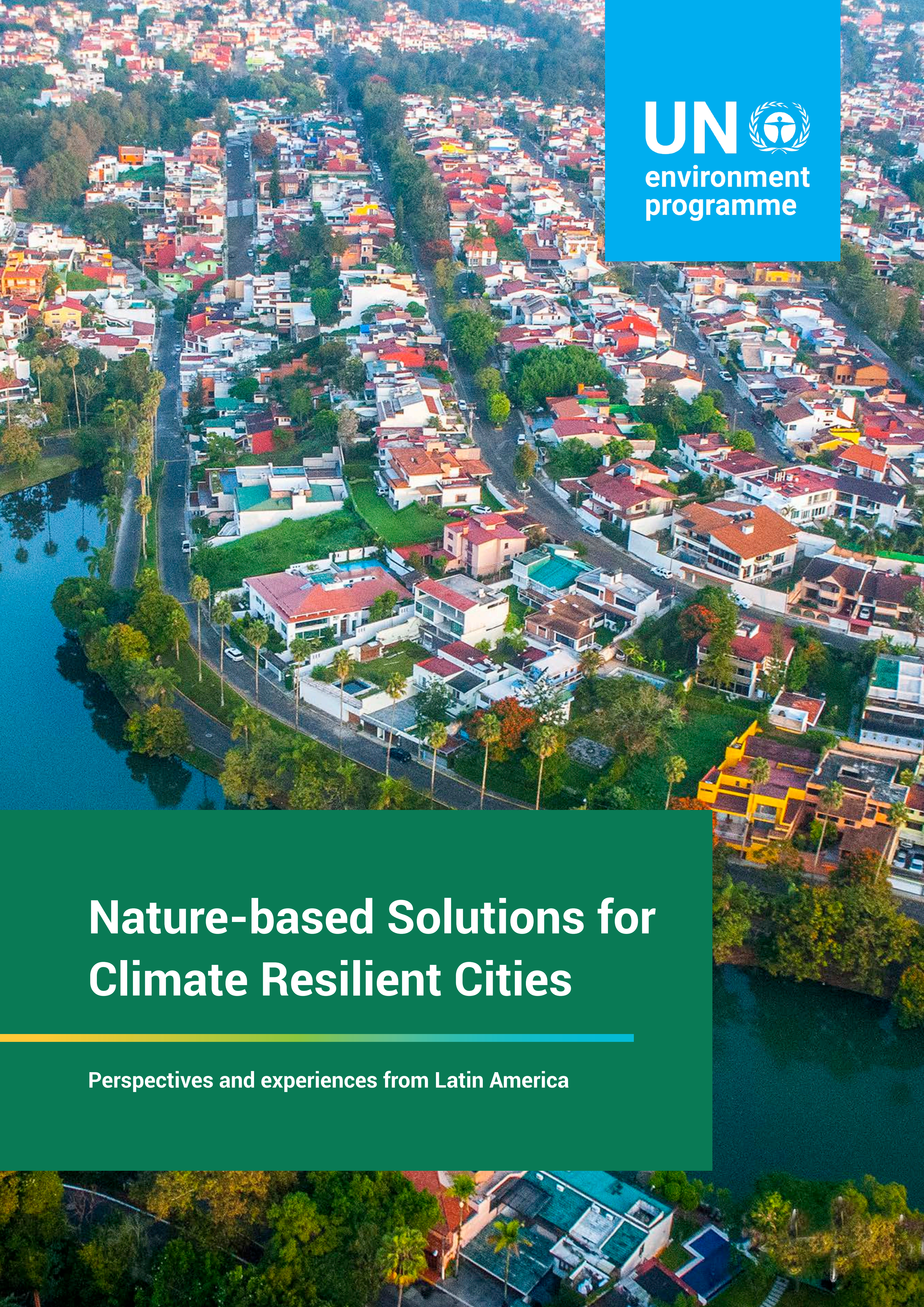


Nature-based Solutions for Climate Resilient Cities

Perspectives and experiences from Latin America

UN environment programme

Published by the United Nations Environment Programme (UNEP), December 2023.

ISBN: 978-92-807-4109-4
Job Number: ROLAC/2599/PA
DOI: https://doi.org/10.59117/20.500.11822/44437

Disclaimer

Suggested citation

United Nations Environment Programme (2023). Nature-based Solutions for Climate Resilient Cities. Perspective and experiences from Latin America. Panamá.

With the support of:

City Adapt
Euroclima
Funded by the European Union
gef
Norad
CONEXUS Urban nature connects us

Editorial design:

Practical ACTION

Cover photo credit:

Xalapa, México. © UNEP / Héctor Montes

For more information about CityAdapt, visit the website at:
www.CityAdapt.com

UNEP promotes environmentally friendly practices globally and in its own activities. Our distribution policy aims to reduce its carbon footprint..

Contributions

Authors

Daniel Kozak, Manuel Winograd, Jorgelina Hardoy, Begoña Arellano, Melinda Maldonado, Tom Wild, Mariana Baptista, and Mariana Giusti

This publication was edited by:

Daniel Kozak, University of Buenos Aires (UBA) and the National Council for Scientific and Technical Research (CONICET), Argentina.

This publication was led by:

Marta Moneo, Lili Ilieva, and Ophelie Drouault (Adaptation Team, Climate Change Unit, UNEP - Latin America and the Caribbean). It is a result carried out as part of the CityAdapt regional project, implemented by UNEP in El Salvador, This publication was edited by: Jamaica, and Mexico between 2017 and 2023.

We thank the following experts for reviewing the chapters and their valuable contributions to the report:

- Leyla Zelaya (UNEP)
- Sergio Angon (UNEP)
- Carolina Ana Diaz (UNEP)
- Karem Rivero (UNEP)
- Maria Paula Viscardo (UNEP)
- Carlos Rodriguez Otero (INOTU - Cuba)

We thank the following experts for providing inputs for the publication and case studies:

- Fernando Williams
- Andres Borthagaray
- Lorena Vecslir
- Michiel van Eupen (WENR)
- Hernando Arenas (Institute of Urban Development of Bogota)
- Cristina Arango (Bogota Aqueduct and Sewer Company)
- Arturo Mejia
- Mauricio Marin
- Maria Jose Escudero
- Ninike Celi Atala
- Karina Suarez
- Adriana Avila Santacruz (District of Quito)
- The Knowledge Network for Research, Strengthening, and Promotion of SUDS, as a Measure of Adaptation to Climate Change of Bogota.

This report has been made possible thanks to the generous contribution of our donors:

The European Union EUROCLIMA+ Programme, the Global Environment Facility (GEF) and the support of the Norwegian Development Cooperation Agency. The research reflected in chapter 6 has been funded by the European Union as part of the Horizon 2020 research and innovation programme (Grant Agreement No 867564), through the CONEXUS project.

Technical support and editorial production:

The editorial design process of this publication has been directed by the Practical Action team:

- Jacqueline Gotuzzo
- Silvia Gonzales
- Dennis Gonzales
- Gabriela Ramos
- Marita Obregón Rossi (proofreading)
- Solution Comunicaciones (design and layout)
- Carla Dongo (translation)

With support from the UNEP communication team:

- Karla Delgado-Olguin
- Irati Durban Aguinagalde
- Natalia Lopez Alvarez
- Daniel Diaz Rivas
- Javier Bianchet

Acronyms

AGEB:	Basic Geo-statistical Areas
AMSS:	Metropolitan Area of San Salvador
AU:	Urban Agriculture
BGI:	Blue and Green Infrastructure
CAF:	Development Bank of Latin America
CBD:	Convention on Biological Diversity
CC:	Climate Change
CDKN:	Climate and Development Knowledge Network
CDR:	Climate-Resilient Development
CEPAR:	Center for Agroecological Production Studies
CIRIA:	Construction Industry Research and Information Association
CMAS:	Drinking water and sanitation Municipal Commission
COCUPIX:	Pixquiac River Basin Committee
COD:	Onerous Concession of Rights
CONAGUA:	National Water Commission
CPI:	Climate Policy Initiative
CRC:	Climate Resilient Cities
WSUD:	Water-Sensitive Urban Design
EAAB:	Bogotá Aqueduct and Sewerage Company
EC:	European Commission
ECLAC:	Economic Commission for Latin America and the Caribbean
EEA:	European Environment Agency
EGIRH:	Comprehensive Water Resource Management Strategy
ES:	Ecosystem Services
EURAC:	Eurac Research, European Academy Bozen-Bolzano
FAO:	Food and Agriculture Organization of the United Nations

FFEM:	French Global Environment Facility
FFLA:	Latin American Future Foundation
FUNDASAL:	Salvadoran Foundation for Development and Minimum Housing
GCA:	Global Commission on Adaptation
GIS:	Geographic Information System
GIZ:	German Agency for International Cooperation
GEF:	Global Environment Facility
GHG:	Greenhouse Gas
GWP:	Global Water Partnership
IDRC:	International Development Research Centre
IDU:	Institute for Urban Development
INTA:	National Institute of Agricultural Technology
IPBES:	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC:	Intergovernmental Panel on Climate Change
IPTU:	Urban Territorial Property Tax
IUCN:	International Union for Conservation of Nature
IWRM:	Integrated Water Resources Management
LAC:	Latin America and the Caribbean
LOOTUGS:	Organic Law on Territorial Planning, Land Use, and Management
MARN:	Ministry of Environment and Natural Resources
MEA:	Millennium Ecosystem Assessment
NAU:	New Urban Agenda
NbS:	Nature-based Solutions
OECD:	Organization for Economic Cooperation and Development
PACQ:	Quito Climate Action Plan
PMDOT:	Metropolitan Development and Territorial Planning Plan
POT:	Land Management Plan
PROCOMES:	Association of Community Projects in El Salvador

PUGS:	Land Use and Management Plan
REVIVE A.C.:	Biodiversity Nurseries Network
RCP:	Representative Concentration Pathways
RVO:	Netherlands Enterprise Agency
RWHS:	Rainwater Harvesting Systems
SDGs:	Sustainable Development Goals
SENDAS:	Pathways and Encounters for Sustainable Autonomous Development Civil Association
SINFRA:	Secretariat of Infrastructure and Sustainable Territorial Planning
SUDS:	Sustainable Urban Drainage Systems
UHI:	Urban Heat Island
UN:	United Nations
UNDP:	United Nations Development Programme
UNDRR:	United Nations Office for Disaster Risk Reduction
UNEA:	United Nations Environment Assembly
UNEP:	United Nations Environment Programme
UNESCO:	United Nations Educational, Scientific and Cultural Organization
UNFCCC:	United Nations Framework Convention on Climate Change
UNR:	National University of Rosario
UNU:	United Nations University
WSUD:	Water-Sensitive Urban Design
WUNR:	Western Urban Natural Reserve

Table of Contents

List of Figures

List of Tables

Executive summary and key messages

Reconnecting cities with nature

Climate impacts in Latin America and the Caribbean are increasing in frequency and intensity. According to the World Meteorological Organization (WMO), between 2020 and 2022, 88% of the extreme events recorded in the region were caused by meteorological, climatic, and hydrological factors. These events accounted for 40% of the deaths and 71% of related economic losses (WMO 2022). Considering that currently, 8 out of 10 people in the region live in urban areas, and it is estimated that this figure could reach 85% by 2040 (UN-Habitat 2022), and that 48% of the capitals of Latin America and the Caribbean are exposed to extreme risk due to the impacts of climate change (Development Bank of Latin America [CAF] 2014), it becomes essential to increase resilience in urban spaces.

Strengthening the adaptive capacity of cities requires a rethinking of the urban development process, as it involves a significant transformation of territory and land use. Historically, this development has been unsustainable, depleting the natural resources on which cities rely. Urban environments have developed separately from natural ecosystems, resulting in the channelingchannelling of rivers and estuaries, deforestation of hillsides, transformation of wetlands into landfills, and consequently, the loss of key functions that these ecosystems provide.

Cities in Latin America and the Caribbean not only face inadequate land planning, housing deficits, and inefficient and unevenly distributed infrastructure; they also lack landscape or watershed planning that integrates ecosystem services into their sustainable development. With population growth and concentration in urban areas, most citizens now live in high-risk areas exposed to climate events. They are increasingly exposed to river and coastal flooding, heatwaves, extreme rainfall, and storms, as well as water scarcity, resulting in increasingly significant impacts.

These high levels of exposure to climate risks compel us to recognize the need to change the current unsustainable model of regional urbanization. To reduce vulnerability, it is necessary to transform these processes and reconsider the relationship between cities and their natural environment. This involves investing in and planning the recovery of ecosystems and their regulatory functions, as well as promoting orderly urban growth as an integral part of the landscape.

So how can we transform urban planning? Are there accessible and cost-effective tools that allow us to begin building resilience in these cities? The answers, as we will explore throughout this publication, may be closer than we think.

Nature-Based Solutions (NbS) are an effective way to strengthen the resilience of urban communities by enhancing the natural functions of ecosystems and providing social, ecological, and economic benefits. Ecosystems within and around urban areas


Photography: Xalapa, Mexico
Source: © UNEP / Author: Josephat Kariuki.

play an essential role in retaining and infiltrating water, regulating temperature, controlling soil erosion and loss, among many other services; our actions, when properly planned and measured, can maximize their positive impacts.

NbS are not a product but a process. They require long-term commitment and informed and effective citizen participation to ensure their sustainability. This implies a paradigm shift in the urban planning of many cities, with the aim of addressing the multidimensional nature of vulnerability through integrated solutions.

Wider adoption of Ecosystem-based urban Adaptation strategies and scaling up NbS require coherent institutional and political frameworks, urban planning tools informed by climate risks, inclusive, intersectional, and participatory processes, as well as a sustainable financial strategy that guides investment and urban development toward resilience. Cities play a fundamental role as key actors in local climate action and must demonstrate ambition consistent with the needs of their residents.

This publication aims at providing tools for those involved in urban planning to more effectively integrate climate risks and the opportunities offered by the ecosystem context of each city. This way, it seeks to contribute to Latin America and the Caribbean resilient urban development.

The publication is organized around six key themes:

Chapter 1.
Key concepts of NbS for adaptation in cities

Introduces the concept of NbS and the fundamental role they can play in urban adaptation to climate change. It is illustrated with specific examples from Mexico City (Mexico) and the cities of Santa Fe and Buenos Aires (Argentina).

Chapter 2.
Climate risk analyses in cities and how to use them in NbS planning and design

Presents a methodology for assessing climate risks, emphasizing the importance of such analysis for planning urban adaptation strategies based on ecosystems. The chapter includes examples from the cities of Xalapa (Mexico) and San Salvador (El Salvador).

Chapter 3.
Citizen participation in NbS planning and design

Highlights the importance of building participatory processes involving key actors in territorial planning, design, and implementation of NbS in cities. The chapter includes tools and examples from the cities of Rosario (Argentina) and Xalapa (Mexico).

Chapter 4.
Resilient infrastructure in urban adaptation

Analyzes the potential of NbS and hybrid solutions to reduce climate risks and impacts in cities. The chapter focuses on technical, governance, and monitoring and evaluation aspects relevant to the design and implementation of NbS, using case studies from the cities of San Salvador (El Salvador) and Oaxaca de Juárez (Mexico).

Chapter 5.
Overview of planning and financing instruments that support urban NbS

Provides an analysis of financing instruments that enable the transition from planning to implementation and seek self-sustaining models of local financing. The chapter includes examples from the cities of Quito (Ecuador) and Bogotá (Colombia).

Chapter 6.
Analysis and valuation of NbS impacts

Identifies the main references on NbS financing and valuation today, describing possible business models, and exploring the relationships between the co-benefits of NbS and valuation frameworks. The chapter includes examples from the cities of Medellín (Colombia) and São Paulo (Brazil).

Key messages

1. Cities are intrinsically connected to their surrounding watersheds and depend on them for various services contributing to climate resilience.

Cities and the watersheds surrounding them maintain an essential connection in the context of climate change. Urban areas depend on their watersheds for a range of vital ecosystem services that play a fundamental role in climate resilience. In this context, healthy watersheds play a key role in managing the water cycle for urban areas, acting for water regulation, distribution, and flow. This in turn, contributes to reducing the risk of flooding and increasing water security.

2. Climate risk analysis at the watershed scale: a key approach for an integrated urban planning based on climate impacts and risks.

Climate risk analysis at the watershed scale is a key tool that drives resilience in cities. Climate risks are complex and encompass multiple dimensions, from climate patterns to land use, water resources, and ecosystems. But to truly understand vulnerability and risks, we must look beyond the city limits and consider a multiscale perspective. By analyzing climate risks at the watershed, peri-urban, and urban levels, we gain a comprehensive view of how climate change impacts vital ecological functions for urban resilience. From the identification of critical vulnerability points to the understanding of the origin of floods, this approach provides us with a holistic and precise understanding of how to address climate challenges and build cities prepared for the future.

3. The transformative power of ecosystems in building resilient cities.

Ecosystems have the ability to control floods, mitigate droughts, improve air quality, and regulate the urban microclimate, making them a key element in building urban resilience. At all scales, from wetlands to forested areas in cities and peri-urban areas, they act as natural sponges that absorb and retain rainwater, reducing the risk of flooding and ensuring groundwater recharge and retention. Restoration and conservation actions for valuable ecosystems as part of NbS can foster a path to sustainable urban adaptation. Through NbS, we can maximize their potential to ensure a resilient future for our cities and build an urban environment better prepared for current and upcoming challenges.

4. Participatory governance for an inclusive and sustainable future in resilient urban environments.

Participatory governance in the construction of urban resilience with NbS is essential to ensure inclusion, recognition of local knowledge, community empowerment, and accountability. By involving a wide range of stakeholders in the decision-making process, it is possible to develop and implement more effective and sustainable solutions that address urban challenges and promote long-term resilience. Empowering citizens in all their diversity, as well as involving actors from the private sector, civil society, academia, and others, is fundamental to the effectiveness of the solutions.

5. Investing in innovative financial instruments for NbS implementation.

Financing and urban management tools, as well as land-based instruments, offer a unique opportunity to support the implementation of NbS. By leveraging local resources and the participation of diverse stakeholders, funds can be generated to drive their development. In urban planning or construction projects, NbS or financial resources can be legally required to finance them. Property taxes can incorporate NbS through their use for fiscal purposes, such as tax collection or through additional incentives that promote NbS implementation.

6. Profitability, benefits, and co-benefits of NbS for urban resilience building.

NbS and resilient infrastructure offer greater social, economic, and environmental benefits, such as improved health and the creation of green jobs, compared to conventional solutions, and complement climate mitigation actions and biodiversity conservation. NbS can replace or complement grey infrastructure, such as levees and conventional drainage systems, which are often costly to build and maintain. By using nature as a resilient infrastructure, it is possible to reduce construction, maintenance, and long-term operational costs.

Photography: San Salvador, El Salvador
Source: © UNEP / Author: Josephat Kariuki.

Introduction

The role of cities in the climate change and biodiversity agenda

There is increasing evidence of the destructive impacts of climate change on the human population, nature, and infrastructure (Intergovernmental Panel on Climate Change [IPCC] 2022a). Meanwhile, biodiversity has declined unprecedentedly in human history (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES] 2019). Addressing this crisis requires joint action that establishes complementary synergies between climate and biodiversity agendas.

Cities can play an important role in accelerating these actions and addressing both challenges: strengthening the climate resilience of the population and critical infrastructure while conserving and creating habitats to boost biodiversity. The New Urban Agenda (ONU-Habitat 2020) and the Regional Action Plan for the implementation of the New Urban Agenda in Latin America and the Caribbean (Economic Commission for Latin America and the Caribbean [ECLAC] 2018) highlight the need to integrate nature into urban planning and design. Likewise, the Paris Agreement on Climate Change (United Nations Framework Convention on Climate Change [UNFCCC] 2015) and the Post-2020 Global Biodiversity Framework (Convention on Biological Diversity [CBD] 2021) recognise the potential of cities to contribute to achieving commitments on climate change and biodiversity.

The construction of climate-resilient cities must be carried out inclusively, recognizing the interrelationships between gender and the environment, as stipulated in international agreements and by the Convention on Biological

Gender and environmental interlinkages are necessary and are called for in international agreements. The construction of climate-resilient cities must be carried out inclusively, recognizing the interrelationships between gender and the environment, as stipulated in international agreements and by the Convention on Biological Diversity (CBD 2021).

Cities vulnerable to climate change in Latin America and the Caribbean

Latin America and the Caribbean is the second most urbanised region in the world: 8 out of 10 people live in cities, and it is estimated that the proportion of the urban population could reach 85% by 2040 (ONU-Habitat 2022). Cities are highly exposed, vulnerable, and strongly affected by climate risks, such as river and coastal flooding, heat waves, extreme rainfall, storms, and water scarcity (IPCC 2022b, p. 1).

Cities face multidimensional challenges as climate risks impact urbanisation, loss of biodiversity and ecosystem services, poverty, and increasing socioeconomic inequalities. As a result of the high rate of urbanisation and inadequate urban-territorial planning, deficient and unevenly distributed infrastructure, housing deficits (both in quantitative and qualitative terms), as well as the recurring occupation of high-risk areas, the urban population in the region concentrates an exceptionally high level of vulnerability (IPCC 2022b, pp. 1-2).

This, on the one hand, disproportionately affects populations already exposed to different types of risks, such as people with disabilities or older individuals who have limited access to resources and public services. On the other, climate impacts exacerbate gender inequalities due to their causal interrelationship with environmental degradation (UN Women, United Nations Development Programme [UNDP], United Nations Environment Programme [UNEP] 2020).

Despite women being seen as agents of change and leaders in addressing challenges linked to climate change, they experience differentiated impacts and are burdened by a changing climate. Women represent majority of the world's poor and are dependent on natural resources for their livelihoods with these resources threatened by weather events.

The limited capacity of governments to plan and finance adaptation to climate change (CC) in cities is an additional barrier to the construction of ambitious and effective adaptation processes, especially in intermediate and small towns. Thus, the need to build innovative urban resilience strategies and obtain sustainable financing becomes urgent in the urban agenda in the region.

Nature as a solution for adaptation to climate change in cities

In response to climate change forecasts highlighting increasing risks for cities, there is a need to increase their resilience and urban ecosystems to withstand climate stress better. Such a paradigm shift can be achieved by adopting urban ecosystem-based adaptation strategies as the preferred urban planning and development model. To maximise the functionality of ecosystems in building resilience, the ecosystem approach must be at the centre of urban planning processes, which are informed by climate risk data, ecosystem assessments and participatory vulnerability analyses.

Working with nature to strengthen urban resilience can be cost-effective in addressing climate change adaptation while reaping broader benefits for biodiversity, communities, and the local economy. Nature-based solutions (NbS) are, first and foremost, actions inspired and sustained by natural processes to protect, manage, and restore ecosystems to address societal challenges such as climate change. These interventions should be integrated into designing new urban developments and retrofitting existing infrastructure wherever possible. Nature-based solutions have been increasingly effective in tackling complex urban challenges such as unregulated urbanisation and climate change.

Wider adoption of ecosystem-based urban adaptation strategies and scaling up of NbS require strengthened institutional and policy frameworks, adequate and climate risk-informed urban planning tools, inclusive and participatory processes, and a sustainable financial strategy for choosing and implementing the most appropriate and cost-effective NbS interventions.

Objectives and scope of the publication

This publication hopes to provide urban planning professionals with tools to better understand, assess, plan, and act on climate change in cities. The purpose of this publication is to:

1. Provide information and practical tools to guide urban planning processes in order to integrate climate risks and plan for medium and long-term urban resilience.
2. Support the integration of NbS in urban development and adaptation strategies and urban infrastructure design.
3. Promote an inclusive and participatory planning process that includes everyone and integrates urban planning activities with the participation of local communities.
4. Improve understanding of the financial landscape and opportunities for mobilising and accessing sustainable financing to invest in NbS interventions and ensure their sustainability.

Key topics

The publication is organised around six key topics:

- Key Concepts on NbS for adaptation in cities.
- Resilient Infrastructure in urban adaptation.
- Climate Risk Analyses in cities and how to use them in NbS planning and design.
- Overview of the planning and financing instruments that support urban NbS.
- Citizen participation in NbS planning and design.
- Opportunities and challenges for the analysis and valuation of NbS impacts.

To illustrate the practical use of the tools and approaches presented in each of the six topics, this publication includes case studies from cities across the region, from Mexico to Argentina (see Figure 0.1).

Chapter	Case	City	Location
1	1	Santa Fe, Argentina	h
2	2	Xalapa, México	a
2	3	San Salvador, San Salvador	c
3	4	Rosario, Argentina	i
3	5	Xalapa, México	a
4	6	San Salvador, San Salvador	c
4	7	Oaxaca, México	b
5	8	Quito, Ecuador	f
5	9	Bogotá, Colombia	e
6	10	Medellín, Colombia	d
6	11	São Paulo, Brasil	g

Figure 0.1 Case study map in Latin America

These are some of the guiding questions that will serve as the common thread throughout the publication:
What are the most appropriate NbS to reduce climate change impacts in cities and urban regions in Latin America and the Caribbean?

How to overtake the pilot and demonstration-only project stage? That is, a change of scale is brought about by:
a) increasing the size of the interventions;
b) expanding the territorial coverage; and, mainly,
c) mainstreaming its implementation in decision-making and budget allocations.

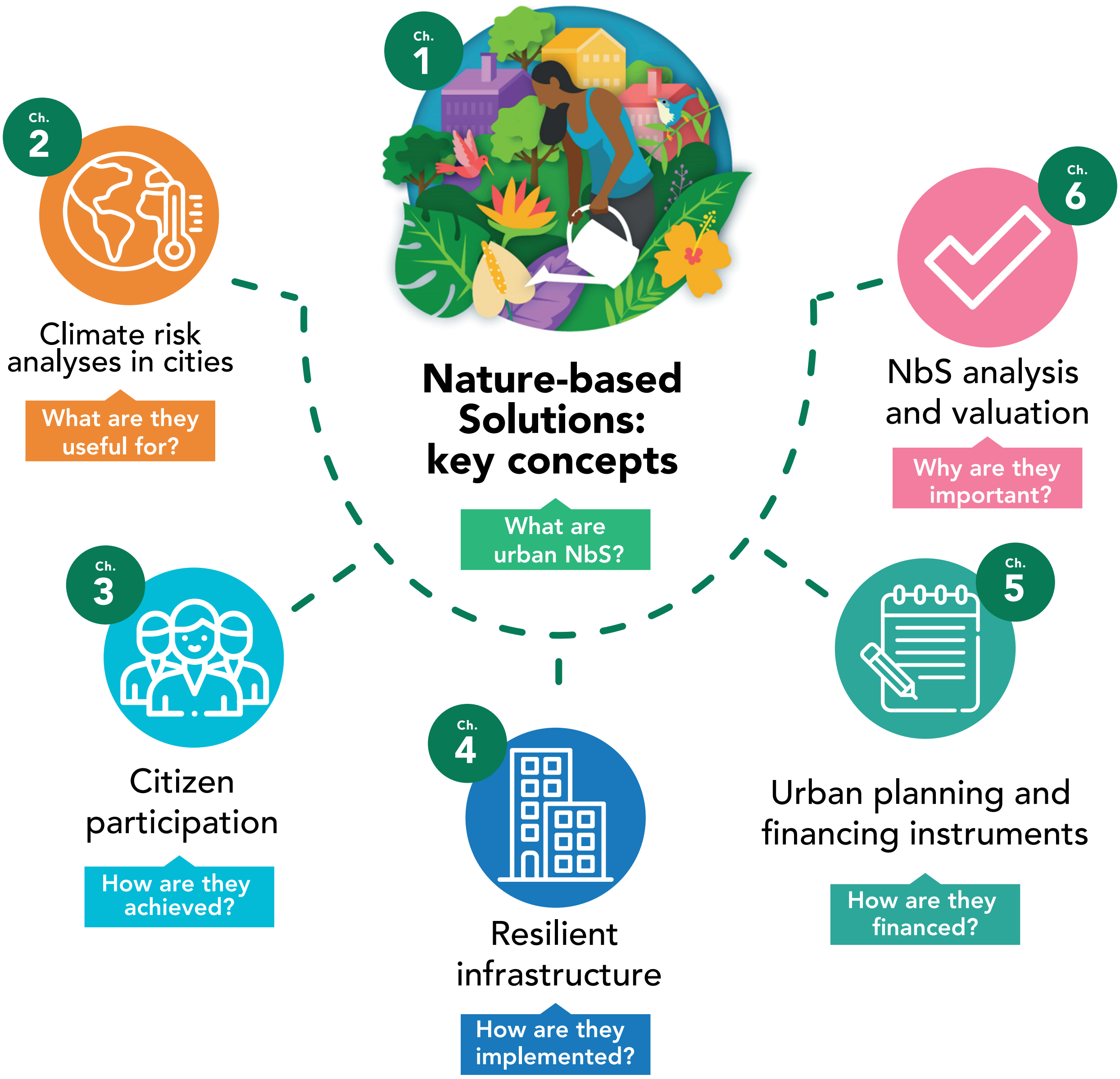


Figure 0.2. Publication Structure

Photography: San Salvador, El Salvador
Source: © UNEP / Author: Josephat Kariuki.

Chapter

1

Key concepts on NbS for adaptation in cities

Author: Daniel Kozak

1.1 Nature-based Solutions for adaptation to climate change

Over the last few years, Nature-based Solutions (NbS) have been widely recognised as an **approach that can address most of society's critical challenges; climate change.** These solutions are inspired and supported by the ecosystem approach that promotes ecosystem conservation and sustainable use (CBD 2000). Protected and well-managed ecosystems (such as forests, wetlands, coastal dunes, and mangroves) generate critical ecosystem services (ES) for adapting people and infrastructure to climate change and reducing the impact of extreme events (Kapos *et al.* 2019).

There is increasing evidence that **NbS can be complementary or an efficient and effective alternative to gray infrastructure to achieve climate adaptation and increase resilience** (Chausson *et al.* 2020). In adaptation, NbS contribute to coping with multiple climate threats (e.g., floods, landslides and water stress) while generating additional benefits such as biodiversity conservation and income generation opportunities.

Box 1. Ecosystem Services (ES)

Ecosystem services (ES) are the benefits that people derive from ecosystems. ES are classified as:

- *Provisioning:* food, water, fiber, wood and fuel.
- *Regulating:* air quality, soil fertility, flood control.
- *Cultural:* aesthetic inspiration, cultural identity, and spiritual well-being.
- *Supporting:* necessary for the production of all other services.

Source: Daily 1997, Millennium Ecosystem Assessment [MEA] 2003

Box 2. Nature-based Solutions (NbS)

"NbS are actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits".

NbS for adaptation to climate change:
Solutions to reduce the impacts on and vulnerability of people and infrastructure to climate hazards.

NbS for climate change mitigation:
Solutions to reduce Greenhouse Gas (GHG) emissions or increase their capture through green or blue sinks.

Source: UNEA 5, 2022

Depending on adaptation needs, NbS can be implemented in various ecosystems – terrestrial, freshwater, coastal and marine, natural or modified – and at different scales and contexts –urban, peri-urban, rural, or river basin. Examples of NbS for adaptation include the conservation and restoration of wetlands and forests in upstream basins, improving water retention capacity and reducing flood risk for downstream areas. In contrast, the availability of water in dry periods is ensured. In addition, the conservation and restoration of forests lead to stabilising slopes, thus reducing the risk of landslides (Figure 1.1).

NbS have the potential to act efficiently on both dimensions of climate action – mitigation and adaptation– reducing trade-offs and building synergies.[1] Thus, NbS is important **in Climate Resilient Development** (Intergovernmental Panel on Climate Change [IPCC] 2022a), an objective that can only be achieved by equitably integrating the role of women and vulnerable groups.

[1] Unlike other types of actions that seek to respond to CC in one dimension. For example, some solutions focused solely on mitigation, such as the monoculture of a tree species with a high CO2 sequestration capacity, may be effective as green sinks but detrimental to biodiversity, and therefore, do not constitute an NbS faithful to the definition adopted in UNEA-5, mentioned at the beginning of this chapter.

Figure 1.1. NbS examples at multiple scales
Source: UNEP 2022

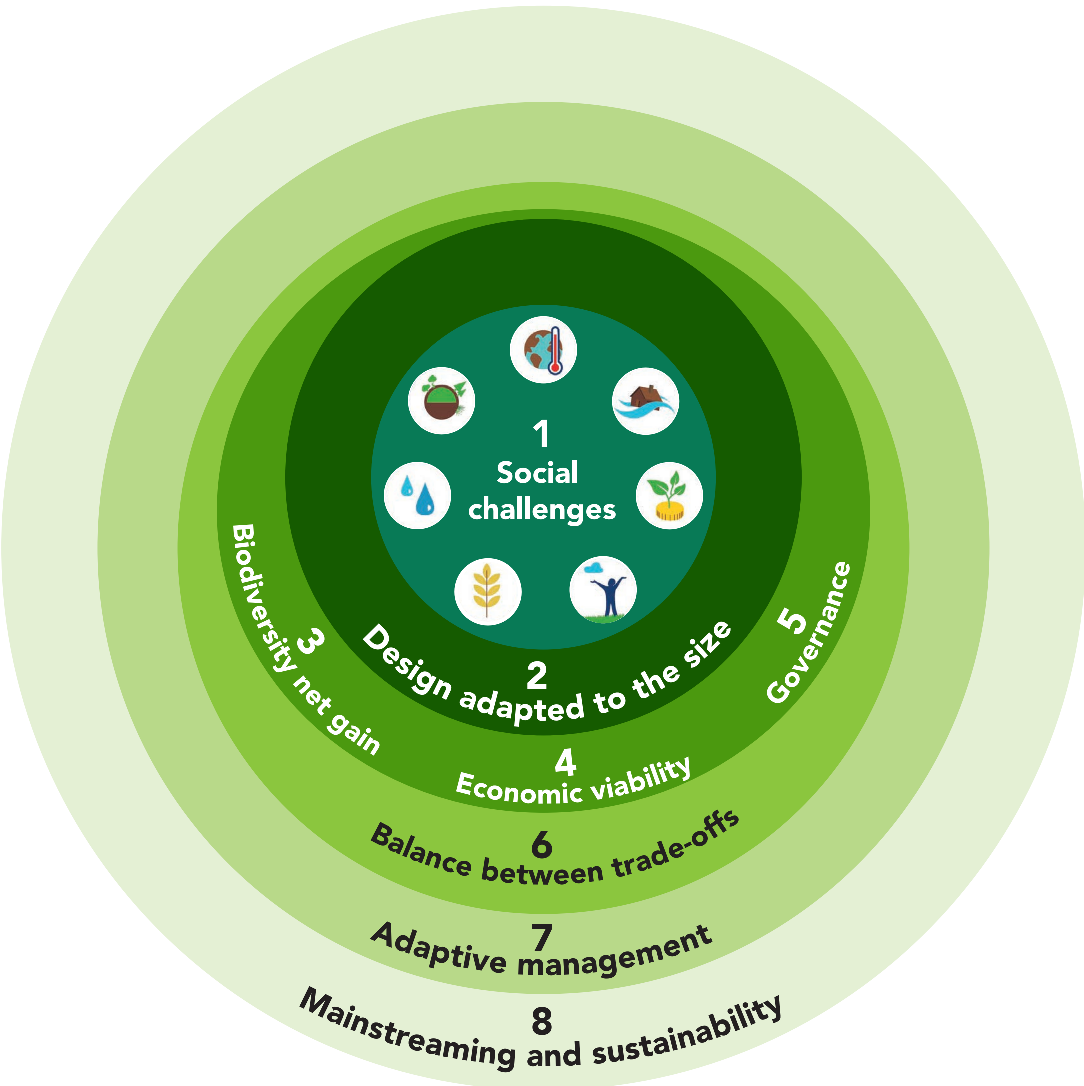
- Water drainage through permeable areas that infiltrate rainfall
- Temperature control thanks to the provision of shade and heat absorption by the foliage
- Resilient gardens that provide an alternative source of food and can use drip irrigation and/or rainwater harvesting
- The provision of quality water for human consumption thanks to the regulation capacity of forests
- Control of erosion and prevention of landslides by vegetation on slopes and in riparian areas
- Reducing the risk of sea level rise, coastal erosion or violent tides due to mangroves and coral reefs

New development models imply a more inclusive social model that leaves no one behind. By incorporating popular traditions, indigenous knowledge, intersectoral sensitivities, and ancestral knowledge into their design, and above all, by considering the multidimensionality of vulnerabilities, **NbS can contribute to improving the exercise of citizen rights and promoting gender equality and women's empowerment.**

To create a "framework for designing and verifying NbS that deliver desired results by solving one or several societal challenges," the Global Standard for NbS (Box 3) was developed by the International Union for Conservation of Nature (IUCN 2020).

Box 3. Global Standard for NbS

The Global Standard for NbS includes eight criteria with 28 indicators.



Source: IUCN 2020.

1.2 Nature-based Solutions for adaptation in cities

NbS are increasingly applied in urban areas to increase climate resilience, support sustainable development, and safeguard biodiversity. Unlike single-purpose grey infrastructure options, NbS offers numerous co-benefits regarding public health, job opportunities, social cohesion, biodiversity and climate change mitigation. NbS are important for urban areas at three levels:

1

Within cities, where they can provide natural shade and reduce urban heat island effects and cooling needs, manage runoff water, improve health and well-being, reduce air pollution, and provide recreational space.

2

Close to cities (peri-urban areas), where they can strengthen connectivity between urban-rural ecosystems to reduce flood and drought risks and provide sustainable alternative livelihoods to communities.

3

Around cities (water basins), where they can become part of city-water basin interrelationships related to basin management, flood risk reduction, and safeguarding access to water during dry periods.

Many NbS provide direct and indirect benefits in both urban and non-urban settings, such as increased biodiversity or improved water quality from the ability of certain plant species to capture and metabolise pollutants. Other NbS provide specific ecosystem services to cities, such as temperature regulation to reduce the heat island effect in urban centres and, consequently, the reduction of energy demand for thermal conditioning in summer and the adverse impact on the population's health due to heat waves. NbS with the potential to increase urban resilience to climate change include:

Permeable surfaces, green roofs, riparian forest systems, and floodplains reduce the adverse effects caused by heavy rains. Absorbing excess rainwater, they reduce flooding and stagnation risks in city centres. Rain gardens, bioretention ditches, and natural and constructed wetlands collect and remove pollutants from stormwater.

Maintenance of vegetation cover and afforestation along slopes stabilise soils, mitigating landslides in urban areas located in valleys or slopes.

Urban trees reduce air temperature, green corridors offer better ventilation, and green roofs and walls improve thermal comfort for residents.

Restoration and management of wetlands, mangroves, and reefs form a natural buffer between the sea and the land that reduces the intensity of waves and prevents erosion that affects coastal cities.

It is essential to consider that urban NbS have certain limitations and potential,[2] such as complexity around land control, fragmentation of natural habitats in metropolitan regions, high level of dispute involved in producing urban space, and the existence of dense underground infrastructure networks, among others.

NbS design must therefore integrate a climate justice approach and prioritise the necessary safeguards that include the rights to own and control land, territories, and resources and the rights to free, prior and informed consent. They must be developed through participatory processes that ensure climate impact mitigation does not increase social risks, nor gender-based violence or insecurity towards certain population groups such as children, elderly, pregnant women and people with disabilities, as it may happen

[2] Those located in rural areas also require specific studies, but they are not the focus of this publication.

with creating parks or green spaces without considering social sensitivities and gender indicators criteria.

Implementing urban NbS for CC adaptation implies the challenge of producing space for natural environments in cities. Although it may seem obvious, creating space in cities – making room for more absorbent surfaces, vegetation, open-air streams and bodies of water, enough areas to constitute urban ecosystems– usually represents one of the main barriers to NbS adoption. For this reason, NbS must be integrated into urban and land planning processes.

1.3 Integrated solutions for building climate resilience in cities

NbS should be applied through an **integrated approach to ensure the achievement of specific adaptation objectives,** such as water security or improved infrastructure resilience. Some of the most widespread approaches to urban planning using NbS are (i) Water Sensitive Urban Design (WSUD); (ii) Blue-Green Infrastructure (BGI); (iii) Sustainable Urban Drainage Systems (SUDS); and (iv) Hybrid solutions.

The approach shift from conventional grey infrastructure to Water Sensitive Urban Design (WSUD) implies a reversal of direction. WSUD promotes the conservation and reuse of water, recreating its natural cycle as faithfully as possible and "draining only when necessary" (Figure 1.2), as suggested by the "Towards a water-sensitive Mexico City" program (Hacia una Ciudad de México sensible al agua. Government of Mexico City, De Urbanisten y Deltares 2016). Contrary, the objective of the previous paradigm was focused on increasing the drainage capacity and speed.

Water Sensitive Urban Design (WSUD)

This shift implies rethinking the place of water in the city: "generating space for water", as postulated by the Dutch *Room for the River* program (Rijke *et al.* 2012). It also requires anticipating the different conditions that those spaces designed to hold water (e.g., flood-prone parks and natural reserves with bioretention capacity) will adapt to over time. The challenge is also sociocultural; overcoming the perception of a flooded park as a negative contingency is necessary to reformulate it as an opportunity to recreate new landscapes and beneficial uses, for example, equivalent to a snowy park (Kozak 2021, pp. 37-38).

The Western Urban Natural Reserve in the City of Santa Fe, Argentina, - designed and built as part of an agreement between the Municipality of the City of Santa Fe and the French Global Environment Fund, presents a representative example of this approach (Case 1).

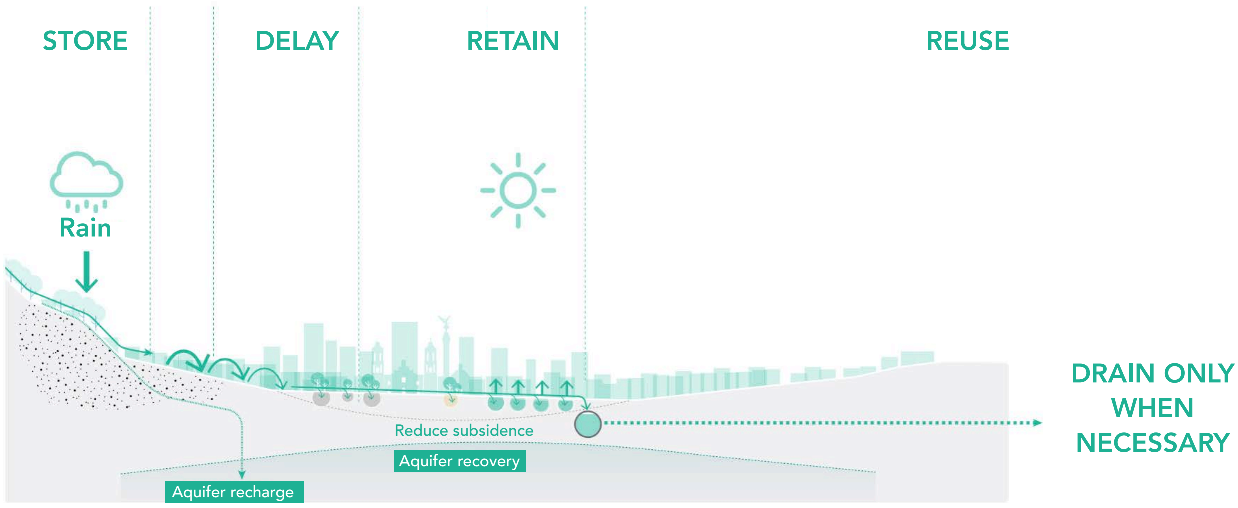


Figure 1.2. Towards a water-sensitive Mexico City.
Source: *Hacia una Ciudad de México sensible al agua*, Government of Mexico City, De Urbanisten y Deltares 2016, p. 118. Diagram drawn by De Urbanisten.

Case 1

Western Urban Natural Reserve (RNUO)
Location: City of Santa Fe, Argentina
Funded by: Municipality of the City of Santa Fe and FFEM
Executed by: Municipality of the City of Santa Fe
Year: 2015-2020

Built on two hydraulic reservoirs designed to reduce flooding risk, the objective of the RNUO is to provide protection, particularly in the event of a combination of an extreme water event and the flooding of the Salado River on the western bank of the city and the Parana River on the eastern bank.[3] The reservoirs, in this case, work as large artificial wetlands.

Following the RNUO Management Plan (Haene *et al.* 2018), native vegetation was reintroduced, which, in turn, called for the appearance of native fauna. In this way, a measure primarily aimed at managing the city's flood risk, contributes to the regeneration of a complex urban ecosystem that provides an enormous amount of ecosystem services, including an increase in biodiversity, capturing atmospheric pollution, improving the quality of the rainwater discharged into the river, regulating the temperature as a microclimate is generated, among many other services (Borthagaray, Kozak, and Maldonado 2022).

[3] The current strategy for protection against flood risk in Santa Fe essentially responds to the tragic flooding that occurred in April 2003 (Bacchiega, Bertoni, and Maza 2003).

Figure 1.3. Western Natural Urban Reserve, Santa Fe, Argentina.
Sources: Santa Fe, Municipality of Santa Fe 2022, p. 7; Borthagaray, Kozak, and Maldonado 2022.

Blue-Green Infrastructure (BGI)

The Blue-Green Infrastructure (BGI) concept is particularly relevant here,[4] as it is understood as a type of NbS and sometimes also included under the Nature-based Infrastructure or Natural Infrastructure category.[5]

The BGI concept recognises **the innate capacities of green space and water, and the ecosystems in which they are immersed, to produce environmental benefits and quality of life.** It meets the demand to improve ecological quality in cities, and respond to the limitations of conventional grey infrastructure solutions, by taking advantage of topography and climate (Kozak *et al.* 2021, p. 223).

To a large extent, the essential components of BGI have always existed in most cities or are innovations based on traditional urban elements. This includes green spaces, courses and bodies of water –of different sizes and shapes– that have been and are part of the conventional city landscapes. The advantages of considering them as part of a BGI are manifold. First, considering them –and consequently, planning and designing them– in terms of infrastructure sets the focus on one of their primary functions: establishing biodiversity corridors and networks, which run through cities and metropolitan regions, connecting them with their hinterland, allowing biological continuity to flow. Like all infrastructures, BGI requires a fixed support anchored to the territory, allowing a service's circulation and distribution. Understanding BGI in these terms facilitates its planning and management.

Second, thinking of green spaces, watercourses, and bodies of water in cities as network nodes, connecting pieces and connectors –and not as isolated episodes– not only enhances the capacity to produce ecosystem services and manage their distribution but it also enables the creation of circuits and itineraries of high environmental quality, thus creating new ways of moving around in cities. For this reason, BGI synergises with sustainable mobility networks, particularly non-motorized networks.

Finally, planning and managing in these terms, quantifying the benefits and socio-environmental contribution of ecosystem services, also makes it easier to discuss BGI on an equal footing with the rest of the urban infrastructures, including –and very especially with– resource allocation. This means moving landscape planning and design from the place of the ornamental, sumptuous and accessory to that of the productive and essential, understanding their budgets as an investment (in the same sense that the rest of the urban infrastructures are understood) and not as an expense without return.

[4] BGI: "Strategically planned network of natural and semi-natural areas with environmental features designed and managed to deliver a wide range of ecosystem services" (Joint Nature Conservation Committee [JNCC] 2019).

[5] Natural Infrastructure: "Network of natural spaces that preserve the values and functions of ecosystems, providing ecosystem services. The network of natural spaces is understood as the set of ecosystems recovered and conserved, through interventions considered as investments or activities" (Ministry of the Environment of Peru 2015). The use of the term *natural infrastructure* is more common in areas with arid climates, where the reference to blue-green is inaccurate.

Sustainable Urban Drainage Systems (SUDS)

Sustainable Urban Drainage Systems (SUDS)[6] can be understood under the conceptual umbrella of NbS and BGI. The change from the conventional approach to that of SUDS can be summarized in four main objectives (Construction Industry Research and Information Association [CIRIA] 2015):

1

Controlling the *amount*
of water to avoid rainwater floods and recover the urban hydrological cycle;

2

Taking care of water *quality*
by reducing pollution in bodies of water through the implementation of unitary processes typical of the natural hydrological cycle;

3

Promoting *biodiversity*
through the recovery of micro-ecosystems and habitat for native flora and fauna, together with the replenishment of aquifers; and

4

Generating *amenities*
from improvements to the urban landscape and creating more pleasant spaces for people to exercise their rights fully.

The SUDS toolbox includes, for example, rain gardens, infiltration wells and trenches, and green swales, among many other bio-infiltration devices. Sometimes, the SUDS solve the complete excess water treatment cycle without connecting to the conventional rainwater network. In other cases, particularly in densely occupied urban contexts, they are connected to the conventional network, forming hybrid solutions. In those instances, the contribution occurs from subtracting pressure at the time of peak demand from the network by absorbing a runoff percentage, slowing down the contribution that cannot be retained and, fundamentally, improving the water quality before its discharge in the receiving body of water (generally a river or the ocean).

[6] SUDS and WSUD are terms that are part of the same batch of related concepts that have emerged from the stormwater management shift described here (Fletcher *et al.* 2015).

Hybrid solutions

Urban ecosystems must coexist and, wherever possible, establish synergies with many conventional infrastructures and city components, making up hybrid solutions or, at minimum, not impeding one another. In line with what was described in the paragraph above, this also implies a substantial shift from how urban infrastructures in cities have traditionally been conceived, usually built in opposition to nature, which was sometimes considered, "at worst, an obstacle to development" (IUCN 2020, p. 1).

NbS design requires its adaptation to the sites where they are located

Generating space, solving possible interferences with other infrastructures, and having the population's support, among other considerations. Conversely, conventional grey infrastructures must also be retrofitted to complement NbS. Figure 1.4 below offers an example of a *hybrid solution* that can be illustrative. This is a typical case of culverting a historical watercourse covered by an avenue under which a relief tunnel was subsequently built.

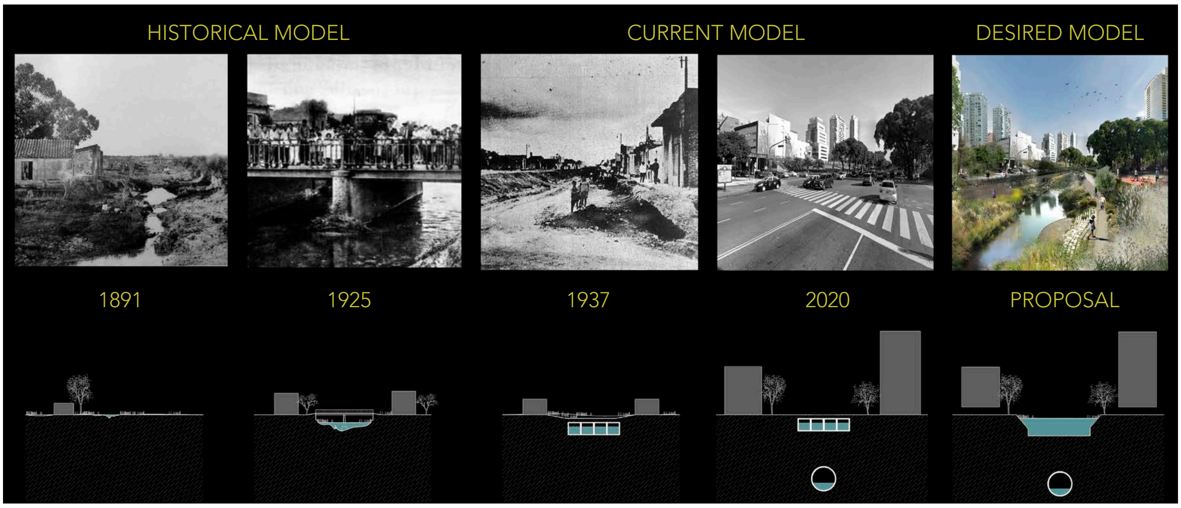


Figure 1.4. Historical model, current model and desired model of pipe removal of the Maldonado stream, Buenos Aires.
Source: Kozak *et al.* 2021 / Graphics: Pilar Costa and Camila Lennon

Photography: Xalapa, Mexico
Source: © UNEP / Author: Josephat Kariuki.

The proposal from an NbS approach (the desired model) consists of opening the primary culvert and renaturalisation the surface watercourse, creating a linear park that would serve as a biodiversity corridor, marked by open-air reservoirs in artificial wetlands strategically located in parks that make up a BGI network with the capacity to provide numerous ecosystem services. This proposal also suggests the readaptation of the recently built relief tunnel to operate by the BGI on the surface.

Relief tunnels are usually designed to fill through communicating vessels gradually. In other words, as soon as it starts to rain, surface runoff, or first flush,[7] is channeled through the gray infrastructure and, generally, dumped into receiving bodies without treatment, generating the pollution in rivers, their surroundings, and on marine coasts.

The hybrid solution proposed in the figure consists of readjusting the tunnel system at depth to operate as a relief system that would be activated only in cases where the BGI capacity was exceeded. This implies that the underground infrastructure should not operate through communicating vessels but rather through overflow once the system's absorption, retention, and expansion capacities are saturated.[8] That is, it would not be part of the daily rainwater management in the basin. Under the most favorable circumstances, it would play a role only in rainwater that falls exceptionally (Kozak *et al.* 2022, p. 19). Such a solution significantly increases the protection against flooding, providing resilience to the system.

[7] First flush is the first discharge at the beginning of each rainfall. It usually generates the most pollution because it drags dirt from the streets, including highly polluting substances such as oil residues and car tire particles.

[8] The design of these systems would require complex overflow structures, with the difficulty of establishing an optimal level to transfer water from the existing system to the relief tunnel. However, these would significantly reduce contamination at the mouth of the channel (Kozak *et al.* 2022, p. 19).

Conclusions

Nature-based Solutions (NbS) constitute a valuable resource available to cities in Latin America and the Caribbean to respond to the challenges posed by climate change. Whether replacing or complementing traditional gray infrastructure, NbS can contribute to climate change adaptation in cities and bring multiple benefits, direct and indirect, with positive impacts on society and the environment.

Wider adoption of NbS in urban planning requires improved institutional and policy frameworks, adapted and climate risk-informed urban planning tools, and a sustainable financial strategy to guide the selection of the most appropriate and cost-effective NbS interventions. Additionally, gender-sensitive approaches should be mainstreamed in NbS frameworks to ensure that integration of women's, men's and other gender's concerns/needs are part of analysis, planning, and implementation. Planning with NbS works at the system level, enhances connectivity, and acts at multiple scales, each of which is critical to advancing NbS in an urban context:

1 **Systems:**
Cities are complex socio-ecological systems in which ecosystems are critical. Urban development processes are a powerful force within urban areas and their surrounding peri-urban areas and show dynamics and structures that vary across spatial and temporal scales. The design and implementation of NbS require the consideration of these dynamic systems.

Connectivity:
Connectivity is an important ecosystem concept and is, along with its multifunctionality, fundamental to the planning, design, and implementation of NbS in cities. Cities rely on landscapes and ecosystems within their peri-urban areas for a range of climate resilience functions, including watershed-based flood management. At more minor scales, maintaining and enhancing the connectivity of urban ecosystem networks is critical to delivering ecosystem services, for example, linked to biodiversity conservation and improvements in health and well-being.

Multifunctionality:
Urban NbS can bring many additional benefits to human beings and the environment, such as creating green jobs, positive health benefits, and improved habitats for biodiversity. With alarming levels of biodiversity loss, cities are responsible for contributing to global efforts to restore, strengthen and enhance biodiversity by protecting critical habitat areas and providing supplemental habitat.

Scale:
NbS exist at different scales, from individual parcels to the water basin scale. However, NbS do not exist in isolation. They connect across spatial scales with other ecosystems and elements of the urban system. Therefore, the generation of ecosystem services associated with NbS requires understanding the dynamics of the linkages between NbS interventions operating at different scales to ensure that they function in harmony.

Photography: San Salvador, El Salvador
Source: © UNEP

Chapter 2

Climate risks analyses in cities and how to use them in NbS planning and design

Author: Manuel Winograd

Contributor: Michiel van Eupen

2.1 Introduction

Urban expansion in Latin America and the Caribbean affects ecosystems that provide essential services and contribute to the well-being of communities, increasing the risks in infrastructure and vulnerable communities, such as the elderly, women, children, migrants, and Afro-descendant communities, among others. For this reason, adaptation to climate change in cities appears as the most effective way to reduce risks in the face of extreme events and address the challenges generated by the climate crisis. This implies the need to reintroduce nature in cities as an asset in their development to promote more inclusive and climate-resilient cities. Integrated climate risk management to reduce the vulnerability in urban areas can be catalyzed by incorporating adaptation into urban planning processes (UNEP 2020).

Hazards are extreme events such as heavy rains, droughts, heat waves, landslides, and hurricanes, with negative consequences on population and city infrastructures, disproportionately affecting populations in socially vulnerable situations, including those from poor socio-economic backgrounds, people with disabilities, women and the elderly. Depending on the intensity of hazards and exposure, different areas and social groups have different degrees of vulnerability. Societies and ecosystems, in turn, have various adaptation capacities; that is to say, that cities exhibit varying degrees of exposure to flooding, coastal erosion, salinization of soils and aquifers, heat island, and landslide. These risks have various impacts, such as mortality, loss of infrastructure and housing, food security, diseases, and water availability.

There is no single approach to assessing risks and vulnerability in cities, but rather a number of practical methodological approaches and indicator frameworks which depend on the planning process and decision scopes (Intergovernmental Panel on Climate Change [IPCC] 2022). Risk analyses must be carried out to identify social groups, infrastructures, livelihoods, and ecosystem services (ES) in a greater climate vulnerability situation. This allows for identifying the differentiated impacts and the exposure to hazards caused by current and future climate variability, enabling the assessment of the effects and response capacity of nature and societies. This analysis provides critical points that consider risks and actions in cities (key points).

The key points are especially important for urban planning since they help identify the areas, the moment, the type of actions, the groups, and the infrastructures where to intervene. In the context of cities, it is essential to identify the key points in different zones that constitute the urban area, such as urban, peri-urban, or rural areas, as this has important implications for decision levels and the implementation of solutions for adaptation, mitigation, and resilience building.

This chapter exemplifies **how climate risk and vulnerability assessment can be used as a structured approach for identifying appropriate actions and sites to implement adaptation measures and potential co-benefits for climate change mitigation and urban planning, particularly from a Nature-based Solutions (NbS) perspective.**

Within this risk analysis and climate vulnerability framework for urban planning, the methodological approach, rather than a rigid theoretical framework, should involve a series of stages to facilitate the integration of vulnerability dynamics into decision-making processes through the generation, communication, and provision of relevant and usable information (table 2.1):

Photography: San Salvador, El Salvador
Source: © UNEP / Author: Josephat Kariuki.

Table 2.1. Elements and essential variables for risk and vulnerability analyses in cities

a. Identifying and assessing current and future climate risks about exposure and sensitivity using current information and climate scenarios.

b. Analyzing climate impacts on ecosystems (including goods and services), the differentiated impacts on society according to vulnerability, and infrastructures and sectors.

c. Assessing the differentiated adaptation capacities and opportunities for nature and society according to the risk and vulnerability situation of different social groups, including gender indicators.

d. Reporting and having credible and solid data on the spatial location of current and future climate risks and impacts and the temporary planning of adaptation and mitigation actions.

e. Contributing to a transparent and effective system for monitoring and evaluating adaptation actions, considering the city as a set of dense urban areas, peri-urban areas, and rural areas within the surface and underground basins, diversity of landscapes and land uses.

Table 2.2. Examples of hazards, vulnerability and risks and adaptative capacity per type of city

Type of city	Example	Hazards		Vulnerability and Risks		Adaptation Capacity	
		Threat	Exposure	Ecosystems	Society	Structural	Non-structural
Costal/ Delta	• Havana • Maracaibo • Cartagena • Guayaquil • Belem • Buenos Aires	• Sea level • Temperature • Rainfall • Water balance • Extreme events (rains, droughts, heat waves, winds)	• Population (gender, age, ethnicity, origin occupation) • Social groups (women, the elderly, boys, girls, young people, people living in poverty) • Infrastructures • Housing types • Livelihoods • Natural resources • Ecosystem services	• Flooding • Coastal erosion • Soil erosion • Landslides • Drought • Heat waves • Fires • Water availability • Biodiversity loss • Reduction of traditional food production	• Mortality • Morbidity • Infrastructure losses • Mobility • Housing • Groups (poor, elderly, women, Infants) • Food security • Diseases	• Gray/green/ blue infrastructures • Ecosystem based adaptation • Reforestation • Protection • Restoration • Connectivity • Crop movement and adaptation	• Disaster management • Climate insurances • Social security • Conditional transfers • Planned relocation • Efficient use of resources • Urban instruments • Public policies
Flat/ Riverfront	• México DF • San Pedro • Sula • Manaus • Asunción • Curitiba • Rosario						

Sources: GIZ, Eurac Research and UNU 2018a; IPCC 2022.

2.2 Methods for risk and vulnerability assessment

Methodological framework: Depending on the use, there are many vulnerability and risk assessment methods. In the disaster management area, **risk** is considered "the probability of a hazard multiplied by its consequences", whereas, in the domain of climate change adaptation, **risks** are "the result of the interaction between hazards, exposure, vulnerability, and adaptive capacity" (Development Bank of Latin America [CAF] 2019; IPCC 2022).

Therefore, **vulnerability and risk assessments should consider the specificity of the biophysical and socioeconomic context, including exposure to climate threats, while contemplating the social determinants and their differentiated impacts.** In addition, special attention should be paid to differential and cascading impacts depending on ecosystem types and city circumstances, which can influence adaptation capacities. In addition, in the case of urban areas, vulnerability and risks, as well as adaptation actions, differ according to the type of city and within the cities themselves. Therefore, the metric system gains great importance to ensure the production of useful information for decision-making and planning.

No fixed rule defines which variables and indicators should be considered for risk and vulnerability assessments. The metric system will depend on each city's context, user needs, and available information. Hence, it is important to identify the type of components and metrics useful for risk and vulnerability analysis based on spatial and temporal scales rather than a rigid conceptual framework (Oppenheimer *et al.* 2014; Deutsche Gesellschaft für Internationale Zusammenarbeit [GIZ] GmbH, European Academy of Bozen-Bolzano [Eurac Research] and United Nations University [UNU] 2017; IPCC 2022), as seen in figure 2.1. In this way, it will be possible to address fundamental questions based on the use of information and user needs, namely:

- What are the climate hazards and risks?
- Who and what is at risk?
- Where and when do impacts occur?
- What adaptation options exist and are they necessary?

In the case of the cities of Latin America and the Caribbean, climate risks and vulnerability show different facets depending on the socioeconomic contexts. This variation increases the impacts and restrictions for planning and implementation of adaptation and mitigation actions, such as displacement of social groups, income inequality, unequal access to health and basic services, dependency ratio, location of infrastructure and population in risk areas, extreme poverty, food insecurity, and participation and governance mechanisms (IPCC 2022; Villamarin G. *et al.* 2019).

The fastest increase in vulnerability in occurs in cities, where over 80% of the population resides. It has been determined that intermediate cities in coastal, flat delta, and hillside areas are experiencing the fastest demographic and unplanned urban growth (particularly unplanned and informal settlements in

Impacts
- Effects of mortality/morbidity
- Increase of communicable diseases
- Housing losses
- Effects on vulnerable groups
- Effects on food safety
- Effects on water supply
- Effects on water regulation
- Effects on soil erosion
- Effects on temperature regulation

Adaptation
- Disaster management plans
- Land-use plans
- Climatic insurance
- People/infrastructure relocation
- Poverty reduction plans
- Conditional transfers
- Adaptation policies
- Gree/Gray infrastructure plans
- Conservation and restoration plans
- Crop displacement

Figure 2.1. Example of a framework and metrics to assess vulnerability and risks in cities.
Sources: GIZ-EURAC-UNU 2017; IPCC 2018; IPCC 2022; Winograd *et al.* 2021

hillside and coastal areas); consequently, they have fewer capacities for disaster mitigation and adaptation (IPCC 2018; IPCC 2022).

Most vulnerable groups, such as low-income people, women-headed households, the elderly, boys and girls, indigenous populations, Afro-descendant, migrant populations, or LGTB+ communities, are an integral part of the analyses. For example, in marginal urban areas, the number of women-headed households with minor children and/or elderly dependents imposes greater domestic responsibilities, work, and family burdens, contributing to their social, economic, and climate vulnerability.

Data:

A significant amount of data and information is available in the cities to evaluate vulnerability and risks. However, there are often information gaps at the required scale or a need for more confidence in time series data. For example, disaggregated social data at district, neighborhood, or block level on gender, income, and livelihoods are often unavailable; consequently, not all the needed information can be collected. Mixed approaches, cross-referencing, or alternative information collection methods can partly overcome these deficiencies. Therefore, in many cases, the use of "proxies" is necessary, and although they are less accurate than a direct indicator, proxies are the most cost-effective and easy to measure. These may include available data correlated with unavailable data or data and information collected on a broader scale for appropriate downscaling (Winograd *et al.* 2021).

Furthermore, information on climate scenarios at the city scale needs to be used and adapted to provide relevant information for urban planning to reduce future climate effects. Therefore, it is necessary to scale the resolution of the information provided by climate scenarios. For instance, climate scenarios generally have low resolution (100km x 100km grid cells), which limits their use on a city scale and is more commonly used to define national policies and sectoral strategies. For urban planning and a selection of adaptation alternatives, information must be produced at medium scales (10km x 10km grid cells), while high-resolution information (10 m-20 m x 10 m-20 m grid cells) is required for exploring, designing, and implementing adaptation measures.

Uncertainty:

As in any assessment of future medium- to long-term scenarios, uncertainty needs to be taken into account, as part of the information about climate change risks and impacts is based on future climate models and scenarios. For example, it is vital to transparently analyze the uncertainty related to the type and scale of information used, as understanding the information gaps on climate change and its impacts will help stakeholders better understand the evaluation results and utilize them more effectively and comprehensively in urban planning (GIZ, Eurac Research and UNU 2017). In addition, new useful information can be generated to assess current and future vulnerabilities and risks, thus compensating for information gaps.

Multi-stakeholder involvement:

Stakeholder mapping is essential to identify key individuals and groups in planning and decision-making processes related to city risks and vulnerability. Through this mapping, the organization and dynamics of ongoing city processes can be understood. It also allows gathering perceptions and collecting thematic information (e.g., land use and urban fabric, risks and threats, physical and social vulnerability, services and infrastructure, planned or ongoing projects, etc.) that are usually dispersed across different offices, departments, institutions, and individuals.

Additionally, stakeholder mapping enables the identification and analysis of the type of relationships among actors, whether cooperative, conflictive, or synergistic. It also helps evaluate the existing gaps between information production and use, decision-making and planning, and interests and sectors involved. During and after the risk and vulnerability assessment, the results must be validated to discuss with the actors, thus generating contrast and enrichment based on local knowledge and perception. Validation can be carried out through participatory workshops or consulting with expert personnel, ensuring the parity and representativeness of different social groups.

Photography: San Salvador, El Salvador
Source: © UNEP / Author: Josephat Kariuki.

Scale:

Regarding the scale of evaluation and decision-making levels, given the nature of vulnerability and adaptation, it is important to highlight that urban ecosystem services are those produced in urban and peri-urban spaces within widespread metropolitan limits. This includes spaces that are inserted within continuous and discontinuous urban areas, defined by the city's physical structure and not only by its administrative definition, which in many cases can include basins, landscapes, and territories that are beyond what is commonly understood as a city (Hardoy *et al.* 2019). For example, water recharge zones in a basin, urban forested areas on hillsides that support soil conservation and landslide control, or parks and promenades as air pollution concentration and temperature regulators. (see Box 2).

Usefulness:

An essential aspect of risk and vulnerability assessments is producing accurate, transparent, and usable information that can be translated into the context of urban planning and policy-making to be relevant to decision-making. The results must be presented in a way that is easy to understand for the general public (Coninx Nuesink and Brazao Vieira Alho 2021). Uncertainty, which is inherent to the science of climate change, is only sometimes integrated into urban planning. Particular attention should be given to communicating information so decision-makers can act upon the assessment's results and effects (IPCC 2022; Coninx Nuesink and Brazao Vieira Alho 2021).

Results:
The way results are presented is central to assessing risks and vulnerability, considering the needs of the users and the audience (GIZ EURAC UNU 2017). The evaluation must describe the objectives, methods, and tools used, as well as the main findings and conclusions that facilitate the interpretation of results; the visualization format enhances understanding. There are several tools to present the results, such as maps, diagrams, and graphs; however, the selected visualization implies different levels of data capacity and interpretation. For example, as illustrated in Boxes 1 and 2, maps allow visualizing where risks are located and comparing impacts. Diagrams and graphs, such as radar charts, can also be used to understand change dynamics and when impacts occur.

Case 2

Assessing risks and vulnerability in cities
Location: Xalapa, Veracruz, Mexico
Donor Agency: GEF
Executing agency: UNEP
Team: Pladeyra and Gulf of Mexico Fund
Year: 2019

The assessment identifies those areas in greatest danger caused by weather-related occurrences such as landslides, erosion, and flooding (Map 1). From this, those areas where people, their productive systems, and ecosystems are most exposed to the accumulation of these hazards were delimited (Map 2).

In parallel, using various social and economic variables, a socio-economic sensitivity indicator was set up for basic areas (Basic Geo-Statistical Areas - AGEB) (Map 3). Finally, the adaptive capacity was analyzed by estimating the areas that provide greater ecosystem services (surface water supply, sediment retention, carbon storage) and connect with the city's ecosystems (Map 4).

With these inputs, it is possible to calculate the accumulated exposure to hazards in the natural and productive systems and the population (Map 5) and carry out ecosystem valuations (Map 6). Cumulative exposure and socio-economic sensitivity allow calculating of the potential impact (Map 7), and the accumulation of ecosystem services is used as an adaptive capacity indicator (Map 8). Thus, socio-environmental vulnerability (Map 9) was established by relating areas with a higher degree of impact from climate events to the adaptive capacity based on their ecosystems, both in rural and urban areas of Xalapa and Tlalnelhuayocan.

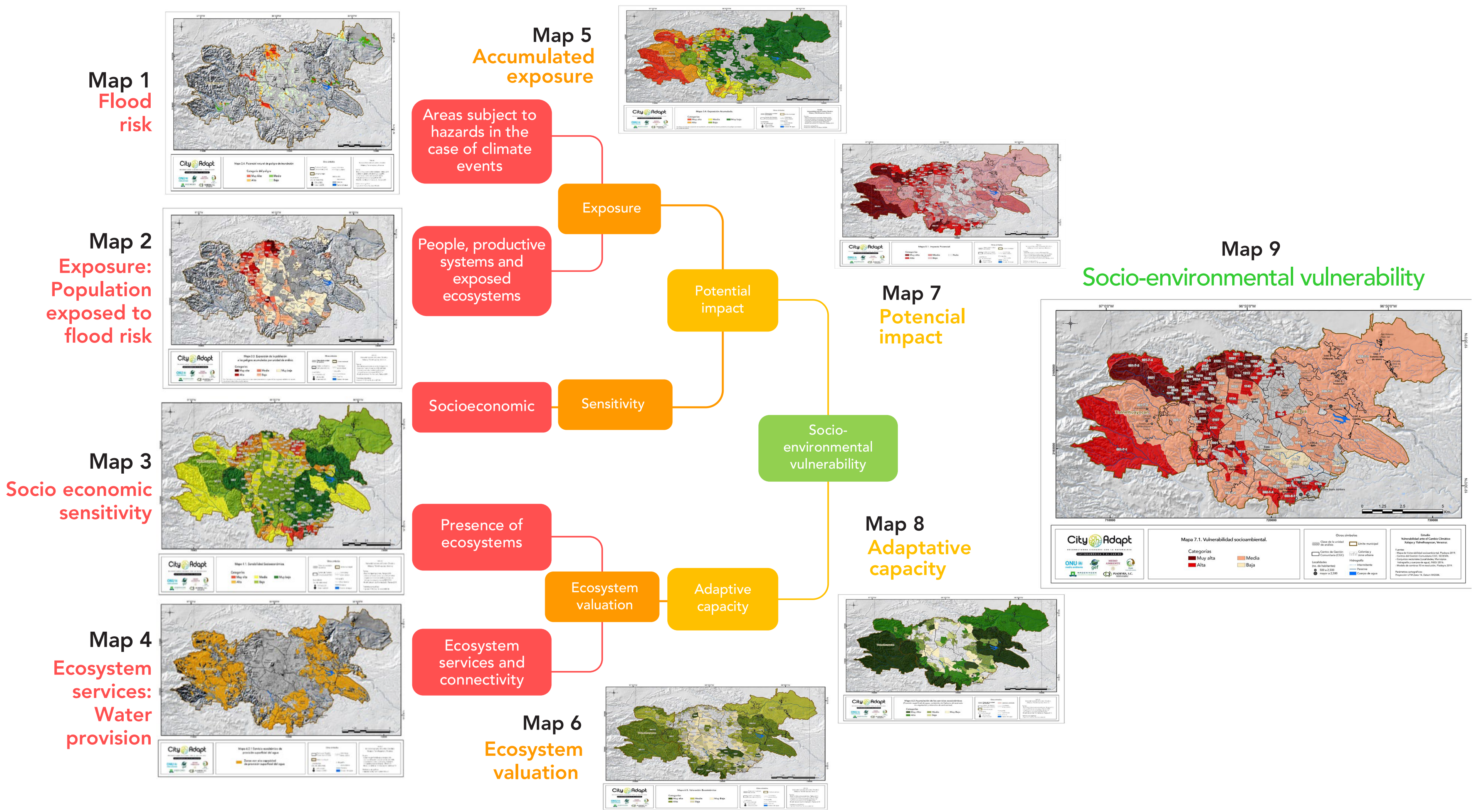


Figure 2.2. Elaboration of a socioenvironmental vulnerability map
Source: Pladeyra and the Gulf of Mexico Fund 2019.

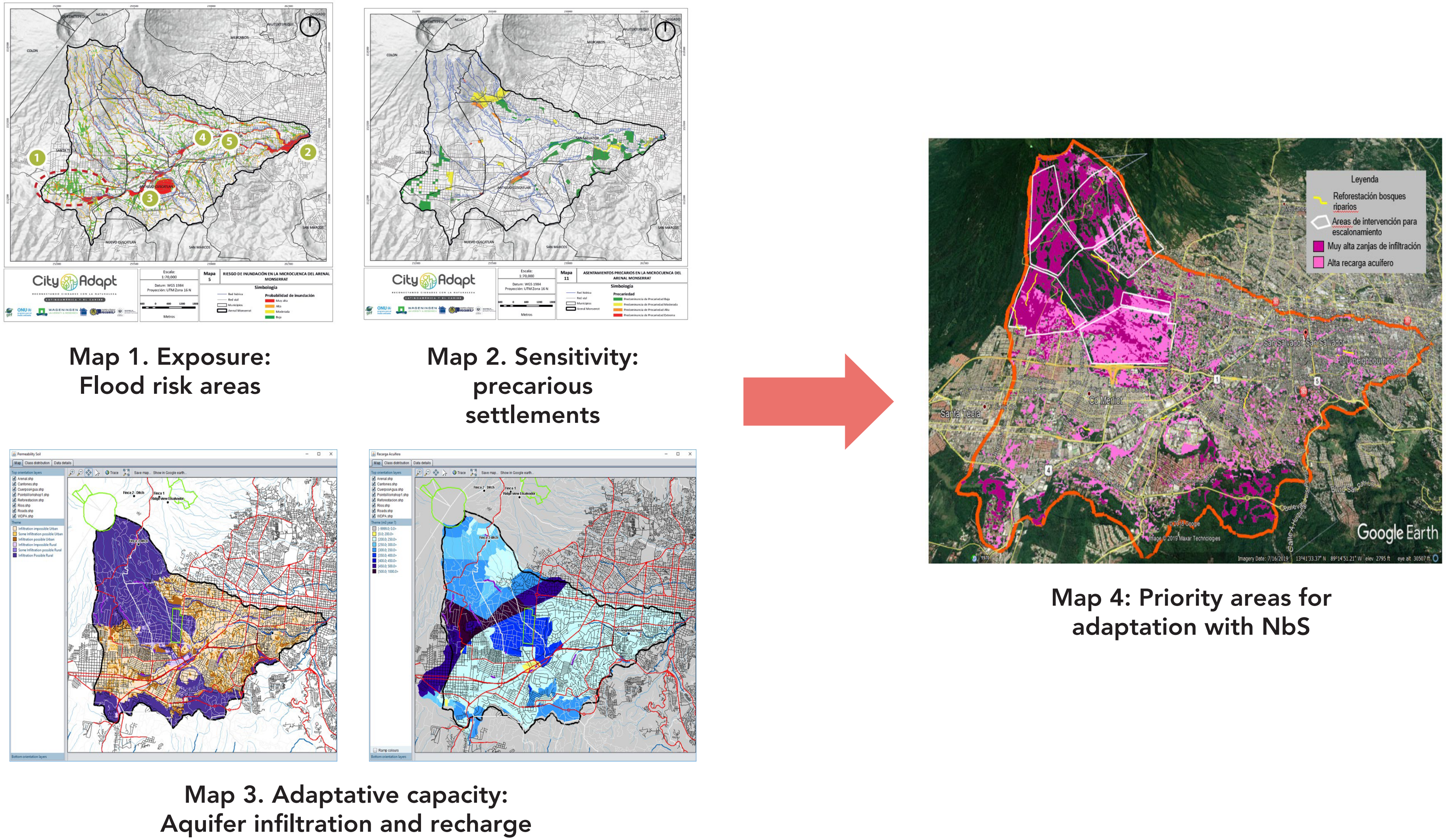
Based on this analysis, the most appropriate measures to promote NbS were identified. Vulnerability assessments can focus on problems and impacts that are often overlooked: for this reason, a gender approach was incorporated in the case of estimating the socioeconomic vulnerability index in Xalapa. Five variables -which have available data- were selected for this purpose: average school grade among the female population, women family heads, female economic participation rate, households with water availability outside the home, and households without access to a washing machine.

The vulnerability index in Xalapa showed that the most vulnerable areas are located on the outskirts of the city and in rural areas, and that the areas with the highest vulnerability for women coincide with the zones of general socioeconomic vulnerability.

Case 3

Risk assessment to integrate NbS in cities
Location: Arenal Monserrat Basin, San Salvador, El Salvador
Donor Agency: GEF
Executing agency: UNEP
Team: FUNDASAL
Year: 2020

San Salvador Metropolitan Area (AMSS) includes 14 municipalities. The CityAdapt project focused on the Arenal Montserrat micro-basin, which is located on the part of the territory that covers three AMSS municipalities: San Salvador, Santa Tecla, and Antiguo Cuscatlan. In this example, the objective of the vulnerability assessment was to identify current and potential hotspots as entry points to NbS interventions. For this reason, areas that are exposed to risks were first identified in order to link data such as rainfall with the natural attributes in the area, such as slopes, soil cover and type, and infiltration capacity, among others. Population density is added to this information to obtain exposure to flood risk (Map 1). To identify sensitivity, data on the population's social and economic variables were added, such as precarious human settlements (Map 2). To evaluate adaptive capacity, the provision of environmental services that mitigate part of the adverse climate impacts was determined. In this regard, an analysis of the ecosystems present in the area was conducted, which shows the different ecosystem services they provide, in this case, aquifer infiltration and recharge capacity (Map 3). The aggregation of this information allows for the characterization of the priority areas for adaptation with NbS based on the ecosystem characteristics in the area of analysis (Map 4).



Source: Fundación Salvadoreña de Desarrollo y Vivienda Mínima [FUNDASAL] 2020.

Figure 2.3. Identification of priority areas for adaptation with NbS

To provide this type of ecosystem services (regulation of water cycle and water supply), NbS are materialized through infiltration ditches and absorption wells in the rural and peri-urban areas of the city, with direct benefits in controlling drought and erosion in agricultural areas and flooding in the denser urban area. This ensures not only the conservation of soils and the recharge of the aquifer that provides drinking water to the city, but it also complements the capacity of the reservoir built to slow down violent water flows and reduce peak flows. It should be noted that these activities were carried out mainly in the upper zone of the basin (volcano area), but their impacts and effects influence runoff water in the entire basin, especially in the city of San Salvador (lower basin).

2.3 Barriers and challenges to integration in urban planning

Barriers and challenges related to climate risk analysis in cities can be analyzed as they are grouped around two central themes: **availability of and access to information and integration in urban planning.**

These stages imply transforming knowledge into actions to build resilience and improve adaptation to climate risks. Addressing the adaptation challenge in cities requires balancing multiple, often conflicting objectives specific to the local context. Consequently, **the vulnerability and risk assessment process must include several stages of data search and consultation, exchange, validation, and co-construction of information.**

Considering the benefit of using risk and vulnerability information to support decision-making processes and urban planning, it is striking that, despite the increasing availability of data and tools, this information is often limited due to the need for more capacity to translate information into action. Numerous risk, vulnerability, and impact assessments are related to climate variability and change. Still, there needs to be more useful information on ecosystem services in urban areas and the potential for integrating different types of solutions to achieve maximum benefits and co-benefits. This integration can be achieved by facilitating and promoting data sharing, access, and use to produce valuable and relevant information for the active use of assessments in urban planning (Hardoy *et al.* 2019).

For this reason, **although there is plenty of data, it is necessary to address the challenge of accessing and making available information for specific issues** (especially social and economic issues such as gender mainstreaming and an intersectional approach for vulnerable populations, analysis on the distribution of economic inequality, and differential impacts and costs of mitigation and adaptation). This can be achieved by using proxies to generate information for decision-making. The lack of data, information at the required scale, or confidence in the time series are the most significant limitations for carrying out vulnerability assessments that integrate all components, which must be analyzed using spatially explicit methodologies.

When using information –especially in the form of maps– it is important that it is understandable to non-technical actors so they can grasp the spatial representation of vulnerability instead of perceiving it as fragment pieces of a puzzle.

In a context of uncertainty regarding climate change impact, and as knowledge increases, climate data and scenarios are updated and staggered, and environmental and socioeconomic data are enhanced, maps must be adjusted. In this sense, the production and use of technical information need to be demystified and integrated into participatory processes, creating capacities to use data in various formats. In turn, it is also important that technical bodies are consolidated within government structures to gradually generate greater autonomy and address the diversity of issues involved in integrating vulnerability into the urban planning process (Hardoy *et al.* 2019).

Finally, to address the complex challenges faced by cities in Latin America and the Caribbean, decision-makers need access to accurate and updated information to explore and implement creative solutions. These actions must be profitable, accepted by the communities, technically feasible, and should provide multiple benefits. A growing number of cities have territorial management plans, climate action plans, and public policies regarding risk management. However, the compartmentalized structure of municipalities usually hinders information exchange between areas. On the other hand, staff fluctuations over short periods limit the empowerment and understanding of approaches that prioritize NbS. In many cases, the integration of these issues in urban planning is limited to the assessment of past situations without providing inputs to support the exploration and implementation of solutions that allow for safeguarding livelihoods, reducing risks in the face of natural disasters, improving the habitability of cities, and using, restoring and conserving ecosystem services, among many other social, economic, and environmental benefits (Winograd *et al.* 2021).

Recommendations and conclusions

To facilitate access to information and its integration into urban planning, **there is a need to consider the gap between decision-making timeframes, policy formulation, implementation of actions to reduce vulnerability, and the impacts of climate change actions and effects,** ranging from the very short term (1 to 3 years) to the very long term (25 to 50 years).

Although the methods and tools are generic, the use of data, the production of information, and the integration of indicators in decision-making are specific to the context and ongoing processes in each city and to the needs and capacities of the actors involved. **Practical implications of methods and uses to evaluate the present or the future must be taken into account,** as analyzing current risks with low uncertainty is different from assessing future risks with high uncertainty.

Given the diversity of interests, **one of the main difficulties in the evaluation processes is relating different scales of action** (farm, home, neighborhood, commune, city, basin) **and the actors involved in decision-making** (community leaders, cooperative members, local authorities, national government, decentralized institutions, private sector). This process facilitates the consolidation of technical visions with community needs and political and institutional realities, balancing the decision-making process with urban planning.

These steps help reduce the risk of politicization of actions, ensure support for ongoing processes, and separate them from short-term government mandates or support from individual actors. Thus, by integrating risk assessments and climate vulnerability into city decision-making, it is possible to have a **significant impact on urban planning and public policies.**

Finally, there is an excellent opportunity to create capacities in cities with minimal investment by using information systems based on opensource and user-friendly programs that can easily be updated:

First, by harmonizing formats and scales of all databases and information and using this process to strengthen municipal capacities.

Second, by moving away from isolated and siloed work in municipalities and incorporating open and transparent methods and processes.

In this way, all actors will become familiar with the rules, it will be easier to share and use available information, and it will be possible to share and validate the evaluations generated by institutions and the different sectors or actors.

Lastly, it is necessary to communicate the results of the analysis to all stakeholders to build truly participatory and transparent processes, ensuring that information becomes an input in every municipal decision-making process (Hardoy *et al.* 2019; Villamarin *et al.* 2019; Winograd *et al.* 2021).

Photography: San Salvador, El Salvador
Source: © UNEP / Author: Josephat Kariuki.

Chapter

3

Citizen participation in NbS planning and design

Author: Jorgelina Hardoy

3.1 Introduction

In this chapter we address citizen participation in Nature-based Solutions (NbS) projects in urban and peri-urban contexts in Latin America and the Caribbean. In NbS literature there is an **important consensus on the importance of starting from a transdisciplinary approach, involving citizens in the process of change and being innovative to integrate the different efforts and capacities of the parties involved** (Wamsler *et al.* 2020). From a broader perspective, and from the understanding of NbS as part of a set of actions that promote Climate Resilient Development (CRD), the latest IPCC report highlights that people, ethics and justice are core to the very conception of sustainable development and emphasizes the need for CRD trajectories where different social interests, values, and worldviews are combined through inclusive and participatory processes (Intergovernmental Panel on Climate Change [IPCC] 2022).

There are several reasons why NbS should be developed from participatory processes:

a. Climate change and its impacts present **challenges that are beyond the ability of local governments to act** on their own. They require climate governance schemes where governments do not make decisions in isolation, but rather negotiate policies and practices with those who are part of it or are affected by them.

b. **Citizen involvement is recognized as a means to ensure and increase the relevance, ownership, and sustainability** of different measures such as NbS and, essentially, to ensure their fairness.

c. The possibility of **mainstreaming the gender perspective** in NbS policies and programmes, making differentiated impacts visible and work collaboratively to address them.

On the other hand, **NbS facilitate participatory processes in urban planning and management.** Due to their modular, decentralized, and low capital-intensive characteristics, NbS can be sources of work for cooperatives and small businesses, generating green employment opportunities, promoting different ways of working and producing, and engaging with the population at much more citizen-friendly scales.

In this chapter we review how to integrate different actors and sectors to generate new urban planning practices in the short, medium and long term, that integrate the participatory use of NbS in all stages of a process –reflected in this publication– from identifying vulnerabilities and risks, planning resilient infrastructure and selecting, planning and financing instruments, to analyzing and valuating impacts in order to review and adjust collaboratively. Finally, some barriers and challenges to participation in NbS projects are highlighted, along with recommendations and conclusions.

What is meant by citizen participation?

Participation refers to an "inclusive process, where actors can be part of, have a part, and take part in processes and decision-making" (Cabrera, Gravez and Pereira 2011, quotes in Cabrera 2016, p. 1). Citizen participation is an essential part of a good governance process where governments do not make decisions in isolation, but instead negotiate policies and practices with those who are part of, or are affected by decisions (Mitlin 2004; Hardoy and Velásquez Barrero 2014). In this sense, good governance determines that participation, accountability, transparency, social justice, the performance of roles and responsibilities, and the vision built among all actors are elements that enrich decision-making, and contribute to the processes being sustainable and effective (Villamarín *et al.* 2019). People only participate when they feel that by doing so, they will actually bring about some important change (Arnstein 1969).

Through participation, the aim is to avoid a "pre-defined product" prepared beforehand on an office desk with a technocratic approach and, seeks a "target-product" that arises from a participatory and concerted process. There is a **goal** towards which the actions of the process are directed, allowing modifications both on the path chosen and the strategies used to achieve the objectives, as well as on the final product sought (Motta and Almansi 2017).

3.2 Citizen participation in NbS projects for adaptation

As in different development projects, the active role of the community is key in the analysis, design, establishment of priorities and scales of action, steps to follow, budget review, implementation, and monitoring of a NbS project.

There are three basic conditions to ensure that participation affects actions and generates the sought changes (Climate and Development Knowledge Network [CDKN], Foundation Future for Latin-American [FFLA] and International Development Research Centre [IDRC] 2016):

- **a** the **involvement** of the participating actors
- **b** the **commitment** to assume roles and responsibilities
- **c** the sense of **identity and trust** that is generated.

Each participatory process has specific and unique characteristics. **The success of NbS as an innovative type of intervention depends to a large extent on how well it is integrated into a particular local, social, and geographic context.** Throughout this process all participants must learn and adapt some of their expectations and points of view. It is essential to build consensus in the diagnostic and co-design stages so that the measures developed respond to particular contexts and needs, as well as generating appropriation throughout the process to ensure the continuity and sustainability of the adopted measures.

NbS actions and policies –like the rest of urban actions and policies– are not neutral to gender and generate differentiated impacts on women and men. The possible consequences of gender relations and inequalities in the design of NbS policies and programmes need to be assessed. Similarly, positive actions that ensure equitable access to NbS resources and benefits need to be identified and promoted.[9]

Therefore, in order to integrate and sustain NbS actions and policies, spaces for equal participation for women and men need be created and ensured. In this regard, it is important to work on several fronts:

- Training technical teams and decision-makers in the methodological tools for incorporating the gender approach into policies and programs that develop NbS and climate resilience in general.
- Strengthening women's organizations and representations of diversity from other civil society groups for their empowerment and active participation in the design and implementation of NbS projects.
- Developing participatory assessments that analyse territories from a gender and intersectionality perspective, highlighting existing gaps in order to identify NbS measures that not only do not exacerbate inequalities, but are functional for reducing gaps and achieving gender equality.
- Generating both quantitative and qualitative gender indicators that account for the reduction of inequalities.
- Developing a budget with a gender perspective that ensures resource allocations for those NbS actions that contribute to the reduction of gender gaps.

9 For example, in the Urban Agriculture (AU, in Spanish) Programme of the City of Rosario (see Case 4), participation has always played a key role and, from the beginning, women gardeners played a leading role, almost two thirds of the people who work in the sector are women, and marketing mechanisms appropriate to their needs and possibilities were developed.

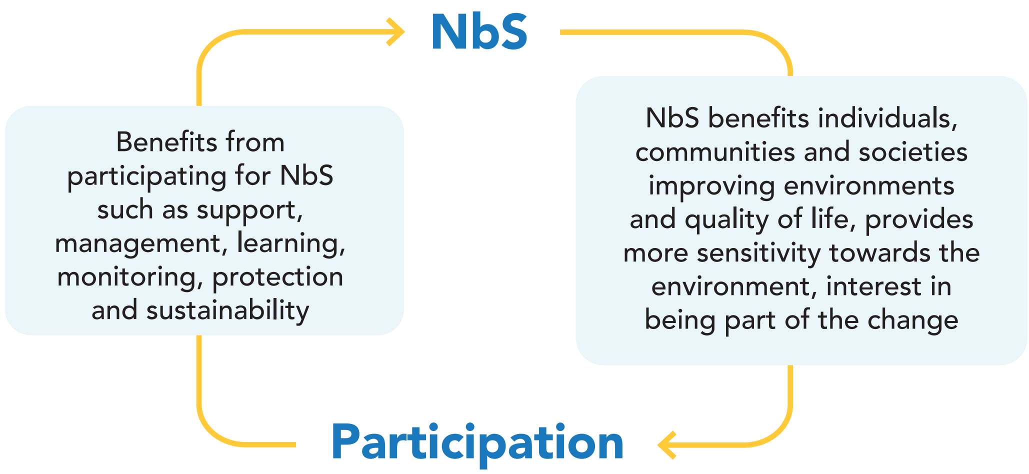


Figure 3.1. Circular benefits of NbS.

Source: Adapted from Cárdenas *et al.* 2021.

Therefore, the participation of a broad group of actors is key to ensure that NbS are at the core of the development process in the longer term and do not become "one-off" and isolated measures in the urban territory that reinforce inequality and gender inequity patterns. There are mutual benefits between NbS and participation as seen in figure 3.1. On the one hand, people, communities, and societies benefit from participating in NbS, improving their quality of life, mental health and well-being, gaining a greater sensitivity towards the environment, a desire to be part of the changes; whereas NbS benefit from participation by receiving greater support, follow-up and being integral to the urban development process (Cárdenas *et al.* 2021).

Moreover, participation brings several other benefits:[10]

- **Greater transparency and involvement** of people improves trust, the acceptance of ideas and appropriation.
- **Integration of visions and perceptions of the people who may be affected or have some type of interest in the project;** therefore, it allows taking different opinions into account and improving the project design and implementation, reducing negative impacts and enhancing positive ones, including a gender perspective.
- **Bringing together and generating an information and knowledge exchange** that helps making better decisions.
- **Helping people understand and defend their rights,** including being able to live in healthy, safe, inclusive and quality environments.

It is important to highlight that frequently, like any other types of measures and actions, NbS are not necessarily formulated as a response to climate change. However, as they gain recognition and are integrated into public policies, their climate value is acknowledged.

[10] Based on Kvam 2019.

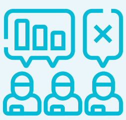
3.3 Development of a participatory process

People are involved in different ways within participatory processes, according to project objectives, the goals set by the process, the stage at which they join the process, and the type of participation that is of interest or can be managed. It is key to have transparency and clarity regarding the scope of participation in order to achieve an honest exchange from the outset.

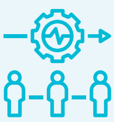
It is common to visualize participation in the form of a ladder where there is no participation at the lower levels, but only some kind of concession or manipulated involvement to carry out actions that the population does not understand and that responds to interests other that their own. Then, it goes through a façade participation (information, consultation, advice) before moving towards increasing citizen power, which involves collaboration, a progressive delegation of power, and citizen control. It is in the last stages where participation manages to influence public policies, monitor and control processes (Arnstein 1969; Hart 2001).

Three types of inclusion can be distinguished to understand the levels of participation in a project (CDKN, FFLA and IDRC 2016)

- **Basic Participation:** People participate by setting up working groups to respond to objectives predetermined by the project. They do not affect the formulation, but they are taken into account in activity monitoring and adjustment. This is probably the most frequently used participation style in projects.



- **Interactive participation:** Locally organized groups participate in the project formulation, implementation, and evaluation; this implies systemic and structured teaching-learning processes, and a progressive control of the project. Possibly this is the participation style to which the vast majority of projects aspire, where the *type of relationships and rules* that are established and matured for the project design and implementation matters more than *who* initiates them.



- **Self-development:** Locally organized groups take initiatives without waiting for external interventions. In its purest state, this is the least common style used for project and initiative developments; it requires enormous organizational capacities.


Photography: San Salvador, El Salvador
Source: © UNEP / Author: Josephat Kariuki.

A good example of interactive participation is participatory budgeting developed in different cities around the region and which funds are currently being allocated to the development of climate change adaptation and mitigation initiatives. Innovative approaches led by citizen groups (organized or not) and their governments are used, along with a strong political will to act and support participatory budgeting programmes. The cases of the cities of Rosario and Xalapa, briefly presented here, are also examples of interactive participation where consensual and dynamic rules and relationships have given predictability and permanence to the programme or strategy over time. In both cases, some self-development can be seen as they were initiated through the actions of civil society groups and then integrated as a state policy with clear leadership from the local government.

It is necessary to highlight that **these participation levels throughout a project or programme are dynamic,** with breakthroughs and setbacks depending on the circumstances and needs of each stage and the people involved. Both cases clearly have ups and downs in participation, but they show what is possible to achieve when large groups of actors work collaboratively.

Case 4

Rosario (ARG): Urban Agriculture (AU, in Spanish)[11]
Location: Municipality of Rosario, Argentina
Executors: CEPAR, Municipality of Rosario, orchard and vegetable garden farmers, INTA.
Year: *ca.* 1988–present

The Urban Agriculture (AU) programme in the city of Rosario has become a cornerstone of the city's response to climate change. AU activities began in Rosario at the end of the 1980s as a strategy for food production and access, and for genuine income generation. It began as an initiative of the NGO *Centro de Estudios de Producciones Agroecológicas* (Center for the Study of Agroecological Productions - CEPAR) that worked with organizations at the neighborhood level to grow vegetables in community gardens. The initiative gained strength with some official programmes both at the municipal level (creation of the *Departamento de Huertas* [Department of Orchards and Vegetable Gardens] 1991-1995), and at the national level (creation of the *Pro Huerta* Food Security programme [Pro-Orchards], National Institute of Agricultural Technology [INTA, in Spanish]). In December 2001, faced with the acute economic and social crisis suffered in Argentina, AU was introduced as a strategy to overcome the emergency. In this new stage, the alliance of actors from previous years was woven again and in February 2002, the Government of Rosario launched the AU Programme in collaboration with these key partners.

A wide variety of actors took part in the development and strengthening of the AU programme. Among the initial actors, CEPAR, the municipal government, INTA with Pro Huerta and orchard and vegetable garden farmers[12] stood out. The programme worked cross-sectionally from different municipal government offices that provided inputs (seeds, tools, fabrics), technical support, services (water and electricity), and facilitate marketing spaces (fairs, municipal markets). They have also been supported by different schools of the National University of Rosario (UNR), private companies, international cooperation, and the local press. It is also worth noting the participation of the national government in assigning vacant land for agroecological production. Regarding product commercialization, a direct marketing system was chosen through fairs, an agreed list of prices, and commercialization zones.[13] In general, women played a key role overseeing marketing and production management. This allowed them to generate their own income and a certain economic independence.

[11] Interviews with Raul Terrile (6/1/2022) and Paula Hoyos (6/13/2022). See Organización de las Naciones Unidas para la Alimentación y la Agricultura [FAO] 2014; Lattuca *et al.* 2005.
[12] Neighbors organized into a network of producers with municipal support that included member registration, establishing the promoting board and a delegate council to coordinate activities, with the importance of opening spaces for participation and avoiding strong leadership. Although the network is not currently active, it was until recent years. It is worth noting the legal status that was gained and allowed resource management.
[13] Interview with Raúl Terrile (6/1/2022).

Today, more than 2,400 families practice sustainable AU and generate income from this economic activity. There are 75 ha under production in urban orchards, 800 ha for peri-urban agriculture, 2,500 tons of fruits and vegetables produced each year, 40 points of sale and 7 markets in operation. The different decisions have been supported by ordinances to grant predictability to the programme that has received different awards, including the Ross Prize for cities in 2021.[14]

Figure 3.2. Urban Agriculture Programme (AU), Rosario. .
Source: AU, Rosario, May 2022.

[14] See: https://prizeforcities.org/project/sustainable-food-production-rosario

3.4 Stakeholder map and baseline construction for an NbS project

Carrying out a participatory NbS project in general requires identifying which persons to work with (stakeholder mapping), building a solid baseline (being clear of the starting point), and being able to take advantage of all existing knowledge and information. Stakeholder mapping is a methodological tool that facilitates the identification of key actors, analyse connections and relationships between them, their interests, importance, or influence on a given topic or project. It is important to specify aims and purposes of the mapping. It is recommended to prepare it at the beginning of the project and adjust and monitor it throughout the entire process, since reality is continuously changing and actors can modify their perceptions, levels of influence and interest, etc. (Ortiz, Matamoro and Psathakis 2016). Likewise, mainstreaming a gender perspective and ensuring the inclusion of a broad set of actors is essential.

Regarding the usual steps taken to start a participatory process (figure 3.3), a long list of preliminary identification of institutions, organized groups or people relevant to an NbS project is prepared, and they are classified according to, for example, who holds information, knowledge, power, and control. It is done based on the initial knowledge that exists about the site, information obtained from meetings with political, social and technical focal points, as well as brainstorming sessions, among others.

A graphic representation of the stakeholder map is created by identifying the levels or scales at which they operate (for example, neighbourhood, local, regional, or national scale), types of relationships (whether they are collaborative, conflicting, or non-existent), the individual resources, be it by knowledge of the territory, experience in NbS, technical capacities, leadership, information, data generation and management, financial resources, etc. In general, the actors are positioned in a table or matrix. They can also be analysed based on the function they fulfil in relation to the topic, which serves to design the best work strategy with each one and ensure that a gender perspective and attention to diversity are integrated.

The initial stakeholder map leads to the identification of the core stakeholders to be interviewed, with whom to hold focus groups and with whom to build and develop the project. In parallel, but in constant dialogue with the stakeholder mapping, the project baseline is built, which allows knowing the general context in which it is embedded, including the institutional and governance structure, projects and programmes already underway, the type and quality of information and knowledge that already exists on the subject, where it is located and in what formats, and the existing gaps, for example, in relation to who and which groups are invisible and voiceless (various actors who, due to age, ethnicity, gender, income, etc. inhabit and make differential use of common spaces, and may have specific needs both in relation to the development of NbS and for participation). As presented in the previous chapter, it also helps to understand who and what is at risk and what response options are being implemented. In this way, the chances of success of the project proposal are increased, ensuring a real co-design of the entire NbS development and implementation plan and validation.

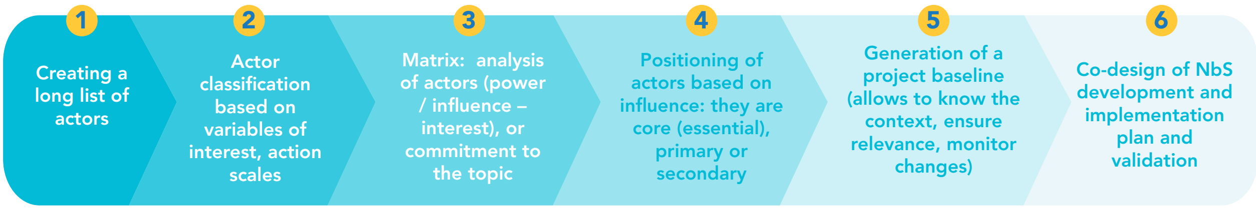


Figure 3.3. Typical steps in a participatory process to develop NbS.

Source: Prepared by the author.

3.5 Co-design and validation, support to decision-making

Once the stakeholder mapping and the baseline have been developed, the information is analyzed, integrated, and organized with the aim of returning it to the participating stakeholders seeking to provoke a second reflection. Integrating all the information allows to finish shaping questions in NbS projects, such as for whom and with whom? what?, when?, where? and for what? With this validation, the following stages begin, which will vary in content depending on the project scope. It is important to highlight that, throughout the entire project-process, both the stakeholder mapping and the baseline are dynamic and will be updated (figure 3.4).

Photography: Xalapa, Mexico
Source: © UNEP / Author: Josephat Kariuki.

From this stage it is usual to develop a series of workshops to iterate, deepen issues, prioritize lines of action, propose innovative ideas, co-design, develop indicators to monitor scopes of action, agree on a workplan, assign roles and responsibilities, budget, and enhance the necessary agreements to carry out the NbS project in all its stages.[15] There is a wide range of tools and methodologies to carry out participatory workshops. It is key to generate appropriate mechanisms to address the diversity of stakeholders' needs and ensure that all voices are represented, integrating a gender perspective throughout the process. This includes looking for ways for everyone to participate and get involved in a safe and comfortable manner, taking into account schedules, location, or the type of information.

The proposal design and goals, and the workplan, vary depending on the timelines (short-, medium-, long-term) and action scales (local micro - neighborhood, city, region, country/basin, urban, peri-urban, rural). Participatory processes must also ensure building consensus around these times and scales of the project.

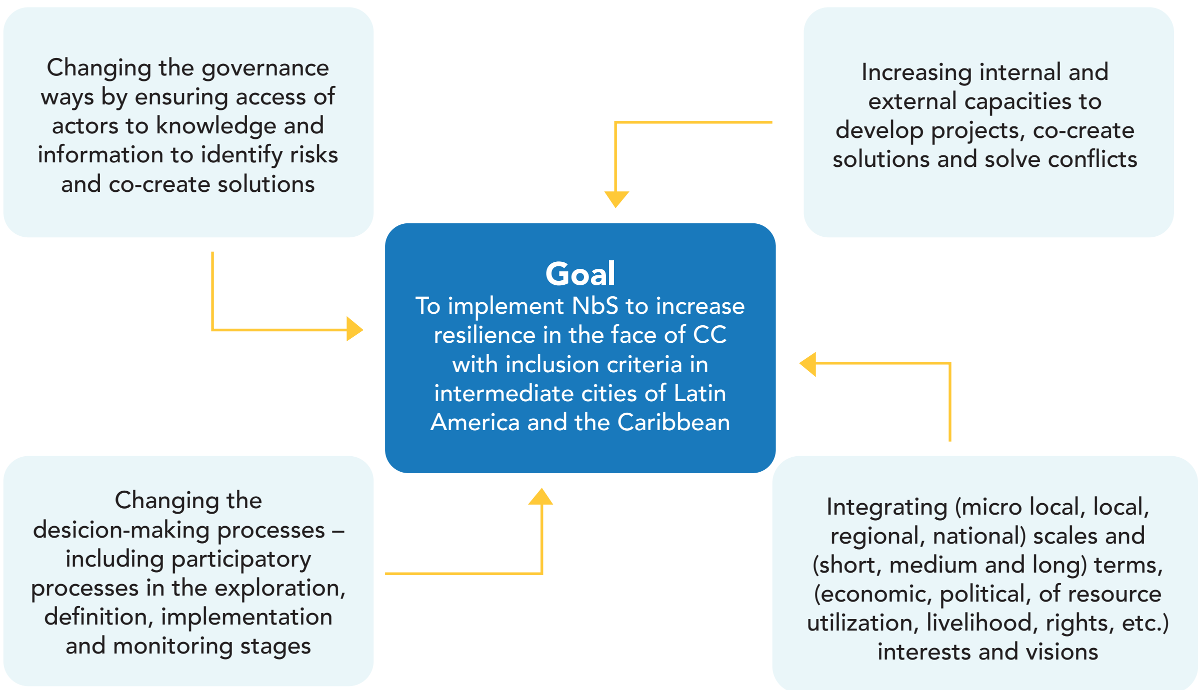


Figure 3.4. What changes do we look for throughout an NbS development process?

Source: Prepared by the author.

[15] See chapter 4 *Resilient infrastructure in urban adaptation* and chapter 5 *Overview of the planning and financing instruments that support urban NbS.*

Case 5

Xalapa (MEX): Integral Water Resource Management (IWRM)[16]
Location: Xalapa City Hall, Mexico
Executors: *Senderos y Encuentros para un Desarrollo Autónomo Sustentable* Civil Association (SENDAS, in Spanish), Xalapa City Council through the Drinking water and sanitation Municipal Commission – (CMAS, in Spanish) and the support of the United Nations Environment Programme - CityAdapt
Year: 2005 – present

The city of Xalapa, together with its neighboring municipalities, faces increasing challenges to meet its population's drinking water needs. The city seeks to face this challenge from a comprehensive natural resource management vision. In 2005, the *Senderos y Encuentros para un Desarrollo Autónomo Sustentable* (SENDAS) civil association began a comprehensive co-managed project for the Pixquiac river sub-basin. In 2008 the Pixquiac River Basin Committee (COCUPIX, in Spanish) was created to manage resources for the conservation and restoration of forests and generate more sustainable productive alternatives. A Fund Scheme for Payment for Environmental Services in the basin was developed. In 2014, the "Coordination for Water and Social Liaison" was created in the Drinking Water and Sanitation Municipal Commission of Xalapa (CMAS, in Spanish). In 2019, the Strategy for the Comprehensive Management of Xalapa Water Resource (EGIRH, in Spanish) was prepared based on the collaboration between civil society and the city council. It became the governing public policy for the conservation of forests, basins and water that supplies the city. In this framework, throughout 2020-2021 CMAS proposed and developed a voluntary contribution from the population of 2% of their consumption for the payment of environmental services, and the Council of Environmental Services[17] was created.

A wide variety of actors have been participating in the Integral Water Resource Management of Xalapa (IWRM) and in the development and implementation of the EGIRH. The process is carried out by the municipality of Xalapa through CMAS, the Coordination of Water and Social Liaison, and its respective Department of Basin Management and the Department of Water Culture. Civil society organizations such as SENDAS participate and receive the support of academic institutions (National Autonomous University of Mexico, University of Veracruz, and the Institute of Ecology A.C.), environmental associations (Marangola, A.C., Pladeyra, S.C., Gulf of Mexico Fund), professional groups, the Environmental Fund of Veracruz, the National Water Commission (CONAGUA,

[16] Interview with Sergio Angón and Isabel García Coll, coordinators of the CityAdapt Project in Xalapa, (6/13/2022). See Angón Rodríguez *et al.* 2021; Programa de Naciones Unidas para el Medio Ambiente [CityAdapt] 2022.

[17] An auxiliary, collegiate, plural, and participatory body that helps to formulate and evaluate the projects to be implemented with the funds from the voluntary contribution.

in Spanish), and the United Nations Environment Programme [CityAdapt]. This broad involvement of actors demonstrates the collective effort carried out by organized civil society, academia and the municipal government to achieve comprehensive water resource management. There is a mainstreaming of the resource management within the structure of the Xalapa City Council, since environmental, urban planning and public works directorates and advisers participate.

EGIRH became a State policy. An instrument was generated to ensure funds for the payment of environmental services that can be redirected to basin protection. Today more than 1,400 ha of the Pixquianc sub-basin are being conserved. As part of the CityAdapt project, Rainwater Harvesting Systems (domestic RWHS) were installed in 10 schools and public buildings and the riparian restoration of the Papas-Carneros stream began, implemented through the Biodiversity Nursery Network (REVIVE A.C.).[18] Based on this initiative, the municipality invested in 10 additional rainwater harvesting systems and the financing was arranged, and another 90 were installed. Rainwater harvesting systems are planned to be installed in homes located in vulnerable areas of the city, followed by riparian restoration with funds from the payment for environmental services. The Manifesto for Water for Xalapa was signed and the Pixquiac experience is planned to be replicated in the Huitzilapan river basin (in the state of Puebla) and the El Castillo springs (rural area of Xalapa).

As a whole, the participatory process strengthens the internal and external capacities of actors to develop projects, co-create solutions, and resolve conflicts (Hardoy *et al.* 2019). It is important to highlight the role played by various actors in the construction of a collective assessment and in the development of a long-term process. For example, a challenge in the City of Rosario was to have long-term vacant land to develop AU. A study carried out between municipal secretariats and the National University of Rosario identified areas unsuitable for construction but suitable for agriculture.[19] Later, a 2004 municipal ordinance formalized the concessions of vacant urban land to orchard and vegetable garden farmers in exchange for their care, and successive bylaws contributed to giving strength to the program.[20] The development of knowledge, learning, awareness and participation of users, organized society and citizens was and is key, both in the IWRM development process and in the voluntary contribution instrument on water consumption for the payment of environmental services implemented in Xalapa.[21]

[18] See Programa de Naciones Unidas para el Medio Ambiente [CityAdapt] 2022.
[19] Railway sidetracks and urban highway side-lanes, flooded or floodable soils and public spaces for green areas awaiting completion due to lack of budget.
[20] See Lattuca *et al.* 2005.
[21] See Angón Rodríguez *et al.* 2021 and CityAdapt 2022.

3.6 Barriers and challenges to citizen participation

Despite the recognition of the usefulness of developing participatory processes for NbS projects in urban and peri-urban contexts, it is often complex to successfully carry them out in practice. There are common barriers and challenges to urban development processes in general and others that are specific to NbS. Anticipating these barriers and planning the appropriate ways to solve them according to each context is an important starting point in any project.

The most common political-institutional barriers are related to:

- **a** lack of mechanisms and structures that facilitate stakeholder participation beyond public consultation mechanisms in real decision-making instances;
- **b** lack of capacities and resources at the local level to carry out participatory processes;
- **c** traditional approaches to planning (limited stakeholder involvement, technocratic perspectives); and
- **d** elections and cyclical government transitions that frequently generate interruptions or changes in governance practices, affecting the quality of citizen participation.

Photography: San Salvador, El Salvador
Source: © UNEP / Author: Josephat Kariuki.

On the other hand, the integration of priorities, perspectives, and capacities of each actor, is not usually co-designed or implemented jointly and, in addition, there is a tendency to rush the timeline for designing and developing ideas. In this sense, it is usual to find:

- **a** little interest or recognition of the value of incorporating the perspectives, priorities, and needs of "others";
- **b** short-term agendas that do not allocate time to develop participatory processes;
- **c** biased perceptions, visions, and beliefs; and
- **d** pre-defined projects that do not contemplate the development of participatory processes beyond some form of consultation.

Access to and dialogue on information and knowledge result in better decision-making while empowering the actors. However, there is often:

- **a** lack of shared information and data and in compatible formats to be usable;
- **b** lack of knowledge and skills to be able to get involved in an informed manner;
- **c** little interest and capacities to generate knowledge exchange and recognize different capacities; and
- **d** few exchanges that promote learning and build upon it.

Finally, as a consequence of actors' beliefs and preferences, that are closely linked to the process of generation and appropriation of knowledge and resources, biased or conflicting visions and perceptions are usually encountered. This results in: a) an overvaluation of the role and the ability of grey infrastructure to mitigate risks in comparison to NbS or hybrid solutions and b) a disengagement of citizens from natural landscapes and their functions.

Conclusions and recommendations

Developing NbS in cities through citizen participation processes is an opportunity to renew and improve urban planning from an integrated perspective that is much more attentive to resolving situations of vulnerability and exclusion, in an environmentally sustainable manner. **Citizen participation is key to ensure that NbS are the core to a comprehensive long-term urban development process and gain scale and incidence.** Through participation, efforts should be made to ensure that NbS are not seen as an additional isolated implementation but rather as an integral part of the range of solutions to address the different challenges of climate change. In turn, participation is key to integrating diverse knowledge and perceptions and ensuring that the implemented initiatives and measures are sustained over time.

Participation is not generated automatically, nor is it an item to be checked off a list of actions to be taken, let alone a recipe to be followed. It must be thought and designed, reviewed and adapted to each particular context and for each and every stage of a process. Although NbS are not new measures, their valuation and integration into urban development are new in many aspects. Therefore, it is recommended to develop participatory processes that give enough time to iterate and generate consensus, for which access to and integration of information are key, along with the generation of adequate spaces for real participation and incidence in decision-making.

Photography: Xalapa, Mexico
Source: © UNEP / Author: Josephat Kariuki.

Chapter

4

Resilient infrastructure in urban adaptation

Author: Begoña Arellano Jaimerena

4.1 Introduction

Resilient infrastructure is the foundation of social and economic activities, protecting and connecting communities, industries, and markets and providing essential services such as energy, water, communications and transportation networks, which enables the flow of goods, services and information. This type of infrastructure allows cities to recover from disruptions caused by different kinds of threats, including adaptation to changing conditions and the uncertainty presented by climate change (Organization for Economic Co-operation and Development [OECD] 2018). **Nature-based Solutions (NbS), understood as a type of resilient infrastructure, are multifunctional solutions that not only make it possible to address the various threats that affect cities, including impacts related to climate change, but also contribute to sustainable development,** as already discussed in Chapter 1.

There are various approaches, criteria, and principles for the design of resilient infrastructure, depending on the perspective taken. For example, from a risk management perspective, the United Nations Office for Disaster Risk Reduction (UNDRR) is developing a set of principles for resilient infrastructure (United Nations [UN] 2022a) focused on systemic resilience, continuity in the provision of critical services, and the Sustainable Development Goals (SDGs); while from an asset management point of view, the focus is on critical infrastructure, infrastructure systems and service provision (OECD 2021). **For the development of NbS as a type of resilient infrastructure, adopting a systemic vision in collaboration with nature is necessary.** This allows developing flexible solutions that are part of an integrated strategy for safer and more sustainable cities, avoiding the perception of the presented solutions as individual components.

Photography: Xalapa, Mexico
Source: © UNEP / Author: Josephat Kariuki.

4.2 NbS as resilient infrastructure for climate change adaptation in Latin America and the Caribbean

As discussed in Chapter 2, there are various climate hazards and risks that affect cities in Latin America and the Caribbean. Their impact varies not only depending on how exposed they are, but also on their level of sensitivity and accumulated vulnerabilities. Urban areas, in particular, are highly exposed to climate change-related risks.[22] especially floods, droughts and landslides, as well as storms, water stress and heat waves (World Meteorological Organization 2022). Some urban areas also present heat stress, with heat islands in areas that experience considerably higher temperatures than their surroundings (Villanueva-Solís, Ranfla and Quintanilla-Montoya 2013; Siclari 2020). In addition, the urban population in Latin America and the Caribbean already exceeds 80%. Although its growth has slowed down in recent years, it is expected to continue increasing (UN 2022b), affecting a greater number of people, especially women and communities in greater vulnerability conditions, further stressing urban areas.

Regarding hazards, some may occur at the same time (multi-hazards), or on different time scales, such as cyclical hazards; long-term hazards such as droughts, and others of sudden origin such as tornadoes. For the purpose of this chapter, we group urban NbS according to the following hazards: (i) pluvial and fluvial floodings, (ii) coastal floodings, (iii) water scarcity and droughts, and (iv) landslides. It should be noted that the NbS shown below contribute to some extent to mitigate the effects of heat islands, predominantly strong in cities, as heat stress is reduced by increasing green or water surfaces. Figure 4.1 shows examples of the overlap between functions and co-benefits of the different NbS mentioned, without being an exhaustive list of possible NbS.

[22] See Chapter 2, Table 1: Elements and essential variables for risk and vulnerability analyses in cities.

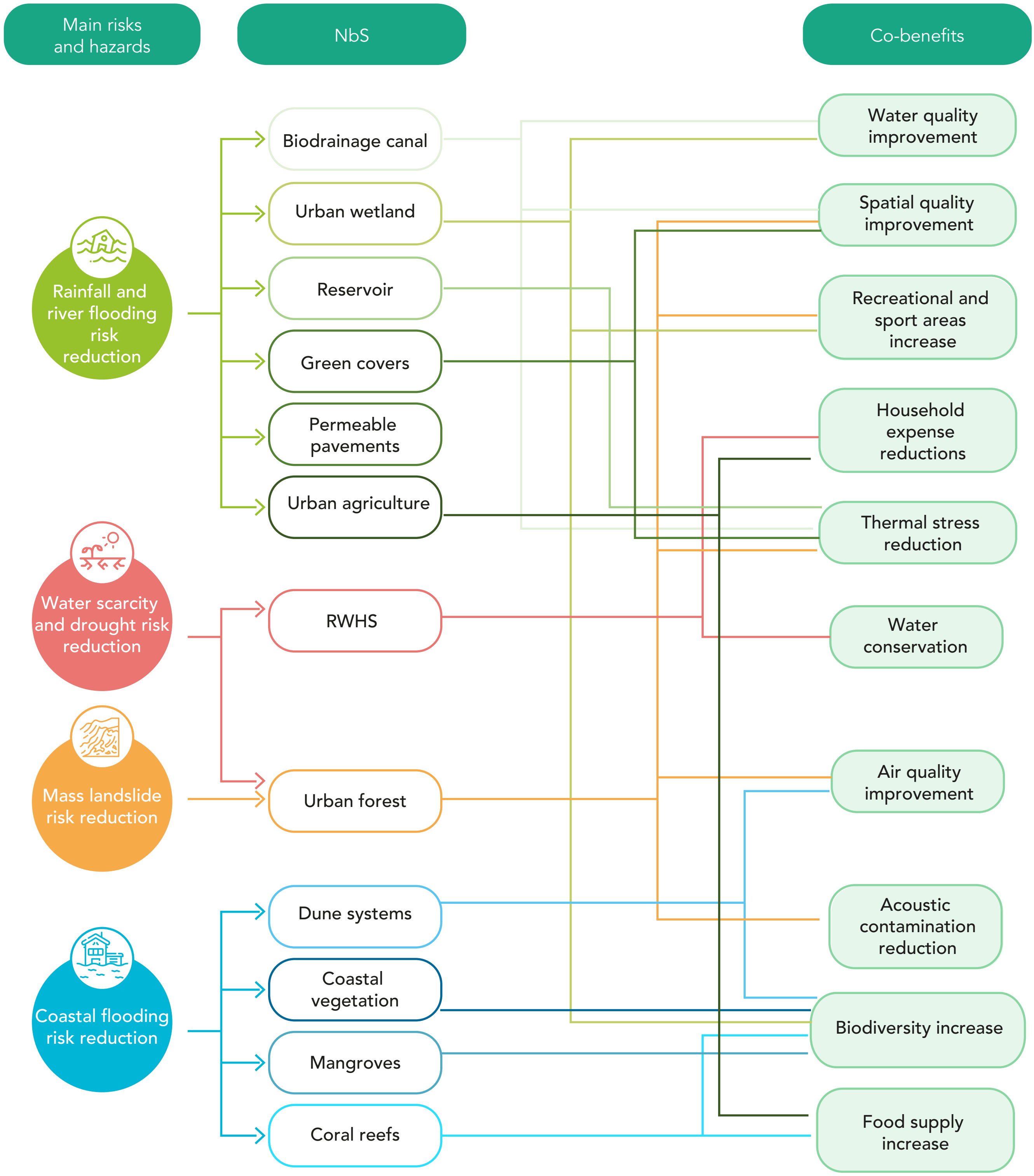


Figure 4.1. Example of NbS, the risks and hazards they address and the co-benefits they bring about.
Source: Prepared by the Author

Pluvial and fluvial floodings

Examples of suitable NbS.
NbS used to mitigate flood risks should focus on: (i) improving rainwater infiltration into the subsoil, and (ii) creating more space for water, either by increasing the rainwater storage capacity or by increasing the water conveyance capacity of rivers and streams. Additionally, in the case of fluvial floodings, it is appropriate to reinforce river and stream banks through riverside vegetation restoration and reforestation (Ozment *et al.* 2021). Other measures such as those included in sustainable urban drainage systems (SUDS)[23] are adequate to reduce stormwater flooding risks, contributing to urban water management. For example, some solutions provide an area for stormwater storage on the surface, such as retention and detention reservoirs and urban wetlands. Furthermore, green roofs allow a portion of the rainwater to be captured on the roof of a building, which is useful for the irrigation of vegetation and allows its evaporation. Bioswales are linear solutions that convey stormwater runoff to then allow its slow infiltration into the subsoil. Urban agriculture can also be an appropriate NbS on green roofs or in gardens, contributing to improve infiltration into the subsoil.

Co-benefits.
NbS that mitigate flood risks are very varied, so their co-benefits will depend to a large extent on the type of specific solution. Although they all contribute to reducing heat stress and to some extent improving spatial quality, larger-scale solutions such as reservoirs and wetlands can also provide spaces for recreation, improving the quality of life of communities. Wetlands have a major impact on increasing biodiversity, and in a similar way, but to a lesser extent, so do bioswales. Both NbS also contribute to improving the quality and quantity of available water. Urban agriculture and, in some cases, green roofs can provide food, contributing to food security, which can have a great impact on the expenses of vulnerable households and the health of their members. Low-income families will be able to have access to a healthier diet through community kitchens that get their supplies from urban vegetable gardens.

Implementation.
Depending on site-specific conditions, for example, space availability, slope, and soil type, some solutions will be more appropriate than others. Linear and/or smaller-scale solutions such, as bioswales, are suitable for situations where the available space is scarce, as long as the type of soil is permeable enough to allow infiltration. If, for example, the soil type is not permeable enough, or the groundwater is very close to the surface, there will not be enough space left in the subsoil for the water that is being infiltrated to be stored, which will result in an ineffective solution. On the other hand, if the available space is greater but the soil type does not allow suitable infiltration, retention basins can be a good solution since they allow permanent surface storage of rainwater and can become a landscape element as an urban park.

It is important to note that, in contexts of extreme rainfall, such as in the tropics, NbS alone may not be sufficient for rainwater storage and flooding mitigation. In those cases, it is particularly beneficial to consider complementing NbS with traditional solutions, thus creating a hybrid solution.[24]

[23] For more information refer to Chapter 1 – Key Concepts on NbS for adaptation in cities.

[24] See chapter 1 – Key Concepts on NbS for adaptation in cities.

Maintenance and monitoring.

All urban NbS require some type of regular maintenance and ideally some monitoring, in order to identify potential performance problems and take the necessary actions in time. In general, maintenance focuses on pruning and weeding, as well as avoiding sediment and solid waste accumulations that may prevent the measure's proper functioning. For example, if bioswales are not properly maintained, they can accumulate sediment to such an extent that they no longer have the capacity needed to receive the runoff for which they were designed. The monitoring will depend on the type of measure; but in general, it is possible to carry out regular (monthly) visual monitoring to check the measure's status. For example, whether there are solid wastes that hinder water flow, or if the infiltration capacity has changed. It will always be necessary to carry out an inspection after either rainfall or river flooding events. In this way it is possible to evaluate the measure's performance over time and make modifications to its design or maintenance if necessary.

Photography: San Salvador, El Salvador
Source: © UNEP / Author: Josephat Kariuki.

Coastal floodings

Examples of suitable NbS.
NbS used to mitigate the risk of coastal flooding should focus on dissipating wave energy in coastal areas. Some appropriate NbS for this purpose are man-built or natural coastal forests such as coral reefs (Silva *et al.* 2020), mangroves, coastal vegetation, and dune systems (TNC 2021).

Co-benefits.
By dissipating the energy of waves and marine currents, this type of NbS contributes to reducing coastal erosion. They also contribute to provide recreation and tourist areas (Silva *et al.* 2020), to increase biodiversity and to improve the spatial quality of coastal zones. In some cases, they can support mitigating wind action, as is the case with mangroves, or even to work with the wind, as is with dune systems. Coral reefs are also the habitat of various essential marine species both for human life and for other species. In addition, they allow sustaining fishing activities, contributing to food security and local economies. Mangroves are not only high biodiverse ecosystems, but they contribute to reducing seawater intrusion, and therefore, reduce saline intrusion risk (Hilmi *et al.* 2017).

Implementation.
All the aforementioned NbS belong to a landscape scale, since their application generally exceeds the limits of the urban area, making it impossible to implement them on a smaller scale. This especially applies to dune systems since they are dynamic systems in constant movement. The implementation of these measures requires a considerable area along the coastline to have a real impact on wave energy dissipation. However, the urban coastline is generally an attractive area, so NbS should be designed as multifunctional areas that allow for other uses (for example, recreational use, fishing, transportation, etc.) in addition to disaster risk mitigation.

Maintenance and monitoring.
In the case of dune systems, due to their high dynamism, fragility, and susceptibility to human activity, maintenance and monitoring tasks are carried out on foot or with the use of non-motorized transportation. The use of motorized vehicles in coastal areas negatively impacts the vegetation that is part of the dune systems, which has a stabilizing effect. Without that vegetation, sand movement will vary. Periodic maintenance and monitoring will allow the identification of unwanted changes in the dune dynamic processes. By comparison, coastal forests are more stable, and their maintenance focuses on their early years, while the species are in their growth stage. Although maintenance will be less intensive in later years, long-term monitoring is essential, especially after coastal flooding events.

Water scarcity and droughts

Examples of suitable NbS.
NbS used to mitigate the risk of water scarcity and drought should focus on improving water conservation and storage capacity at the local level (United Nations Educational, Scientific and Cultural Organization [UNESCO] 2018). Although water scarcity and droughts are long-lasting events that cover a larger scale than just cities, it is possible to implement measures at the urban level that contribute to water conservation and storage strategies at the landscape or basin level. Some appropriate NbS in these cases are those that involve afforestation, reforestation, restoration, and revegetation (OECD 2020), using species with low water requirements and, ideally, native species. Increasing the urban area covered by vegetation can also allow aquifer recharge, depending on their depth and specific soil conditions. Additionally, urban vegetation helps regulating temperature and mitigating the heat island effect in urban areas, especially those located in arid zones (Villanueva-Solís, Ranfla and Quintanilla-Montoya 2013). Measures involving rainwater harvesting may contribute to water conservation efforts and management at a local level.

Co-benefits.
Some of the co-benefits of NbS involving afforestation, reforestation, revegetation and restoration are increased biodiversity, improved air quality, carbon sequestration, and reduced noise pollution. In addition, these NbS provide spaces for recreation and sports that contribute to a better quality of life in the communities. On the other hand, rainwater collection has the co-benefit of reducing household expenses. These

co-benefits are particularly valuable for the most vulnerable groups that have scarce resources to cover their basic needs and limited access to quality green areas for public use. Also, women play a key role in water resource supply and management (Global Water Partnership [GWP] 2011), since women and girls are responsible for providing and managing water in approximately 80% of households that experience water scarcity (UN n.d.).

Implementation.
Most NbS that are suitable to mitigate the risk of water scarcity and drought are measures whose effectiveness is generally related to their size; commonly they are larger-scale NbS, such as urban forests. However, rainwater collection that contributes to water scarcity risk mitigation is a measure that can be implemented on a smaller scale, for example, at home. Available space and average rainfall are the main criteria for the selection of this type of NbS. In extreme drought contexts, for example, rainwater harvesting is not recommended, since the amount of water collected does not compensate for infrastructure spending. A native species urban forest may be an appropriate measure for this context.

Maintenance and monitoring.
Maintenance is essential in solutions such as urban forests in a drought context. Although the use of native species allows a better adaptation, during the first years of life of the trees more intensive maintenance will be necessary until the forest is consolidated. On the other hand, Rainwater Harvesting Systems (RWHS) will require regular maintenance throughout their lifecycle. Both types of measures will benefit from a long-term monitoring system, especially if considering that droughts are long-lasting events, generally over years or decades.

Case 6

Rainwater Harvesting Systems (RWHS) in schools in San Salvador
Location: San Salvador, El Salvador
Executor: CityAdapt Project, implemented by the United Nations Environment Program (UNEP) and the Ministry of the Environment and Natural Resources (MARN, in Spanish) of El Salvador, with the support of the Salvadoran Foundation for Development and Minimum Housing (FUNDASAL) and the Association of Community Projects of El Salvador (PROCOMES, in Spanish).
Beneficiary: Selected schools in the municipalities of Santa Tecla and Antiguo Cuscatlán
Year: 2020 – 2021

The objective of this project was to facilitate the collection of rainwater for daily community use in schools in San Salvador, to mitigate climate risks caused by droughts, changes in rain patterns, and high temperatures. Through the installation of RWHS, this project seeks to provide ecosystem services for the mitigation of climate events and water provision.

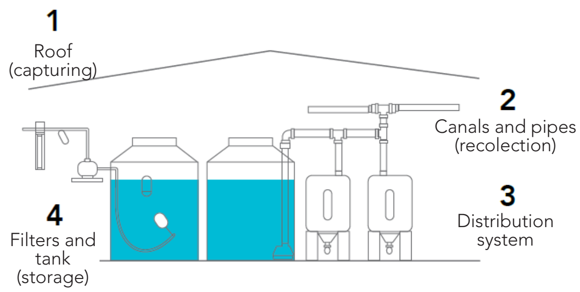


Figure 4.2.
Left: Diagram showing RWHS main components. Right: Example of RWHS implemented in one of the schools.
Source: CityAdapt.

This area is characterized by an insufficient drainage system, informal settlements, and heavy rains with flooding and mass landslide risks in certain areas. Available space, basic infrastructure and land tenure were taken into account for the selection of schools. The implemented systems have a storage tank, a centrifugal pump and a hydropneumatic tank, sediment filter and a double filter to make the water drinkable. They are connected to the rainwater downspouts coming from the school rooftop, collect the water that is captured on the roof and treat it before distributing it for consumption, use in bathrooms and irrigation of vegetable gardens. The system maintenance must be carried out on a regular basis, in order to ensure a good quality of the collected water.

The results of this project were characterized by exchange of knowledge, local capacity building on climate change adaptation and rainwater harvesting, and the successful demonstration of RWHS. For example, in the *Jardines de la Sabana* School in the Municipality of Santa Tecla, RWHS and urban vegetable gardens were installed. RWHS in this location have benefited 643 students, not only by supplying them with water for consumption and use in bathrooms, but also by allowing them to irrigate the vegetable garden. The yield from that vegetable garden is then distributed among students' families. Through this process, education and awareness are combined with the practical application of this type of NbS that contributes to reducing water scarcity.

Landslides

Examples of suitable NbS.
Landslides –commonly rock and earth– are associated with various either natural or anthropic factors resulting from human action. Some contributing or even triggering events are intense and prolonged rainfalls that erode and saturate the soil, and changes in the land use that modify the natural drainage system of an area (Olarte 2017). The suitable NbS to reduce landslide risks in cities may focus on restoring or improving soils in areas with steep slopes, protecting them and avoiding their saturation. As with droughts, some appropriate NbS for this case include reforestation, rehabilitation, and restoration, aiming at increasing vegetation cover, strengthening the soil structure and restoring the natural drainage system.

Co-benefits.
As with NbS that mitigate water scarcity and drought, co-benefits of NbS that mitigate landslides contribute to increasing biodiversity, improving air quality and reducing noise pollution. In addition, they provide spaces for recreation and sports that support a better quality of life in the communities, which is particularly beneficial for the most vulnerable groups, who often have limited access to quality green areas for public use. Also, by mitigating landslide risks in certain locations, this type of NbS offers the co-benefit of protecting critical infrastructure, such as transportation infrastructure systems (Ozment *et al.* 2021) and public services (for example, electricity, telecommunications, health, and education).

Implementation.
The implementation of such measures depends on the specific context, the type of landslide and what causes it, and the type of soil, among others. In general, NbS should be implemented on a landscape scale, using native species on sloping lands that have been affected by anthropic actions, such as areas with informal settlements on gully slopes, or where extreme events have increased rock decomposition.

Maintenance and monitoring.

The maintenance and monitoring of this type of NbS is necessary since landslide processes are complex. Once NbS are implemented, it is necessary to monitor them to prevent the vegetation from being degraded or removed. This happens in some cases, either to use wood for timber, or to illegally develop areas intended for other purposes. Even when native species are used, it will be necessary to carry out maintenance during the first years of the trees' life, while the forest consolidates.

Case 7

Calzada de la República **(La República Avenue), Oaxaca de Juárez – Mexico**

Location: Oaxaca de Juárez, Mexico

Beneficiary: Secretariat of Infrastructure and Sustainable Territorial Planning (SINFRA, in Spanish) – Oaxaca de Juárez, Mexico.

Funded by: Rijksdienst voor Ondernemend Nederland (RVO), The Netherlands

Year: 2020

Team: BD+P (team leader and design), Deltares (urban resilience), Move Mobility (mobility)

The project was part of a city initiative to increase urban resilience, with an emphasis on climate resilience through the remodeling and improvement of its main avenues, one of which is *Calzada de la República.* The process was guided by urban design, incorporating aspects of mobility and urban resilience. As part of the latter, the conceptual design was assessed using the Climate Resilient Cities (CRC)[25] tool to identify potential NbS and model its contribution to improving urban resilience by mitigating the risk of pluvial flooding as green surfaces are increased. The strategy is based on the idea of a "sponge city", which tries to manage water locally following retention and storage principles, then infiltration and, only when necessary, drainage. The tool allowed quantifying the rainwater storage capacity of the measures, their contribution to reducing heat stress and improving the quality of the water that infiltrates the subsoil. After an iterative process of design, testing and adjustment, a master plan was developed, informed by scientific knowledge and validated by the different institutional actors involved during a workshop. The CRC tool was also used during the workshop to explain the process and the relationships between NbS, urban resilience and pluvial flooding.

[25] https://crctool.org/en/documentation/

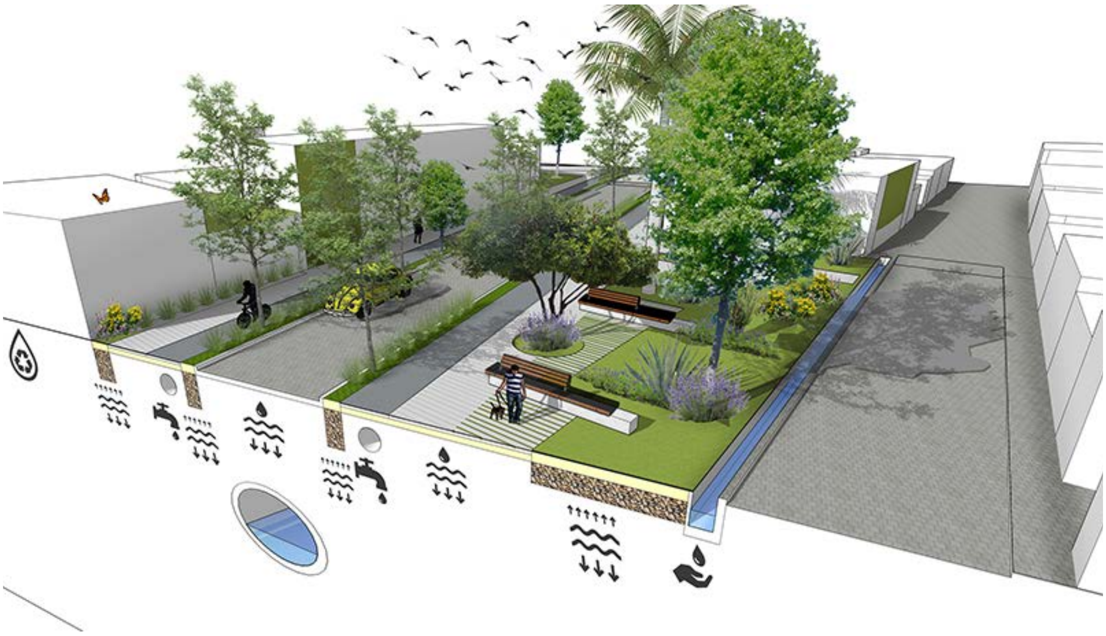
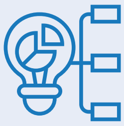


Figure 4.3. Visualizations of the proposed measures, including for example permeable pavements.
Source: © BD+P

4.3 Challenges for NbS implementation and monitoring

Generalize the challenges that Latin America and the Caribbean (LAC) face for NbS implementation in cities is complex. LAC is a vast region, with different climates, landscapes, socioeconomic and institutional contexts, and faces diverse challenges. Some cities are more prepared to face climate risks, while others are still struggling to solve more pressing challenges, such as access to safe drinking water and sanitation, without having the resources, time, and capacity to prepare for future adversities. The region also shares challenges with many others in the world, such as the lack of monitoring of NbS, which prevents understanding its long-term performance and, therefore, adequate planning. From the point of view of NbS implementation and monitoring, the following challenges are particularly relevant:

- **Lack of enabling conditions for NbS implementation,** referring not only to an inadequate institutional context of short-term strategies but also to aspects related to their governance, with actors that are not very committed and involved in their implementation and maintenance.



- **Comprehensive spatial planning in a departmental institutional context,** as discussed in Chapter 5, on NbS implementation with urban financing instruments. This chapter also addresses the existing focus on planning over implementation, with a clear gap between strategic plans and NbS investment plans (Altamirano *et al.* 2021), which is the main obstacle to NbS implementation in LAC (Intergovernmental Panel on Climate Change [IPCC] 2022). This also translates into the difficulty of scaling up or conventionalizing NbS pilot projects.

- **Long-term NbS performance,** given future uncertainties and climate change. Although there is a broad consensus on the great value of NbS, the quantification of their benefits and co-benefits still poses great challenges. The lack of historical data on NbS performance makes it difficult to have a comprehensive understanding of their ecosystem services, as well as to establish the level of service over time. The latter is particularly relevant during the first years after NbS implementation, since these types of solutions usually take time to establish and perform according to the level they were designed for.

- **Lack of a robust and long-term monitoring system that allows understanding the NbS performance in the long term.** This requires an entity responsible for planning, and either implementing or overseeing a monitoring plan implemented by a third party. Furthermore, when aiming to implement a smart monitoring system, certain local technical capabilities and additional resources are required, but they are not commonly available.

Recommendations and conclusions

NbS implementation requires a comprehensive process, with specific objectives and ambitions and including the participation of all actors –from both public and private sectors– throughout the process. The main stages (adapted from Loucks and van Beek 2017) of this process are:

1. **Understanding of the water, environmental, and socioeconomic system** and identification of the main challenges and hazards, both current and future. This allows for the elaboration of a long-term, comprehensive vision, agreed upon by the different groups of actors, combining sustainable development and the needs of different sectors.

2. **Identification and analysis of potential NbS** appropriate for the context, comparing benefits and performances between measures, analyzing synergies and potential trade-offs, and using tools that support the decision-making process. This step also includes mapping NbS life cycles and service levels. [26]

3. **Definition of the preferred approach and strategy** for NbS implementation, which responds to the context in which they are found while prioritizing measures and identifying those that provide guaranteed results.

4. **Implementation, maintenance, and monitoring** of NbS and hybrid solutions, including an implementation plan indicating technical details, and an investment plan and actions to follow, including maintenance and monitoring. Monitoring can also involve the community and schools, creating links between the different sectors.

[26] Refer to Altamirano *et al.* 2021, p. 22.

Education and awareness about the risk and hazards that NbS help to face (for example, *"Diálogos del Agua, Panama"*[27]), are cross-sectional aspects of this process, as well as relevant social and cultural considerations for each context. This refers not only to the education of the communities, but also to the training of technicians and decision-makers. It is necessary to regionally collaborate and share the generated knowledge and the lessons learned in different cases, both from a technical point of view as well as regarding the failure or success factors. Sharing knowledge also entails integrating local, ancestral knowledge and women's perspectives in NbS planning and implementation, in an inclusive and collaborative process. This process should include local communities, indigenous people, and especially groups in vulnerable situations, contributing to creating rooted projects.

In addition to working with communities, suitable enabling conditions and comprehensive strategies at a larger scale (for example region, basin) are essential for scaling up and mainstreaming NbS. Appropriate enabling conditions are built in part by strengthening local capacities, both at the technical and governance levels, and the institutional memory on NbS in public institutions, to ensure the continuity of knowledge on this topic beyond each government's circumstances.

To fully understand NbS performance, long-term monitoring systems need to be established, which are especially relevant considering climate change effects and the uncertainty this poses. Long-term monitoring not only allows understanding the performance of the measures over time, but also their impact, that is, the level of service they provide in relation to the function for which they were designed. Additionally, when this process is carried out with communities, through initiatives such as citizen science, it leads to the community's empowerment and better understanding of their operation, which contributes to more robust NbS.

Finally, it is important to emphasize that, although in this chapter it was decided to break down NbS according to the types of hazards they face, NbS are complex and multifunctional solutions, and part of their value lies in being able to reduce various risks and contextually provide valuable co-benefits to the community.

[27] https://www.wetlands.org/casestudy/living-water-wetlands-flood-risk-reduction-panama-city/

Photography: Xalapa, Mexico
Source: © UNEP / Author: Josephat Kariuki.

Chapter

5

Overview of the planning and financing instruments that support urban NbS

Author: Melinda Lis Maldonado

5.1 Introduction

Recent years have seen important breakthroughs in climate and urban planning which are key to the implementation of Nature-based Solutions (NbS). However, NbS implementation in the cities of the region faces **two important barriers**. On the one hand, a disconnect between urban and climate policies, strategies, and regulations; and, on the other, insufficient, or difficult-to-access, financing sources, that prevent or hinder NbS implementation.

The first barrier is of two orders. The first is a vertical barrier indicating a lack of *carry through* of national policies, strategies, and regulations to the local level. The second is horizontal, expressed as a *disarticulation* or lack of alignment between urban plans and climate action plans or resilience strategies. This can be seen (i) in a disconnect in the objectives of these plans, (ii) in a statement of different issues to be tackled and, therefore, (iii) in the lack of articulation between instruments that are seeking to achieve different purposes. Thus, for example, urban plans do not recognize the climate risks assessed in climate action plans, and urban planning instruments are not designed to serve the fight against climate change (CC). This lack of connection is the result, in many cases, of sectoral planning processes that fail to articulate the responsibilities of each sector, or that are simply the result of processes taking place at different times. It may also be due to the segmentation of available information or due to the lack of information sharing between ministries within the same government. This translates into overlapping policies and profuse and confusing legal regulations that make implementation difficult.

The second barrier is related to NbS financing. Although climate financing has increased in recent years, the gap is still huge, particularly for CC adaptation finance, a situation that is especially critical in Latin America and the Caribbean.[28]

Given these obstacles, the main objective of this chapter is to reflect on **how certain urban planning and financing instruments can offer opportunities to overcome these barriers by supporting and facilitating NbS implementation.**

[28] According to the latest Intergovernmental Panel on Climate Change [IPCC] (2022a), adaptation is more focused on planning than implementation; and within the *soft limits* of adaptation in all regions, financial constraints have been identified as the biggest reported obstacle to climate adaptation in South and Central America, in addition to weak institutional capacity. To better understand these financial limitations, other aspects that are mentioned by the IPCC 2022b are that: a) climate financing has increased, but it has mainly focused on mitigation, b) there is little climate financing for adaptation and most of it comes from public sources, and c) adverse climatic impacts may reduce financial resource availability.

5.2 Urban planning instruments

In recent years, one of the more positive signs that has been detected is the growing rapprochement between climate and urban policies, strategies, and regulations. Indeed, different urban plans now recognize CC challenges, setting climate objectives, and aligning these with the national and international climate and urban agenda. For example, the Land Management Plan[29] (POT, in Spanish) for Bogotá (Colombia) now recognizes the climate emergency and is also aligned with the global Sustainable Development Goals (SDGs). Similarly, the Belo Horizonte Master Plan[30] [31] (Brazil) proposes sustainability as one of its guiding principles for urban development, including for climate change resilience.

This trend has been a gradual process, that has faced barriers, but also presented opportunities. One such opportunity is when the urban plan formulation processes take place simultaneously, or close in time, to the climate action plan formulations. This is the case of the Land Use and Management Plan (PUGS, in Spanish) in Quito and the POT in Bogota (see cases 1 and 2).

Another interesting aspect to highlight is when **urban or territorial plans consolidate previous practices and policies where different actors play key roles.** This can be noted specifically in the Sustainable Urban Drainage Systems (SUDS) regulation in the new POT in Bogotá. This legalizes, in a more systematic way, the different policies, regulations, and practices of the last 20 years, and where different actors —whether governmental, academic or from the private sector— have now promoted its implementation, as illustrated in figures 5.1 and 5.2.

Figure 5.1 shows an extended drainage dry basin in a public park, its implementation being the result of coordination between the local public sector and academia.[32] Figure 5.2 illustrates part of the Blue and Green Infrastructure (BGI)[33] program implemented by a private sector actor on private land, an investment far exceeding the standards required by the urban regulations.[34]

[29] The Land Management Plan of Bogotá, *"Bogotá Reverdece, 2022-2035"* (Greening Bogota), approved through District Decree No. 555 of December 29th, 2021.
[30] Belo Horizonte Master Plan. Municipal Law No. 11.181/19.
[31] Recife Master Plan. Complementary Law No. 2, April 23rd, 2021.
[32] The Bogota Aqueduct and Sewer Company (EAAB, in Spanish) and the District Environment Secretariat (SDA, in Spanish) through the inter administrative agreement No. SDA 01269 of 2013 established the need to promote a SUDS system. Under that agreement, they hired the *De Los Andes* University to study different typologies suitable for each sector in the city. As a result, the EAAB subsequently approved Technical Standard NS – 166-2018, Criteria for Sustainable Urban Drainage Design and Construction (SUDS), Bogota.
[33] For a definition of BGI, see Chapter 1.
[34] One of the developer's motivations was to obtain LEED Platinum certification, with the prestige that this entails, and another was to achieve water and energy savings. Both goals were achieved. The project has received other awards such as The Next Green Award 2016 Design Winning Project, Latin America Category.

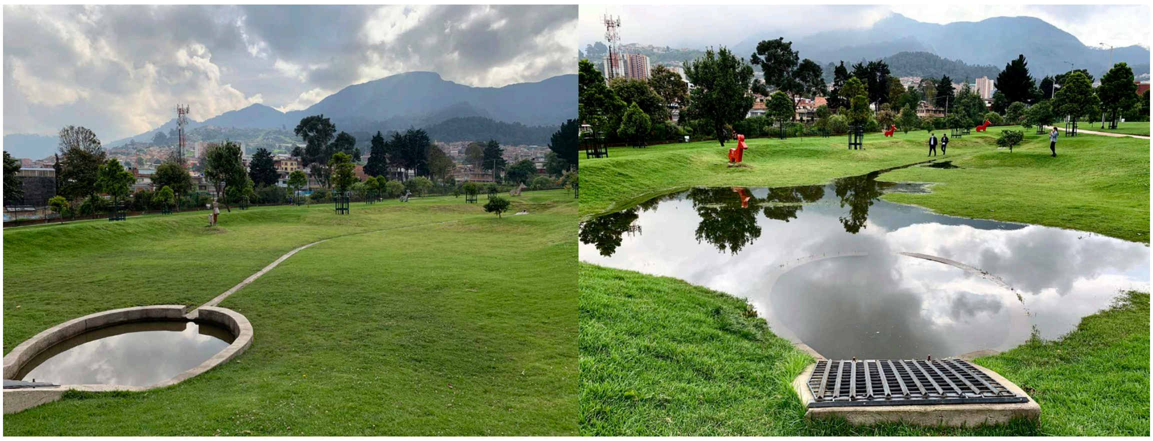


Figure 5.1: SUDS (extended drainage dry basin) in the *Metropolitano San Cristóbal Sur* Park, Bogotá, Colombia.

Source: Urban Development Institute, August 2019 (left) and February 2022 (right).

Figure 5.2: SUDS in *Elemento* Building (69th Avenue and 26th Street), Bogotá, Colombia.

Source: Urban Development Institute, November 2021 (left and center) and Luis Alberto Suarez, July 10th, 2017 (right).

In addition to these trends observed in the region, urban planning offers specific tools to address climate challenges, in the form of land classification, categorization, and qualification.[35]

Land classification and categorization involve the division and subdivision of land according to criteria that typically consider the intended purpose or actual use of the land. The starting point for territorial structuring is the land's ecosystems, its components, functions, and support capacities. Based on this foundation, decisions can be made to intervene in the territory with different measures, including NbS.

Zoning or land qualification is an urban technique through which land is differentiated according to its use, the intensity of its use, and the role it must play. The consideration of risks or climate factors in urban zoning, the assigning of mixed land use (in line with the model of the '15-minute city'), the possibility of changing land use intensities over time or due to adverse or extreme scenarios,[36] are alternatives that can be used to implement NbS effectively in different parts of the land territory. As an example, the primary purpose of harvesting rainwater may be to reduce stormwater runoff in periods of heavy rainfall, but harvested rainwater can also be used in times of drought and even as protection against fire risks. Even though the incorporation of uncertainty in urban planning is a great challenge, urban regulations should consider the risks and diverse scenarios that a city could face, regulating the legal framework for climate adaptation accordingly.

Perhaps the most relevant contribution of these urban techniques to climate challenges is to advance the establishment of a differentiated legal development rights and duties regime for each land class, category or specific territorial area. In many cities in Latin America and the Caribbean, especially those that do not have national regulations that encompasses land policies, these techniques are more concentrated around the recognition of land rights, rather than in the establishment of duties. A notable case is the Quito PUGS, where a set of building standards that include NbS for both urban and rural land have been established. These are mandatory for the basic exercise of development rights and are established in a differentiated way in the territory (see Case 8).

[35] These terms and their meanings in Latin America and the Caribbean are not used in the same way in all countries. However, it is used for educational purposes in this Chapter. For these concepts to be clarified in the comparative regional legislation in Spain, see Beltran Aguirre 2006.

[36] The intensity of water use rights could be modified in drought or water scarcity periods.

5.3 Urban financing instruments

Having navigated the challenges encountered in the planning phase, obstacles regarding implementation then need consideration. How to put in place NbS in practice?

Among the available alternatives, the role of land-based tools or land value capture should be evaluated. These are both management and financing instruments. Thus, they simultaneously answer the questions of how to implement NbS, and how to pay for it. The principles that legitimize the use of these instruments are mainly of two types. The first is that relating to an **increase in land value** brought about by a given public action, that can be recovered from the beneficiaries and reinvested.[37] The other principle is that of the **generation of negative impacts** caused by new urban developments, requiring reduction or mitigation actions. Across the world, there are varied regulatory mechanisms with differing characteristics based on these principles, that are deployed for different purposes.

These instruments show some advantages in relation to other financing mechanisms, two of which stand out. The **first** is that they are local instruments. The local dimension relates to the public powers over territorial planning and management, exercised mainly by municipal entities as well as by supralocal, subnational entities, in accordance with the legal regime in force. The **second** advantage is that these mechanisms allow for the involvement of different actors in financing (depending on the specific case), with obligations that involve doing something, not doing something, or making a payment in cash or in-kind. The involvement of external actors provides greater opportunities for public administration to deal with the budgetary limitations that they face. Through these mechanisms it is possible to manage and finance NbS by requiring private actors, for example, to execute SUDS, to undertake conservation measures, to make payments in cash with a specific purpose of financing an NbS, or to provide land for the development of a BGI. One consequence of the two characteristics mentioned is that these instruments promote ways of local self-financing, strengthening the autonomy of local entities and climate governance.

In previous research, a comparative analysis was carried out across three countries (Brazil, Colombia and Argentina) to measure the potential of certain urban development and tax instruments to address climate challenges (De la Sala, Maldonado and Alterman 2019), further developed into case studies deriving from this research (Maldonado *et al.* 2020). These research studies laid the foundations for an understanding of the subject, allowing the identification of certain types of instruments and their potential to achieve climate objectives.

[37] In this regard, see the Global Compendium of Land Value Capture Policies (*Organización para la Cooperación y el Desarrollo Económicos* [OCDE] and Lincoln Institute of Land Policy 2021).

Photography: San Salvador, El Salvador
Source: © UNEP / Author: Josephat Kariuki.

On this occasion, a proposal is made to advance the conceptualization of these instruments or mechanisms –urban development requirements on the one hand; and property taxes, fees or contributions on the other– based on their main legal characteristics.

Urban development requirements can be understood (in a broad sense) as those conditions that must be followed in exchange for the permission to build or engage in urban development. In this case, there is a bilateral relationship between the applicants (usually the landowners or developers) and public administration. The former seek development rights based on current regulations, and the latter grant or approve planning permits. Urban development requirements are intended to reduce the negative impacts of urban developments and/or finance processes for urban-climate development. In same legal system these conditions are called "developer obligations" or "charges for development rights".[38]

Property taxes, fees or contributions[39] can be understood as those impositions deriving from the power of the State, which can be levied independently of the taxpayer's willingness or desire to meet these charges. Depending on the type of mechanism, these may or may not be linked to some form of public services or works. These tools are characterized by their unilateral and compulsory nature, based on legal principles and the rule of law. They may have the purpose of collecting revenues (fiscal tools) or of promoting certain contributor behavior (extra fiscal tools).

Below is a comparative table of urban development charges and property taxes, fees and contributions emphasizing their main characteristics.

[38] See OCDE AND LILP (2021)

[39] Property taxes, fees or contributions being the three main taxation categories.

	Urban development requirements	Property taxes, fees or contributions
Type of duties	• *Giving something.* For example, giving cash, or the provision of land as a green public space. • *Doing something.* For example, executing a sustainable urban drainage system, or incorporating green roofs or surfaces. • *Not doing something.* For example, not waterproofing the floor.	Giving or delivering something. Generally, this is a payment in cash (for fiscal ends), but there may be exceptions. These exceptions seek to promote specific behaviors, for example, the reduction of waste, through home composting.
Legal source: typologies, level, governing body	Urban regulation, urban plans, urban or building codes. Generally local or supralocal (subnational) level. Legislative or Executive powers.	Taxation legislation. Generally local or supralocal (subnational) level. Always legislative powers (principle of legality).
Source of requi-rements	Voluntary nature: whoever wants to access development rights is not forced into a particular action, rather a bilateral relationship is generated between the developer and the public administration. Once the planning permits have been approved, the different kinds of duties become mandatory.	Power of the State: the State coercively and unilaterally levies certain obligations regardless of the taxpayer's will.
Cause	Linked to the public activity of the State: the granting of urban or building rights framed by a particular regulation.	Linked to owning or having rights of possession (property taxes). Linked to public services (fees) or to public works (betterment contributions).
Principles that legitimize their use	Increase in land value, and/or the negative impacts of the development	Increase in land value, benefits from services and public works.
Penalties for non-compliance with the inten-ded conduct	Not getting the benefit (urban or building rights).	Infraction (pecuniary penalty).

Table 5.1: Characterization of urban development requirements and property taxes, fees and contributions.
Source: Prepared by the author.

Understanding these concepts provides elements to strengthen decision making. Knowing in which cases the bases that legitimize their use can be used, and their purpose, is crucial in deciding their implementation, in communicating and raising awareness about their importance, and even in monitoring and evaluating their operation.

The most frequent modalities or typologies of urban development requirements and property taxes, fees and contributions are presented below. Following this typification, some regulations will be noted which require obligations that can be considered as NbS.

Urban development requirements have two modalities: basic or additional. From a broad perspective, *basic urban requirements* can be considered as the minimum requirements, which are set out in the urban regulations, to obtain basic development or building rights, whether this is for urbanization or for building purposes (identified in many legal instruments as standards or parameters). Some of these requirements have environmental and specific climate components. They have evolved from traditional instruments, such as land provision for parks or green spaces, to building standards that require SUDS, trees, or energy savings. There is a wide variety of regulations that include requirements that can be considered NbS. In some cases, cities have been gradually incorporating them to address priority risks. For example, the city of Santa Fe (Argentina) has incorporated a requirement for stormwater harvesting systems to prevent public drain collapses in the event of heavy rains, along with a requirement for permeable ground surfaces (Maldonado *et al.* 2020). The city of Xalapa (Mexico) requires the building of rainwater storage devices, promoting its reuse for the irrigation of green areas and vegetation in gardens in each dwelling.[40] Other cities are also incorporating different NbS requirements at the time of approval or review of urban or territorial plans, undertaken in a more cross-sectional and comprehensive manner. Such is the case of the PUGS in Quito, Ecuador (see Case 8).

When basic development or building rights have been granted, legislation may consider the possibility of increasing these rights. For this, public administration may require additional conditions be met. These are the *additional urban requirements.* Some of these conditions may incorporate an environmental or climate perspective. They can be of three types:

- **Conditions related to the same plot of land.** These include, for example, the requirement to incorporate green roofs, SUDS, or solar energy on the same plot of land accessed by the developer or landowner.
- **Conditions with a redistributive effect.** These include cash payments for additional development rights using specific instruments, with the possibility of reinvesting and redistributing those revenues to other areas.[41]
- **A combination of both.** They include the combination of tools on the same plot of land, with redistribution as an objective.[42]

[40] Articles 248 and 250 of the Urban Development Regulation for the Municipality of Xalapa, Veracruz, Mexico, published on January 20, 2016.

[41] In one Mexican case, building rights beyond the height limits are granted to a trust, which sells them and uses the proceeds to finance public infrastructure projects, including NbS for flood mitigation (Ozment *et al.* 2021).

[42] An innovative mechanism is the one established in the PUGS in Quito, which, in order to access the additional building rights, requires compliance with certain standards that incorporate NbS in the property, without sacrificing the payment for additional rights (called Onerous Concession of Rights [COD in Spanish]).

Proportionality is a fundamental criterion in designing and implementing urban development requirements. This means that the impact of the duties must be equivalent to the benefits of the builder/ developer. This criterion emphasizes the risks of encouraging the execution of environmental or eco-friendly measures through density bonuses, without measuring the negative impact of the additional development rights granted.

Case 8

Sustainable standards to access building rights in the PUGS in Quito (Ecuador).
Location: Metropolitan District of Quito (Ecuador).
Key actors: Quito Metropolitan Government (mainly Quito's Secretariat of Territory, Habitat and Housing and Municipal Financial Administrative Management).
Year: 2021

In September 2021, the update of the Metropolitan Development and Land Management Plan (PMDOT, in Spanish) and the Metropolitan District of Quito's Land Use and Management Plan (PUGS) were approved. By approving the PUGS, for the first time in its territory Quito anchored the content of Ecuador's recent Organic Law of Land Planning, Use and Land Management (LOOTUGS, in Spanish) creating new rules and methodologies that demand a plan with characteristics that address local and global challenges, including CC. The PMDOT and PUGS preparation process was carried out in parallel with the Quito Climate Action Plan (PACQ-c40 Cities), approved in January 2021. The parallel timing of the two instruments allowed their alignment and integration, which started with the identification of similar problems, and an intent to achieve the same goals (SDGs) through prioritized programs and actions. In territorial terms, this alignment resulted in one of the main decisions made by PUGS: a classification of the territory into urban and rural areas, which must be respected for twelve years. For this, multiple criteria were considered, including risk factors.

One of the most innovative aspects of the PUGS is the regulation of urban management and financing instruments. Through these tools, climate challenges gain greater relevance, and so do the NbS measures to address them. An example of this are the "sustainability" requirements for accessing basic and additional development or building rights. The Quito PUGS establishes basic building rights, which can be exercised when certain standards are followed, without having to pay the Municipality for these. But in order to access to additional building rights, it is necessary to meet additional building standards and to pay the 'Onerous Concession of Rights' (COD), an instrument that captures the increase in land value from these additional rights, so that the revenues generated can be redistributed later.

These standards are applied to both urban and rural land. While in urban land the project scale is the main consideration; in rural land, the type of land use is the main consideration. Sustainable standards that include NbS relate mainly to water management, native vegetation, and vegetable gardens. An example is that on both rural and urban land, 20% plant cover is required, and 5% of plants must be native. Moreover, there is a scoring system that allows these percentages to be increased, with vegetable gardens, rain gardens, and composting generating extra points. In relation to water, there are different measures of permeability and rainwater harvesting and reuse, the efficiency of water consumption, gray water reuse and management, the use of infiltration ditches, and of water effluent management.

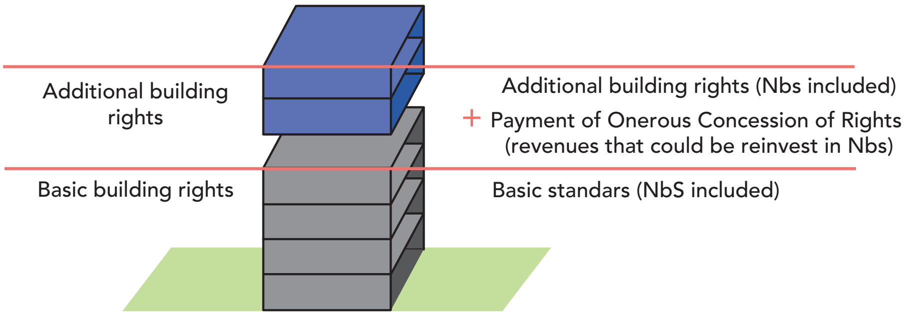


Figure 5.3: Relationship between building rights and building standards.
Source: Adapted from PUGS in Quito (2021), Annex: Standards

One noteworthy aspect is that, in order to access additional building rights, COD payment must not be relinquished. Without the use of this instrument, beneficial measures would only be obtained in the place where the building takes place. Whereas COD generates resources from the use of additional building rights in one place, in order to finance measures in other areas of the city that require priority intervention, a great challenge and opportunity for climate justice.

Regarding financial charges linked to land use, the three most traditional types in Latin America are taxes, fees, and betterment contributions.[43] Many of these have incorporated an environmental/climate perspective for a number of years now; particularly property taxes. Each of these tools has characteristic elements (subject of taxation, tax base, tax rate, etc.), presented below in a generic way:

Property taxes are applied for the mere fact of owning or having certain rights in relation to a property. They generate recurrent resources for territorial entities to fund their general budgets. An observed trend here is the reduction in these taxes as a reward for sustainability measures implemented by the taxpayer. These measures, which can be considered NbS, might include the creation and maintenance of permeable zones on the land, on sidewalks, rainwater harvesting and reuse, among others. In Brazil, for example, there are many cities that have implemented a green property tax (green IPTU, in Spanish) (Azevedo and Portella 2019). This mechanism is an alternative that can be considered given the criticality of climate impacts and the urgency in achieving NbS, when it is not possible to wait to obtain NbS as a condition of the approval procedure of development or building permits.

Fees are tools linked to the provision of public services. They are levied as long as those public services are being provided. These services may have environmental components such as garbage collection, efficient lighting, or storm drain maintenance. In certain localities some proposals for the reduction of municipal fees connected to public services were initiated with the implementation of home composting, but there were difficulties in their implementation and continuity.[44] The approach is interesting, given that it does not only reward the additional environmental effort –of composting– but its implementation means a reduction in waste generation and, therefore, in the public collection service.

Betterment contributions are taxes linked to the implementation of public works that produce an increase in land value that benefit land or property owners or developers. This instrument has a long tradition in countries such as Argentina and Colombia infrastructure levy.[45] Its use is more linked to carrying out gray infrastructure (such as public roads) and, in some cases, to the development of green spaces. The mechanism has a lot of potential for financing BGI or for incorporating complementary NbS in traditional gray infrastructure. A case in point is the incorporation of SUDS as complementary to mobility or transport infrastructure projects as highlighted in Bogota, where infrastructure levy are expected to be used (see Case 9).

[43] These are the more traditional types. However, in some countries some variations can be noted.

[44] In *Puerto Yeruá* and *La Criolla*, two small towns in the province of Entre Ríos in Argentina, the "organic zero" program was proposed, with the idea of reducing the local fees for public services, for residents who adhere to this program by carrying out composting.

[45] According to OCDE-LILP taxonomy (2021).

Case 9

Infrastructure levy to finance sustainable transport infrastructure or other public spaces, with NbS components in Bogotá (Colombia)
Location: District of Bogotá, Colombia.
Key actors: Institute of Urban Development (IDU, in Spanish) of the District of Bogotá.
Year: 2018- present

In recent years, the District of Bogotá has begun to venture into SUDS[46] design and construction that can be financed from different sources depending on their characteristics and the processes to which they are linked. Of these, SUDS financing stands out as an innovator with an infrastructure levy instrument as a component in projects executed by the IDU that are contemplated in local tax legislation. Colombia has a great tradition in the use of this tool. This instrument allows the cost of public works to be distributed among the landowners who are benefited by the works, taking account of their taxable capacity and certain criteria for calculating the benefit accruing to the landowners. In recent years, the IDU of Bogotá has financed some NbS with this instrument,[47] specifically SUDS, as a complement to works in public spaces or transport infrastructure.

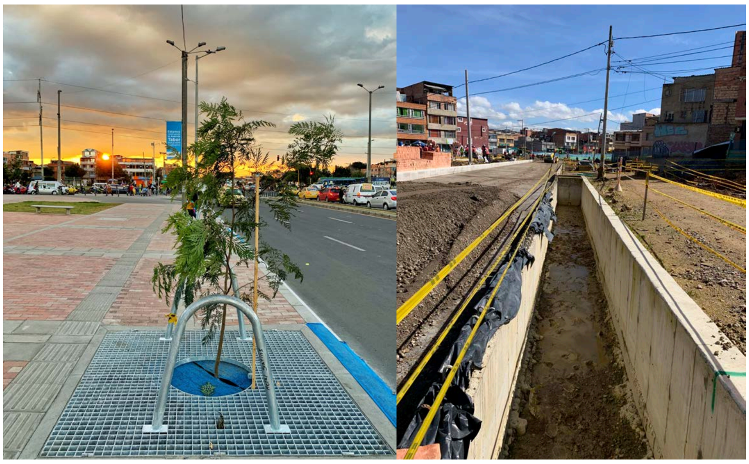


Figure 5.4: Floodable pits on Rincon Avenue, Suba, Bogota (left) and infiltration ditches with bioretention zones under construction on Rincon-Boyaca Avenue (right).
Source: IDU, August 2019 (left) and IDU, June 2022 (right).

[46] In accordance with the Technical Standard NS-166 guidelines of 2018 that identifies the most appropriate SUDS types for implementation in Bogotá.
[47] Not all the works carried out by IDU are financed by infrastructure levy; to be financed by this instrument they need to have legal approval and meet certain requirements.

The execution of public works contemplated in Act 724/2018 is currently underway in Bogotá. This regulation specifies the public works to be achieved and their schedule. Likewise, the areas of influence of the works are set out, based on an analysis of the geographic extent of the benefit for each of these areas, and identified in the map attached to the said regulation. Another relevant aspect is who pays for the works. The norm specifies that the landowners or holders or those with possession rights that are within these three areas of influence (i.e., the direct beneficiaries) are those who pay for the works. Not all pay the same amount. Cadastral value is considered, weighted by the distance of the property from the public works and/or accessibility to the public works (art. 6). This tax is recorded as a levy in the registration of the property, and the property holders are notified of the payment required. They can either pay in cash outright, in installments, or by the transfer of some land to the District municipality as required by IDU, for the construction of public infrastructure works (art. 15).

Among the works committed to in this regulation, IDU has incorporated some SUDS. One example is the sidewalks and bike lanes on 116th Street (Figure 5.5), between the Northern Highway and Boyacá Avenue, financed through the levy infrastructure mechanism. IDU is in charge of execution of the works, and in one area, it has implemented eight bioretention zones.

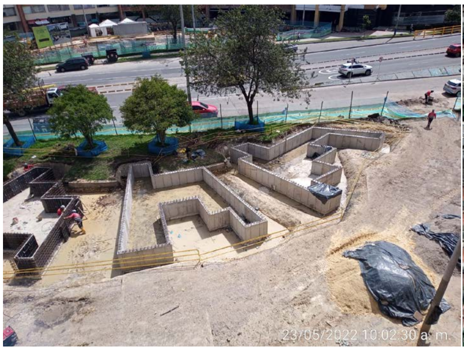


Figure 5.5: Bioretention zones, Bogotá.

Source: IDU, June 2022 (left); bioretention zones implantation area from aerial view of 116th Street and the Northern Highway, based on Google Earth (10/2/2021) (right).

Photography: San Salvador, El Salvador
Source: © UNEP / Author: Josephat Kariuki.

5.4 Challenges in the implementation of land-based instruments using NbS

Urban planning and management instruments have great potential to support NbS implementation. However, their implementation poses some challenges that make these processes difficult, among which the following are notable:

- Limitations in the institutional capacity of local governments
- Misunderstandings about, or overlapping, territorial competence and responsibilities of any given agency
- Segregated, insufficient or unshared information undermining understanding of what is happening or which solutions are being implemented
- Rigidity and unpredictability in urban regulations in dealing with uncertainty and the diversity of climate scenarios
- A lack of knowledge of the principles that legitimize the use of certain land-based financing instruments, the periods of their enforceability, and their legal nature
- An absence of monitoring and evaluation of the instruments that are implemented in order to measure their usefulness and make necessary adjustments.

Conclusions and suggestions for decision-makers

This chapter opened with the recognition of two barriers to NbS implementations. The first is a disconnect in the policies, strategies, and regulations, as implemented vertically and horizontally; and the second barrier is in the financing of NbS, a critical aspect worldwide, but aggravated in the region by limitations in institutional capacities. Recognition of these problems allows some progress in understanding the potential for urban planning and land-based instruments, to address these barriers.

In particular, examining the disarticulation between climate planning and urban planning, there are some urban planning tools that facilitate the connection with climate challenges and that lay the foundations for subsequent NbS implementation, namely land classification, categorization, and qualification.

Land-based financing and management instruments offer specific advantages for supporting NbS implementation, given their local nature and the involvement of other actors in their financing. As a requirement for the granting of development or building rights, NbS or financial resources may be required. Property taxes, fees or betterment contributions can also incorporate NbS, as a means of achieving fiscal (tax collection) or extra fiscal (promoting NbS implementation) purposes.

Although the use of these instruments will depend on the legal regimes of each country and city, some general recommendations are made that could be useful to decision-makers involved in NbS implementation, using these planning and land management instruments. They are expressed as suggestions and take up some of the main aspects highlighted in this chapter.

- The articulation of local policies with national policies and with international urban and climate change agendas.

- The alignment of climate and urban planning at a local level, promoting simultaneous policy formulation processes, or adapting those procedures that have taken place at different times. The following should be sought in particular: the alignment of objectives for climate and urban plans, the evaluation and common recognition of climate risks, the articulation of instruments, a structuring of the territory based on ecosystems, and the establishment of a regime based on the rights and duties of the land in a differentiated and appropriate way for each area in the territory given its problems.

- The analysis and implementation of land-based instruments –urban development requirements and taxation tools– as mechanisms for NbS financing.

- The consideration of the particular characteristics of each case (of the contexts in which they are applied, and the aspects that legitimize their use and their purpose), to decide when and how to use each instrument.

This last point is key. The timing of the approval of building or development permits is a unique opportunity to consider the negative impacts of the development and to require conditions (including NbS) to access the permits, guided by the principle of proportionality, to be duly regulated in a specific piece of legislation. Access to additional building or development rights following on from additional climate action measures, such as NbS, must be carefully evaluated to avoid negative impacts. In particular, it is recommended that these measures do not renounce cash payments for these additional rights (since these allow the redistribution of benefits) and that the measures are based on an assessment which evaluates their contributions to climate plans, with clear rules on the minimums and maximums of these land use rights in each zone in the city. Reductions in property taxes arising from the implementation of environmental measures and NbS can be a viable alternative in the face of the urgency of climate adaptation, but the fact that it implies the reduction of public revenues that could also be used for these purposes must also be considered. Therefore, it could be envisioned as a temporary measure. While the fees and betterment contributions are tools linked to public services and public works, respectively, incorporating NbS within them would allow the financing of these measures.

In all cases, building institutional capacities in planning and especially in climate financing, as well as in the monitoring and evaluation of instrument implementation, is seen as fundamental. This is crucial in determining whether they are working to meet the objectives set and in addressing the challenges that have been recognized.

Those who participate in the legislative, planning, and management processes in urban and climate fields are facing a unique opportunity to vindicate the role of nature through the incorporation of NbS in a cross-sectional and comprehensive way in these matters.

Photography: San Salvador, El Salvador
Source: © UNEP / Author: Josephat Kariuki.

Chapter

6

Analysis and valuation of NbS impacts

Authors: Tom Wild, Mariana Baptista and Mariana Giusti

6.1 Introduction

This chapter focuses on specific aspects of the relationships between the urban climate finance gap, and the need for stronger NbS impact assessments. It does so by unpicking key challenges, examining NbS innovations, business cases and governance, and exploring the use of performance data and indicators to support wider implementation in cities. We build on the earlier chapters' review of key concepts[48] and risk analysis,[49] understandings of the benefits of citizen participation,[50] and cases of planning and decision-making around NbS in Latin America and the Caribbean.[51] These provide invaluable insights into opportunities and challenges to the uptake of NbS, as well as providing the chance to re-examine framings of NbS from elsewhere in the world.

Traditionally, there has been little evidence of private sector investment in nature conservation and restoration (Dempsey and Suarez 2016) although there is the possibility that this may change as a result of natural capital accounting and the international climate mitigation markets, the so-called "carbon market" being the most famous one. At present time, interest has grown rapidly in business cases (Mayor *et al.* 2021) around NbS, and their role in a nature-positive economy (EC 2022a).

In March 2022, the increasing interest in understanding the economic benefits of NbS, as well as the cost-effectiveness of interventions, was addressed at the Fifth Session of the United Nations Environment Assembly (UNEA). The discussion resulted in an updated definition of NbS that takes into account the provision of "economic benefits" as well as other principles, including "cost-effective" and "resource-efficient" interventions (United Nations Environment Assembly [UNEA] 2022).

Whilst there may be legitimate and understandable concerns around the risks of greenwashing (Friends of the Earth International 2021), this oversimplified message may be unhelpful where NbS are viewed from only a climate mitigation perspective or where NbS are framed only in terms of rural, existing green areas, nature reserves and protected habitats.

The term 'Nature-based Solutions' acts as a useful umbrella concept for several valuable intervention types but the assembly of such broad sets of activities may also mask important differences between different NbS. Urban NbS offer real scope to bring nature back into areas where it is urgently needed, including to help solve social and economic problems in cities. Interventions such as sustainable drainage (Kozak *et al.* 2020), urban forestry (Barona *et al.* 2020) and daylighting of culverted rivers (Wild, Dempsey and Broadhead 2019) can deliver multiple wins including reduced flood risk, water pollution, air quality and heat island benefits (Wild, Freitas and Vandewoestijne eds. 2020; European Environment Agency

[48] See chapter 1.
[49] See chapter 2.
[50] See chapter 3.
[51] See chapter 5.

"Overall, there is good evidence related to the costs and benefits of increasing urban green space, albeit almost all in case study form. These demonstrate convincingly a wide range of positive benefits coming from increasing and maintaining higher levels of urban green space. Due to the wide variation, however, in many aspects of the studies, such as the climate/locations/type of urban space, and the (often limited) parameters being investigated - pollution, energy, water runoff, health and well-being, climate mitigation, etc.-, it is not possible to monetize some of these benefits in a generalized manner. Indeed, the high number of multiple co-benefits provided by using NbS to urban challenges tends to mean often the full benefits of urban green space and tree cover are underestimated. So, while it has not been possible to undertake a traditional cost/benefit analysis, as can be done on single issues, evidence points to the clear net positive values of halting the loss of, and then restoring green urban spaces." (EC 2022b, p.94).

[EEA] 2021). With the wide availability of the international stormwater best management practices database (Clary *et al.* 2017), it can hardly be argued that insufficient evidence exists on the specific benefits of sustainable drainage, or the clear case for implementing these NbS.

These demonstrable benefits of NbS and the supporting data encompass the so-called 'business case' for return on investment within appropriate payback timescales. It is important to distinguish that the investor in a business case may be from any sector of a society (including the public sector), whereas the term business model (George and Bock 2011) refers specifically to organisational structures put in place to realise commercial opportunities, i.e. specifically in the private sector.

NbS investments often produce a mix of multiple benefits (including ecosystem services), some of which can be difficult to quantify in monetary terms, including public benefits that do not necessarily produce direct financial revenue streams (Wild, Henneberry and Gill 2017). The use of typical market mechanisms such as private development schemes to deliver Blue-Green Infrastructure[52] is restricted, because the goods arising from such investments have a high degree of non-excludability and non-rivalry (Wilker and Rusche 2014).

In the subsequent sections, the interrelationships between these various strands are further explored, and illustrated using place-specific and strategic case studies.

[52] See chapter 1.

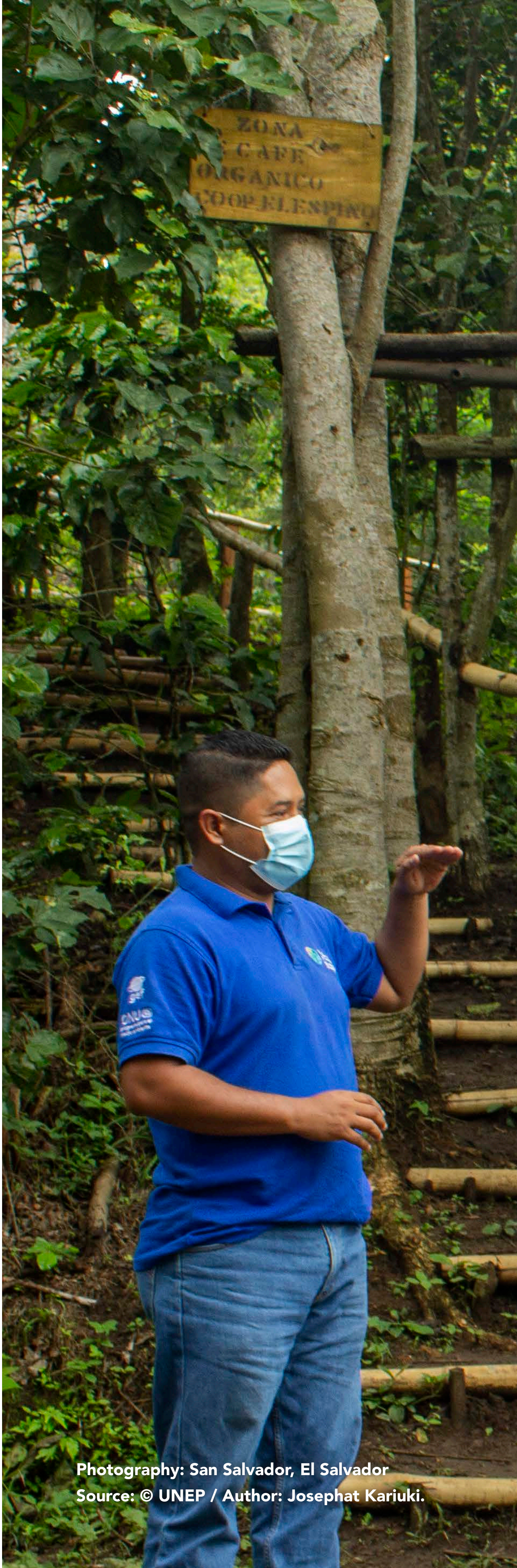
6.2 Background: are better data required to unlock urban NbS Finance?

NbS provide multiple functions and benefits drawing on natural mechanisms, enabling cities to adapt to environmental changes and socio-economic challenges whilst also enhancing biodiversity (Miyahara *et al.* 2022; UNEA 2022).

These functions and benefits deliver across diverse agendas and policy sectors in cities, making NbS cost effective responses to challenges such as climate change adaptation (Wild, Freitas and Vandewoestijne eds. 2020)

However, on a global basis, cities face critical shortages in urban climate adaptation investment for NbS. There is a shared urgent need to find new mechanisms to bridge gaps between cities' funding needs c.f. the finance for adaptation using NbS (Swann *et al.* 2021).

Some authorities have called for the increased monetisation of NbS, suggesting that demonstrable performance metrics may support this process to increase private sector participation and unlock new and diverse funding streams (Marsters *et al.* 2021). This raises the importance of ongoing performance monitoring and evaluations to help verify expectations and provide proof of concept to investors. The lack of economic valuation of NbS benefits remains a key barrier to development and implementation in Latin America and the Caribbean (Vásquez and Dobbs 2020). Demands for better evidence of NbS impacts have been common, particularly as regards the quantification of NbS cost-benefit effectiveness (Whiteoak 2020) but the sharing of data on the prices-side of



Photography: San Salvador, El Salvador
Source: © UNEP / Author: Josephat Kariuki.

NbS remains rare, let alone on the values side (Wild, Dempsey and Broadhead 2019).

These two challenges –to find funding for NbS that deliver benefits across multiple sectors and domains on the one hand, and the need for evidence on cost-effectiveness on the other– may well be strongly related to one another, and this relationship provides the focus for this chapter.

6.3 Why are urban NbS values and valuations becoming increasingly important?

Improved, practicable guidance to bridge the gap between data on NbS performance, and economic valuation, will be vital to support robust proposals to access funding from development finance institutions. For instance, the UN Adaptation Fund, to which the EU alone is contributing US$100m, will require stronger business case analysis, and more robust treatment of the logic chain for management interventions. Established examples include the Food and Agriculture Organisation's (FAO) 'Bankable Business Plans' model and associated guidance (FAO 2021).

Between 2010 and 2014, cities received less than 5% of global adaptation finance (Global Commission on Adaptation [GCA] 2019; Richmond, Upadhyaya and Ortega Pastor 2021) despite containing more than half of the world's population. As discussed in chapter 1, the vast majority of investment in ecosystems restoration using NbS continues to 'land' in rural areas, as exemplified by the Finance Earth Market Review (2021). Notable exceptions often involve water treatment or water management, often at the catchment scale (and so encompassing peri-urban and rural areas).

Urban adaptation finance includes only activities that address urban climate risk which directly affects the city and urban communities and/or occurs within the municipal boundary, whereby, according to the Climate Policy Initiative (CPI) key challenges in mobilising urban climate adaptation finance include (CPI 2020):

1. Incongruity with development finance institutions' mandates;
2. Low diversity of revenue streams lacking use of lucrative income, sales, and fuel taxes;
3. Lack of jurisdictional control at relevant scales;
4. Low credit worthiness;
5. Poor policy, institutional and market environments;
6. High cost of projects and unknown value added;
7. Lack of technical capacity; and
8. Limitations of private insurance.

Three of these challenges are of particular relevance here, namely the added value and cost effectiveness (6), technical capacity (7) and weak (governance) 'environments' (5). Additionally, in Latin America and the Caribbean, a lack of region-specific information and methods may result in different and sometimes erroneous outcomes (Dobbs *et al.* 2019).

The Horizon 2020 Grow Green project reviewed several innovative approaches to financing NbS in cities (Baroni, Nicholls and Whiteoak 2019) addressing direct investment by municipalities and incentives to encourage others to implement NbS. This provides a useful summary of examples across the full spectrum of societal challenges, using a range of instruments (Wild and Henneberry 2020), including:

- using public health budget contributions for, for example, green prescribing;
- implementation within school premises or utilising education department budgets;
- redirection of drainage, leading to cost savings in water treatment;
- use of charitable funds such as lottery budgets to combine NbS with heritage programmes;
- philanthropic contributions at the global and local scales, e.g. donations to support deprived communities;
- crowdfunding of smaller projects not necessarily suitable to benefit from other financing instruments;
- land value capture mechanisms, relating to land sales, leases or developer contributions;
- funds linked to offsetting or compensation, for instance carbon offsetting;
- taxes at the national, regional and local scales;
- bonds, endowments, and other financing facilities.

These challenges are of course interwoven, and may stem from poor assessments of impacts, either in terms of systemic flaws (e.g. double counting; incommensurability of data) or indicators that lack specificity. Either can undermine the business case for NbS implementation by cities (i.e. municipal and regional government authorities).

Furthermore, innovative accounting approaches often employed in NbS propositions may sit too far from cities' socio-political realities, their extant calculative practices, and their norms in terms of economic planning and decision-making processes. The result may be a mismatch between policy-relevant evidence, and policy decisions themselves. Take for example the calculated welfare value of UK greenspaces assessed at £25.6bn (approx. US$31.1bn) which is in stark contrast to deep cuts in UK greenspace budgets (Day and Smith 2018).

However, cities have the option to **remove one of the most important barriers to producing robust NbS business cases** in cities, which is to maintain a coherent, consistent and straightforward narrative for NbS implementation. This can be achieved by basing the argument on less complex economic modelling of a more modest set of societal challenges, using simpler messages that strongly resonate with citizens' perspectives of their city, and the associated socio-political contexts. Doing so may allow proponents for NbS to better handle complexity of land use and land ownership issues, by developing a more manageable scope and span for NbS impact assessment frameworks.

6.4

Why might simpler, participatory frameworks for NbS impact assessment help with valuation and business case development?

Analysing the market for NbS, in terms of demand (buyers) and supply (sellers), can assist in better understanding barriers to adoption as well as strategies and instruments to overcome those challenges (Whiteoak 2020). We can seek to better understand the market for NbS in terms of the cities themselves as customers, and the NbS benefits that those cities want or need to 'buy'. Two such cases are described below:

Photography: Xalapa, Mexico
Source: © UNEP / Author: Josephat Kariuki.

Case 10

Impact assessment of Medellín's Green Corridors
Location: Medellín, Antioquia, Colombia.
Recipient: Medellín's Mayor's Office.
Team: Physical Infrastructure Secretariat and Environmental Secretariat of Medellín with C40 cities and Ramboll.
Year: 2016-2019

Medellín is the capital of the department of Antioquia, Colombia. It is the second most populous city in Colombia with 2.3 million inhabitants. The Green Corridors project (*Corredores Verdes*) was implemented by the Government of Medellín between 2016 and 2019 (*Alcaldía de Medellín* 2021) and includes 36 corridors (18 associated with the transport system –developed by the Physical Infrastructure Secretariat– and 18 associated with streams and hills –developed by the Environmental Secretariat–), covering 65 hectares with 10,270 trees, bushes and palms. The project aims to reverse the negative impacts on the environment and public health from high Urban Heat Island intensity (UHI) and pollution. Medellín recorded the highest diurnal intensity (UHI) and by 2040-2050 it is estimated that for 150 days a year it will exceed the threshold of 29°C (Occam's Typewriter 2012) (although this is not a climate risk, the increase in temperature due to climate change could worsen its effects).

In addition to more traditional assessment of greenhouse gas emissions reductions (i.e. climate mitigation) and the climate change impacts risks (i.e. climate adaptation), relevant co-benefit indicators include environmental, social (employment generation), health and economic data. Using the "Heat Resilient cities tool" (produced by C40 cities and Ramboll with input and feedback from experts and city representatives) two climate change scenarios were evaluated:

- RCP[53] 2.6 (global average temperature increase by 2100 of 0.9 to 2.3°C), followed by emissions decreasing significantly from 2020 and reaching zero in 2100.
- RCP 8.5 (increase in global average temperature by 2100 between 3.2 -5.4°C).

Co-benefits calculated using the Tool (C40 cities 2021) were as follows (Figure 6.1):

For the first scenario, a decrease in urban heat of 2.72° C (above the 1,5°C Paris agreement target) and 49.5 fewer days per year above the risk temperature threshold

[53] RCP, or Representative Concentration Pathway, are scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases (GHGs), aerosols and chemically active gases, as well as land use/land cover. RCP2.6 refers to one pathway where radiative forcing peaks at approximately 3 W m–2 before 2100 and then declines. RCP8.5 One high pathway for which radiative forcing reaches greater than 8.5 W m–2 by 2100 and continues to rise for some amount of time (IPCC, 2022).

would be achieved, which means avoiding 513 deaths per year related to heat stress. This translates to an economic impact of USD 153 million. If this action was projected to the 12% of Medellín, 33,919 avoided deaths between 2020-2030 were associated with savings of USD 10.2 million for the same period.

In scenario 2, the urban heat reduction value is maintained at 2.72ºC, while there are 70 fewer days per year above the risk temperature threshold, avoiding 688 deaths per year with an economic impact of USD 155 million. Projecting this scenario to the 12% of Medellín, 45,471 deaths would be avoided saving USD 10.2 million for the period 2020-2030.

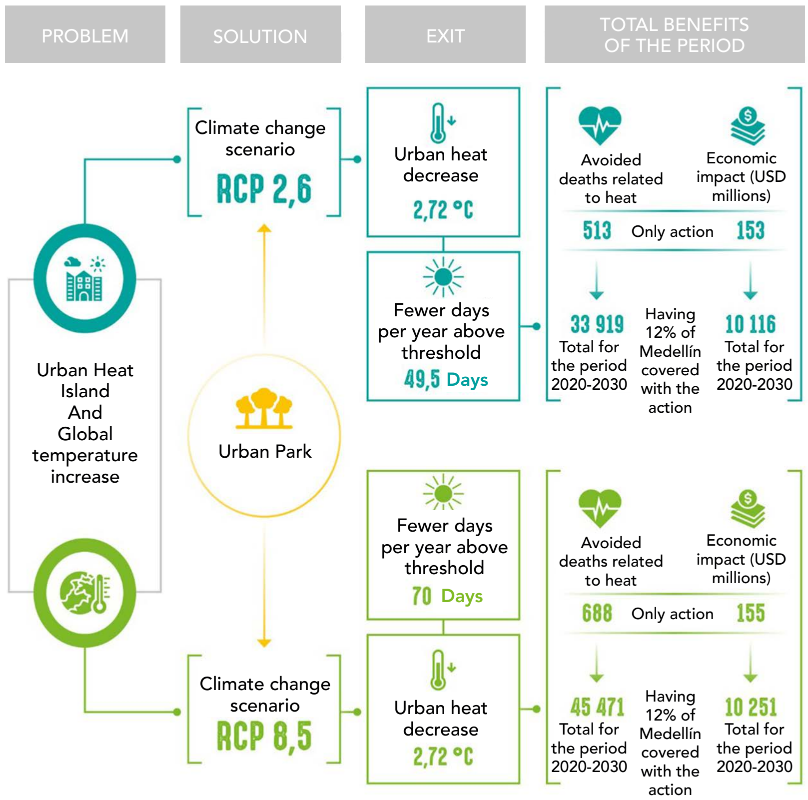


Figure 6.1: Up. Co-benefits of Green Corridors Project. Down. Pictures from the Green Corridors Project

Source: C40 cities 2021; Medellín, *Alcaldía de Medellín* 2017.

Case 11

Urban trees as an asset: monetary valuation of trees, Ibirapuera Park, São Paulo, Brazil.
Location: Sao Paulo.
Research team: Urban Forestry Laboratory, University of São Paulo, ESALQ campus *(Laboratório de Silvicultura Urbana/ESALQ/USP).*
Year: 2010

The Ibirapuera Park is located at the heart of Sao Paulo (Brazil), one of the largest metropolises of Latin America and Caribbean. Created in August 1954, the park has a green area of 1.6 million m², and receives more than 18 million visitors per year (Prefeitura de São Paulo 2021). Much of the park is covered by trees, with approximately 15,000 trees providing multiple benefits for users and surrounding areas. However, the value of these benefits is often not as evident as the costs of implementation and management, which can cause citizens to question whether the investment allocated is justified by the benefits they provide (Silva Filho and Tosetti 2010).

One way to demonstrate the value of trees in a green area is through their monetary valuation. The value of each tree in the Ibirapuera park was calculated using inventory data, which included size, general condition, location, biometric data and frequency of the species at the site. The most valuable tree, a *Cedro* (*Cedrela fissilis* Vell.) located on the jogging track, was valued at approximately Brazilian Reais R$ 21,500 per tree. In total the Ibirapuera trees asset was valued at approximately R$ 31 million (approx. US$17 million or €14 million), considering trees' individual values, and R$ 94 million (approx. US$52 million or €42 million), considering trees' relative values.

Monetary valuation of trees is just one of the indicators that can support decision making and conservation in nature-based solutions interventions, since trees are only one layer of these areas. Other indicators were not considered in this calculation, such as the risk of falling index and more subjective aspects, such as the historical value, and the users' perception of aesthetic value (Silva Filho and Tosetti 2010).

Figure 6.2: Aerial view of Ibirapuera Park
Source: Leo Martins/Veja SP

These invaluable case studies illustrate how a more targeted assessment of economic values of NbS can be both powerful and purposeful. However, which impacts to focus upon, and which indicators to apply, depends on the specific place considered, and this demands more nuanced and participatory assessment frameworks (see *Recommendations* section, below). Establishing the economic case for NbS such as urban green infrastructure is important if local authorities and private enterprises are to continue to invest in urban greening, as is the need to balance social or ecological needs with economic viability.

Several different reasons exist for undertaking such economic analyses, and it is important to understand the contexts for the decisions to carry out such investigations. Such *decision contexts* can include (1) awareness-raising; (2) accounting; (3) priority-setting; (4) design; (5) calculation of economic liability; and (6) understanding development dynamics and economic viability (Barton 2015; Wild, Henneberry and Gill 2017).

Ultimately, most NbS economic valuations share in common some form of analysis of their benefits, utilities or impacts, as the basis of understanding their cost-effectiveness. This may entail comparison with other (conventional, grey) infrastructures or responses. Therefore, the ways in which the various benefits of NbS are framed, synthesised and integrated becomes centrally important in how their economic values are understood.

At present, three main approaches have gained ground in the assessment of NbS impacts: (1) the Eklipse framework (Raymond *et al.* 2017) (2) the IUCN Global Standard (Cohen Stracham *et al.* 2019), and

(3) the EC's Impact Assessment Handbook (Dumitru and Wendling 2021). These frameworks agree on the need to support and enhance biodiversity and ecosystem integrity (Seddon *et al.* 2021); all stress the importance of co-designing NbS with citizens and stakeholders.

Furthermore, these frameworks share in common their comprehensiveness in terms of ecosystem services, the wide variety of benefits to be assessed, and their complex technical support requirements (e.g. IUCN offers training at cost and requires assessment of results by a panel of experts). The scope and span of an envisaged NbS programme or project in an urban area, according to these frameworks, could thus become hugely demanding of data.

In rural areas, where land use management and land ownership patterns tend to be far simpler (fewer larger blocks of land under similar usage and ownership), assessing multiple benefits and impacts in terms of ecosystem services may be relatively straightforward. This may explain why natural capital accounting, which is heavily reliant on GIS and spatial data, has tended to be used more often in agricultural and other non-urban contexts.

However, research in Conexus[54] (an international cooperation on NbS and ecosystem restoration between Latin American and European partners) found that the uptake of these frameworks by cities in Europe and Latin America is limited, and also that such assessment frameworks tend to lack critical governance indicators (Van der Jagt *et al.* 2022). Furthermore, the three frameworks do not explicitly address scaling issues or specify detailed *decision-contexts* described above. The results echo earlier findings that overly complex tools and approaches to promote green economy are rarely applied in urban green space planning (Davies *et al.* 2015). It may be the case that the realms of what may be deemed possible or desirable in assessing NbS impacts could be based on understandings and routines derived in rural areas, which may be less relevant or wholly impractical in urban contexts.

6.5 Summary of barriers and challenges

Urban municipal and regional authorities face dual challenges to adapt to climate change and to secure finance for this transition whilst achieving mitigation through reduced Greenhouse Gases (GHG) emissions. Global climate finance represents a potential opportunity to invest in urban NbS, but investors require sound business cases, usually based on monetary valuation.

The multifunctionality of urban NbS represents their key strength but also means that proving their impact in terms of cost-effectiveness can quickly become complex and onerous. Large amounts of data exist on NbS performance for certain solutions, such as sustainable drainage and urban forestry, but these benefits are often context-specific, and the data may not be readily transferable.

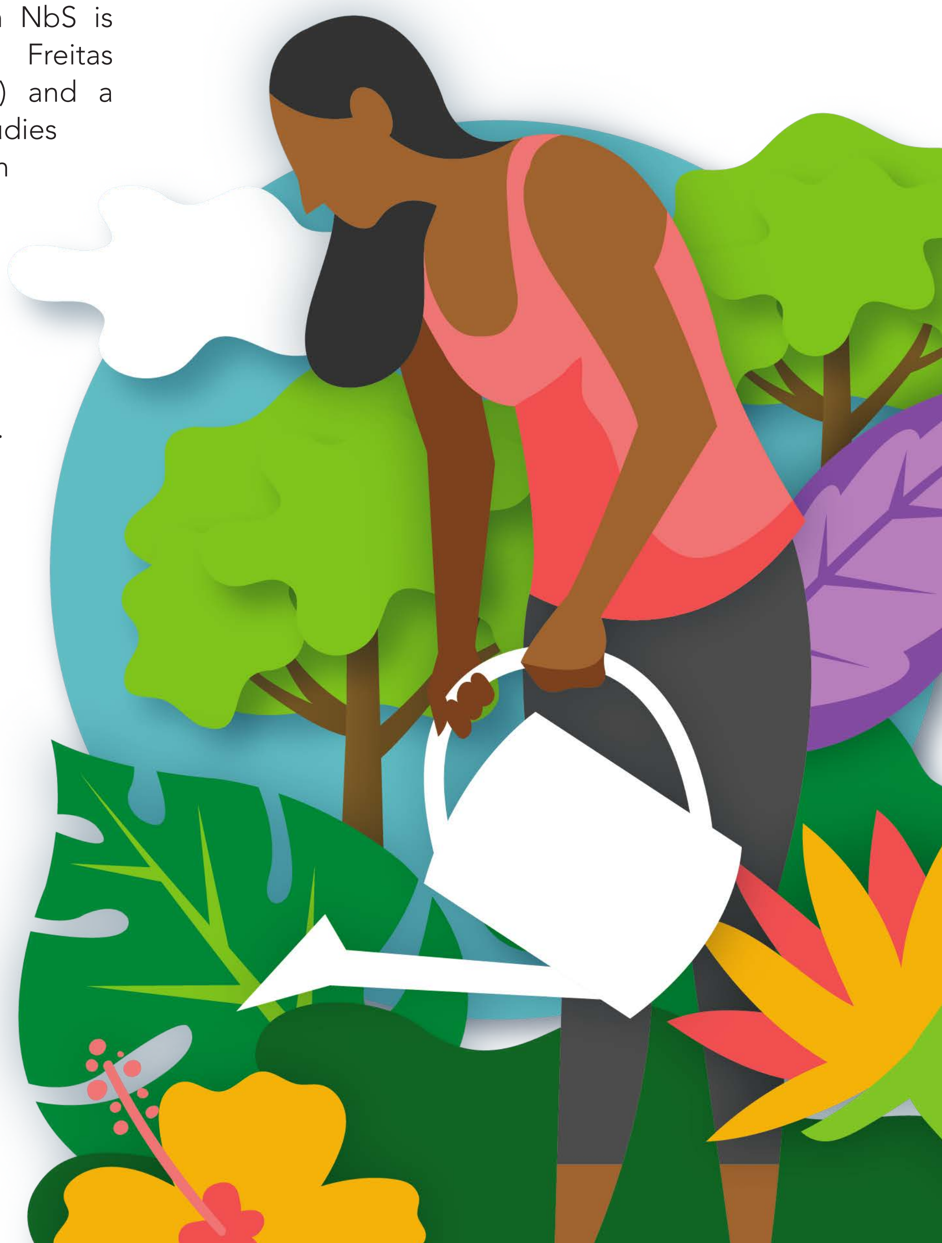
Steadily, NbS impact assessment guidance frameworks are becoming more readily available. However, the most widely known and accepted frameworks to assess NbS

[54] See www.conexusnbs.com

services and disservices tend to promote holistic and comprehensive analyses, requiring extensive datasets and expertise. Onerous or demanding assessment frameworks may be less frequently applied in cities, where land use information is more complex and fragmented than in rural environments.

Participatory assessment frameworks in which stakeholders (such as urban municipal authorities) are responsible for driving the decision-making around which indicators to develop and apply may offer a more productive approach, by bringing NbS assessments closer to local socio-political priorities within cities, and enabling better (access to) data on urban challenges and NbS performance.

The number of publications on NbS is increasing exponentially (Wild, Freitas and Vandewoestijne eds. 2020) and a significant proportion of these studies address the economic valuation of urban NbS, representing a strengthening evidence base to underpin NbS business case development. Indeed, many of these publications stem from studies in Latin America and the Caribbean. We highlight invaluable case studies and signposts to further information, to support the work of stakeholders seeking to improve urban NbS business case development.



6.6 Recommendations for urban NbS impact assessments and valuations

The evident lack of use of NbS assessment frameworks by local governments may indicate that they are overly complex, insufficiently connected with cities' cultural and social imaginaries, or too demanding of data (including extraneous or largely irrelevant data). In other words, perhaps current models for NbS impact assessment do not adequately address the societal challenges that cities face (or provide the tools to do so), nor the socio-political frameworks within which NbS actions are embedded. This potential disengagement also serves to highlight how the 'market' for NbS in terms of cities as their buyers and suppliers (Whiteoak 2020) might be better understood. Clues to this might also come from the more frequent uptake of sustainability appraisals and sustainability action planning (Van der Jagt *et al.* 2021; Salbitano *et al.* 2021).

Building on previous frameworks for integrated sustainability (Weaver and Rotmans 2006; Hurley *et al.* 2010), participatory assessment offers the scope of a cyclical process of scoping, via which a shared interpretation of sustainability is developed and applied in an integrated manner for a specific context (Wild *et al.* 2015). In other words, by involving local stakeholders directly in the process of defining which are the key criteria and indicators of success, this increases the chances of both monitoring and achieving those outcomes. When NbS assessment is more contextualised and based on wide stakeholder participation, it can generate more useful data (Van der Jagt *et al.* 2022), which are also more likely to be meaningful in terms of valuations.

Broad assessments of NbS impacts may be driven by the belief that project financing depends strongly on linkages between green urban infrastructure and other themes such as regional development, climate adaptation and so on (Merk *et al.* 2012) aligning partnership agendas to cross subsidised projects that would not otherwise be viable. However, it has been highlighted previously that this broad scope may also be one of the biggest weaknesses of NbS (Wild, Henneberry and Gill 2017); if propositions are not properly costed, accounting for core benefits can be dismissed as 'jack of all trades, master of none'.

Recommendations

Bearing in mind the above, certain key recommendations can be made

- Firstly, NbS assessments can be narrow or wide in both their span in terms of benefits and their scale geographically. Data demands increase exponentially where both the substance and scale of the assessment are widened. This means that assessments of broad environmental, social and economic outcomes at the city scale are likely to require such extensive data gathering as to become impractical, or to build in so many assumptions that they are unlikely to be convincing or can be readily unpicked.

- Secondly, NbS themselves and the metrics used to ascertain or predict their benefits can be, and should be, closely matched with their city contexts. Most city strategies and plans give strong indications of the most relevant challenges and the NbS propositions should probably address these criteria.

- Thirdly, the integration of gender responsive approaches, intersectional perspective and stakeholder participation is critical not only in the co-design of planned NbS, but also in the co-designing the measures of success. Whilst examples of this are rare, tools do exist to support the creation of participatory assessment frameworks in cities.

- Fourthly and finally, it does not usually pay off to attribute too many benefits to NbS – and overselling the monetary value that NbS providers can offer is rarely convincing. A recurring theme in NbS valuation is that key decision-makers tend to put economic data first in their deliberations. People also tend to believe simpler answers, even when problems such as urban climate adaptation are far from simple.

References

- (2022). AR6 WGII. Fact Sheet Central and South America. https://report.ipcc.ch/ar6wg2/pdf/IPCC_AR6_WGII_FactSheet_CentralSouthAmerica.pdf

- (2022b). Fact sheet - Central and South America. Climate Change Impacts and Risks. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. WMO, UNEP. Available at: https://www.ipcc.ch/report/ar6/wg2/about/factsheets

- (2022). *Implementacion de Infraestructura Azul y Verde (IAV) a traves de mecanismos de captacion de plusvalia en la Region Metropolitana de Buenos Aires. El caso de la Cuenca del Arroyo Medrano* (Implementation of Blue and Green Infrastructure (BGI) through capital gain capture mechanisms in the Metropolitan Region of Buenos Aires. The case of the Arroyo Medrano Basin). Work document. Massachusetts, United States: Lincoln Institute of Land Policy. Available at: https://www.lincolninst.edu/publications/working-papers/implementacion-infraestructura-azul-verde-iav-traves-mecanismos

- Alcaldia de Medellin (Mayor's Office of Medellin) (2017). *Presentacion de la ciudad verde* (Green City Presentation). Available at: https://www.medellin.gov.co/irj/portal/medellin?NavigationTarget=contenido/4546-La-Avenida-Oriental-en-Medellin-sera-un-corredor-verde. [Page consulted in June 2022].

- Alcaldia de Medellin (Mayor's Office of Medellin) (2021). *Plan de accion climatica Medellin 2020-2050. Acción por el clima. Informe tecnico* (Medellin Climate Action Plan 2020-2050. Climate action. Technical report). Available from: https://www.medellin.gov.co/irj/go/km/docs/etc/PortalMedellin/archivos/medio_ambiente/Publicaciones/Documentos/2021/PAC_Medellin_Libro_Digital.pdf. [Page consulted in June 2022].

- Alejandro Restrepo Montoya (2022): director of Strategic Urban Projects of the Mayor's Office of Medellin, 2016-2019. Interviewed on July 12, 2022.

- Altamirano, M.A., de Rijke, H., Basco Carrera, L. and Arellano Jaimerena, B. (2021). *Handbook for the Implementation of Nature-based Solutions for Water Security: guidelines for designing an implementation and financing arrangement,* Deliverable 7.3: EU Horizon 2020 NAIAD Project, Grant Agreement N°730497 Dissemination.

- Angon Rodriguez, S.A., Nava Tablada, M.E., Hernandez Sanchez, M.I. and Valdes Rodriguez, O.A. (2021). *Ventanas de Oportunidad para la adopcion del enfoque de adaptacion al cambio climatico basado en ecosistemas (AbE) en la planeacion urbana de la ciudad de Xalapa.* (Windows of Opportunity for the adoption of the adaptation approach to climate change based on ecosystems (EbA) in the urban planning of the city of Xalapa). Medio Ambiente y Urbanizacion, 94-95. https://www.ingentaconnect.com/contentone/iieal/meda/2021/00000094/00000001/art00010

- Arnstein, S. (1969). A ladder of citizen participation. *Journal of the American Institute of Planners* 25(4), 216-224.

- Azevedo, T.C. and Portella, A.A. (2019). *Incentivos fiscales verdes como instrumento de apoyo a la politica urbana: un estudio sobre el IPTU VERDE en municipios brasileños* (Green tax incentives as an instrument to support urban policy: a study on the GREEN IPTU in Brazilian municipalities). HOLOS 1, 1-18. https://doi.org/10.15628/holos.2019.7913

- Bacchiega, J.D., Bertoni, J.C. and Maza, J.A. (2003). *Descripcion de la inundacion de la Ciudad de Santa Fe. Correlato de hechos y acciones. Anexo XII. Pericia Hidraulica correspondiente al Expediente No 1341/2003 Poder Judicial de la Provincia de Santa Fe.* (Description of the flood of the City of Santa Fe. Correlative of facts and actions. Annex XII. Hydraulic Expertise corresponding to File No. 1341/2003 Judicial Branch of the Province of Santa Fe.) Available at: https://www.santafe.gov.ar/index.php/web/content/download/124132/614444/file/Anexo%20XII%20-%20Descripcion%20Crecida%202003.pdf

- Barona, C.O., Devisscher, T., Dobbs, C., Aguilar, L.O., Baptista, M.D., Navarro, N.M., *et al.* (2020). Trends in urban forestry research in Latin America & the Caribbean: a systematic literature review and synthesis *(Tendencias en la investigacion forestal urbana en America Latina y el Caribe: una revision y sintesis sistematica de la literatura). Urban Forestry & Urban Greening (Silvicultura urbana y ecologizacion urbana)* 47, 126544.

- Baroni, L., Nicholls, G. and Whiteoak, K. (2019). Approaches to financing nature-based solutions in cities (Silvicultura urbana y ecologizacion urbana). GrowGreen Project working document. http://growgreenproject.eu/wp-content/uploads/2019/03/Working-Document_Financing-NBS-in-cities.pdf [Page consulted in June 2022].

- Barton, D. (2015). Monetary valuation of urban ecosystem services-operationalization or tragedy of well-intentioned valuation? An illustrated example. InEcosystem Services: Concepts, Methodologies and Instruments for Research and Applied Use *(Valoracion monetaria de los servicios ecosistemicos urbanos: ¿operacionalizacion o tragedia de valoracion bien intencionada? Un ejemplo ilustrado. Servicios InEcosystem: Conceptos, Metodologias e Instrumentos para la Investigacion y Uso Aplicado).* Nuss-Girona, S., Castañer, M. (eds.).

- Beltran Aguirre, J.L. (2006). *Clasificacion, categorizacion y calificacion del suelo en la legislacion autonomica comparada. Revista juridica de Navarra* (Classification, categorization, and classification of land in comparative regional legislation. Legal Review of Navarra), 41, 81-112.

- Borthagaray, A., Kozak, D. and Maldonado, M. (2022). *Rapport d'evaluation. Projet de Reserve Naturelle Urbaine (RNU) et gestion des risques climatiques dans la ville de Santa Fe (Argentina)* (Evaluation report. Urban Nature Reserve Project (URN) and climate risk management in the city of Santa Fe (Argentina). French Global Environment Fund (FFEM).

- Cabrera, Gravez and Pereira (2011). *Curso de Facilitacion Fundacion Futuro Latinoamericano Taller interno* (Latin American Future Foundation Facilitation Course Internal workshop). Quito, cited in Cabrera, 2016, p. 1). Cabrera, Gravez, Pereira. (2011). *Curso de Facilitacion Fundacion Futuro Latinoamericano Taller interno* (Latin American Future Foundation Facilitation Course Internal workshop). Quito, 2011, cited in Cabrera (2016). *Participacion y Dialogo efectivos para un Desarrollo Compatible con el Clima* (Effective Participation and Dialogue for Climate Compatible Development). CDKN Guide, Climate and Development Knowledge Network. September 2016.

- CAF Development Bank of Latin America (2019). *Guia para el Analisis Detallado de Riesgo Climatico* (Guide for Detailed Climate Risk Analysis), CAF.

- Cardenas, M.L., Wilde, V., Hagen-Zanker, A., Seifert-Dähnn, I., Hutchins, M.G. and Loiselle, S. (2021). The Circular Benefits of Participation in Nature-Based Solutions. *Sustainability* 13(8), 4344.

- Chausson, A., Turner, B., Seddon, D., Chabaneix, N., Girardin, C., Kapos, V. *et al.* (2020). *Mapping the effectiveness of nature-based solutions for climate change adaptation. Global Change Biology.*

- Ciudades C40 (2021). Heat Resilient cities: Measuring benefits of urban heat adaptation. Case Study, Medellin Green Corridors *(Ciudades resilientes al calor: medicion de los beneficios de la adaptacion al calor urbano. Caso de Estudio, Corredores Verdes de Medellin).* Available at: https://ramboll.com/-/media/files/rm/c40---heat-resilience/c40-case-studie-medellin.pdf?la=en. [Page consulted in June 2022].

- Clary, J., Jones, J., Leisenring, M., Hobson, P. and Strecker, E. (2017). International Stormwater BMP Database 2016 Summary Statistics *(Estadisticas resumidas de la base de datos internacional de BMP de aguas pluviales de 2016).* Alexandria, Virginia.: Water Environment & Reuse Foundation (Fundacion para el Medio Ambiente y la Reutilizacion del Agua).

- Climate and Development Knowledge Network, *Fundacion Futuro Latinoamericano y Centro Internacional de Investigaciones para el Desarrollo (2016). Estrategia de Participacion y Dialogo. Iniciativa de Ciudades Resilientes al Clima en America Latina, Anexo 1, Guia de participacion* (Latin American Future Foundation and International Development Research Center (2016). Participation and Dialogue Strategy. Initiative for Climate Resilient Cities in Latin America, Annex 1, Participation Guide). Project document. 23 pages.

- Cohen-Shacham, E., Andrade, A., Dalton, J., Dudley, N., Jones, M., Kumar, C. *et al.* (2019). Core principles for successfully implementing and upscaling Nature-based Solutions *(Principios basicos para implementar y escalar con exito las soluciones basadas en la naturaleza).* Environmental Science and Policy *(Ciencas y politicas ambientales)* 98, 20-29.

- Coninx, I., Nuesink, N. and Brazao Vieira Alho, C. (2021). *Integrating science into climate change policy making: An overview of inspiring real-world practices.* Inspiration and lessons learned. EU-funded SINCERE project. Wageningen University & Research.

- Construction Industry Research and Information Association (2015). *The SuDS Manual 2015.* London: Construction Industry Research and Information Association. CIRIA.

- Convention on Biological Diversity (2000). Decision V/6 Ecosystem Approach. Decision adopted by the Conference of Parties to the Convention on Biological Diversity at its fifth meeting, 15–26 May 2000, Nairobi, Kenya. Available from http://www.cbd.int/decision/cop/default.shtml?id=7148

- Convention on Biological Diversity (2021). *First draft of the post-2020 global biodiversity framework.* Available at: https://www.cbd.int/doc/c/abb5/591f/2e46096d3f0330b08ce87a45/wg2020-03-03-en.pdf

- Daily, G. (ed.) (1997). *Nature's services: societal dependence on natural ecosystems.* Washington, D.C.: Island Press.

- Davies, C., MacFarlane, R., McGloin, C. and Roe, M. (2015). Green Infrastructure Planning Guide *(Guia de planificacion de infraestructura verde),* v1. p1. Available from: https://doi.org/10.13140/RG.2.1.1191.3688.

- Day, B.H. and Smith, G. (2018). Outdoor Recreation Valuation (ORVal) User Guide: Version 2.0 *(Guia del usuario de Valuacion de recreacion al aire libre* (ORVal): *Version* 2.0), Land, Environment, Economics and Policy Institute (LEEP), Business School, University of Exeter.

- De la Sala, S., Maldonado, M., and Alterman, R. (2019). *Politicas de Suelo, Derecho Urbanistico y Cambio Climatico: Instrumentos urbanisticos-tributarios como medidas para enfrentar al Cambio Climatico Etapa 1: Identificacion de mecanismos de financiamiento locales y estudios de casos* (Land Policies, Urban Law and Climate Change: Urban-tax instruments as measures to deal with Climate Change Stage 1: Identification of local financing mechanisms and case studies). Working Paper. Cambridge, MA: Lincoln Institute of Land Policy. Available at: https://www.lincolninst.edu/publications/working-papers/politicas-suelo-derecho-urbanistico-

- De la Sala, S., Maldonado, M. and Alterman, R. (2019). *Politicas de Suelo, Derecho Urbanistico y Cambio Climatico: Instrumentos urbanisticos-tributarios como medidas para enfrentar al Cambio Climatico Etapa 2: Identificacion de mecanismos de financiamiento locales y estudios de casos* (Land Policies, Urban Law and Climate Change: Urban-tax instruments as measures to deal with Climate Change Stage 2: Identification of local financing mechanisms and case studies). Working Paper. Cambridge, MA: Lincoln Institute of Land Policy. Available at: https://www.lincolninst.edu/publications/working-papers/politicas-suelo-derecho-urbanistico-cambio-climatico-etapa-2

- Dempsey, J. and Suarez, D.C. (2016). Arrested development? The promises and paradoxes of "selling nature to save it" *(¿Desarrollo detenido? Las promesas y paradojas de "vender la naturaleza para salvarla").* Annals of the American Association of Geographers 106(3), 653-671.

- Development Bank of Latin America (2014). Vulnerability Index to climate change in the Latin American and Caribbean Region. Corporacion Andina de Fomento. 206 pp. https://scioteca.caf.com/bitstream/handle/123456789/509/caf-vulnerability-index-climate-change.pdf

- Dobbs, C., Escobedo, F.J., Clerici, N., de la Barrera, F., Eleuterio, A., Mac Gregor-Force, I. ***et al.*** (2019). Urban ecosystem Services in Latin America: mismatch between global concepts and regional realities? *(Servicios ecosistemicos urbanos en America Latina: ¿desajuste entre conceptos globales y realidades regionales?).* Urban Ecosystems *(Ecosistemas Urbanos)* 22, 173-187. Available from: https://doi.org/10.1007/s11252-018-0805-3

- Dumitru, A. and Wendling, L. (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners *(Evaluacion del impacto de las soluciones basadas en la naturaleza: un manual para profesionales).* EU Publications Office, Luxembourg. Available from: https://data.europa.eu/doi/10.2777/244577

- Equipo del Instituto de Desarrollo Urbano de Bogota (Institute of Urban Development of Bogota Team). Interviewed on June 9, 2022.

- European Commission (2022a). The vital role of nature-based solutions in a nature positive economy *(El papel vital de las soluciones basadas en la naturaleza en una economia positiva para la naturaleza).* EU Publications Office, Luxembourg. Available from: https://data.europa.eu/doi/10.2777/307761. Doi:10.2777/307761.

- European Commission (2022b). Impact assessment accompanying the proposal for a Regulation of the European Parliament and of the Council on nature restoration *(Evaluacion de impacto que acompaña a la propuesta de Reglamento del Parlamento Europeo y del Consejo sobre restauracion de la naturaleza).* Brussels: European Commission.

- European Environment Agency (2021). Nature-Based Solutions in Europe: Policy, Knowledge and Practice for Climate Change Adaptation and Disaster Risk Reduction *(Soluciones basadas en la naturaleza en Europa: politicas, conocimientos y practicas para la adaptacion al cambio climatico y la reduccion del riesgo de desastres).* https://www.eea.europa.eu/publications/nature-based-solutions-in-europe Copenhagen.

- Finance Earth Market Review (2021). A Market Review of Nature-Based Solutions: An Emerging Institutional Asset Class (Commissioned by the Green Purposes Company). https://finance.earth/wp-content/uploads/2021/05/Finance-Earth-GPC-Market-Review-of-SbN-Report-May-2021.pdf

- Fletcher, T.D., Shuster, W., Hunt, W., Ashley, R., Butler, D., Arthur, S. *et al.* (2015). SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage. *Urban Water Journal* 12(7), 525-542.

- Food and Agriculture Organization (2014). *Ciudades mas verdes en America Latina y el Caribe. Un informe de la FAO sobre agricultura urbana y periurbana en la region* (Greener cities in Latin America and the Caribbean. A FAO report on urban and peri-urban agriculture in the region): http://www.fao.org/ag/agp/greenercities/pdf/GGCLAC/Ciudades-mas-verdes-America-Latina-Caribe.pdf

- Food and Agriculture Organization (2021). Developing bankable business plans: A learning guide for forest producers and their organizations *(Desarrollo de planes de negocios rentables: una guia de aprendizaje para productores forestales y sus organizaciones).* Available from: https://www.fao.org/documents/card/en/c/cb4520en/. Rome.

- Friends of the Earth International (2021). Ahead of UN climate summit Friends of the Earth International spotlights how 'Nature Based Solutions' is being used to disguise climate-trashing business-as-usual. https://www.foei.org/ahead-of-un-climate-summit-friends-of-the-earth-international-spotlights-how-nature-based-solutions-is-being-used-to-disguise-climate-trashing-business-as-usual/ [Page consulted in February 2021].

- Fundacion Salvadoreña de Desarrollo y Vivienda Mínima (Salvadoran Foundation for Development and Minimum Housing) (2020). *Evaluacion de vulnerabilidad socioambiental en la microcuenca del Arenal Monserrat* (Socio-environmental vulnerability assessment in the Arenal Monserrat micro-watershed). Ministry of the Environment and Natural Resources of El Salvador.

- George, G. and Bock, A.J. (2011). The business model in practice and its Implications for entrepreneurship research *(El modelo de negocios en la practica y sus implicaciones para la investigacion del emprendimiento).* Entrepreneurship Theory and Practice *(Teoria y Practica del Emprendimiento)* 35(1), 83-111. Available from: https://doi.org/ 10.2139/ssrn.1490251.

- Gesellshaft für Internationale Zusammenarbeit GmbH (German Agency for International Cooperation – GIZ), European Academy of Bozen-Bolzano and United Nations University (2017). The Vulnerability Sourcebook: Concept and Guidelines for Standardised Vulnerability Assessment. Bonn.

- Gesellshaft für Internationale Zusammenarbeit GmbH (German Agency for International Cooperation – GIZ), European Academy of Bozen-Bolzano and United Nations University (2018). Climate Risk Assessment for Ecosystem-based Adaptation – A guide for planners and practitioners. Bonn.

- Global Commission on Adaptation (2019). Adapt now: a global call for leadership on climate resilience *(Adaptarse ahora: un llamado global para el liderazgo en resiliencia climatica).* https://gca.org/wp-content/uploads/2019/09/GlobalCommission_Report_FINAL.pdf

- Global Water Partnership (2011). Dublin-Rio Principles. *Water* 46 (January 1992), 3-6.

- Gobierno de la Ciudad de Mexico (Government of Mexico City), De Urbanisten y Deltares (2016). *Hacia una Ciudad de Mexico sensible al agua. El espacio publico como una estrategia de gestion de agua de lluvia.* (Towards a water sensitive Mexico City. Public space as a rainwater management strategy). Available at: https://agua.org.mx/wp-content/uploads/2018/01/Hacia-una-Ciudad-de-M%C3%A9xico-sensible-al-agua.pdf

- Haene, E., Beron, C., Rolon, C., Perales, V. and Tabares, P. (2018). *Plan de Gestion 2017-2020. Reserva Natural Urbana del Oeste. Santa Fe, Argentina.* (Management Plan 2017-2020. Western Urban Nature Reserve. Santa Fe, Argentina. French Global Environment Fund. Municipalidad de la Ciudad de Santa Fe (Municipality of the City of Santa Fe).

- Hardoy, J. and Velasquez Barrero, L. (2014). Re-thinking "Biomanizales": addressing climate change adaptation in Manizales, Colombia. Environment and Urbanization 26(1), 53-68. https://journals.sagepub.com/doi/full/10.1177/0956247813518687

- Hardoy, J., Gencer, E., Winograd, M., Montoya, Y., Padilla, C., Ramirez, N. *et al.* (eds.) (2019). *Planeamiento Participativo para la resiliencia climatica en ciudades de America Latina, REPORTE DE INVESTIGACION, Iniciativa Ciudades Resilientes al Clima* (Participatory Planning for climate resilience in Latin American cities, RESEARCH REPORT, Climate Resilient Cities Initiative). FFLA, CDKN, and IDRC.

- Hart, R. (2001). Children's participation in sustainable development. Barcelona: UNICEF.

- Hilmi, E., Kusmana, C., Suhendang, E. e Iskandar (2017). Correlation analysis between seawater intrusion and mangrove greenbelt. *Indonesian Journal of Forestry Research 4(2).*

  https://nanopdf.com/queue/estudio-de-caso-red-de-huerteras-y-huerteros-de-rosario_pdf?queue_id=-1&x=1651514399&z=MTUyLjE2OC40MS4xODM

  https://prizeforcities.org/project/sustainable-food-production-rosario

  https://repositorio.inta.gob.ar/handle/20.500.12123/4815

- Hurley, L., Ashley, R., Molyneux-Hodgson, S., Moug, P. and Schiessel, N. (2010). "Measuring" sustainable living agendas *("Midiendo" agendas de vida sostenible).* Management of Environmental Quality *(Gestion de la calidad Ambiental)* 21(1), 45-57.

- Iniciativa de Politica Climatica (2020). An Analysis of Urban Climate Adaptation Finance (*Un analisis de la financiacion de la adaptacion al clima urbano).* https://www.climatepolicyinitiative.org/publication/an-analysis-of-urban-climate-adaptation-finance/. San Francisco, Iniciativa de Politica Climatica.

- Intergovernmental Panel on Climate Change (2018). Resumen para responsables de politicas. En: Global warming of 1.5 °C. IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and the corresponding trajectories that global greenhouse gas emissions should follow, in the context of strengthening the global response to the threat of global warming, climate change, sustainable development, and efforts to eradicate poverty. Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Pean, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M. and Waterfield, T. (eds.)

- Intergovernmental Panel on Climate Change (2022). Annex II: Glossary [Möller, V., R. van Diemen, J.B.R. Matthews, C. Mendez, S. Semenov, J.S. Fuglestvedt, A. Reisinger (eds.)]. In: *Climate Change 2022:* Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegria, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, RU and New York, NY, USA, pp. 2897–2930, doi:10.1017/9781009325844.029.

- Intergovernmental Panel on Climate Change (2022). Climate Change 2022. Impacts, Adaptation, and Vulnerability. *Synthesis report. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Geneve.

- Intergovernmental Panel on Climate Change (2022): Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. Cambridge, UK. New York, USA, 3056. doi:10.1017/9781009325844.

- Intergovernmental Panel on Climate Change (2022a). Climate Change 2022. Impacts, Adaptation, and Vulnerability. Summary for Policymakers. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. WMO, UNEP. Available at: https://www.ipcc.ch/report/ar6/wg2/

- Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (2019). Global assessment report on biodiversity and ecosystem services. Brondizio, E.S., Settele, J., Diaz, S., and Ngo, H.T. (eds.). Bonn, Germany: IPBES secretariat.

- International Union for Conservation of Nature (2020). IUCN Global Standard for Nature-Based Solutions. A simple framework for NbS verification, design, and extension. First edition. Gland, Switzerland: IUCN.

- Joint Nature Conservation Committee (2019). Roadmap Towards a Blue Green Infrastructure Manual. Bridging the knowledge gap in the field of Blue Green Infrastructures. Available at: https://data.jncc.gov.uk/data/354f40aa-1481-4b7f-a1eb-82c806893409/BGI-Manual-Report.pdf

- Kapos, V., Wicander, S., Salvaterra, T., Dawkins, K. and Hicks, C. (2019). The role of the natural environment in adaptation, background paper for the Global Commission on Adaptation.

- Karina Suarez: Land Planning Coordinator at the Metropolitan Department of Land Policies and Planning. Interviewed on April 22, 2022.

- Kozak, D. (2021) *Nuevos escenarios urbanos para el arroyo Medrano a cielo abierto. Soluciones basadas en la Naturaleza en el taller de proyecto urbano.* (New urban scenarios for the open-air Medrano stream. Solutions based on Nature in the urban project workshop). In: Zagare, V. and Carlino, H. eds. 'Territorios del agua' ('Water Territories'), Buenos Aires: Instituto Torcuato Di Tella, pp. 30-45.

- Kozak, D., Henderson, H., de Castro Mazarro, A., Rotbart, D. and Aradas, R. (2020). Blue-Green Infrastructure (BGI) in Dense Urban Watersheds. The Case of the Medrano Stream Basin (MSB) in Buenos Aires. *Sustainability* 2(6); doi:10.3390/su12062163.

- Kozak, D.; Henderson, A.; Rotbart D., and Aradas, R. (2021). *Beneficios y desafios en la implementacion de Infraestructura Azul y Verde: una propuesta para la RMBA* (Benefits and challenges in the implementation of Blue and Green Infrastructure: a proposal for the RMBA). In: 'Pensar las infraestructuras en Latinoamerica' ('Thinking about infrastructures in Latin America'), Zunino Singh, D.; Gruschetsky, V., and Piglia, M. Eds. Buenos Aires: Editorial Teseo, pp. 223-244.

- Kvam, R. (2019). Meaningful Stakeholder Engagement: A Joint Publication on the MFI Working Group on Environmental and Social Standards. IDB.

- Lattuca, A., Lemos, C., Mazzuca, A., Orue, M., Ponce, M., Ramos, T., Terrile, et al. (2005). *Organizaciones sociales de agricultores urbanos/as. Modelo de gestion y alianzas innovadores para la incidencia publica. Estudio de caso: Consolidacion de la Red de huerteras y huerteros de la ciudad de Rosario* (Social organizations of urban farmers. Innovative management model and alliances for public advocacy. Case study: Consolidation of the vegetable gardener network in the city of Rosario). CEPAR, IDRC, IPES, ETC.

- Loucks, D.P. and van Beek, E. (2017). Water resource systems planning and management: An introduction to methods, models, and applications. Springer.

- Luis Alberto Suarez, Manager of the Company Helecho S.A. Interviewed on October 20, 2022.

- Marcela Noreña Restrepo (2022): Environment Secretariat, Mayor's Office of Medellin. Interviewed on June 03, 2022.

- Maria Jose Escudero: Coordinator at the Metropolitan Directorate of Land Policies and Planning. Interviewed on April 11, 2022.

- Marsters, L., Morales, G., Ozment, S., Silva, M., Watson, G., Netto, M. *et al.* (2021). Nature-Based Solutions in Latin America and the Caribbean: Financing Mechanisms for Regional Replication *(Soluciones basadas en la naturaleza en America Latina y el Caribe: mecanismos de financiamiento para la replicacion regional).* Washington, DC: Inter-American Development Bank and World Resources Institute. Available from: http://dx.doi.org/10.18235/0003688.

- Mayor, B., Toxopeus, H., McQuaid, S., Croci, E., Lucchitta, B., Reddy, S.E., *et al.* (2021). State of the art and latest advances in exploring business models for nature-based solutions *(Avances mas recientes y de ultima generacion en la exploracion de modelos de negocios para soluciones basadas en la naturaleza).* Sustainability *(Sostenibilidad)* 13(13), 7413. Available from: https://doi.org/10.3390/su13137413.

- Merk, O., Saussier, S., Staropoli, C., Slack, E. & Kim, J.H. (2012). Financing Green Urban Infrastructure *(Financiamiento de Infraestructura Urbana Verde).* Publicaciones de la OCDE.

- Millennium Ecosystem Assessment (2003). Ecosystems and Human Well-being: a Framework for Assessment. Washington, D.C., USA: Island Press.

- Ministerio del Ambiente del Peru (Ministry of the Environment of Peru) (2015). *Lineamientos para la formulacion de proyectos de inversion en las tipologias de ecosistemas, especies y apoyo al uso sostenible de la biodiversidad.* (Guidelines for the formulation of investment projects in the types of ecosystems, species and support for the sustainable use of biodiversity). Available at: https://cdn.www.gob.pe/uploads/document/file/319848/RM_N__178-2019.pdf

- Mitlin, D. (2004). Editor's introduction: Reshaping local democracy. *Environment and Urbanization* 16(1), 3-8.

- Miyahara, A.A.L., Wild, T., Sandre, A.A., Pellegrino, P.R.M., da Silva Filho, C.A., Buckeridge, M.S. *et al.* (2022). Developing and classifying urban biomes as a basis for nature-based solutions *(Desarrollo y clasificacion de biomas urbanos como fundamento para soluciones basadas en la naturaleza).* Urban Climate *(Clima Urbano)* 45, 101251.

- Motta, M. and Almansi, F. (2017). *"Gestion y planificacion por proceso-proyecto para el mejoramiento de villas y asentamientos de gran escala. El caso de la Re-Urbanizacion de Villa 20 en la CABA"* ("Management and planning by process-project for the improvement of villas and large-scale settlements. The case of the Re-Urbanization of Villa 20 in CABA") Medio Ambiente y Urbanizacion 86(1).

- Municipalidad de Santa Fe (Municipality of Santa Fe) (2022) *Estabilizacion y Ampliacion de la Operacion de la Reserva Natural Urbana del Oeste.* (Stabilization and Expansion of the Operation of the Urban Nature Reserve of the West). Report 11-22, 2022. Environmental Management Office, Municipality of Santa Fe.

- Ninike Celi Atala: Head of the habitat monitoring and implementation unit of the Secretariat of Territory, Habitat, and Housing of Quito. Interviewed on April 20, 2022.

- Occam's Typewriter (2012). Urban Heat Islands and Climate Change (Islas de calor urbanas y cambio climatico). Available at: Urban Heat Islands and Climate Change | City Limits *(Islas de calor urbanas y cambio climatico | Limites de ciudad)* (occamstypewriter.org). Available from: http://occamstypewriter.org/citylimits/2012/09/17/urban-heat-islandsand-climate-change- [Page consulted in June 2022].

- Olarte, J. M. (2017). *Clasificacion de movimiento en masa y su distribucion en terrenos geologicos de Colombia.* (Classification of mass movement and its distribution in geological terrains of Colombia). Books of the Colombian Geological Service.

- Oppenheimer, M., Campos, M., Warren, R., Birkmann, J., Luber, G., O'Neill, B. *et al.* (2014): Emergent Risks and Key Vulnerabilities. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R., and White, L.L. (eds.). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, 1039-1099.

- Organization for Economic Cooperation and Development (2018). Climate-resilient Infrastructure. *Environment Policy Paper* 14.

- Organization for Economic Cooperation and Development (2021). *Building Resilience New Strategies for Strengthening Infrastructure Resilience and Maintenance.* Informe. https://www.oecd.org/g20/topics/infrastructure/Building-Infrastructure-Resilience-OECD-Report.pdf

- Organization for Economic Cooperation and Development (2020). Nature-based solutions for adapting to water-related climate risks. Environment Policy Paper 21.

- Organization for Economic Co-operation and Development and Lincoln Institute of Land Policy (2021). Global Compendium on Land Value Capture. https://www.oecd.org/cfe/cities/land-value capture.htm#:~:text=About%20the%20Global%20Compendium%20on%20Land%20Value%20Capture&text=The%20Compendium%20will%20also%20aim,planning%20practitioners%2C%20and%20public%20officials.

- Ortiz, M., Matamoro, V. and Psathakis, J. (2016). *Guia para confeccionar un mapeo de actores. Bases conceptuales y metodologicas.* (Guide to make a mapping of actors. Conceptual and methodological bases). Fundacion Cambio Democratico.

- Ozment, S., Gonzalez, M., Schumacher, A., Oliver, E., Morales, G., Gartner, T., *et al.* (2021). *«Soluciones basadas en la naturaleza en America Latina y el Caribe: situacion regional y prioridades para el crecimiento»* («Nature-based solutions in Latin America and the Caribbean: regional situation and priorities for growth»). Washington, DC: Inter-American Development Bank and World Resources Institute.

- Paula Hoyos. Technical Coordinator of the Urban Agriculture Program, Municipality of Rosario, interviewed on June 13, 2022.

- Pladeyra and Fondo Golfo de Mexico, 2019, *Informe final del taller de validacion de AbE ante el cambio climatico: XALAPAYTLAL NELHUAYOCAN, VERACRUZ* (Final report of the EbA validation workshop for climate change: XALAPAYTLAL NELHUAYOCAN, VERACRUZ), CITYADAPT Project, UNEP, Xalapa, Mexico: CityAdapt Project, UNEP.

- Prefeitura de São Paulo (Prefecture of São Paulo) (2021). *Aos 67 anos, o Parque do Ibirapuera atrai 18 milhões de visitantes* (At 67 years, Ibirapuera Park attracts 18 million visitors). Prefecture of São Paulo – Press Room. Available from: https://imprensa.prefeitura.sp.gov.br/noticia/aos-anos-parque-do-ibirapuera-atrai-milhoes-de-visitantes [Page consulted in June 2022].

- Raul Terrile: Founder of CEPAR, currently, Coordinator of the Food Program (Secretariat of Economic Development and Employment) and Coordinator of the Green Belt Program (Intersecretarias). Municipality of Rosario, interviewed on June 1, 2022.

- Raymond, C.M., Frantzeskaki, N., Kabisch, N., Berry, P., Breil, M., Nita, M.R., *et al.* (2017). A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas *(Un marco para evaluar e implementar los beneficios colaterales de las soluciones basadas en la naturaleza en zonas urbanas).* Environmental Science and Policy *(Ciencia y Politica Ambiental)* 77, 15-24.

- Richmond, M., Upadhyaya, N. and Ortega Pastor, E. (2021). An analysis of urban climate adaptation finance *(Un analisis del financiamiento de la adaptacion climatica urbana).* San Francisco, Climate Policy Initiative (Iniciativa de Politica Climatica). https://www.climatepolicyinitiative.org/wp-content/uploads/2021/02/An-Analysis-of-Urban-Climate-Adaptation-Finance.pdf [Page consulted in June 2022].

- Rijke, J., van Herk, S., Zevenbergen, C. and Ashley, R. (2012). Room for the River: Delivering integrated river basin management in the Netherlands. *Int. J. River Basin Manag* 2012(10), 369-382.

- Rosario, (Argentina): Sustainable Food Production: Green Belt https://www.rosario.gob.ar/inicio/produccion-sustentable-de-alimentos-cinturon-verde

- Salbitano, F., Ortiz-Guerrero, C.E., Kauark Fontes, B., Hernandez-Garcia, J., Marchetti, L. and Cruz-Suarez, M.A. (2021). Integration of NBS in local governance contexts and urbanisation trajectories in Conexus EU and CELAC cities. Evidence from Barcelona, Buenos, Aires, Bogota, Lisbon, Santiago, São Paulo, and Turin *(Integracion de SbN en contextos de gobernanza local y trayectorias de urbanizacion en ciudades Conexus UE y CELAC. Evidencia de Barcelona, Buenos Aires, Bogota, Lisboa, Santiago, São Paulo y Turin).* Horizon 2020 Conexus project deliverable D2.2.

- Seddon, N., Smith, A., Smith, P., Key, I., Chausson, A., Girardin, C., *et al.* (2021). Getting the message right on nature-based solutions to climate change *(Captando bien el mensaje sobre las soluciones basadas en la naturaleza para el cambio climatico).* Global Change Biology *(Biologia del Cambio Global)* 27(8), 1518-1546.

- Sergio Angon and Isabel Garcia Coll, Coordinators of the CityAdapt Project in Xalapa, interviewed on June 13, 2022.

- Siclari, P., (2020) *Amenazas de cambio climatico, metricas de mitigacion y adaptacion en ciudades de America Latina y el Caribe* (Climate change threats, mitigation, and adaptation metrics in Latin American and Caribbean cities), Project Documents LC/TS.2020/185, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).

- Silva Filho, D.F. da, and Tosetti, L.L. (2010). Valuation of trees at Ibirapuera Park - SP: Importance of urban green infrastructure *(Valorizacion de arboles en el Parque Ibirapuera - SP: Importancia de la infraestructura verde urbana).* Revista LABVERDE (1), 11-25. Available from: https://doi.org/10.11606/issn.2179-2275.v0i1p11-25

- Silva Zuniga, M.C., Watson, G., Watkins, G.G., Rycerz, A. and Firth, J. (2020). Increasing infrastructure resilience with nature-based solutions (NbS).

- Swann, S., Blandford, L., Cheng, S., Cook, J., Miller, A. and Barr, R. (2021). Public international funding of nature-based solutions for adaptation: a landscape assessment *(Financiamiento publico internacional de soluciones basadas en la naturaleza para la adaptacion: una evaluacion del paisaje).* Washington, DC: Instituto de Recursos Mundiales. Available from: https://doi.org/10.46830/wriwp.20.00065.

- The Nature Conservancy (2021). Blue Guide to Coastal Resilience: Protecting Coastal Communities Through Nature-Based Solutions. A manual for disaster risk reduction professionals. The Nature Conservancy. The Nature Conservancy. Arlington, VA.

- UN-Habitat (2020). La Nueva Agenda Urbana *(The New Urban Agenda).* Available at: https://publicacionesonuhabitat.org/onuhabitatmexico/Nueva-Agenda-Urbana-Ilustrada.pdf

- UN-Habitat (2022). *World Cities Report.* Available at: https://unhabitat.org/sites/default/files/2022/06/wcr_2022.pdf

- UN Women, United Nations Development Programme, United Nations Environment Programme (2020) *De las Palabras a la Accion: Proyectos con Soluciones Innovadoras para la Naturaleza, la Accion Climatica y la Igualdad de Genero* (From Words to Action: Projects with Innovative Solutions for Nature, Climate Action and Gender Equality). Panama City, Panama

- United Nations Economic Commission for Latin America and the Caribbean (2018). *Plan de Accion Regional para la implementacion de la nueva agenda urbana en America Latina y el Caribe, 2016-2036* (Regional Action Plan for the implementation of the new urban agenda in Latin America and the Caribbean, 2016-2036). Available at: https://onuhabitat.org.mx/index.php/plan-de-accion-regional-para-la-implementacion-de-la-nau-en-lac

- United Nations Educational, Scientific and Cultural Organization (2018). *Informe Mundial de las United Nations sobre el Desarrollo de los Recursos Hidricos 2018: Soluciones basadas en la naturaleza para la gestion del agua* (United Nations World Water Development Report 2018: Nature-Based Solutions for Water Management). Paris.

- United Nations Environment Assembly (2022). *Resolucion aprobada por la Asamblea de las Naciones Unidas sobre el Medio Ambiente el 2 de marzo de 2022. Asamblea de las Naciones Unidas sobre el Medio Ambiente del Programa de las Naciones Unidas para el Medio Ambiente Quinto periodo de sesiones. Nairobi, 22-23 de febrero de 2021 y 28 de febrero a 2 de marzo de 2022.* (Resolution adopted by the United Nations Environment Assembly on March 2, 2022. United Nations Environment Assembly of the United Nations Environment Program Fifth session. Nairobi, February 22-23, 2021, and February 28-March 2, 2022). Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/39867/NATURE-BASED%20SOLUTIONS%20FOR%20SUPPORTING%20SUSTAINABLE%20DEVELOPMENT.Spanish.pdf?sequence=1&isAllowed=y

- United Nations Environment Assembly (2022). UN Environment Assembly concludes with 14 resolutions to curb pollution, protect and restore nature worldwide *(La Asamblea de las United Nations para el Medio Ambiente concluye con 14 resoluciones para frenar la contaminacion, proteger y restaurar la naturaleza en todo el mundo),* March 2. Available from https://www.unep.org/news-and-stories/press-release/un-environment-assembly-concludes-14-resolutions-curb-pollution. Page consulted on June 8, 2022.

- United Nations Environment Programme (2020). The Post-COVID-19 recovery: how to articulate integrated responses to the health, economic and climate crises in Latin America and the Caribbean. https://wedocs.unep.org/bitstream/handle/20.500.11822/32673/COVID19_CLIMATE_LACSP.pdf?sequence=2&isAllowed=y

- United Nations, Environment Programme, CityAdapt (2022). *Desarrollo urbano en crisis climatica* (Urban development in climate crisis). Available at: https://cityadapt.com/cityadapt/que-es-cityadapt/

- United Nations Environment Programme [CityAdapt] (2022). *Proceso de construccion de la gestion integral del recurso hidrico y el manejo integrado de las cuencas que abastecen de agua a la ciudad de Xalapa, Veracruz* (Case Study: Construction process of the integral management of water resources and the integrated management of the basins that supply water to the city of Xalapa, Veracruz) (mimeo).

- United Nations Framework Convention on Climate Change (2015). Paris Agreement. Available at: https://unfccc.int/sites/default/files/spanish_paris_agreement.pdf

- United Nations Organization (2022a). *Oficina para la Reduccion del Riesgo de Desastres.* (Principles for Resilient Infrastructure). Version prefinal.

- United Nations Organization, Department of Economic and Social Affairs, (2022b). *World Population Prospects 2022: Data Sources.* UNDESA/POP/2022/DC/NO. 9.

- United Nations Organization (n.d.). UN Women. SDG 6: Ensure availability and sustainable management of water and sanitation for all. https://www.unwomen.org/en/news/in-focus/women-and-the-sdgs/sdg-6-clean-water-sanitation

- United States Environmental Protection Agency (2022). Reduce Urban Heat Island Effect. Available at: https://www.epa.gov/green-infrastructure/reduce-urban-heat-island-effect

- Van der Jagt, A.P., Buijs, A., Dobbs, C., van Lierop, M., Pauleit, S., Randrup, T.B. and Wild, T. (2022). An action framework for the participatory assessment of nature-based solutions in cities *(Un marco de accion para la evaluacion participativa de soluciones basadas en la naturaleza en las ciudades).* Ambio, 1-14.

- Vasquez, A. and Dobbs, C. (2020). Ensuring equitable GREENSPACE to deprived social groups *(Asegurando un ESPACIO VERDE equitativo para grupos sociales desfavorecidos). In The Routledge Handbook of Urban Ecology (El Manual Routledge de Ecologia Urbana).* Douglas *et al.* (eds.). 817-825. London: Routledge. Available from: https://doi.org/10.4324/9780429506758.

- Villamarin G., Pacha M., Vasquez A., Villacis M., Wilkinson E. 2019. *Documento de Sintesis: Aportes de la Iniciativa Ciudades Resilientes al Clima,* (Synthesis Document: Contributions of the Climate Resilient Cities Initiative). Quito, Ecuador: Fundacion Futuro Latinoamericano (FFLA)

- Villanueva-Solis,J., Ranfla, A., Quintanilla-Montoya, A.L. (2013). *Isla de calor urbana: modelacion dinamica y evaluacion de medidas de mitigacion en ciudades de clima arido extremo.* (Urban heat island: dynamic modeling and evaluation of mitigation measures in cities with extreme arid climates). Technological Information, 24(1), 15-24.

- Wamsler, C., Alkan-Olsson, J., Björn, H., Falck, H., Hanson, H., Oskarsson, T. *et al.* (2020). Beyond participation: When citizen engagement leads to undesirable outcomes for nature-based solutions and climate change adaptation. *Clim. Chang.* 158, 235-254.

- Weaver, P.M. and Rotmans, J. (2006). Integrated sustainability assessment: What is it, why do it and how? *(Evaluacion integrada de la sostenibilidad: ¿Que es, por que hacerla y como?)* International Journal of Innovation & Sustainable Development *(Revista Internacional de Innovacion y Desarrollo Sostenible)* 1(4), 284-303.

- Whiteoak, K. (2020). Market challenges and opportunities for NBS *(Desafios y oportunidades del mercado para SbN).* En Nature-based solutions: State of the art in EU-funded projects *(Soluciones basadas en la naturaleza: lo ultimo en proyectos financiados por la UE).* Wild, T. *et al. (eds.).* 203-222. EU Publications Office, Luxembourg. Available from: https://data.europa.eu/doi/10.2777/236007.

- Wild, T.C. and Henneberry, J.M. (2020). Nature-based solutions and water challenges: financing an accelerated transition to more sustainable cities using NBS *(Soluciones basadas en la naturaleza y desafios del agua: financiacion de una transicion acelerada hacia ciudades mas sostenibles utilizando SbN).* In C. Herzog *et al.* (eds.). EU-Brazil Sector Dialogue on Nature-Based Solutions *(Dialogo Sectorial UE-Brasil sobre Soluciones Basadas en la Naturaleza).* EU Publications Office, Luxembourg. ISBN: 978-92-76-18445-4. Available from: https://doi.org/10.2777/95912

- Wild, T.C., Bernet, J.F., Westling, E.L. and Lerner, D.N. (2011). Deculverting: reviewing the evidence on the 'daylighting' and restoration of culverted rivers *(Eliminacion de alcantarillas: revision de la evidencia sobre la 'iluminacion natural' y la restauracion de rios entubados).* Water and Environment Journal *(Revista Agua y Medio Ambiente)* 25 (3), 412-421.

- Wild, T.C., Dempsey, N. and Broadhead, A.T. (2019). Volunteered information on nature-based solutions - Dredging for data on deculverting *(Informacion voluntaria sobre soluciones basadas en la naturaleza: dragado para obtener datos sobre la eliminacion de alcantarillas).* Urban Forestry and Urban Greening *(Silvicultura urbana y ecologizacion urbana)* 40, 254-263. Available from: https://doi.org/10.1016/j.ufug.2018.08.019.

- Wild, T.C., Freitas, T. and Vandewoestijne, S. (eds.) (2020). Nature-based solutions: state of the art in EU-funded projects. *(Soluciones basadas en la naturaleza: lo ultimo en proyectos financiados por la UE).* Bruselas: Oficina de Publicaciones de la Union Europea. Available from: https://doi.org/10.2777/236007.

- Wild, T.C., Henneberry, J.M. and Gill, L. (2017). Comprehending the multiple 'values' of green infrastructure - valuing nature-based solutions for urban water management from multiple perspectives *(Entendiendo los multiples "valores" de la infraestructura verde: valorar las soluciones basadas en la naturaleza para la gestion del agua urbana desde multiples perspectivas). Environmental Research (Investigacion Ambiental)* 158, 179-187. Available from: https://doi.org/10.1016/ j.envres.2017.05.043.

- Wild, T.C., Wilker, J., Tack, B., Rymsa-Fitschen, C., Moore, T., van de Steene, S., *et al.* (2015). Policy lessons and recommendations *(Lecciones de politica y recomendaciones). VALUE+ Final Report (informe final VALOR+).* Sheffield: South Yorkshire Forest Partnership *(Sheffield: Asociacion Forestal de Yorkshire del Sur).*

- Wilker, J. and Rusche, K. (2014). Economic valuation as a tool to support decision-making in strategic green infrastructure planning *(La valoracion economica como herramienta de apoyo a la toma de decisiones en la planificacion estrategica de infraestructuras verdes).* Local Environment *(Ambiente Local)* 19(6), 702-713.

- Winograd M., C. Figueroa, M. van Eupen, J. Hardoy. 2021. *Guia metodologica sobre Soluciones Basadas en la Naturaleza (SbN) para ciudades de America Latina y el Caribe* (Methodological Guide on Nature-Based Solutions (NBS) for Latin American and Caribbean Cities) Panama: CityAdapt.

- World Meteorological Organization (2022). State of the Climate in Latin America and the Caribbean 2021 - No. 1295

Additional Material

Chapter 2

Manuals and guides on methods and tools

- ECLAC (2018). *Guia de ejercicios para la evaluacion de desastres* (Exercise guide for disaster assessment), ECLAC and GIZ, Chile.
- GIZ, EURAC and UNU (2017). The Vulnerability Sourcebook: Concept and Guidelines for Standardised Vulnerability Assessment. Bonn.
- GIZ, EURAC and UNU (2018). Climate Risk Assessment for Ecosystem-based Adaptation – A guide for planners and practitioners. Bonn.

Storymaps on case studies in cities

- *Construccion de resiliencia climatica en sistemas urbanos mediante SbN* (Building climate resilience in urban systems through NbS). https://www.arcgis.com/apps/MapJournal/index.html?appid=73fd061ae8514816b4e11368ba388360
- *Interrumpiendo 'trampas de riesgo' urbano: integrando conocimiento e inversión para una planificación justa y resiliente en Lima* (Disrupting urban 'risk traps': integrating knowledge and investment for fair and resilient planning in Lima) https://climasinriesgo.net/online-story-maps/?lang=es
- Climate Vulnerability Map https://storymaps.arcgis.com/stories/29e8195408564e369752361e0d7c6d36

Internet sites to search for information on climate and climate change scenarios

- Climate knowledge https://climateknowledgeportal.worldbank.org/
- Data for scenario scaling up http://www.ccafs-climate.org/climatewizard/
- Methods for scaling up http://www.ccafs-climate.org/data_spatial_downscaling/
- Platform for disaster reduction https://www.preventionweb.net/english/

Chapter 3

- Cabannes, Y. (2020). Contributions of Participatory Budgeting to climate change adaptation and mitigation. Current local practices around the world & lessons from the field. Barcelona: IOPD; Barcelona: UCLG; Dakar: Enda ECOPOP; Paris: FMDV; Surakarta: Kota Kita Foundation; London: UCL / DPU.
https://www.uclg.org/sites/default/files/contributions_of_participatory_budgeting_to_climate_change_adaptation_and_mitigation_current_local_practices_around_the_world_lessons_from_the_field.pdf
https://oidp.net/es/publication.php?id=1716

- *Observatorio Internacional de Ciudadania y Medio Ambiente Sostenible* (International Observatory for Citizenship and Sustainable Environment - CIMAS) (2009). *Metodologias participativas. Manual* (Participatory methodologies. Manual). https://www.redcimas.org/wordpress/wp-content/uploads/2012/09/manual_2010.pdf

- *Observatorio Internacional de la Democracia Participativa* (International Observatory for Participatory Democracy - OIDP). (2006). *Guia para la deteccion de buenas practicas en procesos participativos* (Guide for the detection of good practices in participatory processes). https://www.oidp.net/docs/repo/doc599.pdf

- Winograd M., C. Figueroa, M. van Eupen, J. Hardoy (2021). *Guia metodologica sobre Soluciones Basadas en la Naturaleza (SbN) para ciudades de America Latina y el Caribe* (Methodological guide on Nature-Based Solutions (NbS) for cities in Latin America and the Caribbean), CityAdapt, Panama. https://cityadapt.com/guiassbn/

- WWF (2021). *Soluciones urbanas basadas en la naturaleza. Ciudades que lideran el camino* (Urban nature-based solutions. Cities leading the way). https://wwfint.awsassets.panda.org/downloads/exe_wwf_a4_template_sbn_final_es.pdf

UN
environment
programme