Nature-based Solutions

for Latin American and Caribbean cities

- Methodological Guidelines -

M.Winograd (WENR), C.Figueroa-Arango (Humboldt Fellow),
M. Van Eupen (WENR), J. Hardoy (IIED-AL)

City Adapt
RECONNECTING CITIES WITH NATURE
LATINAMERICA AND THE CARIBBEAN

UN environment programme

gef

Euroclima+

Funded by the European Union

© 2021 United Nations Environment Programme. Published by the United Nations Environment Programme (UNEP) June 2021.

Attribution
Non Comercial
No Derivatives
CC BY - NC - ND

This publication may be reproduced in whole or in part and in any form for educational or non-profit services without special permission from the copyright holder, when provided acknowledgement of the source is made.

UN Environment Programme would appreciate receiving a copy of any publication that uses this publication as a source. No use of this publication may be made for resale or for any other commercial purpose whatsoever without prior permission in writing from the United Nations Environment Programme. Applications for such permission, with a statement of the purpose and extent of the reproduction, should be addressed to the Director, Communication Division, Programa de la ONU para el Medio Ambiente, Oficina para América Latina y el Caribe, Edificio 103, Calle Alberto Tejada, Ciudad del Saber, Clayton, Panamá.

Disclaimer

The opinions expressed in this publication are those of the authors and do not necessarily reflect the views of the United Nations United Nations Environment program. This document has been produced with the financial support of the European Union through the EUROCLIMA+ Programme. The collection of information, the writing of the report and its publication are carried out independently and do not in any way reflect the views of the funder, the European Union. We regret any errors or omissions that may have been unwittingly made.

The mention of a company or commercial product in this document does not imply the endorsement of UNEP or the authors. No use of the information in this document for advertising or marketing purposes is allowed. The names and trademark symbols are used in an editorial manner with no intention of infringement of trademark or copyright laws.

© Maps, photographs and illustrations as specified.

Suggested citation

This document can be cited as:
UNEP (2021). Nature-based Solutions for Latin American and Caribbean cities - Methodological Guidelines. United Nations Environment Programme, Office for Latin America and the Caribbean, Panama.

Production

United Nations Environment Programme (UNEP)

A copy of this report together with supporting annexes can be found at the following link: **https://cityadapt.com/guiassbn/**

With the support of:

gef

Euroclima+

Funded by
the European Union

Acknowledgements

Practical guide for the identification, design, implementation and monitoring of Nature-based Solutions (NbS) for Latin American and Caribbean cities.

Authors

M.Winograd (WENR), C.Figueroa-Arango (Humboldt Fellow), M. Van Eupen (WENR), J. Hardoy (IIED-AL)

Contributions

S.Angón, I.Garcia Coll, O. Drouault, M. Moneo, L. Zelaya, D. Kinston, N. Lopez (United Nations Environment Programme)

Translations

C. Clarke, N. Falero Larrosa, R. Ortega

Communication and dissemination

S. Arocha (PNUMA)

Graphic Design

K. Delgado, D. Rogoza (UNEP)

Web platform design

J. Bianchet (UNEP)

Thanks also to the European Union, in particular the EUROCLIMA+ Program, and the Global Environment Facility for supporting the creation of these Guidelines.

For more information about EUROCLIMA+ Program initiatives in Nature-based Solutions, please visit www.euroclimaplus.org

The UNEP promotes green practices globally and in its own activities. Our distribution policy aims at reducing UNEP's carbon footprint.

www.cityadapt.com/guiasSbN

Content

5 Introduction

9 Recommended reading
9 Web resources

10 Section 1.
Vulnerability analysis and identification of hotspots for Nature-Based Solutions (NbS)

13 **Step 1.a.** Context of livelihoods and ecosystem services
18 **Step 1.b.** Stakeholder mapping
22 **Step 1.c.** Risk assessment, vulnerability analysis and hotspots identification

31 Section 2.
NbS design

34 **Step 2.a.** Exploratory workshop
36 **Step 2.b.** Validation workshop
39 **Step 2.c.** The technical model: scope, planning and technical design of the NbS

45 Section 3.
NbS implementation

47 **Step 3.a.** The business model: assessing and documenting the direct and indirect costs and benefits of NbS
51 **Step 3.b.** The financial model
55 **Step 3.c.** Advocacy and synergies of NbS with other solutions, programmes and/or policies

63 Section 4.
NbS monitoring and assessment

65 **Step 4.a.** NbS monitoring and impact indicators
70 **Step 4.b.** Communications, training and replication of NbS

75 Tools and References

80 Glosary

Navigate through the guides by clicking on the menu at the bottom of the on the menu located at the bottom of the pages.

Introduction

The CityAdapt project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP), promotes climate resilience in urban areas by implementing Nature-based Solutions (NbS) for adaptation[i] to climate change[ii]. Based on the CityAdapt experience in 3 Latin American cities, Xalapa, San Salvador and Kingston, this guide explains practical methods for identifying (Section 1), designing (Section 2), implementing (Section 3) and monitoring (Section 4) NbS in urban contexts. This includes using different types of data, assessing risks and vulnerability[iii], fostering the exploration of NbS by doing participatory workshops, ensuring implementation; and subsequently, scaling up[iv], replication[v] and monitoring. This guide aims at supporting stakeholders in the urban territory during the decision-making process. Stakeholders are provided with tools, examples and skills for capacity-building, so that they can effectively apply NbS. In this way, the implementation of strategies for resilient urban planning and development is facilitated.

What are NbS in cities?

"They are hard or structural (green, grey, mixed infrastructure) and soft or non-structural (management, policy, education) actions that improve the use and conservation of ecosystem services in urban, peri-urban and rural areas of cities to ease adaptation to the impacts of climate change" (European Union, 2014).

Advantages

- Generally more cost-effective than grey infrastructure in providing climate change adaptation solutions.
- Social and economic co-benefits as reducing poverty are achieved while utilising and protecting ecosystem services.
- It integrates social, environmental, and economic components to achieve a systemic approach (social-ecological system)
- The focus is on processes, thus long-term capacity-building for communities, individuals and institutions is facilitated.

For more information on NbS:
The ABC of NbS

Despite the increasing availability of data and state-of-the-art software, their use to support decision-making processes in territorial planning is limited. This is mainly because of the gaps between technological supply and demand by local stakeholders, and due to limited skills to translate such information into action.

There is a lot of data on risks, vulnerability and impact in the case of climate variability,[vi] climate change and natural disasters. However, facilitating the exchange, access and use of such data for understanding and applying it in urban planning processes is still necessary. This document seeks to transform such knowledge into action, so as to build resilience and improve adaptation to risks in urban and peri-urban areas. This requires tools and methods to combine social (e.g. livelihoods/financial means), environmental (e.g. ecosystem services), institutional (e.g. public policy), cognitive (e.g. type of information) and technical (e.g. geoinformatics) perspectives into urban design and planning in a flexible, fast and transparent manner.

Therefore, based on practical examples, this guide illustrates how data and tools should be strengthened and used in the identification, determination, exploration and validation of NbS actions. The ultimate goal is to show how to add value to information and demonstrate how to enhance participation for a common understanding. In the context of the CityAdapt project, actors' capacity to select strategies and actions is enabled through the use of tools as a means to facilitate and support changes and transformation - it is not oriented towards a technological development of complex tools.

Major social and environmental challenges, such as quality of life, access to healthcare, climate change and the availability of resources and ecosystem services,[xiii] will be determined by the form, pattern and function of urban and peri-urban environments. An understanding of their dynamics and functioning is required to mobilise massive financial investments (Keeler et al., 2019). Addressing the challenge of sustainable development and adaptation in cities requires balancing multiple, often conflicting objectives specific to the local context, and involving a variety of actors with limited resources. The involvement of communities is necessary to achieve equitable economic development that facilitates access to sufficient food, water and energy, as well as recreational opportunities, city planning and renewal, and a minimization of risks in the event of natural disasters.

This document seeks to transform knowledge into actions to build resilience and enhance adaptation.

Considering that urban areas face complex challenges, decision-makers need to explore and implement creative solutions, especially actions that are cost-effective, accepted by communities, technically feasible and which prove to be beneficial. A growing number of cities are exploring NbS, which aim to promote livelihoods, minimize risks in the event of natural disasters, improve the liveability of cities, utilise, and restore and conserve ecosystem services, among other benefits.

However, ecosystem services in cities are difficult to define. Given the nature of NbS, urban ecosystem services in this guide are conceived as those services produced in urban, peri-urban and rural spaces within city boundaries, i.e. spaces that are embedded within continuous and discontinuous urban areas defined by the physical structure of the city and not only by its administrative definition (Hardoy et al, 2019).

Other approaches refer to urban ecosystem services only for continuous urban areas and do not conceive the administrative city as a whole (Inostroza et al., 2020). In addition, useful information is needed to support the planning and decision-making processes. However, existing data does not always produce relevant and usable information that translates into knowledge and insight.

Photo: San Salvador

Therefore, there is a need to improve and/or build more capacity to select, manage and use the large amount of data and tools available in order to guide and support local decision-making and future urban planning.

At the end of the document, a list that summarises all the tools used in the different modules is provided. Finally, this guide is accompanied by a series of annexed documents which elaborate on some of the most important topics and examples from the implementation of the CityAdapt project.

Supporting documents

- El ABC de las SbN
- Glossary

Section 1

- San Salvador Vulnerability Assessment
- Xalapa Vulnerability Assessment
- Help memory proxies for social vulnerability

Section 2

- San Salvador Scanning Workshop
- Using QUICKscan Validation workshop in San Salvador
- Use of QUICKscan Validation workshop in Xalapa
- Multi-criteria analysis in the identification of municipal strategies for adaptation
- NbS San Salvador protocols and NbS Xalapa protocols with all the technical sheets of the different SbN: infiltration ditches, infiltration ditches, absorption wells, agroforestry, wetland restoration, riparian restoration, rainwater harvesting, and soils and soil conservation

Section 3

- The cost-benefit analysis of BNS
- Sources of financing for BNS
- Case study on water harvesting in Xalapa

Section 4

- Dissemination and capacity building materials

Recommended reading

European Commission. 2019. Green Infrastructure – Environment

GIZ. 2017. El Libro de la Vulnerabilidad: Concepto y lineamientos para la evaluación estandarizada de la vulnerabilidad Available at this link.

Ilieva L. 2020. Observaciones sobre la Adaptación basada en Ecosistemas Historias de América Latina y el Caribe, ONU Medio Ambiente y Practical Action, Publicación Comunidad AbE.

IPCC, 2018: Annex I: Glossary Available at this link.

Millenium Ecosysem Assessment (MEA). 2005. Ecosystems and human wellbeing: synthesis. Island Press. Available at this link.

Renner I., 2019, Integración de los servicios ecosistémicos en la planificación y gestión urbana: Un enfoque sistemático en pasos para profesionales, Programa Protección del Clima en la Política Urbana de México (CiClim), SEDATU, SEMARNAT y GIZ, México.

Berghöfer A, Mader A, Patrickson S, Calcaterra E, Smit J, Blignaut J, de Wit M, Zyl H van. 2011. TEEB Manual for Cities: Ecosystem Services in Urban Management. Geneva, Switzerland: Author. Available at this link.

Figueroa-Arango C. 2020. Guía para la integración de las Soluciones Basadas en la Naturaleza en la planificación urbana. Primera aproximación para Colombia. Berlín: Alexander von Humboldt Stiftung, Ecologic Institute, Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. Available at link.

Web resources

- Urban Nature Lab
- Urban Nature Lab (Publications)
- Oppla: Repository of Nature-Based Solutions
- Nature for Cities
- Amigos de las SbN
- The Nature of Cities (TNOC)
- Metropolitan solutions
- Connecting nature
- Global Climate Adaptation
- Ciudades Resilientes al Clima
- SbN sur-sur
- Microfinanzas para la Adaptación basada en ecosistemas

Section 1.
Vulnerability analysis and hotspot identification for Nature-based Solutions (NbS)

Step 1.a. Livelihoods and Ecosystem Services (ES) context

Example: Identifying livelihoods in San Salvador

Step 1.b Stakeholder mapping

Example: Map of stakeholders in Xalapa

Step 1.c Risk assessment, vulnerability analysis and hotspot identification

Example: Climate risk and vulnerability assessment in Xalapa

Support material

Objective

This section aims at assessing vulnerability,[iii] including the analysis of risks[vii] to people's livelihoods[viii] and ecosystem services[xiii] (provision, support and regulation) (Figure 1). This analysis leads to identifying common problems, hotspots (Figure 2) and possible solutions, integrating the perspectives and ways of acting of all stakeholders in the city. Based on this diagnosis, a set of strategic actions are identified, which are necessary to be implemented in the short term.

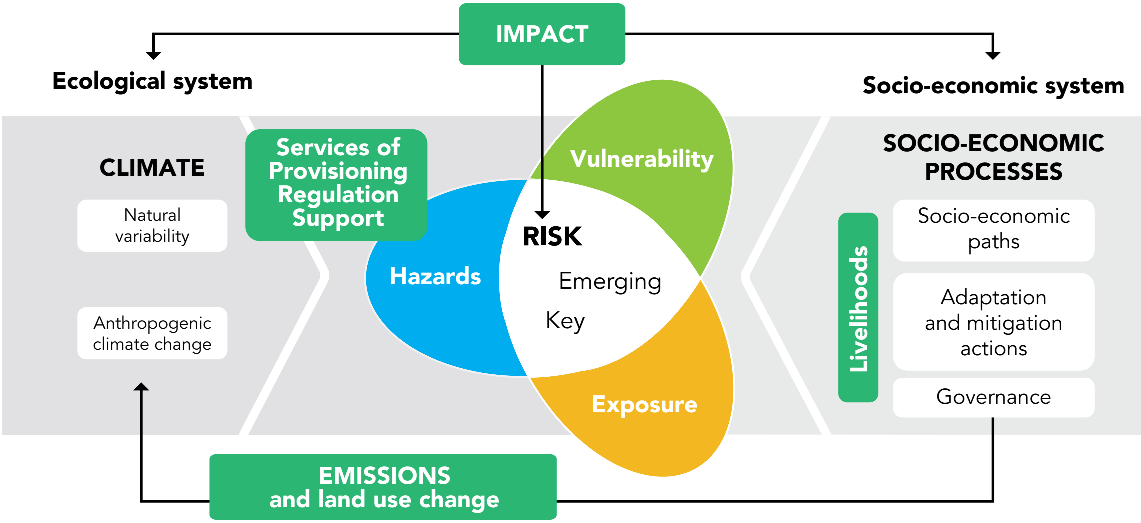


Figure 1: Context of vulnerability analysis. Source: IPCC 2014, as amended.

Climate risk-related impacts on a social-ecological system result from the interaction of climate-related hazards[ix] (including hazard events and trends), vulnerability and exposure[x] of natural and human systems (GIZ, 2018, modified).

Module guiding questions

- Who or what is vulnerable?
- What are you vulnerable to?
- How vulnerable are you?
- What are the causes that make you vulnerable?
- How can you reduce your vulnerability?

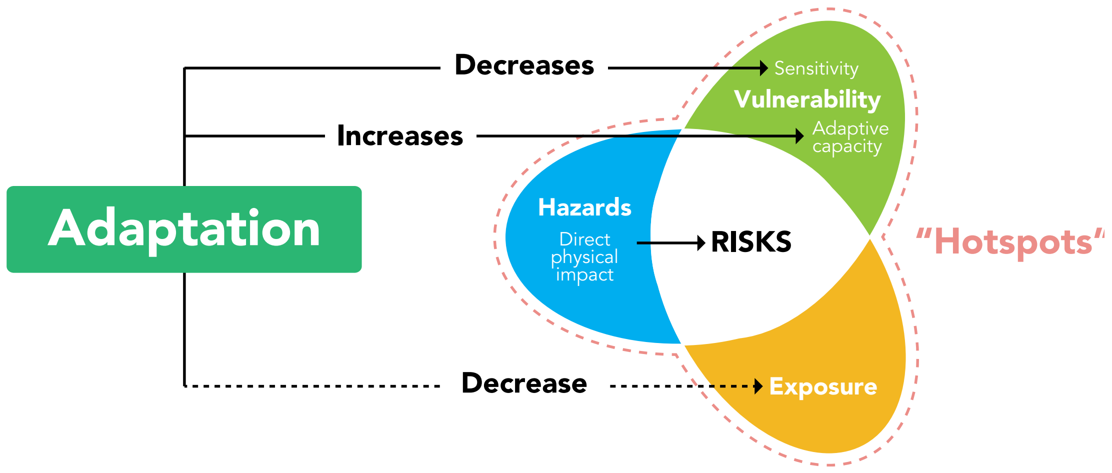


Figure 2: Identification of hotspots for retrofitting. Source: GIZ-EURAC-UNU, 2018, as amended.

Areas with high risks resulting from exposure, hazards and vulnerability, whether to population, infrastructure, livelihoods or ecosystem services are hotspots[xi] for adaptation. Measures can thus reduce sensitivity and increase adaptive capacity.[xii] In this context, NbS can reduce sensitivity, risks, vulnerability and, in many cases, exposure (GIZ, 2018).

Stakeholders involved

Vulnerability analysis involves the participation of decision-makers at local and regional level to set the overall context. Directors of secretariats, departments and project managers; advisors, project supervisors, departmental and sectoral technicians; members of cooperatives and NGOs, technicians involved in implementing actions, local managers involved in specific themes and sectors are needed to carry out the comprehensive assessment, including thematic and sectoral perspectives.

Results

Baseline of livelihoods and ecosystem services[xiii], analysis of climate risks[viii] identification of vulnerability hotspots[iii] and early identification of possible adaptation measures.[i]

Estimated duration

The estimated time for this step is between 3 and 6 months.

Step 1.a. Livelihoods and Ecosystem Services (ES) context

During this first stage, the city's context in terms of livelihoods and ecosystem services[xiii] is rapidly assessed. This requires a literature review, identifying where and who has the information, who can make decisions, and identifying the city's main challenges, etc.

The socio-ecological system[xiv] in cities is composed of the ecological subsystem, which primarily provides, supports and regulates ecosystem services, and the socio-economic subsystem, where society uses ecosystem goods and services (Figure 3). Socio-ecological systems in cities are characterised by interaction between and within their components and structures that give rise to functions and services such as temperature regulation, water flow control and support soil formation.

Objectives

- Understand and assess the condition, uses and users of ES in terms of livelihood activities.
- Analyse livelihood strategies and associated activities.
- Identify city challenges, assess trends in use, degradation, conservation, enhancement of ecosystems and ES in relation to livelihoods.

Results

- Spatially identified livelihoods (mapping);
- Trends in ecosystem use, degradation, conservation and enhancement and their relationship to identified livelihoods.

Tools

- Interviews or focus groups.
- Participatory GIS.

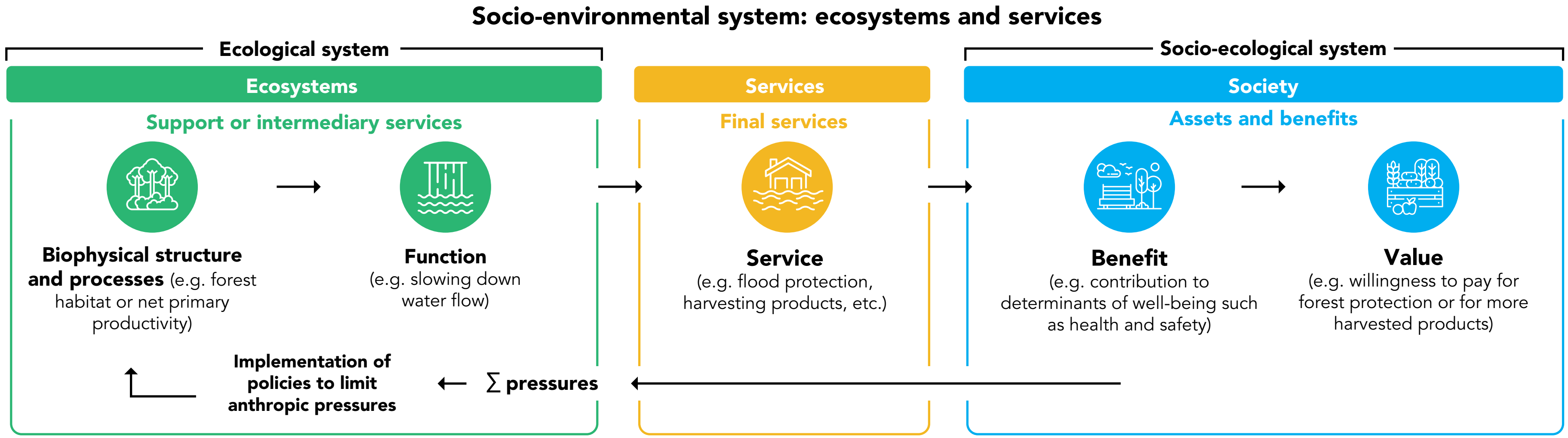


Figure 3: Socio-ecological system, ecosystems and ecosystem services. Source: Pérez-Soba M 2020.

Ecosystem services are the variety of benefits provided by nature to society. Ecosystem services make human life possible, for example, by providing food, timber and clean water; by regulating disease and climate; by supporting crop pollination and soil formation; and by providing recreational, cultural and spiritual benefits (MEA 2005). In cities, ecosystem services are services produced in urban, peri-urban and rural areas and in some cases, they extend beyond their administrative boundaries. (Inostroza et al. 2020.)

For instance, some ES are: 1.water recharge areas within the city, 2. urban wooded hillside areas that support soil conservation and landslide control, 3. parks that actas regulators of air pollution concentrations and temperature.

The benefits generated by ecosystem services are a fundamental component of securing the **livelihoods** of urban and peri-urban dwellers. The livelihoods of a household or community are the set of means that enable you to secure your vital needs (Carney 1999).

A livelihood includes the capabilities, income, assets (natural, financial, material, social, etc.), and activities required for subsistence. For example, a fisher's livelihood depends on the accessibility and availability of fish, as well as on his or her ability to catch fish and the availability of a fishing rod, boat and other necessary fishing gear (Ashley and Carney 1999).


Photo: Xalapa, Mexico

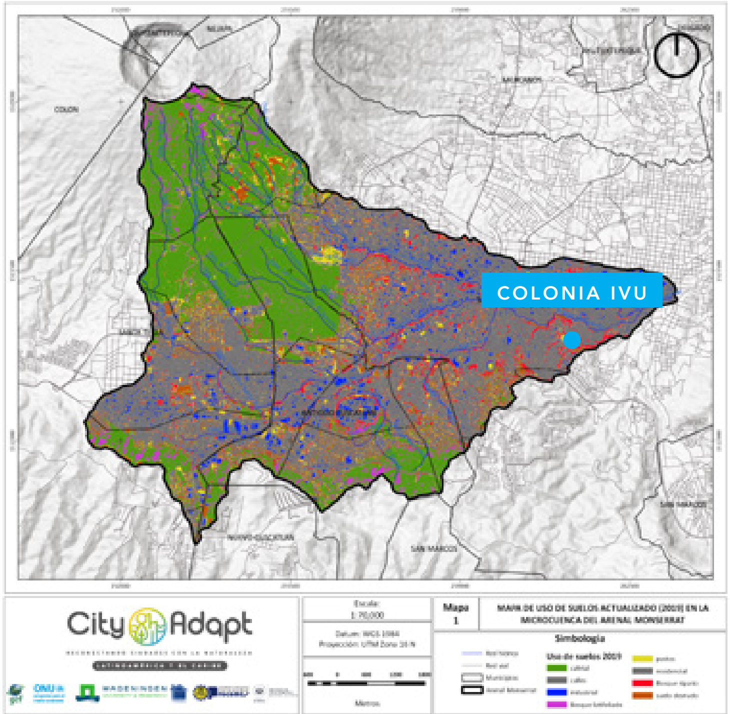
NbS benefits in cities

(Inostroza, Sarasti, Andrade 2020; Winograd et al. 2021):

- **Urban forest areas:** Regulation of water infiltration by 50-70% and water runoff by 10-20%.
- **Parks and green areas:** Regulation of temperature in urban areas by controlling "heat islands" with decrease of 1 degree C for every 10% of green cover.
- **Peri-urban areas:** Water supply, providing around 25-50% of water consumption in cities such as San Salvador.
- **Rural areas:** Provision of timber, coffee and food for the population, contributing to food security and export value chains.

Example: Identifying livelihoods in San Salvador

Land Use Map of Arenal Montserrat with the location of Colonia Ivu. Source: Fundasal 2019.



Climate change[ii] and environmental degradation affect the ecosystem services[xiii] on which the livelihoods of many urban dwellers depend. Through the impacts on ecosystems, the ones that provide key ecosystem services, and their relationship to the livelihoods currently used by people in the Arenal Monserrat micro-basins, are identified.

Figure 4: Identification of livelihoods in a neighbourhood in the Arenal-Monserrat basin, San Salvador Source: Fundasal 2019.

Perceived Ecosystem Benefits

Town	Ecosystems or agro-ecosystems	Focus group			
		Women +18	Men +18	Women 13-17	Men 13-17
San Salvador	Riparian forest	Provisioning of food supply, soil formation, regulation of erosion.	Climate regulation	Provisioning of food supply, soil formation, regulation of erosion.	Provisioning of food supply, soil formation, regulation of erosion.
	Bare ground	Food supply	Not identified	Food supply	Food supply

Figures 4 and 5 illustrate the identification of livelihoods in San Salvador. Figure 4 shows the main livelihoods identified in the city: coffee crops, school gardens and fruit trees. Figure 5 spatially identifies the main ecosystem services in the upper, middle and lower basin of the Arenal-Monserrat in San Salvador.

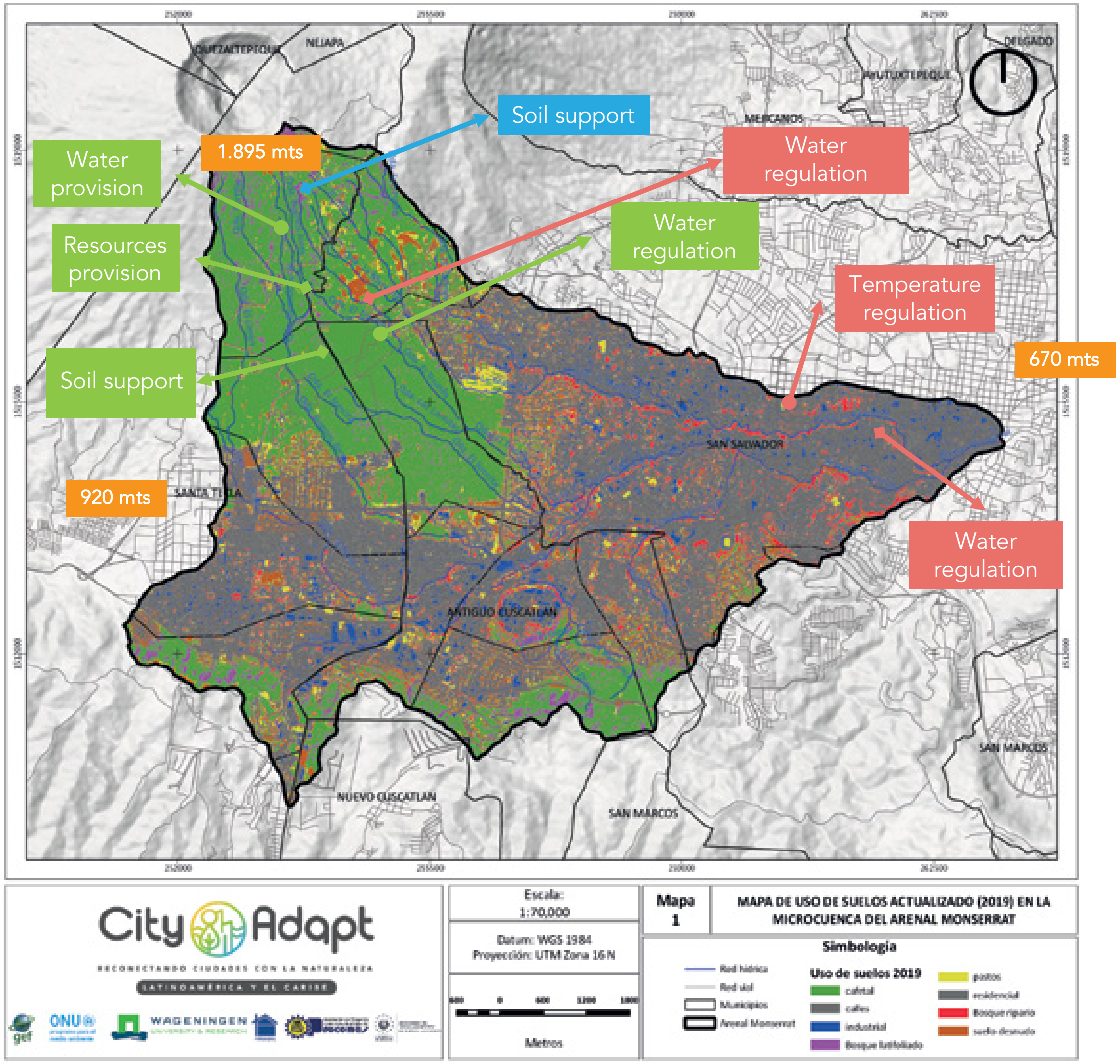


Figure 5. Identification of ecosystem services and land use in the Arenal-Monserrat watershed, San Salvador. Source: Fundasal 2019.

Step 1.b.
Stakeholder mapping

Stakeholder mapping is crucial to identifying key stakeholders in planning and decision-making related to risk[vii] and vulnerability[iii] in the city. It is because of this process that it is possible to understand the organisation and dynamics of ongoing processes in cities.

At the same time, stakeholder mapping allows for the collection of perceptions and thematic information (e.g. land use and urban fabric, risks and hazards, physical and social vulnerability, services and infrastructure, planned or ongoing works, etc.) usually dispersed in different offices, agencies, institutions and individuals

.

Photo: San Salvador

Objectives

- Identify partners/actors in decision making based on context (scales of ecosystem services,[xiii] levels of decision making).
- Identify stakeholder flow and relationships to ensure participation of all actors.
- Understand who/where/how/when they are involved in decision-making and implementation actions.
- Use all available knowledge and information to help improve the processes of urban planning, risk reduction, resilience building and implementation of adaptation actions.[i]
- Active dialogue with stakeholders to ensure engagement and participation.

Results

The expected outcome of this step is that the different stakeholders that play a relevant role in risk management,[vii] ecosystem conservation, urban planning and decision-making in the city are identified. At the same time, this stakeholder map allows to understand the relationships and dynamics between the actors, the institutional, political, social-economic and environmental context and thus to know where the problems are and who is being, or could be affected. This facilitates and ensures the definition of the scope of projects and/or actions. Finally, data and information on socio-economic status (including risks and vulnerabilities), livelihoods (including ecosystem services) and interventions underway and/or needed to adapt to climate change,[ii] reduce vulnerability[iii] and improve urban planning can be identified. This step prepares the ground for facilitating dialogue and information exchange between stakeholders.

Tools

- Interviews or focus groups.
- Participatory GIS

Example:
Map of stakeholders in Xalapa

During the development of the project, different key actors and the way they interact with each other were identified in Xalapa. The objective was to identify, on the one hand, those who were active participants in decision-making and, on the other hand, to identify those who want to participate more actively.

The links between local, municipal and regional institutions were also identified, distinguishing two important moments: 1) at the beginning of the project, where there is an important division between the decision-makers in terms of works, urban development, environment and the citizens as a whole, represented by the social development area which brings together all the requests and demands, as well as serving as a link between needs and solutions; 2) at the moment of implementing the NBS related to the project where a better coordination between the decision-makers in terms of works, urban development, environment and their integration at the local level is defined. In this way, the participation and involvement of all actors in the implementation, maintenance, financing and scaling up to other sites in the city can be ensured (Figure 6).

These two moments are necessary as not all stakeholders are involved in the same way or at the same time in the decision-making process. Depending on the stage, a more or less compact and integrated network emerges, where relationships between key actors need to be identified and monitored in order to know the willingness and need to create alliances, synergies and partnerships in the cities. This implies in some cases creating connections and relationships of trust and exchange, demonstrating the potential for win-win actions and initiating capacity building processes that aim to strengthen capacities in local governments and generate a climate of interaction between actors and decision-makers in order to propose joint solutions to common problem.

Photo: San Salvador

Key actors identified

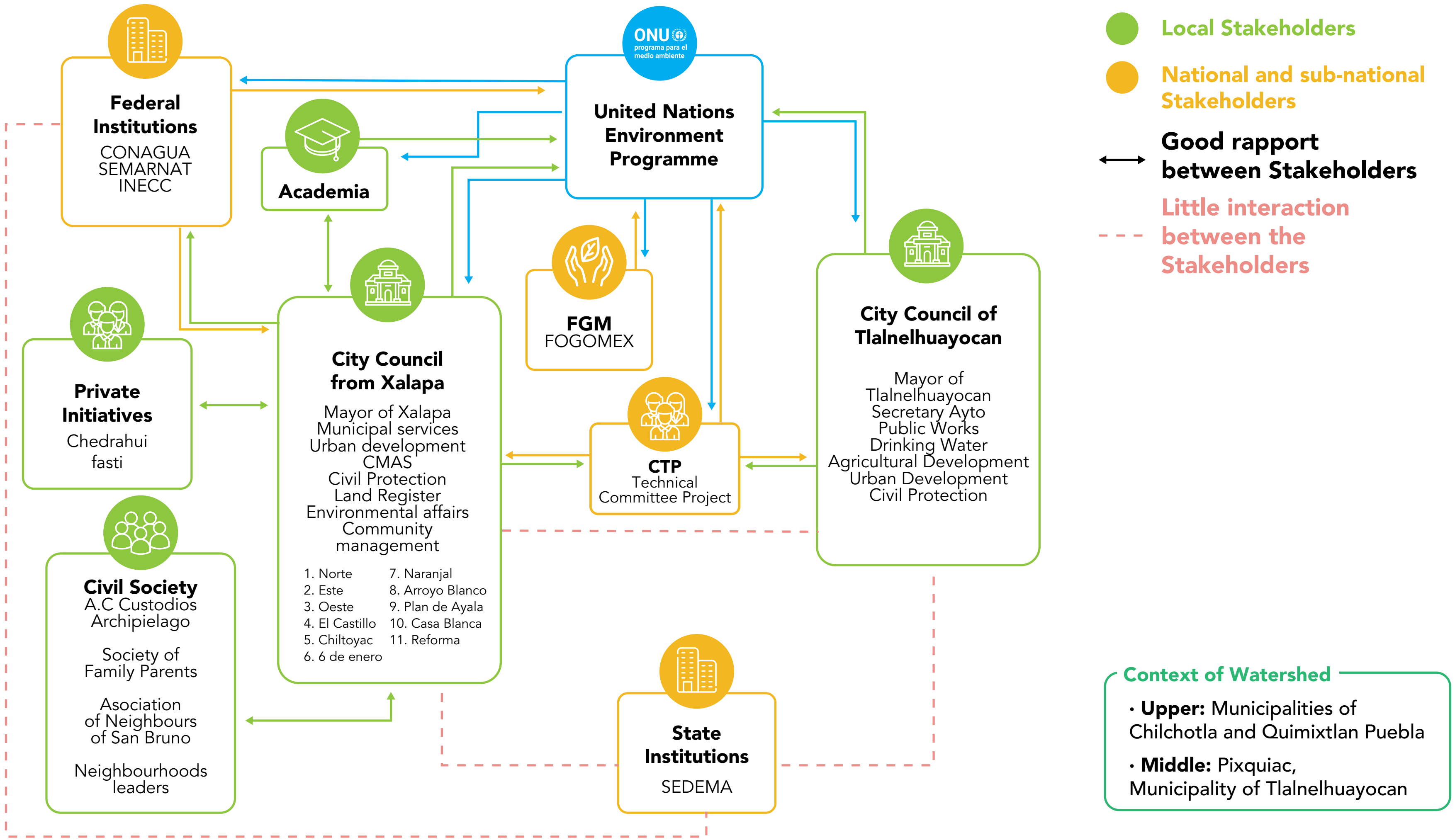


Figure 6: Stakeholder mapping in Xalapa and Tlalnelhuayocan. Source: CityAdapt Xalapa 2019.

Step 1.c.
Risk assessment, vulnerability analysis and hotspot identification

The vulnerability analysis[iii] is carried out with the objective of identifying hotspots.[xi] A hotspot is a prominent point in the city for its vulnerability or high concentration of risks[vii] and hazards[ix] given its exposure[x] and socio-economic sensitivity to climate change related events. Hotspots are especially important for identifying areas, infrastructure and ecosystem services that require NbS and/or risk management and natural resource management. Depending on the context of each city, hotspots can be located in different areas such as coastal zones, hillside areas, wetlands, among others.

A risk analysis is carried out based on climate hazards, which is considered as the potential for adverse consequences to occur, endangering human lives, natural and/or built elements of cities, where an outcome or the magnitude of the outcome is uncertain.

In climate impact assessment, the term risk is often used to refer to the potential for adverse consequences of a climate-related hazard, or of adaptation[i] or mitigation responses to that hazard, on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services[xiii]) and infrastructure. Risks are derived from the interaction of vulnerability (of the affected system), exposure over time (to the hazard), as well as the hazard (climate-related) and the likelihood of its occurrence (IPCC 2018).

Objectives

- Understand climate risks[vii] to livelihoods and ecosystem services in cities, both in urban, peri-urban and rural areas.
- Analyse past and current climate of the area (probability, frequency and magnitude of events, type of disasters, population and infrastructure affected, key areas).
- Use projections of temperature, rainfall, erosion, land use changes, type of natural disasters to analyse trends and tipping points.
- Identify and assess the "when" and "where" impacts and effects of climate variability[vi] and change occur.[ii]
- Identify social groups vulnerable to climate impacts (location, consequences).
- Identify areas and infrastructure vulnerable to climate impacts (location, consequences).
- Identify ecosystem services vulnerable to climate impacts (location, consequences).
- Identify livelihoods vulnerable to climate impacts (location, consequences).
- Analyse impacts of climate and non-climate stressors on livelihoods and ecosystem services to identify vulnerable groups, areas and resources.
- The assessment should pay particular attention to weighting and validation methods, as well as to defining hotspots taking into consideration the urgencies and needs of stakeholders and the timing and frameworks of policies.

Results

- Hotspots[xi] identified;
- Social groups vulnerable to climate impacts (location, consequences) identified;
- Infrastructure areas vulnerable to climate impacts (location, consequences) identified;
- Ecosystem services vulnerable to climate impacts (location, consequences) identified;
- Livelihoods vulnerable to climate impacts (location, consequences)
- Livelihoods vulnerable to climate impacts (location, consequences) identified.

Tools

- Expert judgement
- Indicators
- Cognitive mapping
- Participatory GIS
- Scenario building and/or use

Example: Climate risk and vulnerability assessment in Xalapa

In Xalapa, the assessment of the main hazards[ix] to climate-related events was made on the basis of the main elements of the natural environment used and the weight given to each based on expert analysis. In Xalapa and Tlalnelhuayocan, Veracruz, landslide and flood hazards were estimated and weighted (Figure 7). The results refer to the most hazardous sites, recording the name of the localities in the case of rural areas. In the urban area of Xalapa, the Community Management Centres (CMC) are identified and in some cases the city's neighbourhoods most likely to be affected are mentioned.

For more information on the Xalapa case study, SEE: Xalapa Vulnerability Assessment

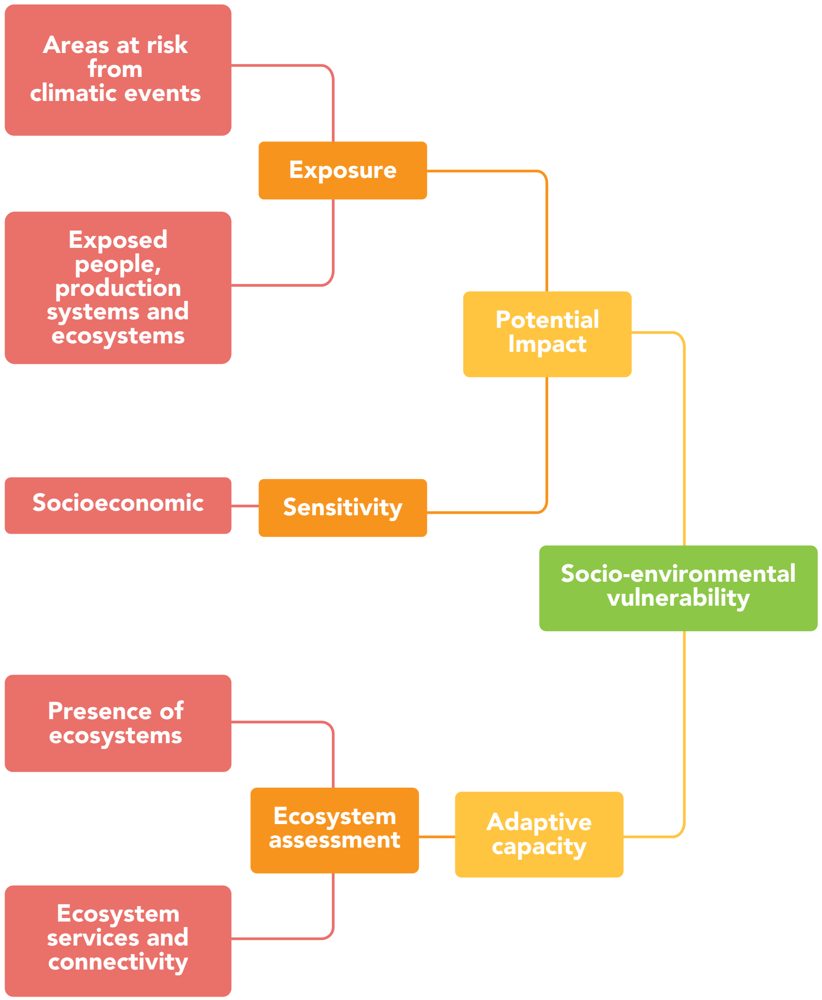


Figure 7: Vulnerability analysis in Xalapa and Tlalnelhuayocan. Source: CityAdapt Xalapa 2019.

Once the first technical Step of the vulnerability assessment had been completed,[iii] meetings were held to present and validate the results.

This was done in order to discuss with the actors in such a way that they could be contrasted and enriched with the local knowledge and perception of both authorities and inhabitants of the different urban and rural areas of Xalapa and Tlalnelhuayocan. The objectives of the meetings were:

- To assess the perceptions of the officials of the 13 Community Management Centres (CGC) of Xalapa on climate variability[vi] y el cambio climático[ii] and climate change, the changes identified in the climate of your climate in their area and the problems related to the effects of these changes, as well as the received information on the actions being taken at the neighborhood level. Identifying their knowledge about public actions and policies related to these issues was also considered as relevant.

- Present the results of the technical study to create a common understanding and trigger an open discussion so that problems and possible solutions are identified.

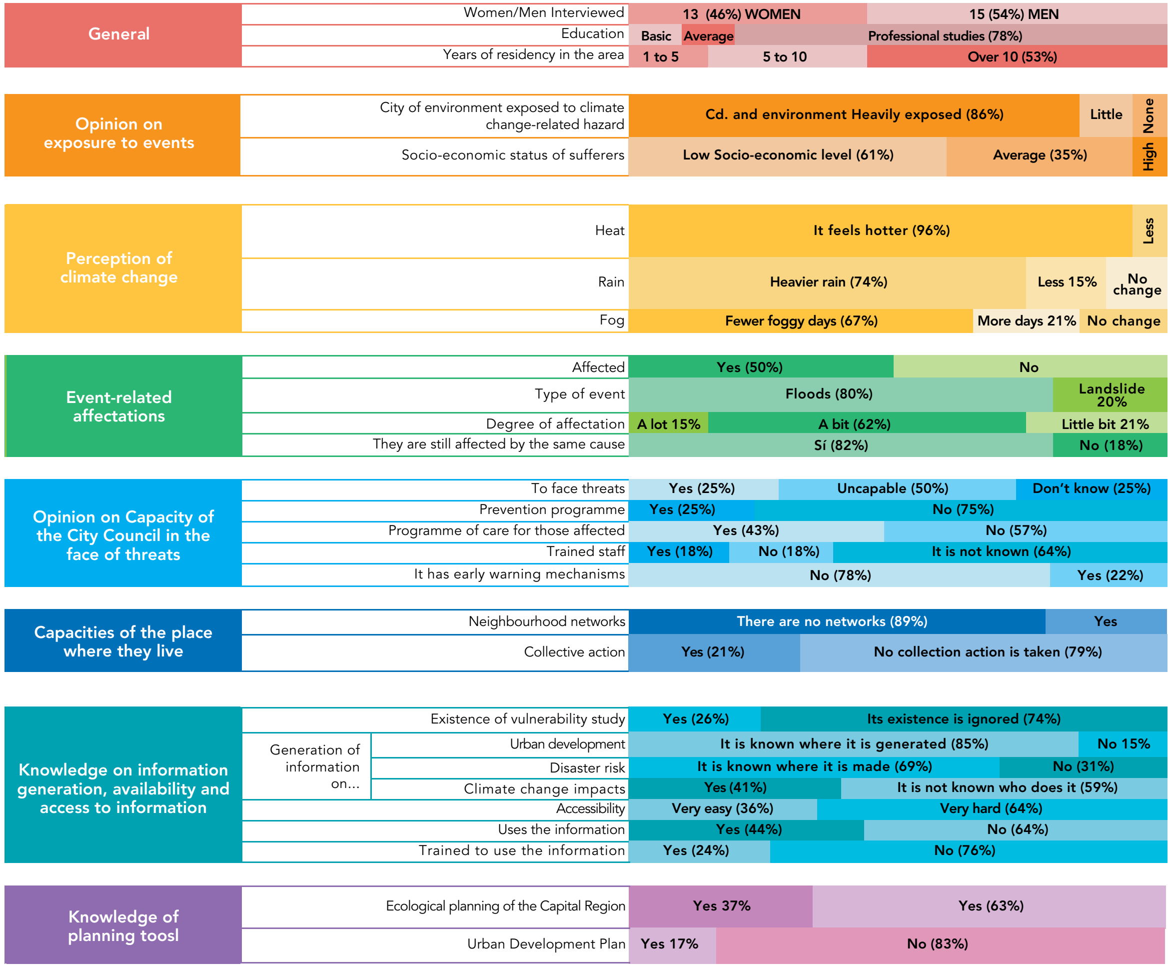


Figure 8: Summary of the results of the analysis of perceptions of climate change risks generated in meetings with community management centres in each neighbourhood of Xalapa.

Source: CityAdapt Xalapa 2019.

.

Definition of Xalapa's and San Salvador's hotspots

In the case of Xalapa, the hotspots[xi] are the result of the analysis of socio-environmental vulnerability by superimposing the potential impact to which an area or colony may be subjected according to its adaptive capacity and ecosystems. In this case, if the potential impact is high, but it has a high adaptive capacity[xii], the vulnerability[iii] of the inhabitants and their assets will be lower than in a place where the impact is also high but they do not have this adaptive capacity based on the condition of their ecosystems. This analysis procedure is carried out using a double-entry matrix where the qualitative values of the potential impact are crossed with those of the ecosystem valuation.

In the case of San Salvador, hotspots[xi] were identified on the basis of population and infrastructure at risk, recurrence and magnitude of floods and landslides, and the type of vegetation at risk and recurrence of fires.

For more information on the case of San Salvador, SEE: Vulnerability estimation in San Salvador.

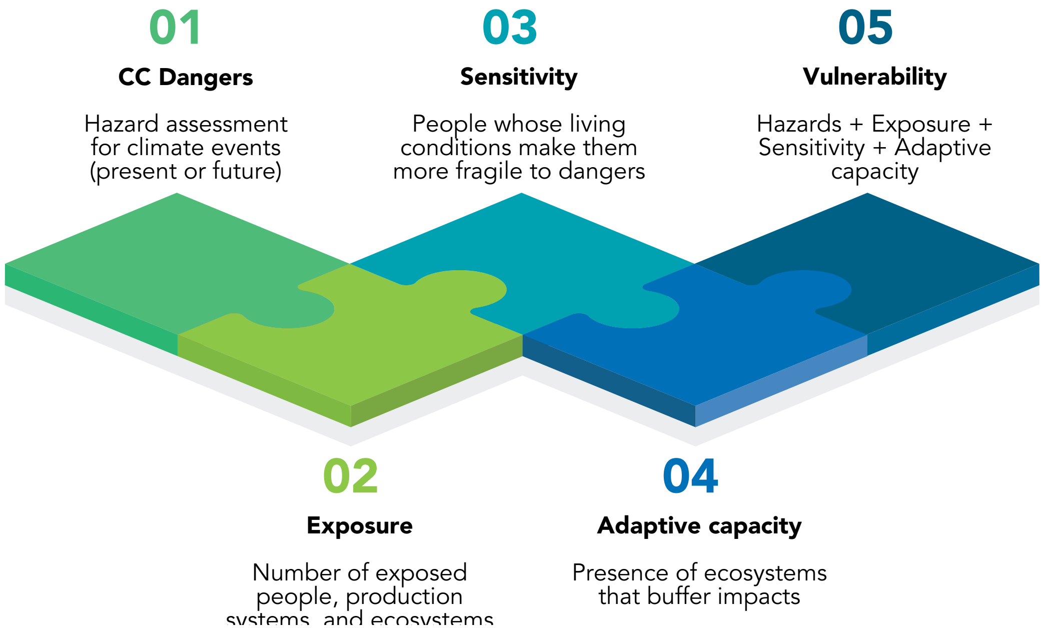


Figure 9: Methodological route for vulnerability assessment in Xalapa and definition of hotspots. Source: CityAdapt Xalapa 2019.

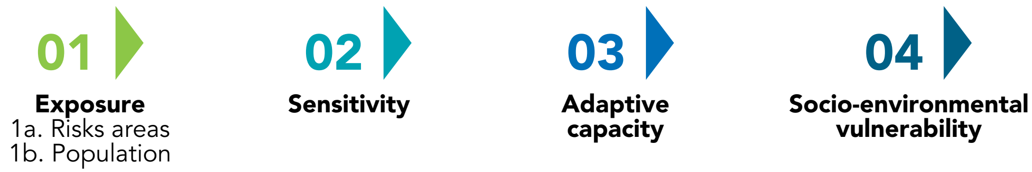


Figure 10: Methodological route for vulnerability assessment in San Salvador (Arenal Monserrat Basin) and definition of hotspots. Source: Fundasal 2019.

Addressing the challenge of data scarcity by the use of proxies

The vulnerability assessment[iii] involves having data and frameworks to organise information in order to analyse the risks [vii], hazards[ix] and sensitivities of the population, livelihoods and ecosystem services (provision, support and regulation). These data are organised according to the adopted framework into indicators, which serve to elaborate a quantitative measure or qualitative observation on the state, condition, impacts and responses to the issues under consideration (Figure 10).

These indicator frameworks should be useful to:

- Describe the baseline or reference situation.
- Visualise changes in risk reduction and vulnerability(ies).
- Relate to the stage of the process (assessment, exploration, validation, implementation, monitoring).
- Facilitate the collection of existing and necessary statistics and spatial data in a simple way.

Information can be organised synthetically in composite indices or in the form of simple indicators, depending on the uses and users of such information (see Figure 11).

	Environment	Social	Economy
Index	Climate risk index (areas at risk of drought, flooding and landslides)	Population risk index (population at risk of drought, flooding, landslides) Social risk index (poor population at risk of drought, flooding, landslides)	Infrastructure risk index (risk of roads and power lines to flooding and landslides)
Indicator	Frequency of natural disasters Probability of natural disasters Flood risk Drought risk Landslide risk Fire location Land use	Population in poverty Population with access to health services Population affected by natural disasters Human losses due to natural disasters Unsatisfied basic needs (UBN)	Economic losses due to disasters Accessibility to markets Accessibility to services Location of infrastructure

Figure 11: Indicators for vulnerability analysis. Source: Winograd 2013.

The lack of data, of information at the required scale, or of confidence in time series, are major constraints to conducting vulnerability assessments that integrate all components and whose analyses must use spatially explicit and quantitative methodologies.

For example, disaggregated data at the commune, neighbourhood or block level on gender, income and livelihood are often not available and consequently not all the necessary information can be collected. These shortcomings can be partially overcome through mixed approaches, cross-referencing or alternative means of data collection. Where data are missing, it may be necessary to use proxies, at least for some types of information. These may include:

- available data that correlates with unavailable data;
- data and information collected on a broader scale for downscaling to the appropriate scale.

Validation can be done in participatory workshops or through expert consultation.

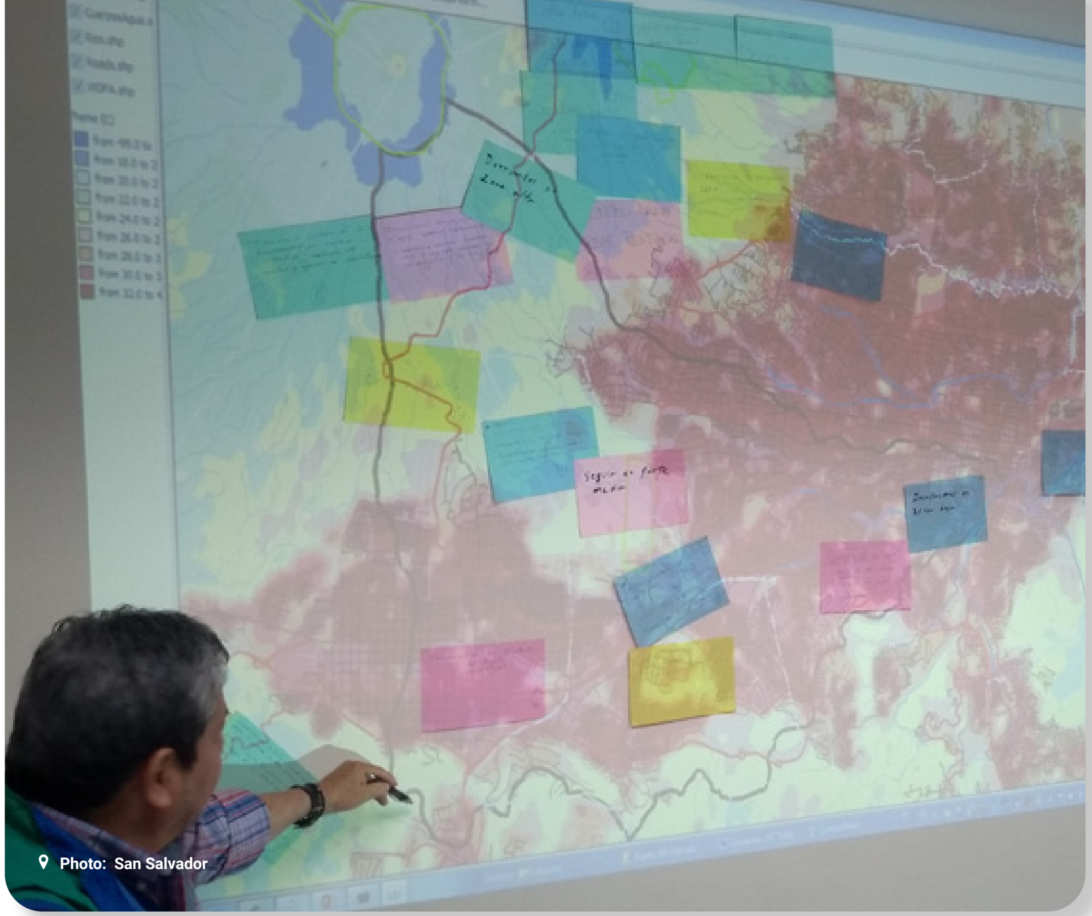


Photo: San Salvador

For more information SEE: Proxis memory aid for social vulnerability analysis

Support material

Attached documents

- Estimación de vulnerabilidad de San Salvador
- Estimación de vulnerabilidad en Xalapa
- Ayuda memoria proxis para la vulnerabilidad social

Additional documents

- **Fundasal. 2020.** Evaluación de vulnerabilidad socioambiental en la microcuenca del Arenal Monserrat, Ministerio de Medio Ambiente y Recursos Naturales, Salvador.

- **ONU Programa para el medio ambiente: CityAdapt. 2019.** Estudio de vulnerabilidad ante el cambio climático en Xalapa y Tlalnelhuayocan, Veracruz. ONU Programa para el medio ambiente, México, 156 pp.

- **GIZ-EURAC-UNU. 2018.** El Libro de la Vulnerabilidad: Concepto y lineamientos para la evaluación estandarizada de la vulnerabilidad. Autores: Kerstin Fritzsche, Stefan Schneiderbauer, Philip Bubeck, Stefan Kienberger, Mareike Buth, Marc Zebisch y Walter Kahlenborn

- **CEPAL. 2018**. Guía de ejercicios para la evaluación de desastres, CEPAL y GIZ, Chile.

- **GIZ, EURAC, UNU-EHS. 2018.** Evaluación de Riesgo Climático para la Adaptación basada en Ecosistemas –Una guía para planificadores y practicantes. Bonn.

- https://www.adaptationcommunity.net/wp-content/uploads/2019/06/giz-eurac-unu-2019-esp-guia-evaluacion-riesgo-climatico-abe-screen.pdf

- **Hallegatte S., Vogt-Schilb, A, Bangalore M, Rozenberg J. 2017.** Indestructibles: Construyendo la resiliencia de los más pobres frente a desastres naturales, Banco Mundial, Washington, DC.

- **Inostroza L., Garay Sarasti H, Andrade Pérez G. 2020.** Servicios ecosistémicos urbanos en Latinoamérica; Documento CODS, número 4, Bogotá, Colombia.

- **Overseas Development Institute (ODI). 2014.** Cambio climático y riesgo de desastre, ODI, Londres, UK. Available in this link.

- **Turnbull M, Sterrett C, Hilleboe A. 2013.** Hacia la Resiliencia: Una Guía para la Reducción del Riesgo de Desastres y Adaptación al Cambio Climático, Catholic Relief Services.

Storymaps

Construcción de resiliencia climática en sistemas urbanos mediante SbN

Webinars

- **Vulnerabilidad y soluciones basadas en la naturaleza en ciudades: Metodologías para la planificación y toma de decisiones**

- **Beneficios y oportunidades de los servicios ecosistémicos para la adaptación y la acción climática en áreas urbanas**

Other resources

- **Adaptation community**
https://www.adaptationcommunity.net/
https://www.adaptationcommunity.net/download/va/vulnerability-guides-manuals-reports/giz_sbv_ES_SOURCEBOOK_screen_v171019.pdf

- **Weadapt**
https://www.weadapt.org/

- **Climate knowledge**
https://climateknowledgeportal.worldbank.org/

- **Platform for disaster prevention**
https://www.preventionweb.net/english/

Section 2. Designing Nature-based Solutions

Step 2.a. Exploratory workshops

Example: Exploratory workshop for the Arenal-Monserrat basin, in San Salvador

Step 2.b. Validation workshop

Example: NbS design through participatory processes

Step 2.c. The technical model: NbS scope, planning and technical design

Example: Water harvesting systems implementation guidelines in Xalapa

Support material

Objective

Exploring options for designing NbS includes the execution of participatory workshops to identify possible and necessary actions. This discussion lays the foundations to validate the implementation of NbS in short-, medium- and long term.

During these workshops, problems, causes and consequences and possible NbS are identified, integrating perspectives and range of action of every actor in the city. Based on this diagnosis, a set of pilot NbS actions are designed to be implemented in the short term. In a following workshop the validation is carried out through an exchange, discussion and approval of the identified NbS options, the integration with ongoing actions and potential new measures, carrying out a first evaluation of direct costs and benefits, co-benefits, compensations and synergies to thus develop a portfolio of actions.

There is no particular approach to NbS, but a series of strategies, processes and actions according to the context and decision levels of each city. For this reason, it is necessary to explore different options through participatory workshops. These events gather a group of people in order to seek their opinions, incorporate their knowledge and solve problems in a collaborative and creative environment. These workshops serve to evaluate a problem, explore different options or validate the implementation of chosen actions.

It is helpful to know that in cities, generally, two different functional components are considered regarding mitigation and climate change[ii] adaptive infrastructures: the green and the grey (or built) infrastructures.

Module guiding questions

- How can NbS be explored and designed considering different actors?
- How should chosen options be validated?
- What criteria should be taken into account?

For more information about NbS, see: NbS ABC

Results

The main result of this unit is a list of NbS options stipulated in a participatory way and validated by strategic social actors in the urban context as well as the development of technical models for the most necessary NbS.

Estimated duration

Estimated time for this step is between 3 to 6 months.

Involved actors

Exploring NbS options implies the participation of local and regional decision-makers in order to determine objectives and needs. Department directors and project managers; consultants, departmental and sectoral technicians; NGO and cooperatives members; technicians involved in the implementation of actions, local managers involved in thematic and specific sectors are necessary to carry out an exploratory process according to the city needs, the population urgency, the ecosystem capabilities and particular demands.

Step 2.a. Exploratory workshops

Objectives

The purpose of step 2.a. Exploratory workshops, is to carry out different options of exploratory workshops to address hotspots[xi] and vulnerabilities[iii] found in Section 1. These exploratory workshops can be carried out by focus groups or by different actors, seeking to:

- Gather participants' knowledge (e.g. tables, matrices, decision trees, networks, spatial algebra) on territory;
- Develop a common language in order to generate confidence among stakeholders;
- Have different identification and exploratory perspectives;
- Compare and analyze results for different options;
- Improve results based on participants' applied knowledge;
- Compare current and future situations;
- Detail and refine alternatives;
- Evaluate possible impacts, conflicts, compensations and stakeholders.

Results

The main result for this step is to generate a collective diagnosis in order to create a portfolio of options to address vulnerability[iii] and respond to the identified hotspots[xi] as well as the identification of new options.

Tools

- Brainstorming
- Interviews or Focus Groups
- Expert Judgement
- Cognitive Cartography
- Scenario Building
- Participatory GIS
- Multicriteria Analysis

Example: Exploratory workshop for the Arenal-Monserrat basin, in San Salvador

The objective of the exploratory workshops is to compare the current situation with future scenarios in order to be acquainted with, and analyze what would happen if, for instance: 1) an NbS option is implemented to solve water issues in an urban area, 2) an option based on grey infrastructure is implemented to solve flooding issues in the city neighborhoods, 3) an integrated NbS and grey infrastructure option is implemented for disaster and water management in urban and suburban areas of the city.

The achievement of this goal should begin with the integration of involved actors' knowledge in order to form a common understanding. This understanding is achieved through the use of statistical, spatial and local data and information by the work groups, concerning the different facts, perspectives and needs related to vulnerability(ies)[iii]. This includes risks[vii], hazards[ix], sensitivity, livelihoods and the ecosystem services affected by variability, climate change[ii], the need for NbS and its effectiveness or other actions. Based on the exploratory workshop results, a collective diagnosis can be formulated to define a broad portfolio of pilot options based on NbS criteria that includes structural and non-structural measures. So, through work groups, NbS alternatives and options can be detailed, to evaluate their impacts and conflicts related to each option in order to select the most appropriate NbS. Next, new options and a proper essential arrangement can be identified to ensure the pilot NbS impact in other areas of the city. Finally, the workshop ends with a summary of learned lessons and recommendations for the following steps originated from the work groups, especially NbS validation and implementation (Figure 1).

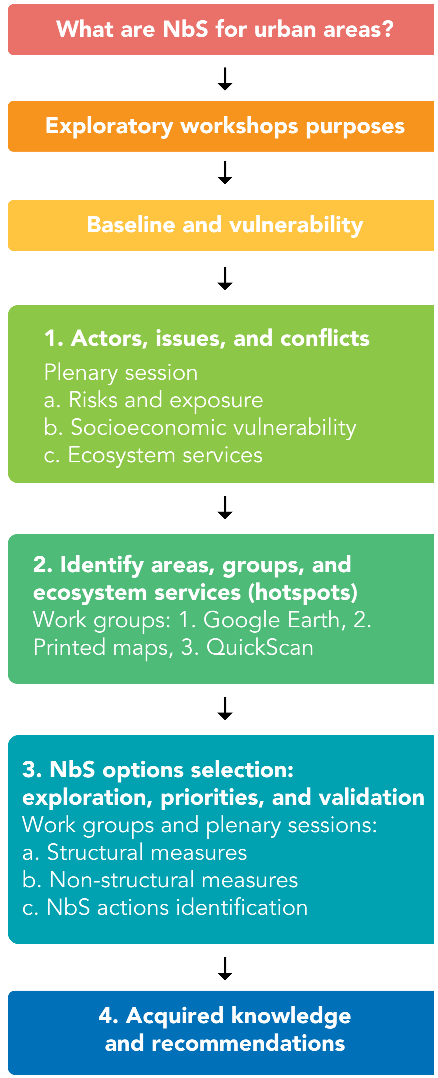


Figure 1: Roadmap of the Arenal-Monserrat basin exploratory workshop, San Salvador. SEE: San Salvador exploratory workshop

Step 2.b. Validation workshop

Based on the results of the first exploratory workshop and in coordination with local teams, another workshop is held to validate a portfolio of NbS actions in cities' urban, suburban and rural areas. These workshops lead to validating actions, justifying locations, verifying and demonstrating undesirable effects and impacts, collecting evidence of compensations and capacity to implement and organize the pilot NbS actions selected in step 2.a.

The **concept of compensations** (assimilated to that of trade-offs) refers to the decision made in a conflicting situation in which the availability of products, factors, services or benefits must be lost or reduced on behalf of another. Generally, these situations occur when supply and demand for the available resources, regulation or support of any service or benefit cannot be simultaneously satisfied. On many occasions, due to their dependence, cost-benefits or advantages-disadvantages, may fall on the same actors or on actors outside the original process (TEEB, 2011).

Objectives

The main objective of this step is to validade selected NbS options through collective construction spaces and various types of tools, aiming to select the most suitable alternatives for the city context and challenges.

Results

- To detail and refine NbS alternatives to respond to hotspots[xi] and vulnerabilities[iii];
- In a positive atmosphere, to debate local development options to improve resilience[xv];
- To identify new demands and capabilities to implement NbS.

Tools

- Indicators
- Multicriteria Analysis
- Cost-benefit Analysis
- Scenario Building
- Participatory GIS

Further, a final check of the selected NbS is recommended so that they meet the following criteria: i) to respond to a specific sociocultural context, easily achieved by the design of interventions and participatory workshops; ii) to strengthen current local ecological conditions, achievable by applying strategies such as enrichment planting, restauration, among others; iii) to improve resilience[xv] in relation to climate change[ii] and risk management; possible since the selected NbS are an answer to vulnerability hotspots[xi] iv) including the creation of extra benefits in its design, originating from ecosystem services[xiii] (Figueroa-Arango 2020).

NbS validation requires tools able to prioritize actions. There are several types of analytical and quantitative tools to evaluate, compare and prioritize the most impactful, efficient and effective measures.

The multi-criteria analysis is the most commonly used to integrate economic, social and environmental aspects into decisions. However, this type of analysis has limitations when the measures and actions are spatially explicit or when the degree of uncertainty about climatic and economic dynamics is very high. In these situations, other methods must be used, such as a knowledge matrix or adaptive management methods.

For this reason, other tools, which are complementary or include multi-criteria analysis, have been developed, such as: Integrated Valuation of Ecosystem Services and Tradeoffs, Adaptation Support Tool (AST), Resource Investment Optimization System (RIOS) and QUICKScan.

In all these cases, the use of these methods and tools must be based on a participatory process whereby criteria and measures can be selected in order to meet the needs of all the actors involved and create the necessary knowledge and dynamics for the implementation stage.

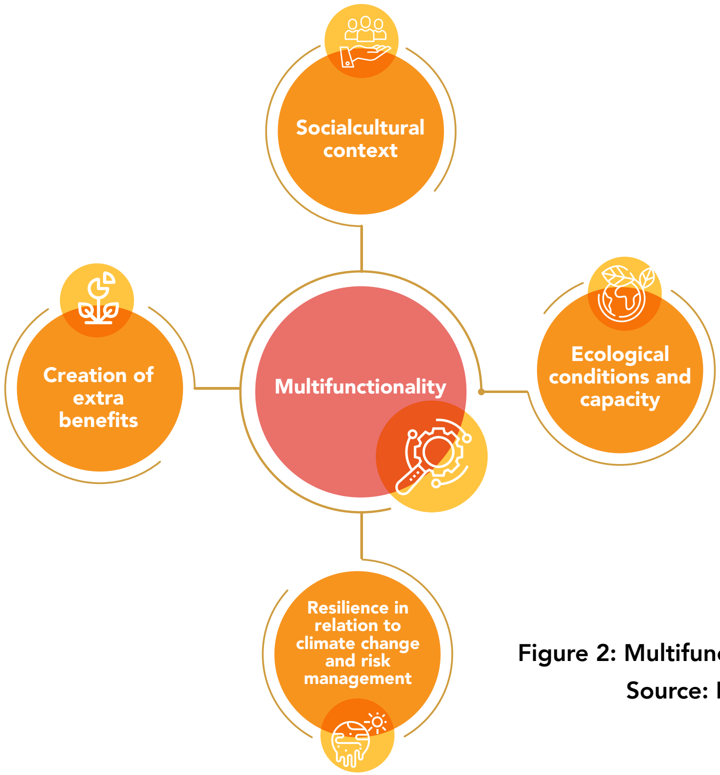


Figure 2: Multifunctionality applied to NbS design. Source: Figueroa-Arango 2020.

For more information about the use of QUICKScan as a tool to prioritize and validate NbS measures in order to build a portfolio of options in cities, See: Xalapa and San Salvador.

Example: NbS design through participatory processes

Given the nature of NbS, during the workshops it is necessary to use open, flexible and transparent tools that permits to clearly visualize data and integrate the knowledge of all actors. This ensures the combination of co-design and useful knowledge in order to advance on the preparation of a portfolio of options and on the validation of options to be implemented.

The workshops' results should be submitted to different decision makers at the urban level to collect their points of view and ensure the support of many of them during the NbS implementation process. Given the different processes and dynamics during decision-making in each city, it is necessary to validate the portfolio of NbS options based on each city's particular demands and needs and its environmental conditions, in order to ensure NbS implementation and facilitate its influence on public policies.

The workshops' results should help to bridge the gap between: i) different levels of action (plot/household, neighborhood/community, river/basin, urban/suburban area), ii) the actors involved in decision-making (neighbors, neighborhood organizations, local/departmental/national governments, universities, NGOs, private sector) and iii) short and medium term (political) and long term (environmental) contexts.

Photo: San Salvador

Step 2.c.
The technical model: NbS scope, planning and technical design

The technical model is an essential step to define technical details of the chosen and prioritized NbS. This information is particular for each context and each NbS.

Objectives

The main objective of this step is the design of a technical model that describes the problem to be solved through NbS; determine the most appropriate technical design for the situation, understanding the magnitude and scale of the problem.

Results

The main result for this step is the elaboration of a technical model able to determine the NbS scope, planning and design. This includes the following results:

- Technical model designed based on the problem to be solved, possible solutions, their design and the magnitude and scale of actions.
- Datasheets and guidelines designed to ensure that the portfolio of actions is technically viable

Tools

- Expert Judgment
- Cost-Benefit Analysis

Example: Water harvesting systems implementation guidelines in Xalapa

Drinking water supply sources in Xalapa are outside its administrative limits (60% came from the Huitzilapan river basin in the state of Puebla, 36% from the Pixquiac river basin in the city of Tlalnelhuayocan Veracruz). Only 4% comes from sources in the rural area of Xalapa.

Currently, the city has water scarcity and rationing issues even in the rainy season because the demand has been increasing and the infrastructure, built 30 years ago, is no longer sufficient to supply the current demand, as it has reached the end of its lifespan.

In order to respond to this situation in Xalapa, there are two alternatives: one, through classical engineering, with gray infrastructure, which would consist of looking for an alternative supply source: the Perote Zalayeta aquifer located 50km from the city, using deep well electric pumping systems. The other, through NbS, consists of installing rainwater harvesting systems to solve scarcity and support an integration between green and gray infrastructure that allows a more resilient water resources management.

Photo: Kingston, Jamaica

Photo: Xalapa, México

These rainwater harvesting systems (RWHS) retain, collect and store rainwater, with the advantage of using an available resource that would otherwise be wasted. In addition, it increases water availability in increasingly frequent periods of scarcity and reduces the consumption of drinking water from the municipal water supply. These are simple installation systems with a relatively low economic investment, that generates good quality water supply for multiple uses. For this reason, they contribute to decreasing the energy consumed for pumping and transporting water to homes, reducing waterflow in manholes and therefore flooding.

This way, overexploration of water bodies and aquifers is reduced, facilitating access to water for populations that normally have to travel long distances to collect water, which is not always of good quality, exposing them to risks of epidemics and diseases (CityAdapt, 2020). The proposed NbS for this situation is the construction of a rainwater harvesting system to solve scarcity and support an integration between green and gray infrastructure that allows a more resilient management of water resources.

NbS implemented by the CityAdapt project

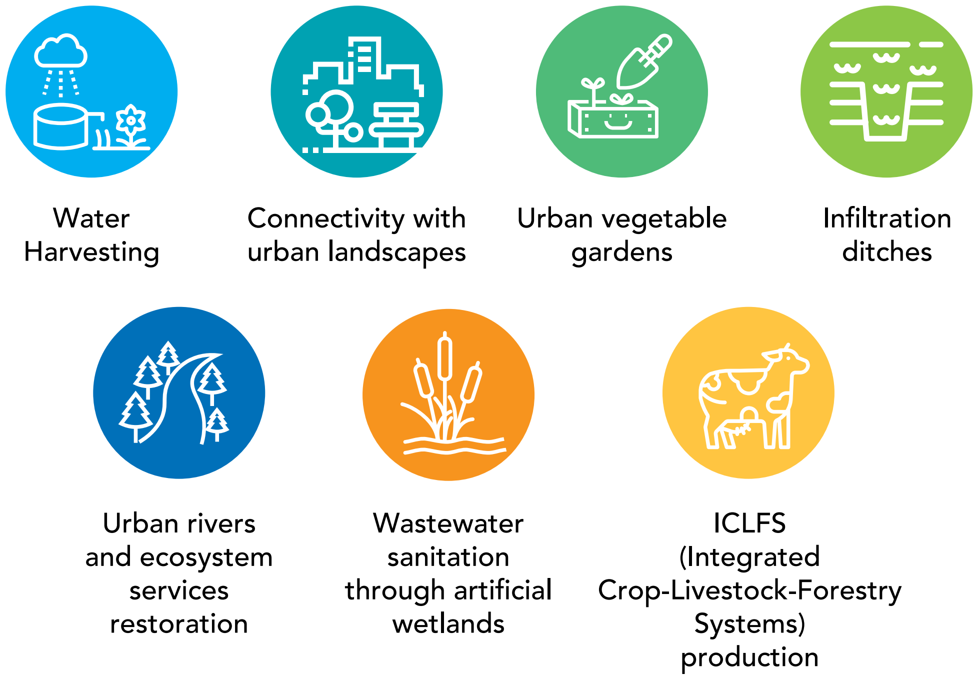


Figure 3: Developed NbS according to CityAdapt Project's context.

For more information, see : NbS guidelines in San Salvador and NbS guidelines in Xalapa, where you can find all the datasheets from different NbS: infiltration ditches, soak pits, agroforestry, water land restoration, riparian restoration, rainwater harvesting.

Support material

Attached documents

- San Salvador exploratory workshop
- Using QUICKScan for San Salvador validation workshop
- Using QUICKScan for Xalapa validation workshop
- Multicriteria analysis for the identification of municipal adaptation strategies

Additional documents

- **Fundasal, Procomes, WENR y MARN, 2019,** Final report for the Arenal de Monstserrat (San Salvador, El Salvador) micro basin exploratory and validation workshop.

- **UN Environment Programme: CityAdapt. 2019**. Vulnerability study about climate change in Xalapa and Tlalnelhuayocan, Veracruz. UN Environment Programme, Mexico, 156 pp.

Tools

- **QUICKScan** Integrated Valuation of Ecosystem Services and Tradeoffs

- **Adaptation Support Tool (AST)** https://www.wur.nl/en/product/Adaptation-support-tool.htm https://publicwiki.deltares.nl/display/AST/AST2.0+Documentation

- **ALivE - Adaptation, Livelihoods and Ecosystems Planning Tool Planning adaptation strategies Community-based Risk Screening Tool –** Adaptation and Livelihoods Resource Investment Optimization System (RIOS)

- **Cost-benefits analysis to climate change adaptation in Latin American urban areas.** Available here.

- **Fundasal, Procomes, WENR y MARN. 2019.** Final report for the Arenal de Monstserrat (San Salvador, El Salvador) micro basin exploratory and validation workshop.

- **Fundasal, Procomes, WENR y MARN. 2019.** Final report for the Arenal de Monserrat micro basin (San Salvador, El Salvador) validation and arrangement workshop.

- **Hardoy, J., Gencer, E., Winograd, et al. 2019.** Participatory planning for climate resilience in Latin American cities. A Ciudades Resilientes al Clima initiative. FFLA, CDKN and IDRC.

- **IIED, IUCN and UNEP-WCMC. 2019.** Nature-based solutions to climate change adaptation, Briefing reports.

- **Lara Pulido A,.2017.** Cost-benefits analysis of climate change adaption measures in Latin American cities urban areas, UN Environment Programme, European Union and Panama. Available here.

- **UN Environment Programme: CityAdapt. 2019.** Vulnerability study about climate change in Xalapa and Tlalnelhuayocan, Veracruz. ONU Environment Programme, Mexico, 156 pp.

- **UNEP-IEMP.2019.** Research on Ecosystem-based Adaptation (SbN): A reference guide. Document produced as part of the GEF-funded SbN South project.

- **UICN. 2020.** Global Standard for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of NbS. First edition. Gland, Switzerlandza: IUCN.

Webinars

- **Vulnerability and NbS in cities: Planning and decision-making methodologies.** Available here.

- **Gender and climate change adaptation: two connected elements in generating urban resilience.** Available here.

Storymaps

- **Nature-based Solutions: Exploration, identification and implementation at the Arenal Monserrat (San Salvador) micro basin.** Available here.
- **Example of identification, and valuation of Nature based Solutions in Kingston, Jamaica** Available here.

Additional resources

- https://pubs.iied.org/pdfs/17606SIIED.pdf

- https://ec.europa.eu/environment/pubs/pdf/factsheets/Ecosystems%20goods%20and%20Services/Ecosystem_ES.pdf

- https://www.esa.org/wp-content/uploads/2013/03/numero2.pdf

- https://www.minambiente.gov.co/images/cambioclimatico/pdf/SbN_/MADS_Guia_SbN_LIBRO_Digital-Cambio.pdf

- https://www.cifor.org/rehab/_ref/glossary/Rehabilitation.htm

- https://www.cifor.org/rehab/_ref/glossary/restoration.htm

- https://www.agronegocios.co/tecnologia/zanjas-de-infiltracion-recuperan-los-suelos-2622977

- https://www.laprensagrafica.com/elsalvador/Que-son-las-lagunas-de-laminacion-que-se-construiran-en-San-Salvador-20180111-0039.html

- https://www.iucn.org/sites/dev/files/content/documents/2019/global_standard_for_nature-based_solutions_spanish_2.pdf

- https://www.youtube.com/watch?v=OoBwC5BAjT8

- https://www.youtube.com/watch?v=I3Hm-eL5rYA

- https://ec.europa.eu/environment/nature/ecosystems/docs/GI-Brochure-210x210-ES-web.pdf

- https://lac.wetlands.org/blog/infraestructura-azul-verde-para-la-adaptacion-al-cambio-climatico-combinando-la-naturaleza-y-estructuras-semi-naturales-para-la-gestion-del-agua-y-reduccion-de-riesgos-en-las-cuencas-peruanas/

- https://www.imip.org.mx/Beta/pdu2016/PDUS_2016/08_VIII_Guia%20III%20Infraestructura%20Verde.pdf

- https://blogs.iadb.org/ciudades-sostenibles/es/campo-grande/

- https://blogs.iadb.org/ciudades-sostenibles/es/infraestructura-gris-y-verde-para-mayor-resiliencia-urbana/

Section 3. Implementation of Nature-based Solutions (NbS)

Step 3.a. The business model: evaluate and document the direct and indirect costs and benefits of NbS

Example: Cost/Benefit Analysis: Business Model for Infiltration Ditches in San Salvador

Step 3.b. The financial model

Example: Water Harvesting Case Study

Step 3.c. Impact and synergies of NbS with other solutions, programs and/or policies

Example: The management of water resources

Support material

Objectives

This module aims to:

- Perform a cost-benefit analysis of NbS, considering quantified and documented costs, benefits and assumptions of technical feasibility .
- Define a financial model that analyzes the feasibility of accessing financial resources to implementate NbS. This includes structuring an organizational (relevant actors) and operational (execution of funds) model in the city.
- Define options and strategies to assess NbS' impact in other policies and/or programs.

Involved actors

For this step, the participation of decision-makers at the local and regional level is necessary to ensure integration into territorial planning. The directors of secretariats, departments and project managers; advisors,, technicians of departments and sectors; members of cooperatives and NGOs, technicians involved in the implementation of actions, and local managers involved in specific themes and sectors, are necessary to ensure implementation at the different scales of staggering.

Module guiding questions

- What are the costs and benefits of NbS?
- How and to whom does NbS generate value and benefits?
- How can NbS be financed?
- What synergies and advocacy can be generated through the implementation of NbS?

Results

- Identification of a business model that reflects the costs and benefits of NbS, including its beneficiaries;
- Identification of strategies for the financing of NbS;
- Identification of the possibilities of incidence, impact and staggering of SbN.

Estimated duration

The estimated time for this step is between 12 and 24 months.

Step 3.a. The business model: evaluate and document the direct and indirect costs and benefits of NbS

The business model seeks to evaluate the costs and financial return of investments, comparing NbS with other types of solutions (Figure 1). The cost-benefit evaluation includes the quantification of financial costs of installation and maintenance, economic and environmental benefits and the assumptions of technical feasibility, and magnitude of the solutions that must be considered. This implies having a good definition of the scope and priority areas that will give the scale so that the proposed NbS can contribute effectively to the integral or punctual solution of the problems to resolve.

Objectives

- Quantify the financial costs, economic and environmental benefits.
- Perform the cost-benefit analysis that shows the alternatives to NbS and if necessary, the integration and linkages with other actions.

Results

The main result of this step is a business model that includes the costs, benefits and impacts of NbS. To elaborate the business model three basic components must be taken into account (GIZ, 2017).

- The benefits: advantages or positive effects of NbS;
- Costs: financial resources required to implement NbS actions and the disadvantages or negative effects caused by these that eventually involve compensation;
- Impacts: effects or changes in vulnerability, livelihoods and ecosystem services that occur as a result of the implementation of NbS.

Tools

- Expert judgment
- Multi-criteria analysis
- Cost-benefit analysis

BENEFITS

Main benefits of the adaptation objective

E.g. mitigation of storm damage and floods, year-round water supply, sustainable agricultural productivity in the face of drought, maintenance of species habitat, etc.

Co-benefits of ecosystem services

E.g. improvement in health and food supply, better and diversified income opportunities, disaster risk reduction, watershed protection, biodiversity enhancement, etc

COSTS

Direct implementing expenditure

E.g. personnel, equipment, transportation, infrastructure, maintenance, etc.

Institutional costs and primary enablers

E.g. training, development of plans, laws, policies, inventive, etc.

Opportunity costs

E.g. income and production that are dispensed with due to restrictions of use of soil, etc.

Social and environmental losses

E.g. negative impacts on women, communities located downstream, etc.

IMPACTS

Temporary impacts

E.g. the pace at which habitat recovery restores ecosystem services, when intervention costs are involved, including the interests of future generations, etc.

Special impacts

E.g. gains and losses for upstream and downstream communities, costs and benefits for ecosystem providers and users, cross-border effects, etc.

Special impacts

E.g. changes in access to resources or opportunities for income between men and women, rich and poor, urban and rural areas, regions, sectors, communities, etc.

Figure 1: Benefits, costs and impacts of NbS. Source: GIZ 2017.

For more information, SEE The cost-benefit analysis of NbS.

Example: Cost/Benefit Analysis: Business Model for Infiltration Ditches in San Salvador

Example of infiltration ditches to face systemic problems in the Basin Arenal-Monserrat, San Salvador

Scale: Basin · Jurisdiction: Intermunicipal

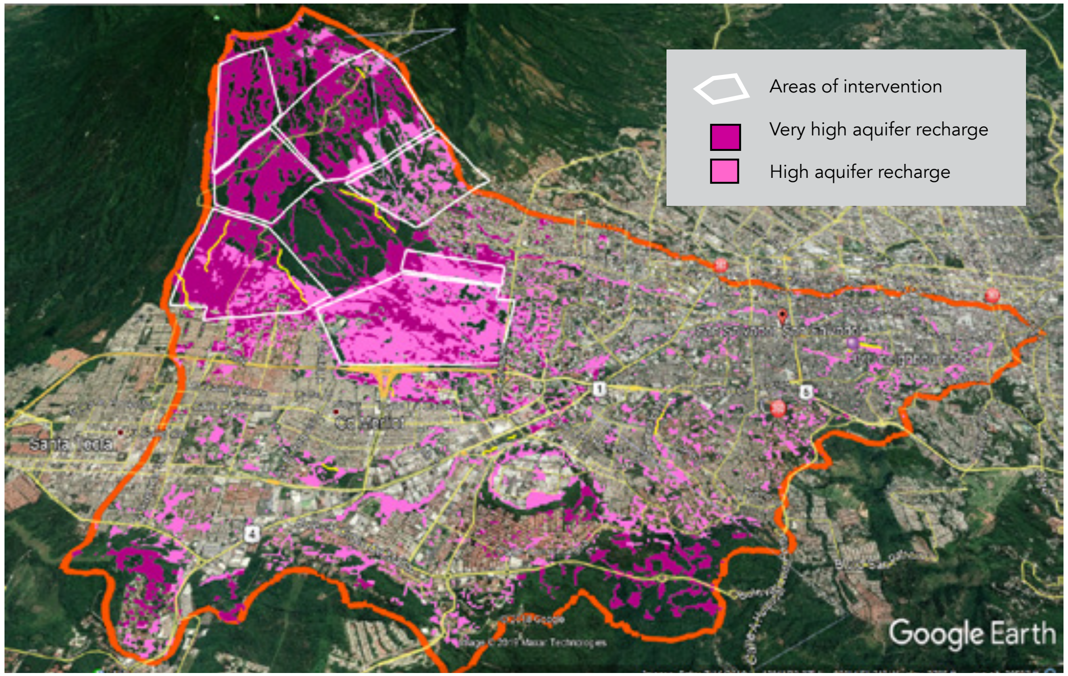


Figure 2: Map of Arenal Montserrat according to its aquifer recharge zones.

Description	Quantity (Days/ person)	Unit (USD)	Total (USD)
Elaboration of stakes	1	10	10
Trenches of the terrain	2	10	20
Elaboration of ditches	80	10	800
Protection	6	10	60
Maintenance	20	10	200
		Total	**1,090**
		Cost per linear meter	**0.545**

Figure 3: Cost breakdown for infiltration ditches in the Arenal Montserrat

General Benefits

1

They increase the resilience of the city and they decrease the vulnerability of urban communities.

2

They reconnect the city with nature, to improve the quality of life of the inhabitants.

3

NbS integrated into the grey infrastructure ensures that the reservoir's ability to slow flows of violent water and reducing peak flow increase substantially, solving the systemic problem of flooding in San Salvador.

Specific benefits

Environmental

- Each linear kilometer with infiltration trenches permits 210 m^3 of water infiltration in the ground.
- With only 50% of the coffee farms in the upper part of the Arenal Monserrat micro-basin restored with infiltration ditches, 110,000 m^3 of water can be infiltrated, which is equivalent to 50% of the reservoir capacity of the rolling lagoon.
- They provide moisture to plants, control erosive processes con farms and prevent nutrient loss.
- They decrease the violent flow of water and help reducing peak flow in the city center.

Social

- Job creation.
- Increased crop yields.
- Improved livelihoods.

Economic

- Reduced investment costs (Infiltration pond = 21.9 million USD against infiltration ditches program in the upper part of the micro-basin = 472,500 USD).
- Reduced maintenance costs.

Source: van Eupen et al.; 2020; PROCOMES, 2019

Step 3.b.
The financial model

When a technical model (Section 2) and a favorable business model (Section 3) are available, it is necessary to secure funding for the implementation of NbS. However, NbS are very diverse. Sometimes, they are small-scale interventions such as small community gardens or capturing water on the roofs of houses and schools. In other cases they involve very large infrastructure investments such as sustainable urban drainage schemes (SUDS), treatment plants through wastewater phytoremediation or ecological restoration projects for the rehabilitation of riverbanks.

Financing refers to securing funding to sustainably create, implement and maintain a NbS (McQuaid S, 2020). That is why public finances are not the only source required for innovation in the financing of NbS. Open and mixed innovation and transition approaches to addressing societal challenges recognize the benefits of engaging citizens and social actors in the creation of these NbS (Figure 2 and 3). The role of government in this approach includes the articulation of user needs, the joint creation of a common vision, the coordination and definition of public policies and governance (Morales, 2020, McQuaid, 2020).

.

Objectives

- Explore traditional financing mechanisms and sources of capital for NbS:
- Identify new bilateral or private sources to finance NbS;
- Develop financing portfolio;
- Create alliances (public-private, inter-institutional).

Results

The main result of this step is the evaluation and documentation of direct and indirect costs and benefits, as an input for a business model and to ensure the identification of the best alternatives to finance NbS in cities.

Tools

- Actor mapping
- Expert judgment
- Participatory GIS
- Relationship flow
- Interviews or focus groups

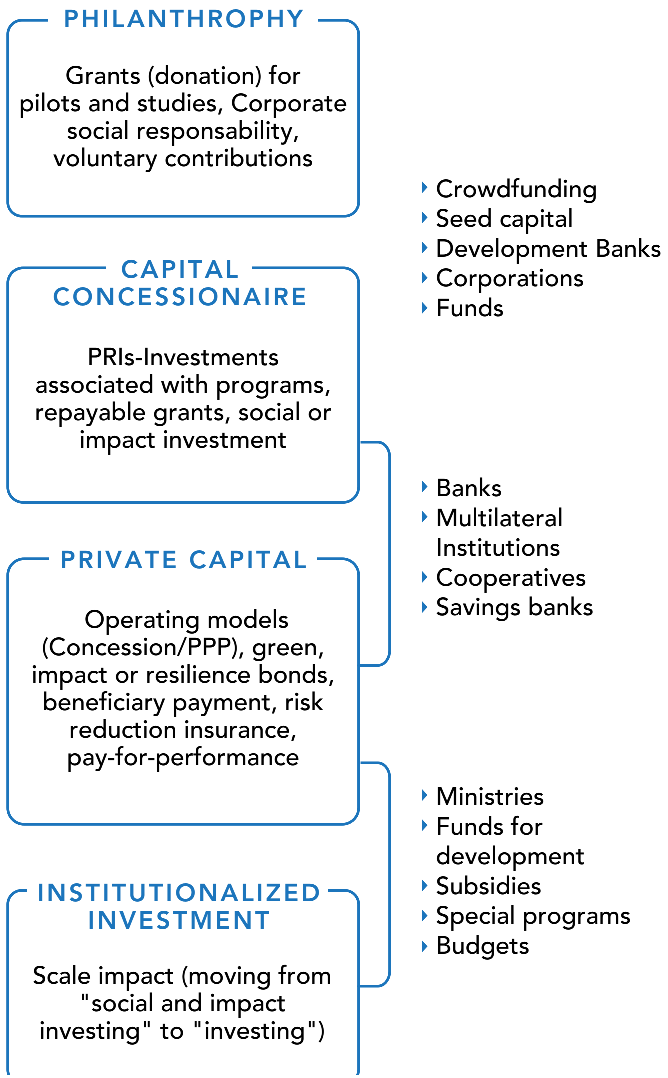


Figure 4: Types of financing and Actors. Source: World Bank, WRI, Moral 2020.

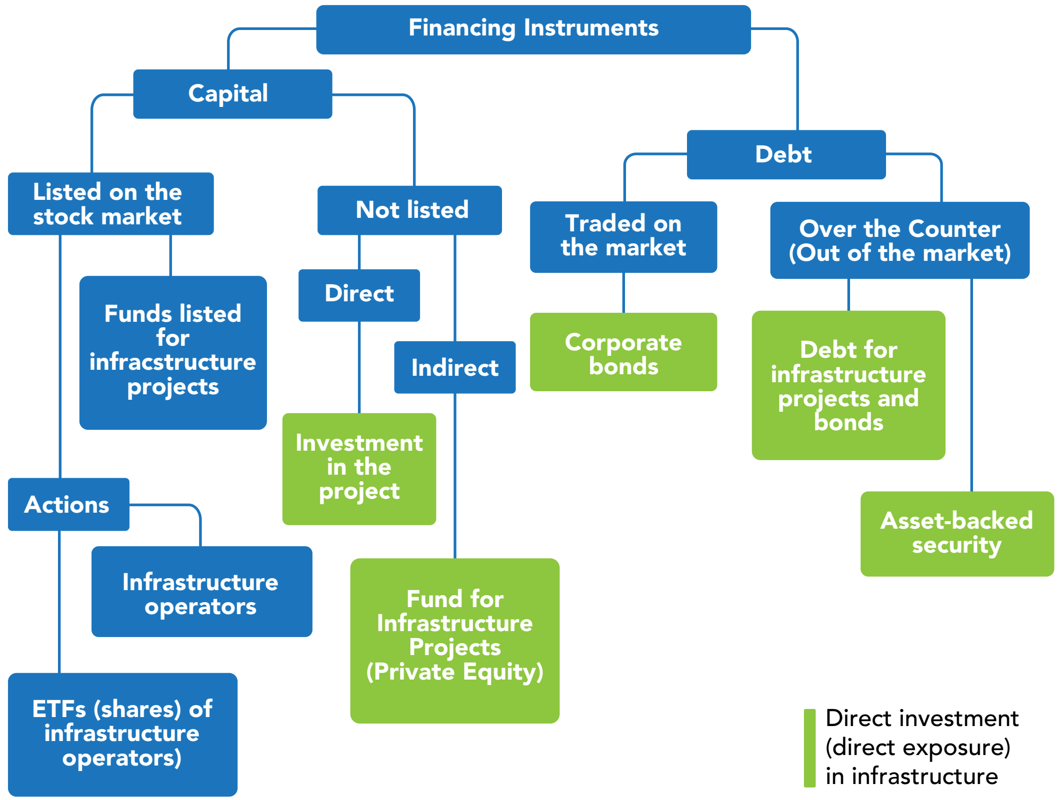


Figure 5: Possible Roads for financing. Source: Moral 2020.

For more information SEE: Sources for the financing of NbS.

Example: Water Harvesting Xalapa Case Study

A case study from the city of Xalapa (Mexico) illustrates in practice how a complete cycle can be carried out from a pilot stand-alone action to the integral financing of an NbS. In the context of the CityAdapt project in Xalapa, the solution to a specific problem of water scarcity in neighborhoods was specifically explored through the use of water harvesting systems on roofs as a model for environmental education and as a demonstration pilot. This is because, in Xalapa, although 1,500 mm of rain falls on average per year, water crises can occur due to changes in the rainfall pattern, population growth and an increase in the demand for services such as quality drinking water.

Financial model: The actions of the CityAdapt project together with those of SENDAS AC, Xalapa City Council and the Municipal Water Commission (CMAS) led to the elaboration of the Water Alliance for All Always – Xalapa, as a mechanism for building a new relationship with water and the water resilience of the city. The Alliance then created the Xalapa Water Resilience Trust (FOREX) to finance the NbS of water capture in the city and other actions to promote the Integrated Management Strategy of the Xalapa Water Resource (Figure 6).

Photo: Xalapa, México

This trust will be fed by the collection of a 2% fee in the consumers' water bill as payment for environmental services. This contribution will first be voluntary, to boost awareness and reduce the resistance of users, and then mandatory, when users and actors visualize the direct and indirect benefits. This way, it will be possible to influence the planning of budgets to finance infrastructure actions and support awareness of water resource management over the long term, regardless of changes in municipal governments. As a result, this initiative will build on the transition from the implementation of a pilot project in schools to solve a specific problem, to the scalling-up of the measure where a comprehensive strategy for water in the city is financed (Figure 6).

For more information SEE: Case study on water harvesting in Xalapa

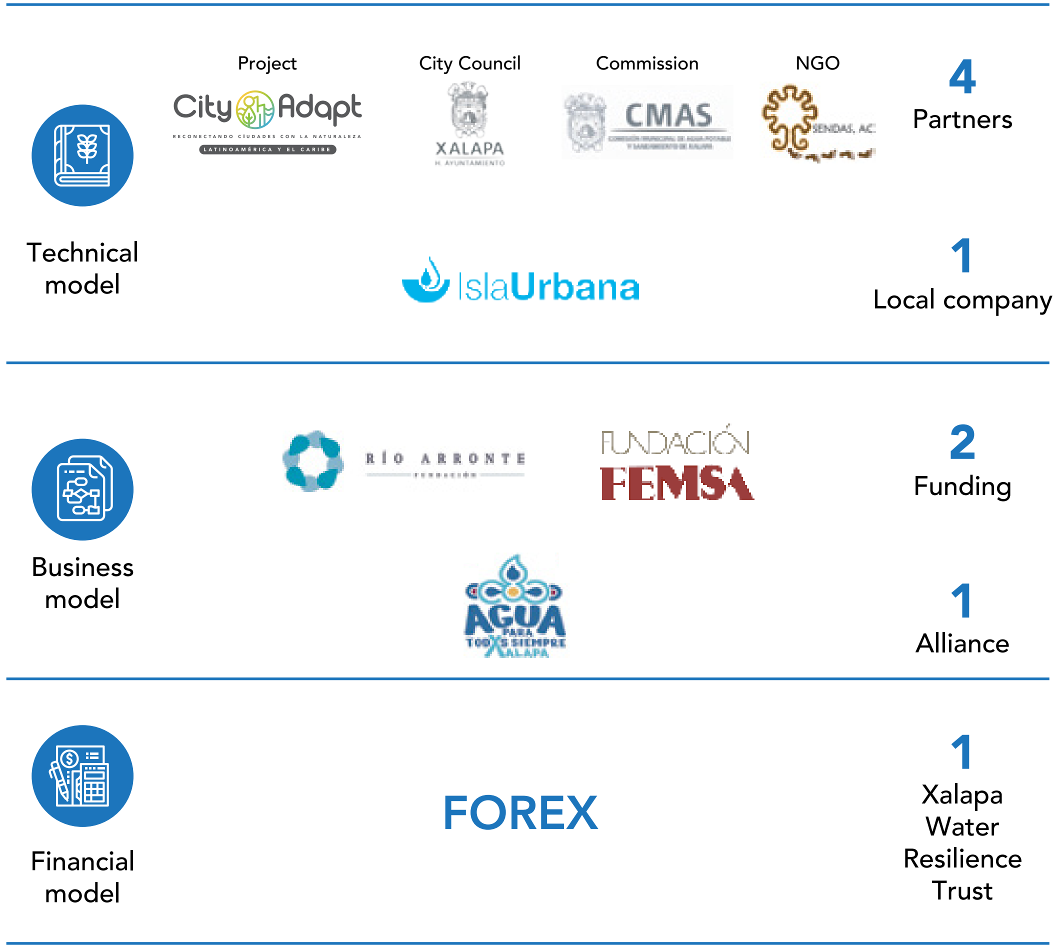


Figure 6: Financial model for water harvesting in Xalapa. Source: CityAdapt Project.

Step 3.c. Impact and synergies of NbS with other solutions, programs and/or policies

Objectives

- Define a portfolio of options inspired by the lessons learned from the first projects;
- Identify the actions needed to upscale NbSs and achieve effects at the city level over the long-term;
- Define the scope, scale and areas to implement NbS
- Identify who should implement (including public sector, private sector, urban and tax policies and instruments, decision levels);
- Define the necessary complementary actions (including other NbS, mixed solutions, grey infrastructures).
- Ensure the impact on policies and municipal planning of the NbS

Results

The main results of this Step are the multiplication of NbS actions at the urban and peri-urban level in several cities in the same region or the same country, through the communication of lessons learned and the inclusion of key institutions and/or sectors that benefit from these actions.

Tools

- Mapping and actors
- Relationship flow
- Interviews or focus groups
- Scenario construction
- Indicators
- Cost-benefit analysis

To ensure the impact and synergies of NbSs with other policies, programs and solutions, upscaling is a critical step in ensuring implementation and impact, and thus demonstrating that the solutions go beyond specific or anecdotal actions.

In general, NbS are a series of actions that can be systemic or focused. Therefore they must be linked and integrated with other NbS and other types of mixed solutions to achieve their effects at the city level and in the long-term. For this, it is necessary to identify (Browder G. et al, 2019; Toxopeus H.; 2019):

1. What is the scope (including specific or systemic problems, technical solution).
2. Where to implement (including location and type of action).
3. How much is needed (including surfaces, costs, and benefits).
4. Who should implement (including public sector, private sector, urban and tax policies and instruments, decision levels).
5. Which complementary actions are necessary (including other NbS, mixed solutions, grey infrastructures).

The NbS must be supported by processes that generate credibility and appropriation in order to reconcile the scales where the actions are implemented (farms, homes, neighborhoods, neighbourhoods, cities, basins) with the interests and capacities of the actors involved in the decision-making that must implement the actions (community leaders, members of cooperatives, local authorities, municipal advisors, national government, private sector).


Photo: San Salvador

This ensures the scaling up of the multiple co-benefits linked to the good use of urban and peri-urban ecosystems, so that they can in turn be translated into economic, social and health dividends for all inhabitants. Additionally, this makes it easier to validate actions, evaluate and visualize costs, benefits and compensation needs of each of the measures. NbSs are ideal because of their multifunctionality to help build climate-resilient urban infrastructures.

NbS have fundamental characteristics and requirements that differentiate them from grey infrastructure and other types of solutions (OECD 2020).

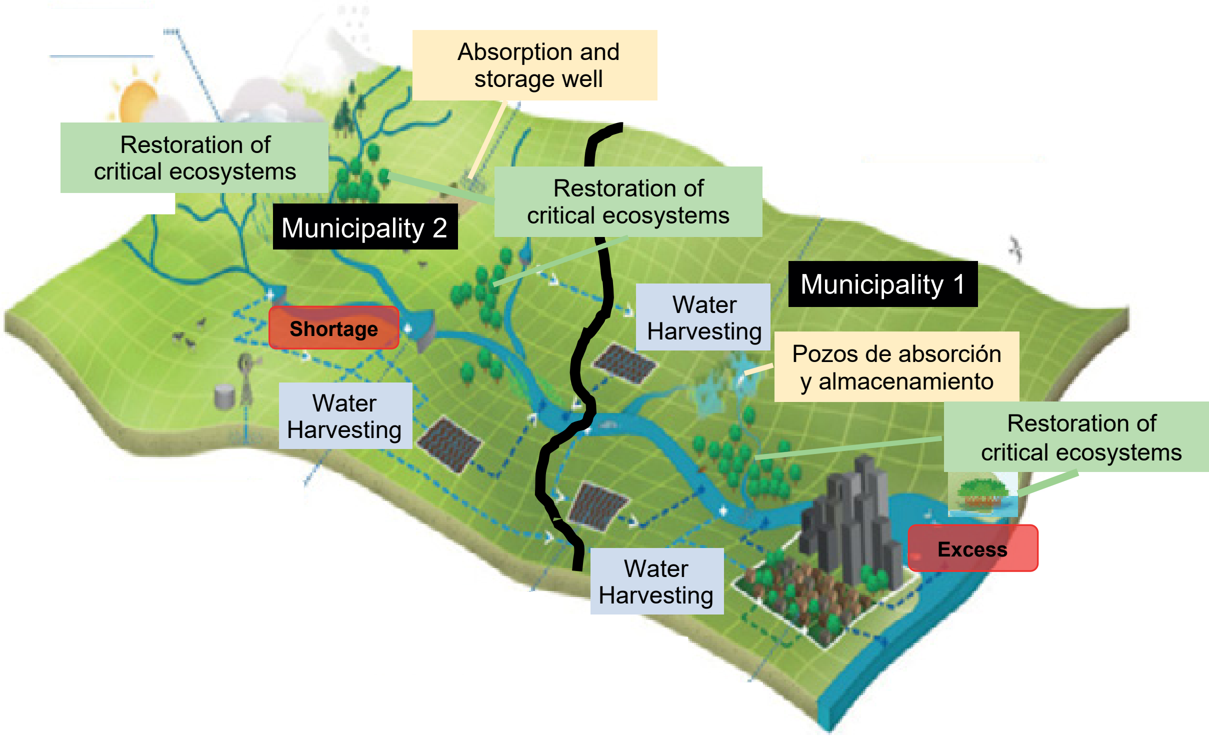
Characteristics	NbS	Flock infrastructure
Timescale	Long term for the benefits to materialize	Benefits are obtained directly after construction
Spatial scale	Although we refer to solutions in cities, in general they must be implemented at the landscape, basin or region scale to be effective. Therefore, in many cases it involves crossing jurisdictional borders beyond the municipality	It is generally implemented "within the defined boundaries" of neighborhood, communal or municipal jurisdictions
Reliability of costs and benefits	Benefit uncertainties may be unknown due to complex natural systems and interactions involved	The uncertainties of costs and benefits are theoretically "known", but cost overruns and excess maintenance costs are recurrent
Quantification of benefits	The calculation of co-benefits is still in many cases on the basis of pilot studies and is difficult to quantify in general (e.g. on human health and livelihoods, food and energy security, biodiversity)	Easy-to-quantify benefits (e.g. avoided damage to assets and road infrastructure)

Figure 7: Characteristics of NbS and grey infrastructure. Source: OECD 2020.

Example: The management of water resources

To illustrate in a practical way the advocacy needs and synergies of NbS with other policies, programs and solutions, it is very useful to use the example of water resource management. Most legal watermanagement frameworks at the municipal, departmental and national levels consider the boundaries of the basin, including natural resources and the actors within them.

However, to address pressure factors, status and impacts on the provision, regulation and support of water resources at the municipal level, it is necessary to consider changes in land use and management, regulatory frameworks jurisdictional water management (including quality and quantity) both at the level of the urban, peri-urban and rural area of the municipality in question, and of the surrounding municipalities (Figure 6).



To ensure the impact of the water harvest, it is necessary to complement with other NbS measures such as:

1. Absorption and storage wells in peri-urban areas.
2. Restoration and conservation of critical ecosystems in peri-urban and rural areas both downstream (Municipality 1, excess water) and Upstream (Municipality 2, water shortages).

Figure 8: Example of upscaling actions, the case of water resources. Source: Winograd 2018.

Considering the territorial characteristics of the water resource, legal and urban frameworks should recognize these characteristics in such a way that interactions, feedback and synergies are taken into account beyond the hydrological space. This way, ecosystem services[xiii] can be incorporated and involve all actors in the planning and ordering of the territory, including the "upstream and downstream" areas. This will also facilitate the design of a portfolio of NbS that ensures the staggering of actions inside and outside the basin and that respond to the demands in terms of ecosystem services and livelihoods of the territory.

In this context, the staggering of NbS should occur on the basis of two integration processes :

1. Vertical integration (top-down): it is the integration of the different public policies designed at the national level at the regional and local level; as well as the integration of policies, strategies, local plans at the regional and national levels.

2. Horizontal (transversal) integration that includes the integration of different actors and sectors in territorial planning decision-making (e.g. basins, landscapes, ecosystems).

Upscaling the NbS measures leads to strengthening the response capacity of cities, as they can then multiply the areas with NbS and the ecosystem services that these spaces provide to cities (Figure 7). In this phase, the measures that were initially pilot actions must become NbS integrated at the landscape level in the city, have methods and tools to support decision-making that simplify and systematize monitoring and maintenance.

Photo: San Salvador

ECOSYSTEM SERVICES

ECOSYSTEM BASED ADAPTATION	Provision of food	Provision of medicines	Provision of wood	Water supply	Capture Carbon	Infiltration of water and reduction of runoff	Control of erosion and sedimentation	Climate and air quality	Pollination	Moderation of weather Events	Habitat for species	Nutrient cycling	Recreation and ecotourism
RURAL AREA (BASIN)													
Restoration of coffee plantations includes infiltration ditches	■		■		■	■	■	■			■	■	■
Sustainable agriculture in the buffer zone of the El Boquerón protected area		■	■		■	■	■	■		■			■
Absorption wells						■							
PERI-URBAN AND URBAN AREA (LANDSCAPES)													
Connectivity of landscapes and restoration of ravines of the Arenal Montserrat	■	■				■	■	■	■		■	■	■
COMMUNITIES' RURAL AREAS													
Water harvesting systems in schools and communities				■						■			
Ecological sanitation system in a community				■						■			
URBAN AREA (NEIGHBORHOODS)													
School gardens	■	■							■		■		

Figure 9: Example of the NbS portfolio of validated interventions in the Arenal-Monserrat basin, San Salvador
Source: FUNDASAL AND PROCOMES 2018, Interventions Validation Workshop, September, 2018.

Support material

Annexed documents

- The cost-benefit analysis of NbS
- Sources for the financing of NbS
- Case study on water harvesting in Xalapa

Additional documents

- **UN Environment Programme. 2020.** Report on staggering and replication of strategies and actions for NbS in cities.

Exploration

- **Climate and Disaster Risk Screening** Available at this link.
- **Adaptation Support Tool** Available at this link.
- weADAPT

Visualization

- ArcGIS Storymaps
- Climate Change Knowledge Portal

Modeling and decision support

- QUICKScan
- Integrated Valuation of Ecosystem Services and Tradeoffs
- Adaptation Support Tool (AST)
- https://publicwiki.deltares.nl/display/AST/AST2.0+Documentation

Decision support

- ALivE - Adaptation, Livelihoods and Ecosystems Planning Tool
- Planning adaptation strategies
- Community-based Risk Screening Tool – Adaptation and Livelihoods.

Climate Risk Assessment and Management

- https://www.climatelinks.org/resources/herramientas-para-la-evaluaci%C3%B3n-y-gesti%C3%B3n-del-riesgo-clim%C3%A1tico

Practical manuals

- **CARE. 2010. Toolkit for incorporating climate change adaptation into development projects.** Available at this link.
- **Beltrán M. et al. 2015. Evaluation of the effectiveness of participatory methods in estimating vulnerability to climate change in Colombia.** Available at this link.
- **CDKN. 2017. Vulnerability studies in Latin America and the Caribbean: recommendations through experience.** Available at this link.
- **Figueroa-Arango C. 2020. Guide for the integration of Nature-Based Solutions in urban planning. First approach for Colombia. Berlín: Alexander von Humboldt**

- **Stiftung, Ecologic Institute, Alexander von Humboldt Biological Resources Research Institute.** Available at this link.

Webinar

- Financing schemes to tackle climate change in cities

Storymaps

- Scaling nature-based solutions for adaptation and resilience in Xalapa: The case of water harvesting
- Storms Amanda and Cristobal in San Salvador: Nature-based solutions to prevent and minimize climate risks in urban areas

Additional resources

- **Adapt-Chile, EUROCLIMA. 2017.** Municipalities and climate change: nature-based solutions. Thematic Studies Series EUROCLIMA No 11. Adapt-Chile and Program

- EUROCLIMA of the European Commission. Santiago de Chile, Chile. 64 p.

- **Browder G, Ozment S, Rehberger Bescos I. et al. 2019.** Integrating green and grey: Creating Next Generation Infrastructure, World Bank and WRI, Washington, D.C.

- **FEBA. 2017.** Making nature-based solutions effective: a framework for defining qualification criteria and quality standards, GIZ, Bonn, Germany, IIED, London, UK, and IUCN, Gland, Switzerland.

- **GIZ. 2017**. Assessing the benefits, costs and impacts of ecosystem-based adaptation measures: A guide book of methods for decision-making, Author: Lucy Emerton, GIZ, Bonn, Germany.

- **Maldonado M, S. de la Sala, R. Alterman. 2020**. Land Policies, Urban Law and Climate Change Urban-Tax Instruments as Measures to Confront Climate Change, Step 2, Working Paper, Lincoln Institute.

- **Toxopeus H. 2019.** TAKING ACTION FOR URBAN NATURE: Business Model Catalogue, Sustainable Finance Lab, Utrecht School of Economics, Utrecht, NATURVATION Project.

Section 4. Monitoring and Evaluation of NbS

Step 4.a. Monitoring and evaluation: impact indicators and monitoring indictors for NbS.

Example: Monitoring and evaluation system of Xalapa

Step 4.b. Communications, training, and replication of NbS

Example: CityAdapt and lessons learned from the replication of NbS in the Project's three countries

Support Material

Objective

Monitoring and evaluation helps us to better comprehend progress with regards to the objectives initially outlined for NbS, and helps us identify opportunities and challenges to improve short, medium, and long-term management. As seen in Module 2, NbS are designed to respond to the specific needs of a city (hotspots[xi] and vulnerabilities[iii]). Monitoring and evaluation is a necessary step to both document, and provide evidence to support, the planning and the decision-making process in NbS. In addition, this information allows us to communicate results and build capacities that guarantee medium and long-term impact and continuity.

Involved actors

Monitoring and evaluation requires the participation of both local and regional decision makers to monitor adherence to the goals and objectives. Secretariats, department leads, project managers; advisors, project leads, technicians, members of co-operatives and NGOs; technicians involved in the implementation of actions, and local managers involved in specific sectors, are all needed to carry out technical evaluations, monitor effectiveness, and conduct cost-benefit analyses of implemented actions. At the same time, participation from stakeholders that benefit from NbS is key (communities, the private sector, local residents), as they play a central role in evaluating and monitoring actions taken, as well as participating in the co-design, modification, and definition of complementary actions. Alliances with educational and community sectors, all direct beneficiaries of NbS, must be considered at all steps of the design and implementation process, guaranteeing its dissemination, training, and replication.

Module guiding questions

- Which indicators are the most adequate for monitoring NbS??
- Which impact indicators are the most adequate for NbS?
- How do you communicate NbS results and achieve its replication and incidence in public policy?

Results

- A group of indicators selected for the monitoring and evaluation of NbS;
- A strategy or identified route for communicating the impact of NbS that facilitates its exposure, replication and advocacy.

Estimated duration

The estimated duration of this step is two to six months.

Step 4.a. Monitoring and evaluation: impact indicators and monitoring indictors for NbS

Having a monitoring and evaluation (M&E) system is essential for the systematic collection of information and/or data on planned activities allowing one to report to stakeholders and carry out modifications to the objectives, goals or processes if needed. The objective is to count on elements that allow one to analyse the effectiveness of NbS in reducing vulnerability[iii] and increasing community resilience[xv] while preserving ecosystem services[xiii] at all steps of the project life cycle. There are different frameworks for development and use of indicators: i) monitoring indicators show the implementation process of NbS, while, ii) impact indicators show the benefits, opportunities, or limitations created by NbS.

Within the context of NbS, the framework selected and combination of M&E indicators chosen will depend on its use to:

- Produce information for both vulnerability and risk analysis as well as for visualizing change.
- Monitor progress to compare and evaluate NbS with mixed or grey solutions, and inaction (including economic and financial feasibility, technical viability, and social acceptance).
- Facilitate the evaluation and monitoring of multiple objectives, such as direct cost-benefits analysis and co-benefits.
- Support the decision-making process in urban planning and related public policy, norms and laws.
- Integrate adaptation to climate change[ii] within the processes of territorial planning through NbS.

It is worth noting that indicators and M&E must allow one to visualize and analyse the distribution and localization of the effects, impacts, and change over time, since the majority of the results and co-benefits achieved from NbS actions manifest in specific areas, following for example a project's life cycle or a particular party government period.

Objectives

- Define the short, medium and long-term objectives of NbS. M&E indicators help monitor the interventions progress and measure its impact as well as its effectiveness in reaching the desired objective.
- Select a group of indicators that measure change so to determine progress when compared with the baseline and help define intermediate objectives. Indicators allow for (i) comparisons with the baseline at various points and (ii) compare interventions.
- Interpret, analyse, validate and disclose the results from monitoring.

Results

- A defined reference framework that justifies the M&E indicators prioritised;
- Selection and definition of indicators that measure change according to the base line;
- Tools, methods of measurement and identified sources of data;
- An implemented monitoring and evaluation system;
- Data is validated, analysed, interpreted and disseminated.

Tools

- Participatory GIS
- Indicators
- Expert judgement

Example: Monitoring and evaluation system of Xalapa

An M&E system for adaptation[i] measures was established in Xalapa, taking into account climate risks[vii] population vulnerability[iii] infrastructure, and ecosystem services. Therefore, the criteria for the selection and design of NbS focused on reducing vulnerability among the human population, their productive systems, and strategic infrastructure and/or favour ecosystem resilience[xv].

The city of Xalapa relies on a diverse range of instruments for territorial planning that consider elements of risk from climate events and that propose the implementation of mitigation and/or adaptation measures. It is within this context that the city relies on PACMUN (Climate Action Plan for Municipalities Programme) as an instrument for climate change planning, which has a budget for implementing adaptation and mitigation measures. The Programme also has at the municipal level an impact assessment of climate change, identifying specific adaptation measures and a list of measures or projects aimed at reducing identified vulnerabilities. Lastly, the programme already has identified sources of income for carrying out adaption measures.

The system in Xalapa means there is a wide range of information and data available, allowing local governments to select and choose existing indicators according to each case, and that integrate civil society in its use and monitoring. This is how CityAdapt established a simple yet flexible system of M&E indicators for NbS actions (see Figure 1).

The NbS options portfolio must integrate actions that are considered as pilot and that can later scale to different zones of the city to assure its impact on planning, livelihoods, and ecosystem services.


Photo: Xalapa, México

In Xalapa the project portfolio includes, among others, the following NbS actions:

- Restoration of ecosystems to ensure the production of edible mushrooms.
- Rainwater harvesting systems.
- Urban gardens.
- Rehabilitation of natural wetlands.
- Forestation of streets and avenues with species adequate for the urban environment.
- Rain gardens and infiltration infrastructure.
- Construction of artificial wetlands
- Restoration of river banks (Papas-Carneros)
- Conservation and revegetation of the basin head to enhance water infiltration.
- Ecological restoration and the implementation of agro-silvopastoral projects.

The Rainwater Harvesting System (RHS) includes an indicator package created in collaboration with CityAdapt, Veracruzana University, and Sendas A.C., which is monitored by an interdisciplinary group of students from the Veracruzana University. This way capacities are created, guaranteeing continuity of the M&E process once the project ends or becomes independent from government change.

.

Action	Indicator	Unit
Riparian restoration	Number and diversity of species planted and their survival rate	Number and %
	Perception of ecosystem health	Index
Rain gardens	Filter capacity	m^3 /year
	Perception of avoided or diminished floods	Index
RHS	Amount of water collected	m^3 /year
	Increased availability of water for residents / avoided or diminished floods	Índice
Production modules for edible mushrooms	Additional income per family	Mexican pesos
	Financial feasibility	Index
	Pressure on natural resources / Cloud Forest	Index
	Gender empowerment	Index
Artificial wetlands	Amount of water with improved qualities	m^3 /year
	Gastrointestinal disease incidence among students	Nº of cases
	Perception of ecosystem health	Index

Figure 1: Some examples of the monitoring framework for NbS used by CityAdapt in Xalapa. Source: García Coll I, Angon S 2020.

For example, when using indicators for RHS, the aim was to monitor the following:

- **Long-term:** diminished vulnerability for residents faced with increasingly scarce water conditions and flooding.
- **Medium-term:** promotion of a scaled economy for RHS that leads to changes in citywide public policy for the adoption of NbS.
- **Short-term:** facilitate access to sufficient quantity and quality of water necessary for the vulnerable school population.

To ensure the impact of actions taken with RHS, one of the conditions was to define and utilize an M&E framework on the basis of:

- Appropriate selection and involvement of key stakeholders.
- Selected indicators and an M&E system relevant for stakeholders; data gathered must be utilized to add value.
- Budget for training, installing, and implementing activities is included in the municipal budget.
- Analysis of all collected data, promotion of a dissemination strategy, and incidence in the decision-making process at the city level

In conclusion, there are two fundamental aspects that must be taken into account for the correct and sustainable use of M&E: i) design a monitoring and evaluation framework for concrete NbS actions, and ii) design an M&E system that informs decision makers responsible for the replication and scaling[iv] of measures.

Photo: Xalapa, México

Step 4.b. Communications, training, and replication of NbS

For more information SEE: Dissemination and capacity building materials.

Communications and training are the main vehicles in ensuring the replication[v] of NbS in other areas of the city or in other cities throughout the country. Therefore, **implemented NbS not only call for empirical evidence regarding their benefits and positive impact** (Section 4), **but also require that information regarding their financial and business model be readily available** (Section 3). To replicate NbS, collaboration and inter-sectorial or intergovernmental communication is also necessary, as ecosystem boundaries rarely coincide with the administrative limits of a city.

To replicate NbS within urban planning, and position it as a central element in the construction of "resilience", **it is necessary to develop participatory processes** so as to generate collective action that responds to the needs and demands of all stakeholders. In addition, participation allows for the co-creation of knowledge, helping involve and incorporate all stakeholders in the assessment, exploration and implementation of NbS.

Therefore, actions taken which are backed by local stakeholders, are credible, can be sustainable, and their appropriation can create actions at all levels (catchment areas, city, commune, neighbourhood, household or estate). In this process of replication, the use of this guide is indispensable, as each module gives the principles and criteria required to facilitate the implementation of NbS while minimizing errors and maximizing co-benefits.

This is why **capacity building** must be tightly connected to the identification of needs in a city, incorporating the demands of different local stakeholders (citizens, private sector, government, non-governmental organisation, etc.). This strategy, in addition to closing the gap between local needs and technological offerings, facilitates the appropriation of results on behalf of stakeholders within the city, which in turn contributes towards the long-term sustainability of NbS.

The **dissemination of results and capacity building** for monitoring and evaluation facilitates the identification of better practices during exploration and implementation of NbS. This in turn, generates the baseline for subsequent steps such as replication and incidence in policy and/or incentives for adaptation[i] to climate change[ii] and urban resilience[xv].

Objectives

- Disseminate results, share lessons learned, best practices and promote exchange with other initiatives and/or cities;
- Improve the capacities of stakeholders and partners and identify new demands and capacities;
- Communicate the options portfolio, discuss its impacts and compare options;
- Contribute towards a strategy of knowledge building;
- Integrate participatory processes as a regular practice in local planning;
- Identify actions necessary to lock-in NbS and achieve long-term impact at the city level.
- Identify stakeholders involved in replication.

Results

- Material for effective dissemination to communicate the impact of NbS that justifies the investment of said actions;
- Facilitate the impact of NbS in decision making with the aim of improving the effectiveness and legitimacy of said measures;
- Knowledge and capacities of local actors (public and private) strengthened through the identification, implementation, and replication of NbS in different urban scenarios, maximizing benefits and synergy.
- Expanded use of NbS in different urban spaces as adaptation[i] and climate change[ii] strategies and the strengthening of resilience[xv].

Tools

- Stakeholder mapping
- Relationship flow
- Expert judgement
- Indicators
- Participatory GIS
- Cost benefit analysis

Tools as such cost benefit analysis and participatory GIS have been used here as results from previous modules are being retaken.

Example: CityAdapt and lessons learned from the replication of NbS in the Project's three countries

The effective replication[v] of NbS starts with a detailed analysis where each solution must respond to the local needs and context and this guarantees its impact. NbS are highly contextual and specific for each city, neighbourhood, or landscape. Ideas must first consider local needs and priorities, followed by technical capacities and the needs of all stakeholders. This then is followed by the opportunities offered by the natural surroundings and the cultural and socioeconomic conditions, as well as existing regulations and policy. For these reasons, actions must be conducted in collaboration with local institutions and stakeholders from all sectors to assure integration into local processes.

For the successful implementation of NbS, credible and documented financial, business, and technical models are needed. Implementation strategies and financing must be hybrid, as they are the most flexible in regards to development and innovation. In these cases, NbS must be supported by a solid and well-documented case study to create the opportunity for multiple sources of financing as well as incorporate the capacity to scale and replicate said NbS.

To ensure incidence in policy, as explained in Section 4, economic, urban, and legal instruments are needed. Scaling in the city and the replication of such measures in other cities represent different steps that involve key stakeholders from key sectors generating change in governance and the decision-making process. Therefore, an options portfolio must be assembled in accordance with the demands and capacities of each city, in order to facilitate and assure implementation and replication processes[v], and in turn create a positive impact in public policy.

Replicating NbS in other cities requires supporting capacity building (technical, financial, regulatory, institutional). Although NbS can be replicated, these must be designed in accordance with the context of each city to guarantee its impact. This can be different for each city, neighbourhood, and landscape.

Replication of NbS in cities as part of climate action integrates the double objective of helping with mitigation and facilitating adaptation[i]. This way the transition from “grey” cities to “green” cities can become a reality. This way, NbS will no longer be seen as peripheral actions of urban planning or fringe measures in mitigation and climate projects.

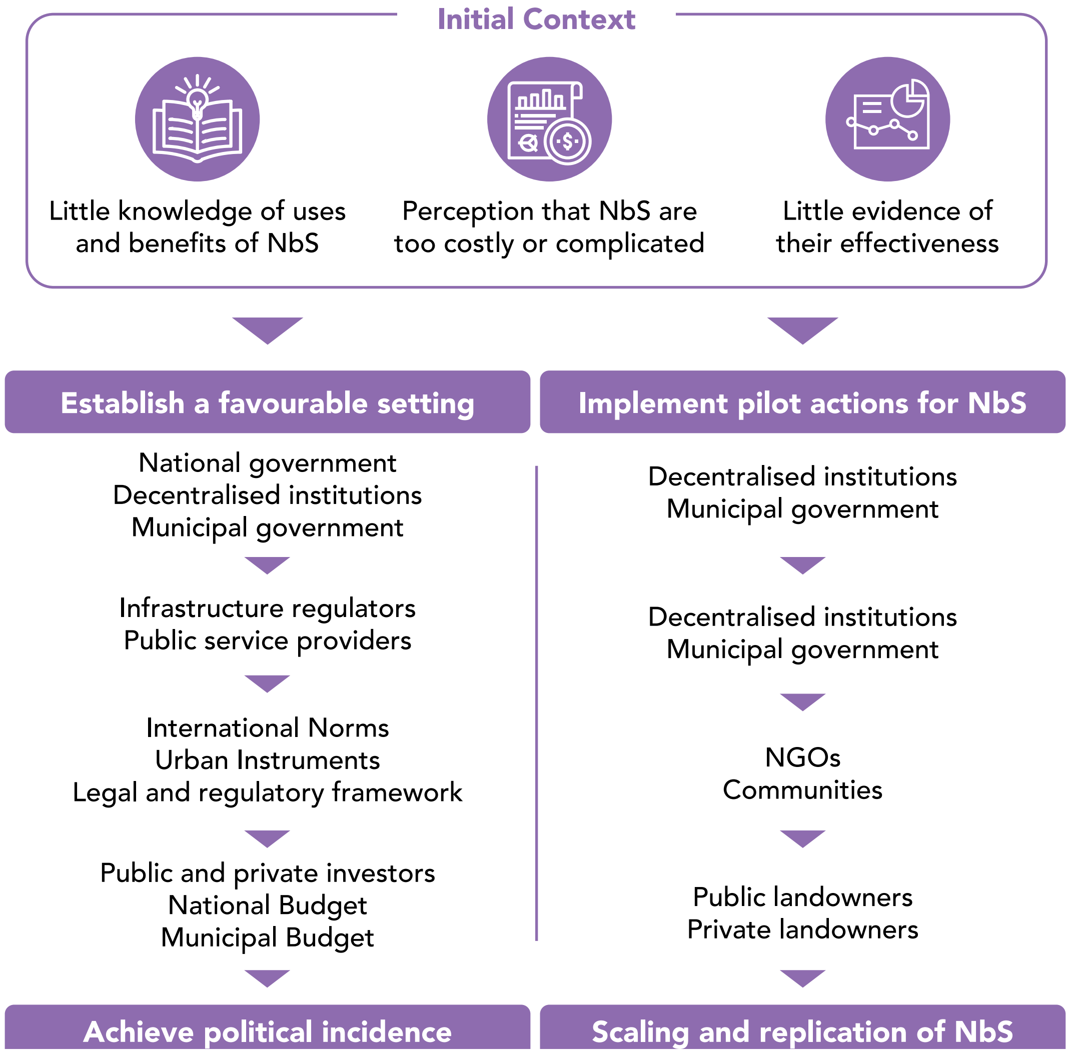


Figure 2: Synthesis of the role of different actors in the implementation, scaling, and replication of NbS. Source: OCDE 2020, UNEP 2021.

Support Material

Annexed documents

- Materials for dissemination and capacity building

Additional documents

- **Guía metodológica de implementación de acciones SbN,** Fondo Golfo México y Programa de las Naciones Unidas para el Medio Ambiente, Xalapa, Veracruz.

- **Metodología para seleccionar indicadores de servicios de los ecosistemas, Complemento de metodologías, Guía metodológica,** CityAdapt, Wageningen, Holanda

- **ONU Programa para el medio ambiente: CityAdpat. 2019.** Medidas de soluciones basadas en la naturaleza (SbN) para Xalapa y Tlalnelhuayocan, FOLLLETO INFORMATIVO, septiembre 2019.

- **ONU Programa para el medio ambiente CityAdapt. 2019,** Medidas de soluciones basadas en la naturaleza (SbN) para la microcuenca Arenal de Monserrat (San Salvador), FOLLLETO INFORMATIVO, septiembre 2019.

- **García Coll I, Angon S. 2020**. CityAdapt en Xalapa: Módulo 4 Curso Financiamiento y acción climática en ciudades.

Webinars

- Soluciones basadas en la Naturaleza (SbN) en ciudades de América Latina y Caribe: Metodología para exploración, identificación, implementación, monitoreo y evaluación de SbN

- Hallazgos y lecciones aprendidas sobre soluciones basadas en la naturaleza (SbN) para la adaptación en ciudades en América Latina y Caribe

Additional resources

- **Dupar, M, McNamara L, Pacha, M. 2019.** Comunicando el cambio climático: una guía para profesionales. Ciudad del Cabo: Alianza Clima y Desarrollo (CDKN).

- **GIZ, UNEP, FEBA. 2020.** Guía para Monitoreo y Evaluación de Intervenciones de Adaptación Basada en Ecosistemas. Available in this link.

- **Jiménez Hernández A. 2016.** Ecosystem-based Adaptation Handbook. IUCN NL, Amsterdam.

- **Iza A. (ed.). 2019.** Gobernanza para las soluciones basadas en la naturaleza. Gland, Suiza: UICN.

- **Reid H, Hou Jones X, Porras I et al., 2019,** Is ecosystem-based adaptation effective? Perceptions and lessons learned from 13 project sites. IIED Research Report. IIED, London.

- **OCDE. 2020.** Nature-based solutions for adapting to water-related climate risks, OECD Environment Policy Paper No. 21.

- **UNEP. 2021.** Adaptation Gap Report 2020, Nairobi. Available in this link.

Module Tools

The following tools help determine the environment, actors, and scope of a project and/or actions. These tools also identify information and details on the socioeconomic context (including vulnerabilities and risks), livelihoods (including ecosystem services), and possible actions of intervention.

Tool	Stage
Interviews or focus groups Guided interviews of groups of selected stakeholders to evaluate, recognise, and identify the conditions and use of ecosystem services and activities related to livelihoods.	1.a
Participatory GIS The use of geographical information systems together with stakeholders to identify target populations, locate key regions and identify critical relationships. In this case evaluate tendencies in the use, degradation, conservation, or improvement of ecosystems or ecosystem services with regards to livelihoods.	1.a 1.c 2.a 2.b 3.b 4.a 4.b
Stakeholder mapping Identification and consultation with stakeholders related to the projects objectives and actions, their position in topics of interest and planning decisions. This tool is used to define together with stakeholders the environmental, socioeconomic, political, and institutional context to identify where problems can be found and who is being affected.	1.b 3.b 3.c. 4.a
Stakeholder Flowchart Spatial location of stakeholders to determine where they are located, and where various relationships are concentrated between the stakeholders and the decision making process.	1.b 3.b 3.c. 4.a
Interviews Guided interviews of groups of stakeholders to identify problems, analyse options, and evaluate alternatives. Identifying options and alternatives for adaptation is to be achieved through interviews with stakeholders.	1.b 2.a 3.b 3.c.
Expert judgement Technical evaluations in the field and workshops regarding specific issues for the construction of knowledge matrices and analysis of specific issues.	1.c 2.a 2.c 3.a 3.b 4.a 4.b

Tool	Stage
Indicators Data collection and knowledge organisation in a framework that allows one to construct information at all decision-making levels and levels of risk. Indicators are used to evaluate and monitor impact, limitations, objectives, and actions, as well as adaptation and mitigation strategies and policies.	1.c 2.b 3.c. 4.a 4.b
Cognitive mapping Cartography and mapping of stakeholder knowledge.	1.c 2.a
Construction and/or use of scenarios Evaluation of the implication of risks, the options and alternatives available through the variation of values and key impacts.	1.c 2.a 2.b 3.c.
Cost-benefit analysis Is the assessment of the benefits, costs, and impacts, as defined by the following: · Benefits: are advantages or positive effects of NbS. · Costs: are the resources needed to apply NbS, and the disadvantages or negative affect these cause. · Impacts: are the affects or situational or circumstantial changes produced by the adoption of NbS. The analysis does not only address monetary measures, but evaluates non-monetary ones as well.	2.b 2.c 3.a 3.c. 4.a
Multicriteria analysis Evaluation method that qualitatively prioritizes a combination of different methods. This form of analysis permits one to select measures in relation to the criteria and weighting defined by the stakeholders involved.	2.a 2.b 3.a
Brainstorming Exchange of knowledge and perceptions in order to identify needs and options with the intention of helping with the construction of information on problems, causes, their consequences, and solutions.	2.a

References

General

Berghöfer A, Mader A, Patrickson S, Calcaterra E, Smit J, Blignaut J, de Wit M, Zyl H van. 2011. TEEB Manual for Cities: Ecosystem Services in Urban Management. Geneva, Switzerland: Author. Available in this link.

European Commission. 2019. Green Infrastructure, DG Environment. Available in this link.

GIZ. 2017. El Libro de la Vulnerabilidad: Concepto y lineamientos para la evaluación estandarizada de la vulnerabilidad. Adelphi y Eurac Research. Available in this link.

Ilieva L.. 2020. Observaciones sobre la Adaptación basada en Ecosistemas Historias de América Latina y el Caribe, ONU Medio Ambiente y Practical Action, Publicación Comunidad AbE.

IPCC. 2018: Anexo I: Glosario [Matthews J.B.R. (ed.)]. En: Calentamiento global de 1,5 °C, Informe especial del IPCC sobre los impactos del calentamiento global de 1,5 ºC con respecto a los niveles preindustriales y las trayectorias correspondientes que deberían seguir las emisiones mundiales de gases de efecto invernadero, en el contexto del reforzamiento de la respuesta mundial a la amenaza del cambio climático, el desarrollo sostenible y los esfuerzos por erradicar la pobreza [Masson-Delmotte V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor y T. Waterfield (eds.)]. Available in this link.

Millenium Ecosysem Assessment (MEA). 2005. Ecosystems and human wellbeing: synthesis. Island Press. Available in this link.

Renner I. 2019. Integración de los servicios ecosistémicos en la planificación y gestión urbana: Un enfoque sistemático en pasos para profesionales, Programa Protección del Clima en la Política Urbana de México (CiClim), SEDATU, SEMARNAT y GIZ, México.

UNISDR, 2009, UNISDR terminology on disaster risk reduction. Available in this link.

Section 1

Ashley C, Carney D. 1999. Sustainable Livelihoods: Lessons from early experience. Department for International Development.

Comisión Económica para América Latina y el Caribe (CEPAL). 2018. Guía de ejercicios para la evaluación de desastres, CEPAL y GIZ, Chile.

ONU Programa para el medio ambiente: CityAdapt Xalapa. 2019. Informe parcial del estudio vulnerabilidad ante el cambio climático en Xalapa y Tlalnelhuayocan, Veracruz. ONU Programa para el medio ambiente, México, 156 pp.

GIZ, EURAC, UNU-EHS. 2018. Evaluación de Riesgo Climático para la Adaptación basada en Ecosistemas –Una guía para planificadores y practicantes. Bonn. Available in this link.

Hallegatte S, Vogt-Schilb A, Bangalore M, Rozenberg J. 2017. Indestructibles: Construyendo la resiliencia de los más pobres frente a desastres naturales, Banco Mundial, Washington, DC.

Inostroza L, Garay Sarasti H, Andrade Pérez G. 2020. Servicios ecosistémicos urbanos en Latinoamérica; Documento CODS, número 4, Bogotá, Colombia.

Overseas Development Institute (ODI). 2014. Cambio climático y riesgo de desastre, ODI, Londres, UK. Available in this link.

Pérez-Soba M. 2020. Servicios Ecosistémicos: ¿Un concepto valioso? Available in this link.

Turnbull M, Sterrett C, Hilleboe A. 2013. Hacia la Resiliencia: Una Guía para la Reducción del Riesgo de Desastres y Adaptación al Cambio Climático, Catholic Relief Services.

Section 2

Fundasal, Procomes, WENR, MARN. 2019. Informe final taller de exploración y validación de acciones SbN para la microcuenca Arenal de Monserrat (San Salvador), Salvador.

Fundasal, Procomes, WENR, MARN, 2019, Informe final taller de validación y escalonamiento de las intervenciones de SbN en la microcuenca Arenal de Monserrat (San Salvador), Salvador.

Hardoy, J., Gencer, E., Winograd, et al. 2019. Planeamiento participativo para la resiliencia climática en ciudades de América Latina. Iniciativa Ciudades Resilientes al Clima. FFLA, CDKN, e IDRC.

IIED, IUCN, UNEP-WCMC. 2019. Nature-based solutions to climate change adaptation, briefing reports.

Lara Pulido A. 2017. Análisis costo-beneficio de medidas de adaptación al cambio climático en áreas urbanas de América Latina, ONU Medio Ambiente y Unión Europea, Panamá. Available in this link.

ONU Programa para el medio ambiente: CityAdapt. 2019. Informe final del taller de exploración de acciones SbN en Xalapa y Tlalnelhuayocan, Veracruz, México. ONU Programa para el medio ambiente.

UNEP-IEMP. 2019. Research on Ecosystem-based Adaptation (SbN): A reference guide. Document produced as part of the GEF-funded SbN South project.

UICN. 2020. Estándar Global de la UICN para soluciones basadas en la naturaleza. Un marco sencillo para la verificación, el diseño y la extensión de SbN. Primera edición. Gland, Suiza: UICN.

Section 3

Adapt-Chile, EUROCLIMA. 2017. Municipios y cambio climático: las soluciones basadas en la naturaleza. Serie de Estudios Temáticos EUROCLIMA No 11. Adapt-Chile y Programa EUROCLIMA de la Comisión Europea. Santiago de Chile, Chile. 64 p.

Browder G, Ozment S, Rehberger Bescos I, Gartner T, Lange GM. 2019. Integrating green and grey: Creating Next Generation Infrastructure, World Bank and WRI, Washington, D.C.

FEBA (Friends of Ecosystem-based Adaptation). 2017. Hacer que las soluciones basadas en la naturaleza sean eficaces: un marco para definir criterios de cualificación y estándares de calidad, GIZ, Bonn, Alemania, IIED, Londres, Reino Unido, y UICN, Gland, Suiza.

GIZ. 2017. Valoración de los beneficios, costes e impactos de medidas de adaptación basadas en ecosistemas: Un libro guía de métodos para la toma de decisiones, Author: Lucy Emerton, GIZ, Bonn, Germany.

Maldonado M, de la Sala S, Alterman, R. 2020. Políticas de Suelo, Derecho Urbanístico y Cambio Climático Instrumentos Urbanísticos-Tributarios como Medidas para Enfrentar al Cambio Climático, Etapa 2, Working Paper, Lincoln Institute.

Toxopeus H. 2019. TAKING ACTION FOR URBAN NATURE: Business Model Catalogue, Sustainable Finance Lab, Utrecht School of Economics, Utrecht, NATURVATION Project.

Winograd M. 2018. Niveles de decisión y escalas de servicios ambientales en la planificación y toma de decisiones: Integrando el contexto de la variabilidad y cambio climático en Guatemala, GIZ, Guatemala

Section 4

Dupar M, McNamara L, Pacha M. 2019. Comunicando el cambio climático: una guía para profesionales. Ciudad del Cabo: Alianza Clima y Desarrollo (CDKN).

GIZ, UNEP, FEBA. 2020. Guía para Monitoreo y Evaluación de Intervenciones de Adaptación Basada en Ecosistemas. Available in this link.

Jiménez Hernández A. 2016. Ecosystem-based Adaptation Handbook. IUCN NL, Amsterdam.

Iza A. (ed.). 2019. Gobernanza para las soluciones basadas en la naturaleza. Gland, Suiza: UICN.

Reid H, Hou Jones X, Porras I et al., 2019, Is ecosystem-based adaptation effective? Perceptions and lessons learned from 13 project sites. IIED Research Report. IIED, London.

OCDE. 2020. Nature-based solutions for adapting to water-related climate risks, OECD ENVIRONMENT POLICY PAPER NO. 21.

UNEP. 2021. Adaptation Gap Report 2020, Nairobi. Available in this link.

Glossary

i. Adaptation: The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to the expected climate and its effects" (IPCC 2014).

Incremental adaptation: Adaptation actions where the central aim is to maintain the essence and integrity of a system or process at a given scale.

Transformational adaptation: Adaptation that modifies the fundamental characteristics and attributes of a socio-ecological system in anticipation of climate change impacts.

ii. Climate change: Changes to the climate system attributed directly and indirectly to human activities that alter the composition of the atmosphere. These changes are in addition to natural climate vulnerability which would be expected over a comparable period. According to the IPCC (2014), climate change "refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change will not only affect the intensity and frequency of extreme climate and hydro-meteorological events, but will also increase existing risks and create new ones for anthropogenic and natural systems as a result of the interaction of hazards related directly to the climate (including extreme events and trends) with the vulnerability and exposure of human and natural systems, including their ability to adapt (IPCC 2014).

iii. Vulnerability: Potential losses (human, physical, economic, natural or social) due to extreme events, or the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard (UNISDR 2009, 34). Vulnerability includes conditions determined by physical, social, economic and environmental factors or processes that increase a community's susceptibility to the impacts of a hazard.

Biophysical vulnerability: Ecological processes related to risk, susceptibility and exposure to environmental change and hazards. Indicators to measure this type of vulnerability include: wet/dry season, flood risk, and risk of landslides, among others.

Social vulnerability: Political, socio-economic, cultural and institutional aspects of vulnerability. Indicators to measure this type of vulnerability include: level of education, income, poverty rates, social capital, degree of livelihood diversification, and land tenure, among others.

iv. Scaling (upscaling): In general, NbS are an array of activities that can be systemic or specific (to a place, an ecosystem, etc). That is why they must be linked to one another and integrated with other NbS and other types of mixed solutions to have an impact at the city scale and with a long-term horizon. These activities are known as scaling.

v. Replication: The guidelines, practices, and processes that facilitate and catalyze broader (on a regional and national scale) adoption and implementation of NbS strategies and activities in other cities based on best practices and lessons learned.

vi. Climate variability: Inherent characteristic of the climate system related to the full range of possible climate activity. The degree of variability can be described as the difference between average climate parameters (for example, rainfall, temperature, humidity, length of seasons) and values observed over the long term. Variability can be assessed on different spatial and temporal scales.

vii. Risk: The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard (IPCC, 2014). In the NbS guidelines, the term risk is used primarily to refer to the possibility, when the outcome is uncertain, of adverse consequences resulting, jeopardizing lives, livelihoods, health, ecosystems and species, economic, social and cultural goods, services (including environmental services) and infrastructure.

viii. Livelihoods: Conditions for and means of sustenance that allow people and societies to deal with adverse or critical situations with households covering their basic needs and coping with extreme situations/periods.

ix. Hazard: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts (IPCC, 2014.).

x. Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected (IPCC, 2014).

xi. Hotspot: A spot or area exceptionally vulnerable to a high concentration of risks and hazards due to its exposure and climate sensitivity. These hotspots are especially important for identifying areas, infrastructure and ecosystem services requiring NbS and/or risk and natural resource management.

xii. Adaptive capacity: “The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences” (IPCC, 2014). “The combination of all the strengths, attributes and resources available within a community, society or organization that can be used to achieve agreed goals” (UNISDR, 2009).

xiii. Ecosystem services: The multitude of benefits provided to society by nature. Ecosystem services make human life possible by, for example, provisioning food, wood, and clean water; regulating diseases and the climate; supporting crop pollination and soil formation; and providing recreational, cultural, and spiritual benefits (MEA, 2005).

Ecosystem services in cities: Services produced in cities, including urban and peri-urban areas, not based on their administrative jurisdictions alone (Inostroza et al., 2020). For example, water recharge areas within a city, forested urban hillside areas that conserve soils and prevent landslides, parks and promenades that regulate the concentration of atmospheric pollution and air temperature.

xiv. Socio-ecological system: Coupled natural and human components making up integrated and complex systems in which nature and humans interact. Socio-ecological systems are based on the perspective of "human beings as a part of nature," in which human societies are considered to be embedded within the limits imposed by the ecosphere.

xv. Resilience: "...the ability of a social, ecological, or socio-ecological system and its components to anticipate, reduce, accommodate, or recover from the effects of a hazardous event or trend in a timely and efficient manner" (IPCC, 2014). According to the UNISDR (2009), it is the "ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions."