetation, such as grasses and other aquatic plants, to recolonize the area. Moreover, bank stabilization techniques can be applied to prevent erosion and ensure the long-term sustainability of these zones. Techniques include:

Native vegetation planting

Planting native grasses, shrubs, and trees along the margins to stabilize the soil with their roots, which reduces erosion caused by water flow.

Vegetated barriers

Creating areas with low-height, resilient vegetation to absorb the impact of water and protect the margins.

Natural protective revetments

Using materials like rocks or pebbles to create surfaces that reduce the force of water against the margins, preventing erosion.

Eco-engineering

Using natural structures such as tree trunks and plant fibers to stabilize the soil. This helps control sediment flow and protects the margins during storms and floods.

NbS in action

Photo: Foto ilustrativa de várzea (MMA)

Photo: Área de recuperação

Restoration of the Floodplain Forest of the Amazon Estuary

Location: Abaetetuba/PA, Brazil

Objective: Biodiversity recovery and sustainable management of açaí groves in floodplain areas to enhance community resilience

Description: The forest restoration project in the floodplains of Abaetetuba, located within the Amazon estuary, focuses on the gradual restoration of native vegetation, which has been impacted by the intensive expansion of açaí groves. In both high and low floodplain areas, the initiative promotes ecological balance through planting native species and fostering natural regeneration processes. Restoration efforts are carried out in collaboration with riverside communities who blend traditional knowledge with agroecological techniques to diversify production and restore the ecosystem. With over 3200 documented restoration initiatives on the islands of Abaetetuba, the project has positively impacted both ecological recovery and the quality of life for local communities. These efforts are supported by private companies and governmental programs, which provide credit and training opportunities for riverside residents. In addition to conserving biodiversity and restoring native vegetation, the project strengthens community resilience in the face of climate change.

Find out more: **Carvalho et al. 2021**; **Ministério da Ciência, Tecnologia e Inovação**

4.1.1.7 Atlantic Forest and Restinga

The Atlantic Forest is one of the most biodiverse forests in the world, originally covering much of Brazil's coastal territory. These forests are composed of large trees such as the jequitibá and pau-brasil, and it also hosts a rich fauna, including endangered species like the jaguar and golden lion tamarin. Restinga, on the other hand, is an ecosystem associated with the Atlantic Forest biome, characteristic of Brazilian coastal areas. It is composed of sandy soil vegetation, including shrubs and grasses adapted to saline conditions and strong winds. Ecologically, these ecosystems play essential roles in biodiversity conservation, protecting endemic species and helping regulate climate and water cycles. The Atlantic Forest also acts as a natural barrier, preventing soil erosion and protecting freshwater sources that supply millions of people in coastal cities. Restingas stabilize dunes and protect coastlines from the erosive effects of winds and tides. Both the Atlantic Forest and restingas are crucial for eco-tourism, offering trails, preserved beaches, and natural landscapes that attract visitors and generate income for local communities. Additionally, the Atlantic Forest provides resources such as wood, fruits, and medicinal plants, while restingas protect urban infrastructure and are essential for maintaining the environmental balance of coastal cities. The conservation of these ecosystems is vital for the sustainability of coastal cities, ensuring protection against natural disasters such as floods and landslides. Thus, they provide economic and social benefits for communities that depend on their resources and for businesses and residences located near the coastline.

Interventions

Atlantic Forest

Planting native seedlings

Seedlings are selected according to local forest formations, ensuring adaptation and ecological diversity. It is important to choose pioneer, secondary, and climax species to replicate the successive growth phases of the forest.

Assisted natural regeneration

This method takes advantage of the spontaneous regeneration of vegetation, with minimal intervention to control invasive species and promote native ones. It might involve excluding unwanted herbivorous animals, controlling fire, and removing exotic species.

Forest diversity enrichment

In degraded areas with some remaining vegetation, new seedlings of rare or ecologically important species are introduced to enrich the forest's genetic and functional diversity or to favor the maintenance of local fauna.

Soil management and erosion control

In slopes and areas at risk of erosion, soil stabilization techniques are essential. This includes the application of geotextiles and vegetation cover to stabilize the soil and prevent nutrient loss.

Restinga

Revegetation

Planting native restinga species such as grasses, shrubs, and small trees to help stabilize the sandy soil and prevent dune encroachment. Choosing salt-tolerant species is crucial.

Control of invasive species

Removal of exotic plants that compete with native vegetation is needed to allow native species to re-establish themselves.

Creation of natural barriers

Installation of wooden fences to contain sand advance and reduce the wind impact on newly planted areas.

Eco-engineering for stabilization

Using logs, plant fibers, and pebbles to stabilize areas vulnerable to strong winds and storms. This helps prevent erosion and protects the areas during storms.

NbS in action

Photo: ICC

Restaura Litoral Project

Location: São Sebastião/SP, Brazil

Objective: Socio-environmental restoration and recovery of the Atlantic Forest.

Description: Launched in 2024, the Restaura Litoral Project focuses on restoring areas devastated by landslides caused by the intense rains of February 2023, which affected the northern coast of the state of São Paulo. The initiative aims to reforest approximately 200 hectares of slopes in the Serra do Mar mountain range, using an innovative combination of drones and biodegradable capsules to disperse seeds of native Atlantic Forest species. One of the biggest challenges has been accessing steep and more remote areas, where aerial seeding has been crucial to achieving success. The capsules protect the seeds until germination, allowing for more efficient and sustainable environmental regeneration. Beyond ecological recovery, the project promotes environmental education and engages the local community, generating jobs and raising awareness about the importance of restoration and conservation. Funded by a private company and led by the Coastal Conservation Institute (ICC), this project demonstrates how partnerships between the private sector and environmental institutions can be decisive in restoring and conserving vulnerable ecosystems.

Find out more: **ICC**

4.1.2 Coastal Realignment

Targeted risks – Coastal flooding and erosion.

Solution – Creation of a new coastline position through engineered land retreat, promoting the development of natural coastal habitats for shoreline protection.

Design – The coastline realignment is designed to restore natural coastal processes and improve coastal resilience, allowing previously defended or developed coastal areas to be intentionally inundated by the sea.

Application – This approach is most suitable for low-lying regions where existing coastal defenses are compromised or costly to maintain. A commitment to sustainable coastal management is essential, together with the need to create intertidal habitats such as salt marshes, mangroves, or oyster reefs, which can reduce wave energy and act as natural barriers. The realignment process begins with modeling studies to understand the impacts of controlled flooding, followed by the removal or lowering of existing barriers to allow managed seawater incursion. Creating natural buffer zones with coastal vegetation is crucial not only to relieve pressure on coastal defenses and protect coastal cities, but also to contribute to carbon capture and the restoration and conservation of biodiversity.

Scale:
City and Regional

Approach Hierarchy:
Recovery and Creation

Benefits:

FUNCTIONAL

- Erosion control
- Flood mitigation
- Coastal protection
- Water purification

URBAN

- Design e planejamento urbano sustentável
- Urban aesthetics
- Civil protection
- Infrastructure protection

ENVIRONMENTAL

- Biodiversity
- Habitat conectivity
- Water quality
- Enhancement of ecological functions
- Carbon sequestration and storage

SOCIAL

- Education
- Community engagement
- Recreation
- Health
- Sense of security

ECONOMIC

- Attractiveness for investments
- Infrastructure cost savings
- Job creation
- Reduced insurance premiums
- Reduced damage costs
- Increased property value

NbS in action

Photo: Medmerry Case Study

Medmerry Coastal Realignment

Location: Medmerry/West Sussex, United Kingdom

Objective: Reduce flood risk and restore natural coastal habitats.

Description: The Medmerry coastal realignment project, completed in 2013, is one of the largest and most ambitious in the UK. The initiative involved the removal of artificial seawalls along the coast and the creation of a new, more inland natural defense line. As a result, the sea now floods in intentionally designed areas, forming a natural floodplain that acts as a barrier against floods and provides new habitats for biodiversity. In addition to protecting around 350 properties and important regional infrastructure, such as roads and pumping stations, the project created 183 hectares of new natural habitats, benefiting various bird species and other coastal organisms. Medmerry also contributes to the local economy by promoting recreational activities such as hiking, birdwatching, and sustainable tourism, while increasing the region's resilience to climate change. This is an innovative example of integrated management between environmental protection and urban safety, demonstrating how natural solutions can provide lasting ecological, economic, and social benefits.

Find out more: **Medmerry Case Study**

4.1.3 Marine Eco-engineering (of urban grey infrastructure)

Targeted risks – Loss of ecosystem services, coastal erosion, and shoreline destruction.

Solution – Integration of natural and artificial structures to revitalize urban aquatic environments and enhance coastal protection.

Design – Marine eco-engineering incorporates elements of natural blue spaces (such as rocky shore micro-habitats and oyster reefs) into traditional grey infrastructure (seawalls, breakwaters, and groynes) to promote more resilient coastal ecosystems. Eco-engineering structures are designed to closely mimic natural marine habitats, creating favorable conditions for the growth and reproduction of local marine life, including economically important and locally consumed species, while retaining the structural benefits of coastal protection.

Application – Eco-engineering structures can be implemented in highly urbanized areas, such as city waterfronts and port zones. This solution can also be used to accelerate environmental restoration processes (e.g., mangroves, salt marshes, and oyster reefs) in strategic urban areas at risk of erosion, flooding, and structural damage.

Scale:
Local and City

Approach Hierarchy:
Recovery and Creation

Responsible marine eco-engineering: Keep the Trojan horse out!

Marine eco-engineering must be carefully planned to address the impacts of human activities on the coastal environment. It serves as a compensatory, rather than a mitigative, measure, as construction often results in the permanent loss of natural habitats, biodiversity, and ecosystem services. This solution thus aims to counterbalance the effects of urban development activities. In highly urbanized settings, or where traditional infrastructure construction is inevitable, eco-engineering can help restore some of the lost ecological functions. However, it is essential that these interventions be used responsibly, avoiding the encouragement of unnecessary construction or practices that could be viewed as greenwashing, which may mask real environmental loss.

Check out the full scientific article on this topic here

Benefits:

FUNCTIONAL

- Adaptability
- Erosion control
- Durability
- Flood mitigation
- Coastal protection
- Water purification

URBAN

- Sustainable urban design and planning
- Enhanced public spaces
- Urban aesthetics
- Space optimization
- Civil protection
- Infrastructure protection

ENVIRONMENTAL

- Biodiversity
- Habitat connectivity
- Water quality
- Enhancement of ecological functions
- Carbon sequestration and storage

SOCIAL

- Education
- Community engagement
- Health
- Food security
- Sense of security

ECONOMIC

- Attractiveness for investments
- Infrastructure cost savings
- Job creation
- Fisheries productivity
- Healthcare savings
- Reduced damage costs

Nbs in action

Photos: Living Seawalls

Living Seawalls Project

Location: Sydney/NSW, Australia

Objective: Increase local biodiversity

Description: The Living Seawalls project, launched in 2018, is an innovative eco-engineering solution aimed at restoring marine biodiversity in coastal areas modified by seawalls. In response to the impact of these structures, which favor invasive species and support low diversity, the project developed a modular system of panels that mimic natural habitats, such as oyster reefs and rocky crevices. These panels are installed in mosaics on seawall surfaces, providing shelter for fish, invertebrates, and marine algae, while also protecting them from high temperatures and predators. Since its implementation, there has been up to a 36% increase in marine organism abundance in Sydney. This project demonstrates how the integration of ecological scientific research and engineering can transform coastal infrastructure into allies of biodiversity, strengthening marine ecosystem resilience and contributing to the sustainability of urban coastal areas.

Find out more: **Living Seawalls**

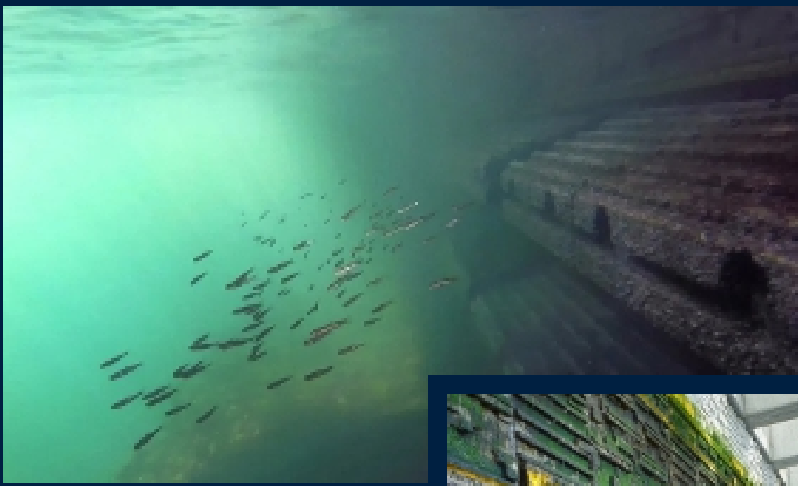


Photo: Mike Caputo/UW

Photo: Eopugetsound

Seattle Seawall Project

Local: Seattle/WA, USA

Objective: Create critical habitats for local biodiversity and a migratory corridor for juvenile salmon.

Description: The Seattle waterfront renewal project is a pioneering large-scale eco-engineering initiative focused on revitalizing marine habitats to support the migration of juvenile salmon, an endangered species of great regional economic importance. The city waterfront has extensive areas of seawalls and deep channels, which hinder the migration of these fish. To overcome this barrier, approximately 1 km of seawalls were rebuilt, including a platform with grooves and cavities designed to encourage the growth of algae and rocky beds at the bay bottom, providing areas where fish can hide and feed. The platform was strategically positioned in the intertidal zone, submerged at high tide and exposed at low tide, creating a shallow habitat during part of the day. Additionally, a suspended sidewalk with a translucent surface was installed to allow light penetration, essential for the salmon during their migration. Since the project completion in 2017, researchers from the University of Washington have been monitoring local biodiversity and the return of salmon to downtown Seattle. The results are promising, with an increase in invertebrate abundance and a record of over 10000 juvenile salmon in a single day.

Find out more: **Encyclopedia of PUGET SOUND**

4.1.4 Terraces and Slopes

Targeted risks – Landslides on steep areas.

Solution – Interventions designed to stabilize slopes, control erosion, and improve water infiltration in steep areas.

Design – Terraces are horizontal platforms built on steep areas to reduce surface water runoff, while slopes refer to terrains that can be treated or reinforced with vegetation or other techniques to prevent landslides and promote soil stability. This solution can maximize space usage by integrating gardens, larger planting areas, and parks, as well as providing areas suitable for water capture.

Scale:
Local and City

Approach Hierarchy:
Protection, Recovery and Creation

Application – This solution can be implemented on undeveloped urban land, highway edges, and hill slopes in urban areas. The use of vegetated slopes and terraces in residential and commercial areas is also recommended to control water runoff and prevent flooding, in addition to contributing to soil stabilization and increasing urban vegetation.

Benefits:

FUNCTIONAL

- Erosion control
- Flood mitigation
- Local production
- Water purification
- Air purification
- Groundwater recharge
- Water flow reduction

URBAN

- Sustainable urban design and planning
- Drainage
- Enhanced public spaces
- Space optimization
- Civil protection
- Infrastructure protection
- Urban cooling

ENVIRONMENTAL

- Biodiversity
- Water quality
- Air quality
- Carbon sequestration and storage
- Healthy soils

SOCIAL

- Education
- Community engagement
- Recreation
- Community resilience
- Health
- Food security
- Sense of security

ECONOMIC

- Food cost savings
- Infrastructure cost savings
- Boost in local economy
- Healthcare savings
- Reduced insurance premiums
- Job creation
- Reduced damage costs

Nbs in action

Photos: Prefeitura de Santos

Stabilization of the Monte Serrat Slope

Location: Santos/SP, Brazil

Objective: Prevent landslides and promote safety for the community

Description: The stabilization of the Monte Serrat slope in Santos is a project designed to reduce landslide risks and ensure the safety of residents. Initiated in 2022, this intervention combines engineering techniques with ecological revitalization. The project involves the installation of efficient drainage systems to control rainfall infiltration and reforesting to stabilize the soil. Additionally, stabilizing barriers with geotextiles were implemented to increase the structural resilience of the area. One of the highlights of the project is the active involvement of the local community in all stages of implementation. The technical team organized meetings and workshops to inform residents about the progress of the work, listen to their concerns, and engage them in planting and maintaining native vegetation. Community participation is essential to ensure the success of the intervention and strengthen the sense of belonging and responsibility toward the territory.

Find out more: **Proadapta**

4.1.5 Floodable parks

Targeted risks – Flooding and inundation.

Solution – Strategic areas designed to flood during extreme events, minimizing the risk of flooding and water overflow in other areas of the city.

Design – Floodable parks are designed with a combination of vegetation, floodable areas, and engineered soils. This solution reduces the risk of flooding and inundation and alleviates pressure on urban drainage systems. Moreover, these parks improve air and water quality, contribute to urban cooling, and provide recreational areas for residents and tourists.

Application – Floodable parks can provide an effective adaptive measure for coastal cities once they are strategically deployed based on local geography. In cities with steep or elevated terrain (more than 10 meters above sea level), floodable parks situated in strategic areas within the city can retain excess rainwater, reducing the risk of urban flooding. In coastal plains, where elevation is minimal, the implementation of floodable parks near the coastline, or around urban areas where it is feasible to restore natural floodable ecosystems, may be more effective in absorbing the impact of storm surges and high tides, acting as a natural buffer zone against coastal flooding.

Scale:
Local, City and Regional

Approach Hierarchy:
Protection, Recovery and Creation

Benefits:

FUNCIONAL

- Conforto térmico
- Controle de erosão
- Mitigação de inundações
- Proteção costeira
- Purificação da água
- Purificação do ar
- Redução de fluxo de água

URBAN

- Design e planejamento urbano sustentável
- Drenagem
- Espaços urbanos aprimorados
- Estética urbana
- Otimização de espaço
- Proteção civil
- Proteção de obras de infraestrutura
- Redução de barulho
- Resfriamento urbano

ENVIRONMENTAL

- Biodiversidade
- Conectividade de habitats
- Qualidade de água
- Melhora em funções ecológicas
- Qualidade de ar
- Redução de estresse térmico
- Sequestro e armazenamento de carbono
- Solos saudáveis

SOCIAL

- Educação
- Engajamento social
- Recreação
- Saúde
- Sensação de segurança

ECONOMIC

- Atratividade para investimentos
- Economia de custos com infraestrutura
- Economia de gastos com transporte
- Fortalecimento da economia local
- Redução de custos com saúde pública
- Prêmio de seguros reduzidos
- Geração de emprego
- Redução de gastos com danos
- Valorização de imóveis

NbS in action

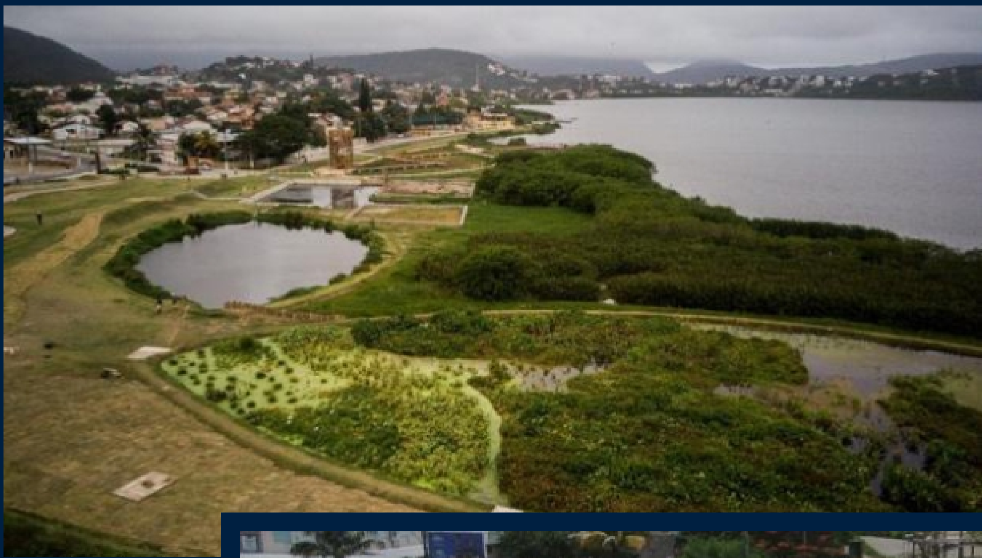


Photo: Alex Ramos (Niterói City Hall)

Photo: Niterói City Hall

Orla Piratininga Park

Location: Niterói/RJ, Brazil

Objective: Environmental recovery and creation of a sustainable leisure space

Description: The Orla Piratininga Park, inaugurated in 2022, is the largest Nature-based Solution (SbN) project in the country, combining environmental recovery with the creation of urban spaces for leisure and recreation in Niterói. Located around the Piratininga Lagoon, the park was designed to revitalize the degraded coastal area to prevent flooding, reduce erosion and sedimentation of water bodies, and improve water quality in the lagoon. This was achieved through ecological interventions, including the recovery of native vegetation, the implementation of bioswales, and floodable areas. The park extends over 680000 m2 with approximately 11 km of bike lanes, 17 leisure areas, trails, 8 piers, 3 viewpoints, and 1 cultural center to promote recreational and educational activities focused on environmental awareness. It particularly includes 35000 m² of constructed wetlands to treat water contamination.

Find out more: **Pro Sustentável**

4.1.6 Green Parks

Targeted risks: Flooding and inundation

Solution: Design urban green spaces to absorb water, reducing the impact of floods without remaining flooded during dry periods. These act as natural buffer zones during heavy rainfall events.

Design: Urban green parks are designed with permeable surfaces, deep-rooted vegetation, and sometimes integrated water elements, such as bioswales or rain gardens. These features function together to effectively absorb and manage rainwater.

Application: The implementation of green parks in urban centers should prioritize strategic locations, such as undeveloped spaces near residential and commercial buildings, high-traffic streets, and vacant lots. Parks near residences enhance the well-being and quality of life for residents, while those in commercial areas provide leisure and rest spaces for workers and visitors. Public undeveloped spaces, like squares and vacant lots, are also ideal as they can be revitalized to improve drainage and urban landscapes, reduce heat, and promote local biodiversity.

Scale:
Local, City and Regional

Approach Hierarchy:
Protection, Recovery and Creation

Benefits:

FUNCIONAL

- Thermal comfort
- Flood mitigation
- Water purification
- Air purification
- Groundwater recharge
- Water flow reduction

URBAN

- Sustainable urban design and planning
- Drainage
- Enhanced public spaces
- Urban aesthetics
- Space optimization
- Urban cooling

ENVIRONMENTAL

- Biodiversity
- Habitat connectivity
- Water quality
- Enhancement of ecological functions
- Air quality
- Thermal stress reduction
- Carbon sequestration and storage

SOCIAL

- Education
- Community engagement
- Recreation
- Health

ECONOMIC

- Attractiveness for investments
- Infrastructure cost savings
- Healthcare savings
- Energy cost savings
- Reduced damage costs
- Increased property value

NbS in action

Photos: Rafael Salim

Realengo Green Park

Location: Rio de Janeiro/RJ, Brazil

Objective: Mitigate heat and prevent flooding

Description: The Realengo Green Park, inaugurated in 2023 in Rio de Janeiro city, is an initiative that combines urban sustainability with community well-being. Projected to reduce high temperatures and prevent frequent local flooding, this park is part of the city's green infrastructure solutions. Spanning a broad area, the park saw the planting of 3700 trees selected for their ability to alleviate urban heat. In addition to tree planting, the project included rain gardens and sustainable drainage solutions designed to capture and filter rainwater, reducing the load on drainage systems and preventing flooding. The park also offers infrastructure for recreation and physical activities, with bike lanes, walking areas, and an amphitheater for community and cultural events. More than a refuge for residents, the park fosters knowledge exchange, promoting environmental education and awareness about the importance of green spaces in cities.

Find out more: **Prefeitura do Rio de Janeiro**; **CicloVivo**

4.1.7 Greenways (bike lanes, sidewalks and streets)

Targeted risks – Flooding, inundation and air quality.

Solution - Integration of natural elements into urban pathways that allow the absorption and management of rainwater and optimize public spaces for pedestrians and cyclists.

Design - Greenways are designed to reduce water runoff, improve urban drainage, and mitigate flooding through the integration of sustainable elements such as trees, permeable pavements, vegetated swales, green strips or rain gardens. These pathways can be enhanced with bike lanes and sidewalks, improving mobility and pedestrian traffic in urban centers.

Application – Greenways are applied to streets and other urban pathways with high impermeability, including areas with moderate slopes, where it is necessary to manage water runoff and reduce pressure on traditional drainage systems.

Scale:
Local and City

Approach Hierarchy:
Recovery and Creation

Benefits:

FUNCIONAL

- Thermal comfort
- Flood mitigation
- Water purification
- Air purification
- Water flow reduction

URBAN

- Sustainable urban design and planning
- Drainage
- Enhanced public spaces
- Urban aesthetics
- Urban mobility
- Infrastructure protection
- Space optimization
- Urban cooling

ENVIRONMENTAL

- Biodiversity
- Habitat connectivity
- Water quality
- Enhancement of ecological functions
- Air quality
- Thermal stress reduction
- Carbon sequestration and storage

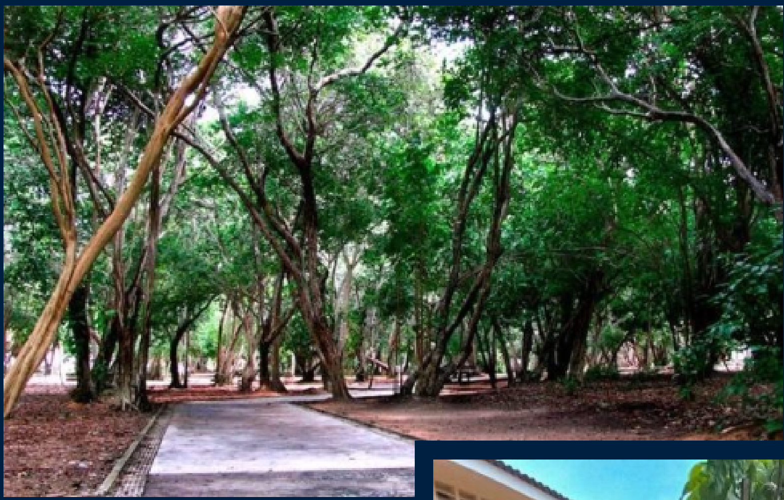
SOCIAL

- Education
- Community engagement
- Recreation
- Health

ECONOMIC

- Attractiveness for investments
- Infrastructure cost savings
- Transportation cost savings
- Boost in local economy
- Healthcare savings
- Energy cost savings
- Reduced damage costs
- Increased property value

NbS in action



Photos: Jefferson Peixoto/Secom PMS

Planta Natal Project

Location: Natal/RN, Brazil

Objective: Reforest urban areas and improve quality of life in the city

Description: The Planta Natal Project was launched in 2019 by the City of Natal to expand the city's vegetation coverage, contributing to urban reforestation and improving the population's quality of life. The initiative aims to plant native and fruit trees in various parts of the city, restoring degraded green areas and encouraging environmental awareness among residents. The project involves partnerships with schools, companies and civil society organizations, as well as local volunteers, who participate in planting campaigns and educational activities. The project's actions are divided into different fronts, including the planting of trees along the street sidewalk, reforestation of riverbanks and urban parks, and the planting of seedlings in schools and health units. To date, the project has planted more than 20000 trees throughout the city, increasing shade on public roads and helping mitigate the effects of urban heat. Planta Natal has contributed to the creation of green corridors that connect natural areas in the city.

Find out more: **Planta Natal**

4.1.8 Rain gardens

Targeted risks – Flooding.

Solution – Bioretention system designed to capture and absorb stormwater runoff from roofs, sidewalks and streets.

Design - Rain gardens are shallow depressions filled with adapted soil and deep-rooted native plants that can withstand both wet and dry conditions. When it rains, runoff from sidewalks, roofs, and streets are directed to these areas, where the water slowly infiltrates the soil. The plants and soil help remove pollutants before the water reaches local water bodies.

Application – This solution can be implemented in any area prone to flooding, whether in public spaces such as streets near curbs, sidewalks and squares, or in residential and industrial areas. In addition, it can be integrated with bioswales systems, increasing their efficiency in managing rainwater.

Scale:
Local

Approach Hierarchy:
Recovery and Creation

Benefits:

FUNCIONAL

- Water flow reduction
- Water purification

URBAN

- Enhanced public spaces
- Urban aesthetics
- Sustainable urban design and planning

ENVIRONMENTAL

- Biodiversity
- Water quality
- Healthy soils

SOCIAL

- Education
- Community engagement
- Recreation
- Community resilience
- Health

ECONOMIC

- Job creation
- Reduced damage costs
- Increased property value

NbS in action

Photo: Diário do Rio

Photo: Ciclo Vivo

Rain garden in Copacabana

Location: Rio de Janeiro/RJ, Brazil

Objective: Mitigate flood-prone area

Description: In 2020, the city of Rio de Janeiro implemented a rain garden on Rua Almirante Gonçalves, in Copacabana, as a natural solution to reduce local flooding. The challenge was to develop a simple and efficient approach to capture rainwater and combat the degradation of the area, which affected residents and local merchants. With the support and participation of the community, a 6m long, 3m wide flower bed with three filter layers was installed. The garden now retains and filters rainwater, improving drainage and revitalizing the square, in addition to minimizing damage caused by flooding.

Find out more: **Prefeitura do Rio de Janeiro**; **Ciclo Vivo**; **Diário do Rio**

4.1.9 Constructed wetlands

Targeted risks – Water contamination.

Solution – Natural wastewater treatment system designed to remove contaminants and promote water purification before it is returned to the environment.

Design - Constructed wetlands are specially designed areas where contaminated water passes through wetlands with aquatic plants adapted to wet environments, such as cattails and reeds. These plants help remove nutrients and pollutants through natural processes such as absorption and decomposition, while the soil and plant roots provide a surface for microorganisms to attach to, which contribute to water purification.

Application – Constructed wetlands can be implemented in urban areas where there is sufficient space to accommodate natural filtration systems. They are particularly suitable for areas close to urban water bodies, such as riverbanks, lakes and ponds. They help to treat surface runoff and reduce pollutant loads before the water reaches natural waterways. In areas of green infrastructure, such as bioswales and floodplain parks, constructed wetlands can be integrated as a natural water treatment area.

Scale:
City

Approach Hierarchy:
Recovery and Creation

Benefits:

FUNCIONAL

- Water flow reduction
- Water purification

URBAN

- Enhanced public spaces
- Urban aesthetics
- Sustainable urban design and planning

ENVIRONMENTAL

- Biodiversity
- Water quality
- Healthy soils

SOCIAL

- Education
- Community engagement
- Recreation
- Health

ECONOMIC

- Job creation
- Reduced damage costs
- Increased property value

NbS in action

Photo: Hélia Scheppa/PCR

Photo: Diego Galba

Constructed wetlands of Caiara Pier

Location: Recife/PE, Brazil

Objective: Restore water quality

Description: The natural system at Caiara Park, in Recife, was implemented in 2023 as an innovative solution to combat pollution in the Cavouco stream, which flows into the Capibaribe river. This initiative is part of a project in partnership with MCTI (Ministry of Science, Technology and Innovation) and covers an area of 7000 m², with five natural filtration areas and the capacity to treat up to 350,000 liters of water per day. The built natural system acts as bioremediators, using aquatic plants and filtering beds to retain and break down toxic substances. Since its implementation, the system has already increased the oxygenation of the stream water by 70%, a significant indicator of water quality improvement. In addition to promoting environmental recovery, the project offers social and recreational benefits, which transformed the park into a revitalized space for visitors and the local community.

Find out more: **Prefeitura do Recife**; **MCTI**; **Cartilha "Jardins Filtrantes do Cais do Caiara"**

4.1.10 Bioswales

Targeted risks – Flooding and water contamination.

Solution – Natural and linear landscape channel designed to receive, conduct and treat rainwater runoff.

Design - Bioswales are linear depressions designed to filter pollutants and facilitate water infiltration into the soil. They are constructed with prepared soil and planted with native vegetation, such as grasses, shrubs and wetland plants.

Application – Bioswales are ideal for many urban areas where stormwater runoff needs to be managed efficiently. They can be installed along urban canals and streams, near curbs, in parking lots, and even in parks and public areas. In parking lots and streets, bioswales help filter and absorb water runoff from impervious surfaces. They are also very effective in areas with moderate slopes, where they can reduce runoff velocity and promote infiltration into the soil, reducing the load on urban drainage systems.

Scale:
Local

Approach Hierarchy:
Recovery and Creation

Benefits:

FUNCIONAL

- Water purification
- Water flow reduction
- Groundwater recharge

URBAN

- Drainage
- Enhanced public spaces
- Urban aesthetics
- Infrastructure protection
- Sustainable urban design and planning

ENVIRONMENTAL

- Biodiversity
- Water quality
- Carbon sequestration and storage
- Healthy soils

SOCIAL

- Education
- Community engagement

ECONOMIC

- Job creation
- Infrastructure cost savings
- Reduced damage costs
- Increased property value

NbS in action

Photos: Jefferson Peixoto/Secom PMS

Bioswales in Itapuã

Location: Salvador/BA, Brazil

Objective: Improve urban drainage in a sustainable way

Description: In 2024, the Salvador City Hall installed the city's first bioswale in the Itapuã neighborhood as part of a sustainable drainage initiative. This ecological structure was designed to capture and filter rainwater, helping to reduce flooding and improve water management in the area. The bioswales consist of a vegetated channel with native plants and filtering layers composed of gravel, sand and soil, which not only retain sediments and pollutants, but also facilitate the infiltration of water into the soil. In addition to its drainage function, the bioswales in Itapuã also contribute to the enhancement of the neighborhood's landscape.

Find out more: **Prefeitura de Salvador**

4.1.11 Green walls and roofs

Scale:
Local

Approach Hierarchy:
Creation

Targeted risks – Urban heat and flooding.

Solution - Integration of native vegetation on rooftops and building surfaces to enhance air quality, provide thermal insulation, and reduce urban heat, meanwhile contributing to rainwater management by decreasing runoff and slowing water flow on city streets.

Design - Green walls and roofs are designed with several functional layers that ensure both sustainability and protection of the building structure. Green roofs include waterproof membranes, root barriers, drainage systems and substrates that support vegetation, helping to maintain thermal comfort and manage rainwater. Green walls, or vertical gardens, can be either integrated directly on the surface or modular, with panels that contain substrate and built-in irrigation to ensure plant growth.

Application – Green walls and roofs can be implemented in different types of buildings, such as residences, commercial buildings, convention centers and large utility structures.

Did you know?

Some coastal cities in Brazil have adopted specific regulations to encourage the adaptation or construction of buildings with green walls and roofs. Examples include the "IPTU Verde", a tax incentive implemented in cities such as Santos/SP (Complementary Law 913/2015) and Salvador/BA (**Decree 36.288/2022**), as well as certifications such as the "Qualiverde" seal in Rio de Janeiro/RJ (**Decree 35.745/2012**).

Benefits:

FUNCIONAL

- Thermal comfort
- Water flow reduction
- Air purification
- Local production[1]
- Water supply[1]

URBAN

- Urban cooling
- Drainage
- Noise reduction
- Urban aesthetics
- Sustainable urban design and planning

ENVIRONMENTAL

- Biodiversity
- Air quality
- Water quality
- Thermal stress reduction

SOCIAL

- Education
- Community engagement
- Recreation
- Health
- Community resilience

ECONOMIC

- Job creation
- Energy cost savings
- Increased property value

[1] Green roofs can be designed to include vegetable gardens and rainwater harvesting systems.

NbS in action

Photos: RioOnWatch

Green Roof Favela project

Location: Rio de Janeiro/RJ, Brazil

Description: The Green Roof Favela project, led by Luís Cassiano Silva in 2016, aims to mitigate urban heat and purify the air in the community of Parque Arará, in Rio de Janeiro, through the implementation of green roofs. Initially met with skepticism, the project focused on raising awareness among residents about the benefits of these roofs, such as reducing the internal temperature of houses and improving quality of life. With the support of Bruno Rezende, who developed the technique based on his doctoral research, the project builds green roofs using vegetation adapted to the tropical climate with simple irrigation systems. In addition to offering a sustainable solution to urban heat, Green Roof Favela promotes educational and cultural activities, highlighting the importance of the presence of green spaces in favelas for emotional well-being and reducing local violence.

Find out more: **OICS**; **RioOnWatch**

Photo: Groncol

Vertical garden - Santalaia

Location: Bogota, Colombia

Description: The vertical garden of the Santalaia building was completed in 2015 to promote sustainability in a densely populated urban area. With a vast coverage of 115000 native plants, this vertical garden offers significant benefits to the urban environment, such as the annual production of oxygen for approximately 3,000 people, and the absorption and filtration of air pollutants (metals, dust and CO2). The garden also contributes to the air cooling, helping mitigate urban heat and neutralize the carbon footprint of approximately 700 people. The Santalaia vertical garden is currently considered one of the largest in the world.

Find out more: **Urban Nature Atlas**; **Groncol**

5. PATHWAY TO IMPLEMENT NbS IN YOUR CITY

To implement **Nature-based Solutions**, it is essential to engage different sectors of society in a collaborative and coordinated process that takes into account the environmental, social and economic context of the territory. When all sectors of society are involved from the beginning of the idea's conception, the process becomes dynamic, enriched by diverse perspectives, questions and contributions. This diversity strengthens the initiative, broadening acceptance, enhancing monitoring and fostering long-term commitment from the community.

The first step is to clearly identify urban challenges and examine solutions that have already been successfully implemented in other similar contexts. It is also crucial to review current legislation and establish efficient governance that integrates NbS into public policies and encourages their adoption. Developing a detailed action plan with clear objectives, timelines, and responsibilities, followed by securing funding from public or private sources, is essential to enable the implementation of these solutions. Finally, continuous monitoring and adaptive management are indispensable to ensure the effectiveness of NbS in the long term, allowing for adjustments as local and climatic conditions change. Below, we outline key steps for implementing NbS, detailing the points to be considered at each stage of the process.

Roadmap for Implementing NbS

5.1 Identify the problem

Identifying local urban challenges such as flooding, urban heat, erosion or biodiversity loss, is the first step in the process. It is important to clearly define the challenge(s) to ensure that the NbS is appropriate to address these issues. The participation of different local stakeholders in this step ensures that NbS are effective and tailored to the real needs of the community. Involving representatives from different sectors, such as government agencies, technical experts, residents, and businesses, allows for a broader view of the challenges faced by the city. Each group can contribute with valuable, unique knowledge. For example, residents can provide information on the daily impacts of climate change or infrastructure issues, while experts bring technical data that helps to understand the magnitude of the problem and suggest practical solutions. Local businesses can support with resources or interventions, while public administrations have the power to implement policy changes.

5.2 Possible NbS

The phase of identifying knowledge of solutions allows designing NbS that are grounded in proven experience and science. The goal is to find approaches that have been effective in solving similar problems and assess how they can be adapted to the local context. This step involves extensive research into existing solutions, with detailed descriptions of both scientific and practical approaches that have already been implemented in other cities or contexts. This includes seeking out case studies, scientific articles, and technical reports that document the application of NbS in different locations. For example, solutions such as green roofs, linear parks, and sustainable drainage systems have been widely studied and applied in cities around the world. Evaluating success stories and understanding the challenges faced during implementation helps to avoid mistakes and anticipate e solve potential barriers.

Beyond traditional solutions, exploring NbS offers a range of opportunities to build more resilient cities in harmony with the environment. In this context, the "menu of Ecosystem-based Adaptation (EbA) measures" - a type of NbS focused on climate adaptation - is a valuable tool. This guide was developed by the Urban Bioconnection Alliance and the Center for Sustainability Studies at FGV (FGVces), in collaboration with the Ministry of the Environment (MMA) and GIZ/ProAdapta within the scope of the Climate Adaptation Plan. It brings together several EbA measures that can be applied to reduce climate risks and improve the quality of life in cities.

Access the complete spreadsheet and get inspired by the various possibilities of integrating EbA and NbS into your city planning!

5.3 Local knowledge

Compiling and synthesizing local knowledge, past and present, ensures that NbS are effective and appropriate to the reality of the territory. This means gathering detailed data on the physical environment, such as climate, topography, hydrology and soil characteristics, as well as considering population and social factors, such as population density, areas of urban vulnerability, and cultural and historical uses. For example, the local climate directly influences the choice of plant species for NbS, while topography helps define how natural drainage systems, such as bioswales, can be implemented to mitigate flooding or erosion. By understanding these particularities, NbS can be better adapted to meet the specific needs of the region, increasing their effectiveness and durability. Furthermore, community participation is a crucial factor in this process. The community can provide practical information on the impacts of climatic events, such as floods or heat waves, and help identify critical areas that require urgent interventions.

5.4 Co-design of the solution

Co-design of the solution involves active collaboration between the local community and other stakeholders in the process of creating NbS. This participatory process ensures that solutions are shaped according to the needs, priorities and values of the local population, while also taking into account the technical knowledge of experts and managers. The participation of different groups – residents, local authorities, non-governmental organizations, academics and the private sector – promotes an inclusive approach that is adapted to the social and environmental specificities of the territory. In addition to increasing social acceptance, co-design helps to anticipate and resolve potential conflicts of interest, ensuring that solutions are sustainable and generate long-term benefits, such as improving quality of life, climate resilience and protecting local ecosystems. There are several participatory design methodologies, which involve workshops and dialogue spaces aimed at seeking consensus. These practices allow for an inclusive process, in which all contributions are heard and valued equally, regardless of sector of society, gender, age or social class. By adopting this collaborative approach, a process is ensured that everyone is involved, minimizing potential power biases and promoting a balanced and fair participation.

Learn, connect, follow, and participate

Learn about climate change adaptations and **connect** with people and organizations working in the field through the **AdaptaCLIMA** platform, created to promote knowledge management on climate adaptation for society. **Follow** Nature-based Solutions initiatives that are underway in Brazil through the **Innovation Observatory for Sustainable Cities**. This platform is dedicated to mapping and disseminating innovative urban solutions, adapted to the particularities of Brazilian cities. Actively **participate** in discussions and contribute to decision-making by registering on the **Sustainable Urban Development Network (ReDUS)**, a collaborative platform created within the scope of the ANDUS Project (Support for the National Agenda for Sustainable Urban Development). ReDUS integrates several actors from different levels of government, promoting the exchange of good practices, training and planning instruments, facilitating the implementation of sustainable urban policies. Through an approach that takes into account the different types of cities and regions, these platforms offer a comprehensive view of sustainable initiatives, facilitating the exchange of knowledge and encouraging the implementation of good practices across the country.

5.5 Laws and governance

To incorporate NbS into Brazilian cities at the scale needed to increase urban resilience amid the climate crisis, it is urgent to evaluate and adjust urban legislation, including city master plans and land use and occupation laws, to ensure that NbS initiatives are encouraged and sustained. The participation of different levels of government — federal, state and municipal — is important for aligning environmental and urban policies with NbS principles. Local governments must ensure that NbS are considered at all stages of urban planning and that incentives are provided to encourage adoption by private companies and local communities. Moreover, laws and governance structures should promote a participatory approach, allowing communities to play an active role in the management and maintenance of implemented NbS, ensuring that solutions adapt to local needs and realities.

A fundamental milestone for establishing strategic initiatives to promote the sustainability of natural coastal ecosystems in Brazil was the National Coastal Management Plan (PNGC in Portuguese), established by Law 7661 of 1988 and regulated by Decree 5300 of 2004. The PNGC defined guidelines for sustainable management of the coastal zones, promoting integration between different levels of government and society in the management of these territories. This decentralized and participatory approach has fostered the conservation of ecosystems and strengthened coastal governance, contributing to enhancing resilience of Brazilian coastal cities in the face of environmental challenges.

Since then, Brazil has been expanding its efforts with specific initiatives to address climate change, most notably with the recent **Law 14.904/24**, enacted in June 2024. The new legislation establishes clear guidelines for states and municipalities to develop adaptation plans, focusing on reducing socioeconomic and environmental vulnerability, and on the integration of climate mitigation and adaptation into the plans. The law specifically establishes the adoption of NbS as part of adaptation strategies, and that the plans must be based on scientific evidence, using modeling and forecasts based on IPCC reports, ensuring a robust and more effective approach. Furthermore, there are initiatives in the Executive Branch that provide a legal and planning framework, aimed at promoting climate resilience. Among these initiatives, the following stand out: the National Plan on Climate Change (which will guide Brazilian climate policy until 2035), the Resilient Green Cities Program (established by the Federal Government through Decree No. 12,041, of June 5, 2024) and the AdaptaCidades Program, which together form the basis for developing comprehensive and integrated climate adaptations for Brazilian cities.

National Adaptation Plan to Climate Change (Plano Clima)

This plan, coordinated by the Ministry of the Environment, seeks to reduce the vulnerability of social and economic sectors to climate change. It is the main guide for Brazilian climate policy, with updated guidelines for a horizon up to 2035. The plan includes specific measures for critical sectors, such as agriculture, cities, health and water resources. The updated version of the plan emphasizes the need for collaboration among different levels of government and the active participation of civil society, in addition to promoting the use of NbS to strengthen the resilience of cities and coastal areas.

Resilient Green Cities Program

This program focuses on promoting urban green spaces and sustainable infrastructure. It reinforces the importance of integrating greenery into urban areas, such as linear parks and green roofs, to increase urban resilience and mitigate climate impacts. Participating cities can use this program as a reference to ensure that NbS are prioritized in urban development.

AdaptaCidades Program

Focused on providing technical and financial support for Brazilian municipalities to develop and implement adaptation plans, AdaptaCidades offers tools to integrate NbS as part of climate adaptation strategies. It also promotes capacity building through the training of public managers to include these solutions in master plans and other governance instruments.

In addition to urban planning initiatives, Brazil has been advancing its Marine Spatial Planning (MSP), an essential, integrative and multisectoral public instrument aimed at managing the country's blue territory. The MSP aims to organize the sustainable use of marine resources, balancing the conservation and protection of coastal ecosystems with the demands of economic activities. This approach seeks to promote the rational use of resources, ensuring that ecosystems such as mangroves, coral reefs, beach and restingas are preserved, benefiting not only the environment but also crucial economic sectors such as fishing, tourism and natural resource extraction.

5.6 Action plan

The action plan is the strategic document that outlines the detailed framework for the NbS implementation project, ensuring that all aspects of the project are clearly defined. It should include a timeline with important milestones and deadlines, identifying the financial, human and material resources needed for each phase. The plan should assign responsibilities to the different actors involved, ensuring that everyone knows their roles in the process. A crucial element is the definition of clear objectives with indicators and metrics to measure progress and evaluate the effectiveness of the implemented solutions. The development of these metrics should involve the consultation and participation of experts and scientists, ensuring technical validation. These indicators should be used for ongoing monitoring and guarantee that the solution is meeting its main objectives. Moreover, the action plan should be flexible, allowing adjustments to accommodate unforeseen climatic, social or economic events, without compromising the core objectives of the project. This adaptability increases the chances of long-term success and ensures that the NbS remains efficient and functional, even in the face of dynamic scenarios.

5.7 Financing

The implementation of NbS projects depends on financing, which can be obtained from several sources. In Brazil, there are several options, including public funds such as those allocated by the Ministry of the Environment and Climate Change and the National Fund on Climate Change (Climate Fund). The recent **Law 14.904/24** strengthens this scenario by allowing states, municipalities and districts to access resources from the Climate Fund to develop their adaptation plans. In addition, national and regional financial institutions play an important role. FUNBIO (Brazilian Biodiversity Fund) works in partnership with state and municipal governments, supporting projects that involve the conservation of natural ecosystems and the promotion of green infrastructure. Regional Development Banks, such as BRDE, through programs such as the Green Fund and the Resilient South Program, are examples of initiatives aimed at financing sustainable and climate resilience projects. The National Bank for Economic and Social Development (BNDES) is also an important source of financial support, which offers specific credit lines for sustainability and green infrastructure projects. Additionally, the private sector, through investors committed to socio-environmental responsibility, also plays a crucial role, especially through public-private partnerships focused on sustainable urban solutions. As an alternative or complement to these sources, international financing is offered by organizations such as the World Bank, the Inter-American Development Bank (IDB) and the Green Climate Fund (GCF). These organizations often provide subsidies and financing for climate adaptation and ecological restoration projects, areas in which NbS fits perfectly. In addition to financial support, these institutions often offer technical support and training to ensure that projects are implemented effectively and sustainably.

5.8 Implementation

The implementation of NbS involves putting the action plan into practice, ensuring that interventions are carried out according to the established schedule and objectives. In this phase, it is crucial that the NbS intervention is built or restored in a technically and responsible manner, suiting local environmental conditions. Technical supervision is essential to ensure that the solutions are functioning as designed and that the positive impact on the environment and the community is measurable. Additionally, continuous community involvement is fundamental not only to ensure social acceptance but also to promote ownership and long-term care for the interventions. Local communities can play roles in maintenance and monitoring, supporting the long-term sustainability and success of NbS.

5.9. Monitoring and Adaptive Management

After implementation, it is essential to regularly monitor the outcomes of the NbS, using specific indicators to assess whether environmental, social, and economic goals are being met, such as the reduction of flooding, improvement of air quality, or increase in local employment. If expected results are not achieved, adaptive management comes into play, allowing for continuous adjustments to strategies, such as modifying maintenance practices, replanting vegetation, or reconfiguring drainage areas. This process ensures the flexibility and resilience of NbS, enabling solutions to adapt to changes in climate conditions, urban environments, or community needs, ensuring long-term effectiveness and sustainability.

This stage provides an important space for learning and communication. Monitoring actions can be carried out in collaboration with the local community through citizen science programs and with the support of universities, strengthening the link between science and social practices. Participatory monitoring and citizen science can engage citizens, journalists, and schools, ensuring a broad dissemination of information and reinforcing the relevance of NbS in the medium and long term. In Brazil, the **Blue School Program** is an inspiring example of how schools can act as local centers of citizen science, integrating community reality into public policies at various levels - municipal, national, and intergovernmental. In Blue Schools, students take a leading role in projects that identify and address local needs, engaging the school community (families, friends, and residents) in discussions. Moreover, Blue Schools can contribute to monitoring NbS in different neighborhoods, serving as data collection centers and developing new professionals committed to citizenship. By doing so, they align local action with global discussions and disseminate knowledge within communities, expanding the impact of these actions.

6. 8 PRIORITY ACTIONS TO IMPLEMENT NATURE-BASED SOLUTIONS IN COASTAL CITIES

I. Governments (Federal, State, and Municipal):

1

Integrate NbS into Public Policies:

• Incorporate NbS into urban development plans, land-use planning, coastal management, climate change adaptation, infrastructure, and environmental policies.

• Create tax and financial incentives for municipalities, companies, and landowners to implement NbS.

• Regulate and encourage the use of economic instruments, such as payments for ecosystem services, to promote the conservation and restoration of coastal ecosystems.

2

Strengthen Governance and Integrated Coastal Management:

• Establish and strengthen coastal management councils and committees with social participation, ensuring representation from various sectors and stakeholders.

• Implement effective coordination mechanisms among different levels of government (federal, state, and municipal) and sectors (environment, urban planning, water resources).

• Include NbS and a climate resilience perspective in existing or future land-use planning instruments.

3

Invest in Science, Technology, and Capacity Building:

• Foster scientific and technological research for the development of innovative Nature-based Solutions adapted to local realities.

• Provide information to the public and decision-makers about the impacts of climate change and potential solutions, integrating NbS wherever possible.

• Train government agency technicians, professionals from the private sector, and members of the civil society on NbS implementation and management.

4

Inform and Educate for Public Awareness:

• Develop campaigns of communication and environmental education to raise awareness about the importance of NbS for climate resilience, the benefits of ecosystem services, and the need to conserve coastal ecosystems.

II. Companies and Private Sector:

5

Incorporate NbS into Operations and Business Practices:

• Adopt socio-environmental responsible practices that promote the conservation and restoration of coastal ecosystems.

• Invest in NbS on the lands and areas of influence of the company, as a form of environmental compensation and generation of shared value.

• Develop innovative NbS-based products and services for the construction industry, water resource management, and sustainable tourism markets, strengthening the NbS value chain.

6

Engage in Public-Private Partnerships:

• Seek collaboration opportunities with public authorities and civil society organizations for the implementation of NbS projects.

• Invest in research and development of innovative technologies in partnership with universities and research centers.

III. Civil Society (NGOs, Local Communities, Citizens):

7

Engage in Participatory Management and Social Accountability:

• Actively participate in coastal management councils and forums, contributing to the formulation and implementation of public policies.

• Monitor and oversee government and corporate actions that impact coastal ecosystems.

• Hold public officials accountable for effective solutions that provide multiple benefits for urban resilience and adaptive capacity.

8

Develop Local Actions and Mobilize the Community:

• Create and strengthen community organizations for the management of natural resources and implementation of NbS projects.

• Participate in beach clean-ups, native species planting, and other practical environmental conservation activities.

• Raise awareness among people about the importance of NbS and encourage the adoption of sustainable practices in daily life.

• Act responsibly toward natural ecosystems:

• Follow management guidelines when visiting Protected Areas or hiking trails.

• Avoid improper disposal of waste or effluents and prevent fires caused by flames or sparks.

• Preserve natural areas, such as restingas and mangroves, by avoiding trampling when visiting or walking along the shore, and take care not to damage corals and other marine organisms during ecotourism activities.

7. TIME TO ACT: TOGETHER FOR RESILIENT CITIES

The future of our cities and communities depends on the choices we make today. This document presents a range of Nature-based Solutions that can be implemented in your city and provides examples of successful cases to inspire and motivate. The solutions presented are just a starting point for initiating a transformative process in your area. Given the increasing climate challenges, it's time to act collaboratively and strategically.

The time is now! We need to join forces — from local to global — to create new models of projects and actions using NbS that can minimize environmental impacts and foster community resilience. Every action counts, and together, we can build a more resilient and sustainable future.

The **Brazilian Ocean Literacy Alliance** is ready to collaborate with governments, businesses, and other governance bodies interested in learning more about NbS and initiating local projects. Our mission is to promote climate resilience in coastal municipalities, aligning our actions with the National Adaptation Plan to Climate Change and the international guidelines of the **Ocean Decade**. We combine scientific knowledge with co-production to integrate efforts and connect local actions to global agendas, turning ideas into tangible solutions.

Contact us to collaborate:
maredeciencia@gmail.com

7.1 About Us

ALIANÇA BRASILEIRA PELA CULTURA OCEÂNICA

Brazilian Ocean Literacy Alliance

A network of municipalities, states, private and public institutions, and organized civil society engaged in implementing local actions aligned with the national and global goals of the UN Decade of Ocean Science, focusing on promoting Ocean Literacy for sustainable development and working toward the creation of Blue Cities.

Visit the website

UNIFESP

MARÉ DE CIÊNCIA

2021 2030 Década das Nações Unidas da Ciência Oceânica para o Desenvolvimento Sustentável

Maré de Ciência UNIFESP

Maré de Ciência is an outreach program at the Federal University of São Paulo (UNIFESP, Baixada Santista Campus), responsible for the executive secretariat of the Brazilian Ocean Literacy Alliance, dedicated to scientific communication and engagement to strengthen the interface between science, public policy, and society.

Visit the website

MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÕES

GOVERNO FEDERAL BRASIL UNIÃO E RECONSTRUÇÃO

Ministry of Science, Technology, and Innovation

The Ministry of Science, Technology, and Innovation (MCTI) serves as Brazil's national focal point for the UN Decade of Ocean Science for Sustainable Development, coordinating the Advisory Committee for the Ocean Decade, established by Ordinance No. 4,534 of March 2021. Actions for the implementation of the Ocean Decade and the Sustainable Development Goal (SDG) related to marine conservation are outlined in Brazil's National Plan for the Implementation of the Ocean Decade.

Visit the Ocean Decade website

UNESCO in Brazil

The UNESCO Representation in Brazil aims to support the formulation and implementation of public policies aligned with the strategies defined by the Member States in the UNESCO General Conferences. This work is promoted through technical cooperation projects, conducted in partnership with government agencies and civil society sectors, particularly when these projects contribute to public policies focused on sustainable development in UNESCO's areas of expertise.

Visit the website

Boticário Group Foundation for Nature Protection

With over 30 years of history, Boticário Group Foundation is one of Brazil's leading corporate foundations dedicated to conserving the country's natural heritage. Focused on adapting society to climate change, particularly in water security and coastal protection, the foundation advocates for biodiversity conservation across all sectors. Aligned with the UN Sustainable Development Goals, it considers nature the foundation for Brazil's social and economic development. Non-profit and supported by Grupo Boticário, the foundation mobilizes diverse stakeholders to seek solutions to major environmental, social, and economic challenges. Founded in 1990 by Miguel Krigsner, it was established just two years before the Earth Summit (Rio-92), a landmark event for global environmental conservation.

www.fundacaogrupoboticario.org.br | @fundacaogrupoboticario (Instagram, Facebook, LinkedIn, YouTube, TikTok)

Visit the website

7.2 Discover Our Other Initiatives

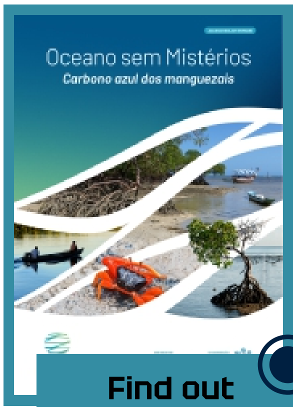
Explore additional initiatives from the **Brazilian Ocean Literacy Alliance** and **Boticário Group Foundation** that can support this journey:

Ocean without Mysteries

Find out more

Find out more

Find out more

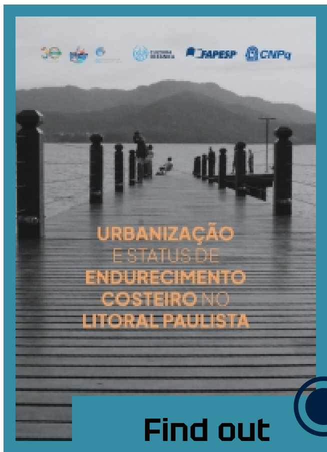


Find out more

Artisanal Fishing and Marine Coastal Conflicts on the Coast of São Paulo (SP)

Find out more

Urbanization and Coastal Hardening Status on the Coast of São Paulo



Find out more

Cities of the Future - Portfolio on Nature-Based Solutions from the Boticário Group Foundation

Find out more

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ISBN: 978-65-85919-46-3

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