STRATEGIC NBS FRAMEWORK GUIDELINES

Rapid Citywide Assessment and Collaborative Identification of Suitable Nature Based Solutions to Advance Water, Heat and Ecological Resilience

MARCH 2024

CONTENTS

INTRODUCTION

Cities across the globe are facing increasing impacts from climate change, including flash flooding, heat waves, severe rainstorms, extreme hot days and droughts (OECD 2021). Unsustainable development and rapid urbanization exacerbate these risks and contribute to increased urban flooding, air pollution and degradation of ecological habitat. These challenges disproportionately impact disadvantaged communities with limited financial resources to recover or address the challenges contributing to further inequality. Nature-based Solutions (NbS) address these urban challenges, while simultaneously providing human well-being and biodiversity benefits (International Union for the Conservation of Nature). NbS can better position these cities and their communities to respond to water, flooding, heat, and ecological risks while realizing additional socio-economic, biodiversity and climate co-benefits.

The World Resources Institute's Cities4Forests[1] and Urban Water Resilience (UWR) in Africa[2] Teams collaborated in the development of a Strategic NbS Framework, a decision support tool that helps cities strategically assess and prioritize the type of NbS interventions that are optimal for their geo-climatic and urban context to address the flooding, heat, and ecological risks they face, allowing them to make the best use of limited resources to address the multiple climate challenges they face. This Strategic NbS Framework Guide has **3 main objectives**:

1. **Introduce the planning framework and methodology** for selecting and implementing NbS to address urban water, extreme heat, and biodiversity resilience challenges.
2. **Catalogue the NbS tools** and provide information on suitability characteristics and implementation strategies.
3. **Provide relevant case studies** to inspire the use of NbS in different urban contexts and for different urban challenges.

The Strategic NbS Framework Guide introduces NbS and describes the proposed framework for selecting Urban NbS to address water, heat and ecological risks in Section 1. The next section describes the step-by-step process for assessing flooding, extreme heat, biodiversity needs, synthesizing composite needs, further analyzing priority areas for NbS and selection of potential NbS tools. Section 3 presents the catalogue of NbS tools, with fact sheets containing relevant information for each NbS tool, and case studies to illustrate how the NbS tools are applied in different city contexts.

KEY TERMINOLOGY

Resilience: "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" (United Nations International Strategy for Disaster Reduction 2009, p. 24)

Nature-based solutions: "Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits." (International Union for the Conservation of Nature).

Green infrastructure: "Natural or semi-natural systems that provide services for water resources management with equivalent or similar benefits to conventional (built) "grey" water infrastructure." (UNEP 2014, p. 5).

Co-Benefits: Infrastructure benefits that are additional to those for which it was primarily designed (UNEP 2014, p. 57-58).

Risk: "The combination of the probability of an event and its negative consequences" (United Nations International Strategy for Disaster Reduction 2009, p. 25).

Hazard: "A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage." (United Nations International Strategy for Disaster Reduction 2009, p. 17).

Exposure: "People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses." (United Nations International Strategy for Disaster Reduction 2009, p. 15).

Vulnerability: "The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard." (United Nations International Strategy for Disaster Reduction 2009 p. 30).

Urban typologies: Used in urban planning, a typology is the classification of characteristics (usually physical) commonly found in buildings and urban areas, according to their association with different specifications, such as form, density, land use, and mobility infrastructure (Gil, Jorge, et al. 2012). In this guide, we use six urban typologies to link the type of urban spaces where NbS interventions can be carried out, namely: green landscapes, blue landscapes, institutional, commercial/commerce, residential, transportation. These were defined using a systems approach, with the objective of having locally relevant but generalizable categories that are useful for solution matching.

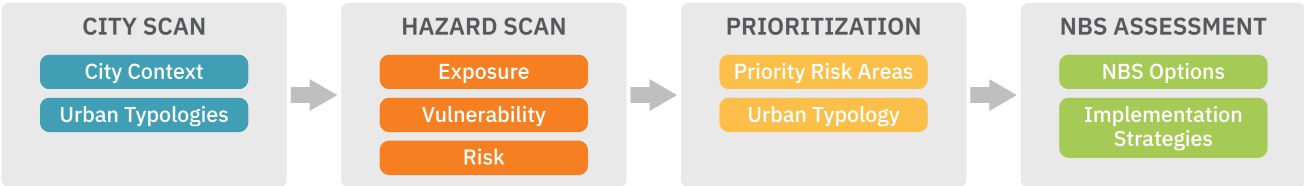
SECTION 1: STRATEGIC NBS FRAMEWORK

Assessment Methodology

The Strategic NbS Framework assesses citywide flooding, heat and ecological risks utilizing globally available data sets contextualized with minimal local data. Combining these assessments into a composite needs map helps to visualize the convergence of these factors, enabling city leaders to better understand the areas where these climate hazards are expected to impact vulnerable communities and therefore the location to consider introducing NbS interventions to reduce those impacts.. This spatial mapping of the needs are then linked to the existing urban typologies, each with a recommended suite of potential NbS tools (See Figure 1).

Details about the data process for this assessment are included in Section 2 Needs Assessment and NbS Selection.

Figure 1 | **Strategic NbS framework approach to identify potential NbS tools to address urban resilience challenges**



In addition to the spatial analysis, the framework recommends a series of touch points with local stakeholders to validate the results, conduct field visits to the identified priority areas of need, and engage in action planning to refine and advance NbS Recommendations.

The success of implementation is often directly linked to these engagements that build awareness, understanding and champions for the proposed recommendations. The engagement should include a broad set of stakeholders from the local, subnational and national government, as well as institutions, non-profit partners, academics, and private industry.

This planning framework provides a highly applicable, effective, and practical rapid assessment methodology to help cities to assess and select suitable NbS types that are most effective to mitigate their risks and restore functional landscapes and habitat.

Nature-based Solutions Tools

Nature-based Solutions can address urban water resilience challenges through the protection, sustainable management or restoration of natural or modified ecosystems (Cohen-Shacham et al. 2016, p. 2). Where natural ecosystems are present, they can be **protected** or **enhanced** to maximize the obtained benefits. It is also possible to **restore** natural ecosystems where they have been degraded, in order to recover their natural functions. In places where natural ecosystems are not present, it is possible to **build** new nature-based solutions to address urban water resilience risks. It is important to note that NbS are context specific and must be designed and implemented carefully according to local conditions and intended outcomes, and with the engagement of locally knowledgeable partners (Seddon et al. 2020). NbS interventions should be monitored over time to ensure intended benefits are being accrued and to inform future NbS design.

This guide focuses on urban NbS to address the risks related to flooding, extreme heat, and biodiversity. Table 1 presents 13 NbS tools, selected for their relevance in addressing the selected risks. Each NbS tool has several project examples that can be implemented. For example, Natural Lands and Forests may include urban forests that are integrated into dense urban neighborhoods, or upland forests that support watershed health, as well as non-forest landscapes, such as shrublands and grasslands. For each NbS tool, implementation mechanisms and examples are listed.

Table 1 | **NbS tools, examples and implementation mechanisms to address flooding, extreme heat, and biodiversity**

NBS TOOL	EXAMPLES[3]	MECHANISMS
Natural lands/ forests	Urban forests, upland/upper-watershed/riparian forests, shrublands, grasslands	Protect/ enhance/ restore/ build
Tree plantings	Street trees, Park trees, Private property trees	Enhance/build
Sustainable agriculture	Agroforestry and Silvopasture, Farmland Best Practices[4] (urban smart agriculture), hydroponic vertical farming	Enhance existing practices/ restore parts of land to natural condition
Open space/ parks	Open spaces, Neighborhood parks, Pocket parks, Stormwater parks, Waterfront parks	Protect/ enhance/ build
Greenways	Tree Corridors, Bioswales	Protect/ enhance/ build
Riparian floodplain	Floodplain/channel reconnections, Sand dams, Slope stabilization	Protect/ enhance/ restore
Creek daylighting	Channelized urban creek, natural open space creek	Restore
Rain gardens	Retention rain gardens, detention rain gardens, bioswales	Build
Rainwater harvesting	Cisterns, Rain Barrels, Detention Ponds, aquifer recharge with infiltration ponds/fields	Build
Green roofs and green walls	Green roofs (intensive and extensive), green walls	Build
Wetlands	Inland wetlands (e.g., wastewater treatment wetlands), constructed wetlands, estuarine wetlands	Protect/ enhance/ restore/ build
Coastal habitats	Mangroves, Salt Marshes, Reefs, Seagrass	Protect/ enhance/ restore
Beaches and Dunes	Beaches, Dunes	Protect/ enhance/ restore

Figure 2 | **Nature-based solutions can address urban water resilience challenges in 4 ways**

PROTECT

In Colombo, Sri Lanka, in response to a series of record-breaking flooding events the Government implemented the Metro Colombo Urban Development Project, combining wetland conservation, flood retention parks, and traditional concrete bank protection walls to reduce flood risk (Ozment, Ellison, and Jongman 2019).

ENHANCE

Water scarcity impacted the villages in Kumbharwadi and the solution was a participatory watershed development program that increasing rainwater capture, storage capacity, and soil fertility, and reducing soil erosion that resulted in improved water access, agricultural yields and income generation. (Cartright 2013).

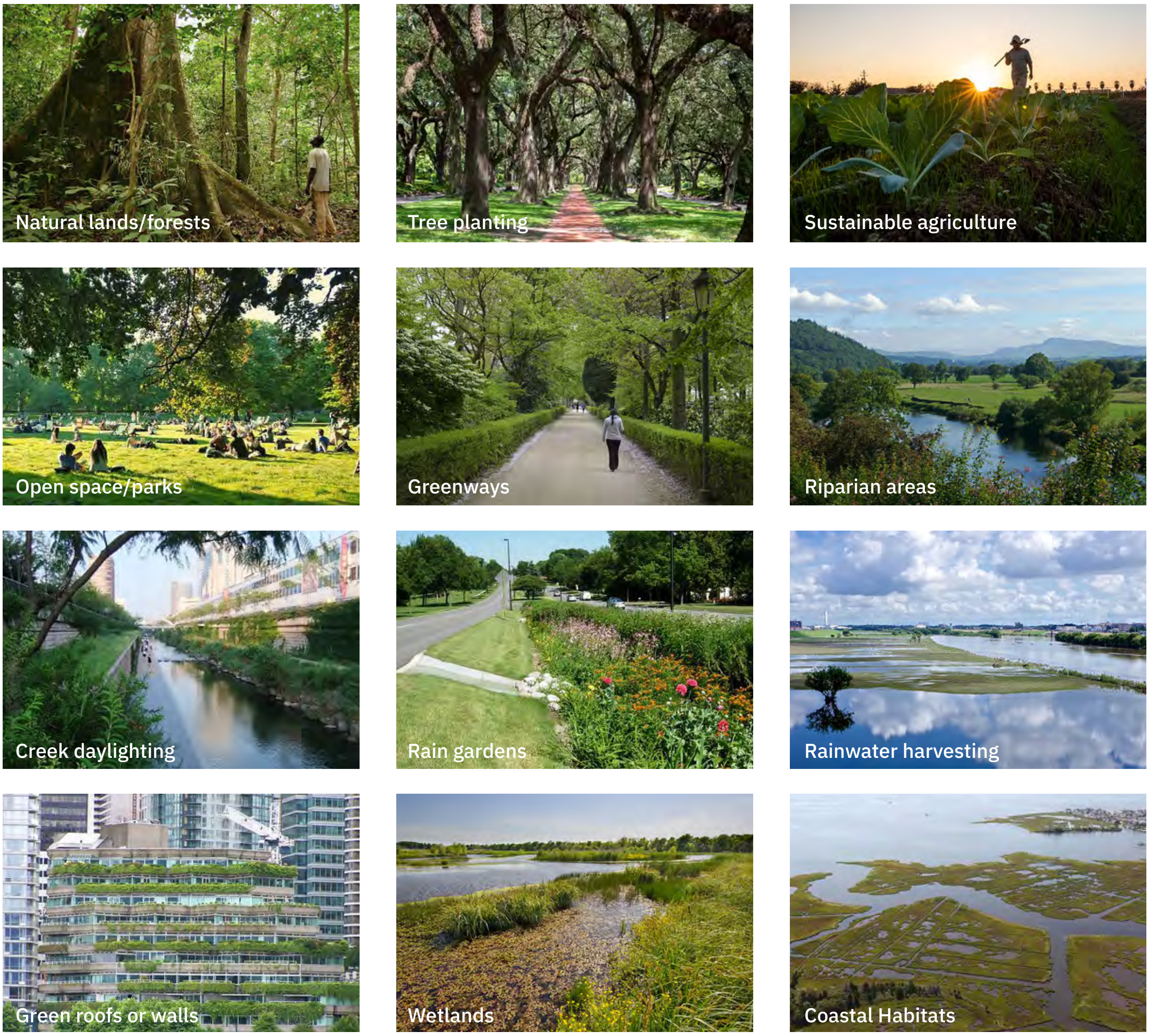
RESTORE

The uMngeni River provides water supply to Durban, South Africa. Degradation of the watershed and growing poulations reduced water supply. The uMngeni Ecological Infrastructure Partnership (UEIP) was created to coordinate restoration activities that that harness ecosystem value. (Ozment 2018).

BUILD

In order to mitigate rising temperatures, the city of Medellin, Colombia created the Green Corridor project, which transformed the verges of 18 roads and 12 waterways into greenways. This initiative won the 2019 Ashden Award for Cooling by Nature Award (UNEP 2019).

Figure 3 | **Example images of NbS tools to address urban resilience challenges**



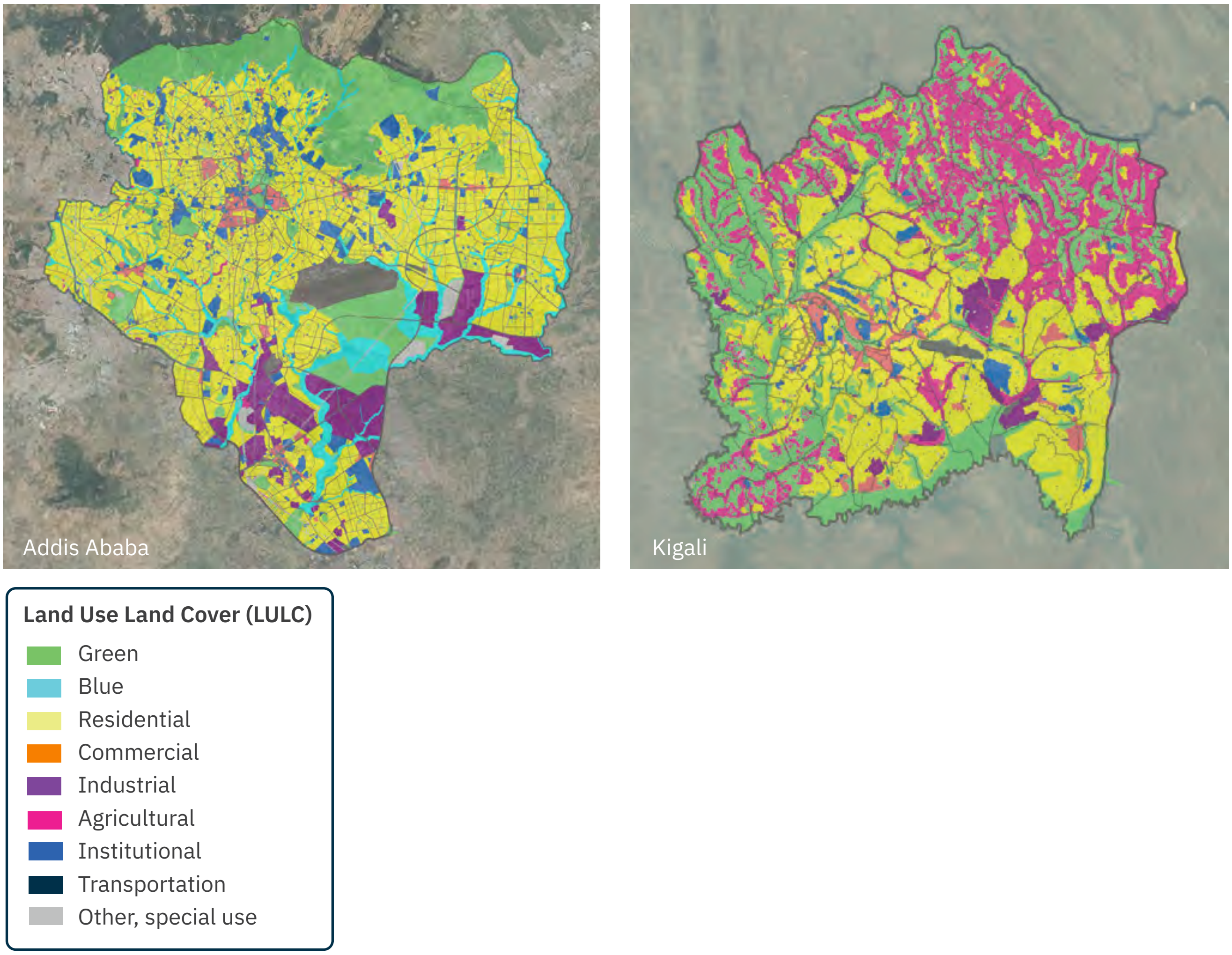
Urban Typologies

Used in urban planning, a typology is the classification of characteristics (usually physical) commonly found in buildings and urban areas, according to their association with different specifications, such as form, density, land use, and mobility infrastructure (Gil, Jorge, et al. 2012). In this framework, eight urban typologies are used to link the type of urban spaces where NbS interventions can be carried out, namely: green landscapes, blue landscapes, residential, commercial, industrial, agricultural, institutional, and transportation. These were defined using a systems approach, with the objective of having locally relevant but generalizable categories that are useful for solution matching.

Land use classes from the planned land use map of the city are translated into these urban typologies. A local land use data set is the basis for reclassifying the cover into the eight typologies. Those classes that don’t fit into the eight urban typologies are assigned to the “other” category. Some examples of this are utilities, such as power facilities or waste facilities.

- Green Landscapes: Forests, Riparian Vegetation, Parks & Open Space, Recreation, Playground, Sports Fields
- Blue Landscapes: Rivers, Reservoirs, Wetlands
- Residential: Single Family Housing, Multi-Family Housing, Informal Housing
- Commercial: Commerce, Business
- Industrial: Mineral, Manufacturing, Storage, Industrial Parks
- Agricultural: Urban Agriculture, Vegetable Farm, Crop Fields
- Institutional: Government, Embassies, Education, Religious Institutions, Historic, Health, Burials
- Transportation: Major Corridors, Local Roads, Transit & Terminal, Rail, Airports

Figure 3 | **Urban Typologies Map from Addis Ababa, Ethiopia and Kigali, Rwanda**



Although each typology includes subcategories, these are not exhaustive, and each city application should seek to assign the category that best matches the local context when using this Guide.

These urban typologies provide insights into potential NbS tools that can be applied. Table 2 illustrates the suitability of the NbS tools for each urban typology. For example, Tree Plantings are suitable for several of the urban typologies. Tree plantings in natural lands can support increased stabilization of soils and shade, or line the streets of residential or commercial areas to support cooling and habitat connectivity, or be integrated into agricultural fields in agroforestry practices.

Table 2 | **NbS suitability for the eight urban typologies**

NBS TOOLS	URBAN TYPOLOGY APPROACH							
	Green	Blue	Residential	Commercial	Industrial	Agricultural	Institutional	Transportation
Natural lands/ forests	+							
Tree plantings	+		+	+		+	+	+
Sustainable agriculture	+					+		
Open space/ parks	+	+	+	+		+	+	+
Greenways	+							+
Riparian floodplain	+	+						
Creek daylighting	+	+		+		+		
Rain gardens			+	+		+	+	+
Rainwater harvesting			+	+	+	+	+	
Green roofs and green walls			+	+	+		+	
Wetlands	+	+				+		
Coastal habitats	+	+						
Beaches and Dunes	+							

NbS Water, Heat and Biodiversity Management Strategies

This guide provides the framework for selecting appropriate nature-based solutions as part of an urban strategy to mitigate the risks from urban water, heat, and ecological hazards. The functions of NbS tools can be classified into water, heat, and biodiversity management strategies.

In this guide, NbS tools address **water management** challenges through 5 strategies:

- **Sink it:** Allowing infiltration of water into the soils and subsurface zones;
- **Slow it:** Temporarily retaining/ detaining water and then slowly releasing it;
- **Move it:** Conveying excess water from one site to another;
- **Reuse it:** Capturing water for reuse in potable and non-potable uses; and
- **Clean it:** Improving water quality.

Figure 4 | **NbS tools can address water management challenges through 5 strategies**

SINK IT

Forests capture and absorb water through their roots, helping prevent flooding.

SLOW IT

Detention basins temporarily store water and then slowly release it, reducing peak flows during extreme rain events.

MOVE IT

Creek daylighting connects former creek areas to existing water channels, relocating water to other parts of the watershed.

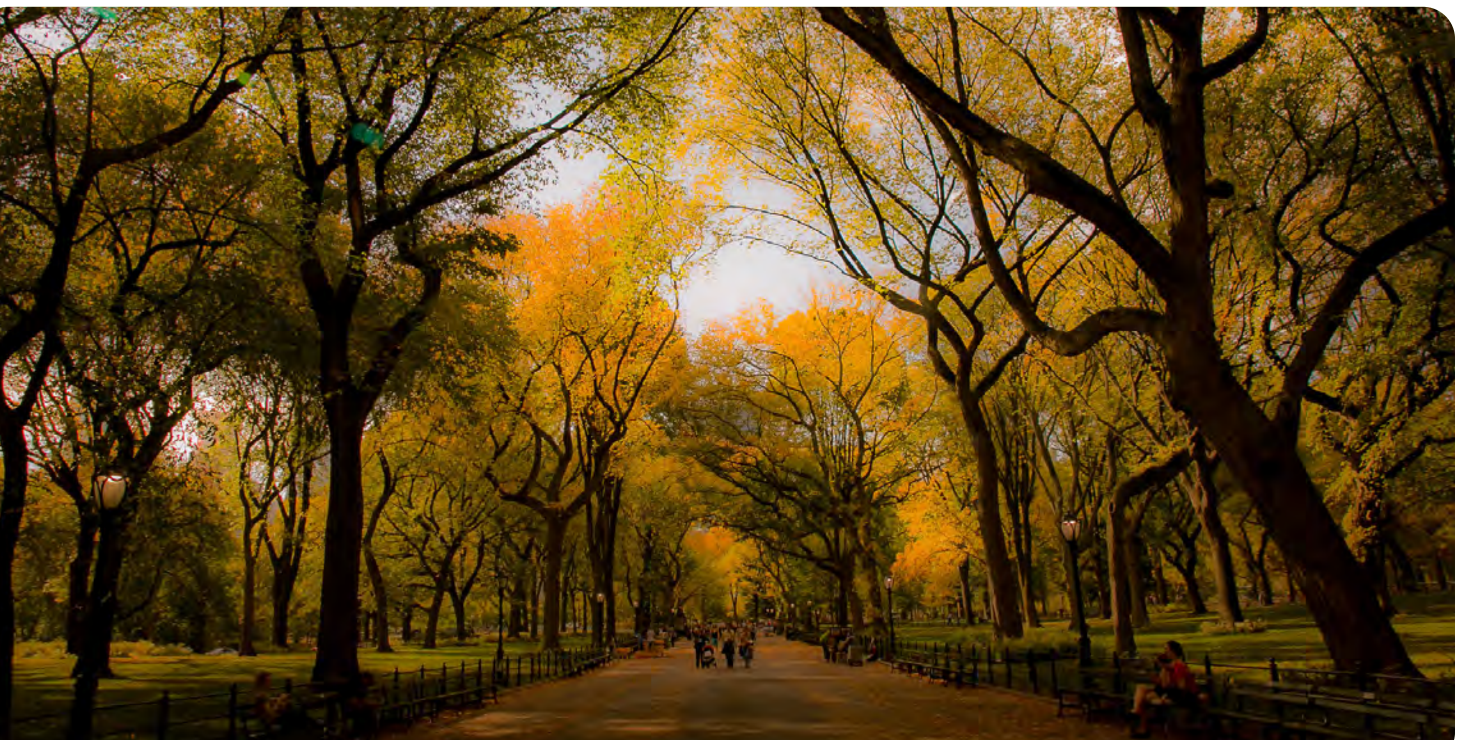
REUSE IT

Water can be captured and reused through rainwater harvesting.

CLEAN IT

Wetlands capture water and improve its quality.

Source: Authors



In the guide, NbS tools address **heat management** challenges through 4 strategies:

Lighten it: Increase albedo by replacing low albedo surfaces such as dark pavements with high albedo surfaces such as blue-green infrastructure that reflect more heat back into the atmosphere;

Access it: Provide access to shade by ensuring residents are able to access shade from their homes and jobs; and

Cover it: Create shade by increasing shade elements such as trees;

Cool it: Increase evapotranspiration by providing vegetated surfaces where evapotranspiration can easily occur.

Figure 5 | **NbS tools can address heat management challenges through 4 strategies**

LIGHTEN IT	COVER IT	ACCESS IT	COOL IT
			
Green roofs generally have higher albedo than their grey infrastructure counterparts.	Trees are an important source of shade in cities, helping mitigate the urban heat island effect.	Greenways help connect humans and nature, and enable interaction with shade-creating elements such as trees.	Forests carry out evapotranspi-ration, consuming heat and helping cool cities.

Source: Authors

In the guide, NbS tools address **biodiversity management** challenges through 4 strategies:

Safeguard it: Protect existing native and natural areas and consider policies and regulations to ensure their long-term protection;

Buffer it: Expand habitat reach by increasing green spaces around open space and riparian areas using tree planting, greenways, urban pocket parks, and green roofs; and

Diversify it: Increase t he diversity of plants, prioritizing indigenous and native, thereby enhancing ecological diversity to support insects, birds, and animals;

Connect it: Create green linkages between existing natural and green spaces to enhance habitat connectivity and access.

Figure 6 | **NbS tools can address biodiversity management challenges through 4 strategies**

SAFEGUARD IT	DIVERSIFY IT	BUFFER IT	CONNECT IT
			
Existing natural areas and forests, when protected, provide multiple benefits to the human and natural world.	Biodiversity is achieved through species richness and ecosystems with native and indigenous species to enhance habitat.	Large natural areas support diverse wildlife and ecosystem services. Riparian buffers and neighborhood green space helps grow these habitats.	New greenways, bioswales, trees, parks, and green roofs provide critical habitat links between existing green spaces.

Source: Authors

NbS Implementation Strategies

The roles and responsibilities for envisioning, implementing, financing, and maintaining urban NbS fall to several different public and private stakeholders. Cities use different approaches depending on the authority over the land and project goals. For public lands, cities can use public funds to develop capital investments and provide staff for operations and maintenance. On private lands, cities may choose to regulate to achieve the desired environmental outcomes by private development, incentivize the private sectors with financial or other benefits to achieve the outcomes, or partner with the private sector to co-design, fund, implement and operate NbS. Community advocates can play a key role in advancing programmatic NbS solutions that benefit neighborhoods. Implementation partners include public agencies and authorities at the city, regional or national level, private developers, property owners, homeowners, and community-based groups. For each NbS tool, there are several implementation approaches that involve different partners.
Table 3 describes the types of investment strategies and partners for nature-based solutions to address urban water resilience challenges.

Table 3 | **Urban NbS Investment Strategies and Partners.**

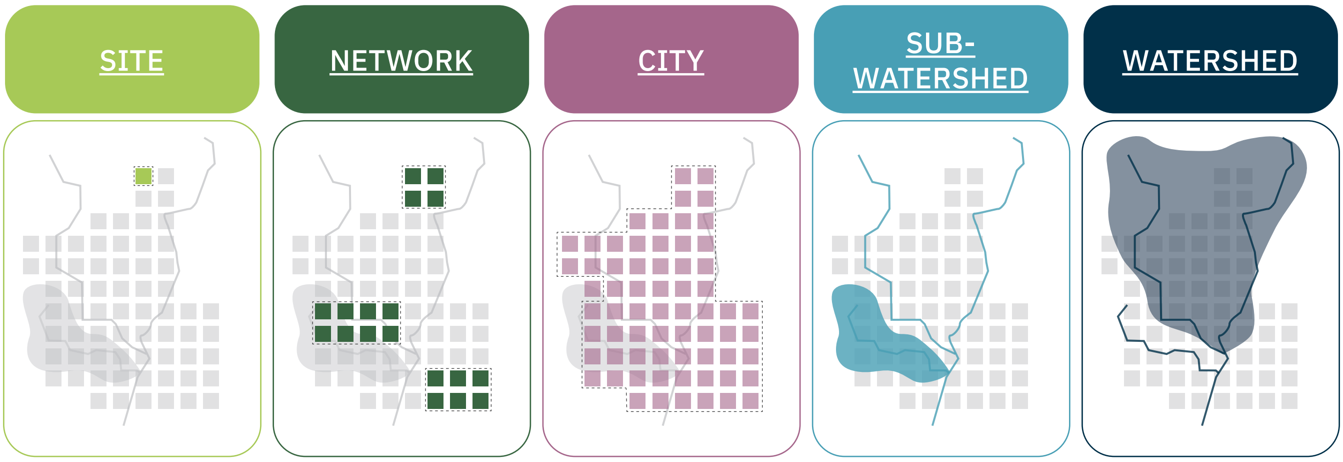
CAPITAL	INCENTIVES	PARTNERSHIPS	LAND CONTROLS
Publicly Funded	**Public Rebates**	**Co-Funded Projects**	**Private Compliance**
PUBLIC PROJECTS This implementation strategy involves the use of public funds to carry out a NbS intervention on public lands. It involves the leadership of public agencies with input from local stakeholders about local needs.	**GRANTS** This implementation strategy involves public provision of monetary incentives to carry out NbS interventions.	**PUBLIC PRIVATE PARTNERSHIPS** NbS interventions can be carried out in alliance with the private sector. For example, NbS projects can be co-led by commercial or industrial partners.	**REGULATIONS** One alternative to implement NbS in urban contexts is regulation on private property. Examples include **pervious requirements** and **stormwater management requirements**, which legally require private actors to implement nature-based solutions in their own lands.
PUBLIC ACQUISITION This implementation strategy involves the purchase of land by a public agency or a group of public agencies from private ownership to address a public purpose. Targeted areas for NbS implementation are **flood-prone properties,** areas of **additional natural spaces**, and areas where the **floodplain can be expanded**.	**REBATE PROGRAMS** For example, public agencies can partner with residential buildings to create a **residential rain garden incentive program**, where benefits such as tax credits are offered to promote the implementation of this NbS tool.	**PROGRAMMATIC CBO/GOV** Local leaders on the ground have the best insight as to the community needs and opportunities for integrated NbS. Government **subsidies to support neighborhood wide efforts**, like tree plantings, greening and stewardship programs, help ensure community ownership and longevity.	**POLICY** Policy can be used as a tool for the implementation of NbS interventions. One example is setting a **tree canopy coverage policy** in urban settings, but there are many other policy instruments that can be used for NbS implementation.

Spatial and temporal scales

NbS interventions can be carried out in a variety of scales. The smallest is the site scale, where the intervention is carried out in a single delimited area. An alternative is to create a network of interventions, composed by a variety of interconnected sites. Interventions can also be made at the city-scale. Likewise, it is possible to carry out interventions at the watershed sub-basin and basin level. The appropriate scale for an intervention depends on several factors, such as the risk addressed, budget constraints, among other factors.

Nature-based solutions operate on differing timescales, ranging from days to years and decades. Built solutions, such as green roofs or rainwater harvesting systems, may reach their full capacity soon after installation, while solutions involving restoration or changes in the management of ecosystems will require longer time frames to reach their full functionality (Browder et al. 2019, p. 32). For example, new forests will take four decades to reach their full potential (Browder et al. 2019, p. 32). According to the World Bank, time frames of at least 20 to 50 years will be the most appropriate for NbS to address flooding (World Bank 2017, p. 9).

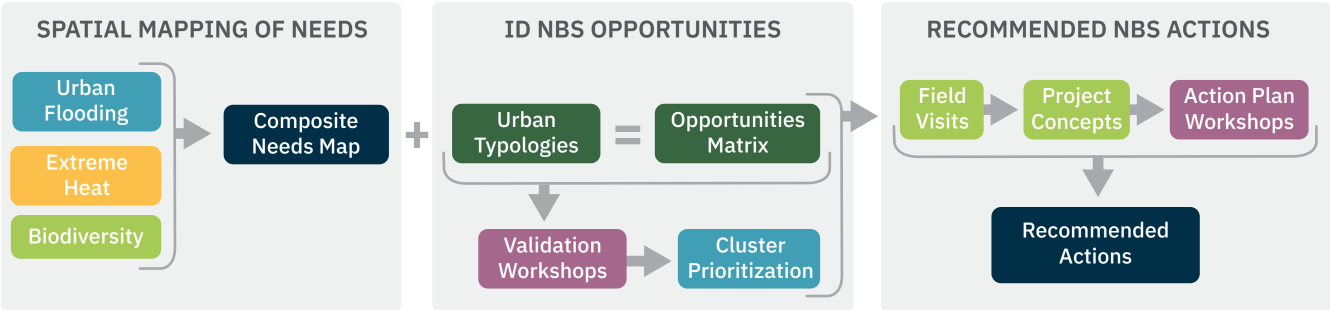
Figure 7 | **Spatial scales for NbS**



SECTION 2: NEEDS ASSESSMENT AND NBS SELECTION

This section outlines the steps to rapidly assess urban flooding, extreme heat, and biodiversity needs, identify priority areas experiencing and most likely to be facing increased climate risks and vulnerability for interventions, identify suitable NbS to support urban resilience based on the specific urban context, and further refinement of priority are project concepts with field work and deeper assessments that result in Recommended Nbs Actions (See Figure 8).

Figure 8 | Needs Assessment and NbS Selection Process



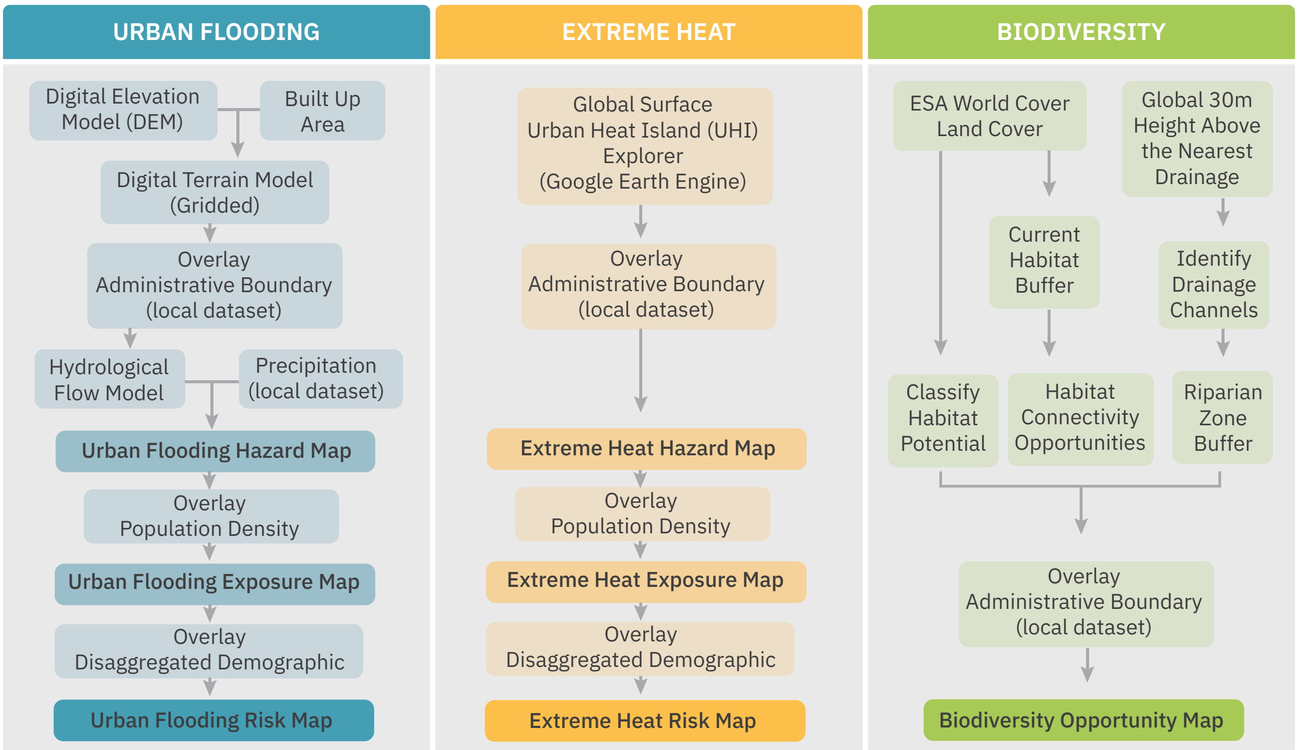
Needs Assessment

This guide proposes the following **3 steps** for the assessment of urban flooding, extreme heat and biodiversity needs and the identification of areas where multiple needs NbS can be applied. This is followed by the NbS selection where the urban typologies are matched with potential NbS tools.

Step 1: Urban flooding, extreme heat, and biodiversity spatial analysis

The first step is a rapid spatial mapping and inventory of existing natural and built assets in the city and its water basin. This includes the mapping and trend analysis of the city's blue-green and grey assets, such as surface water, green assets, built up area, impervious surface, critical assets and lifeline essential infrastructure. Figure 2 shows an example of this mapping for the city of Addis Ababa, Ethiopia.

Figure 9 | Spatial analysis approach for mapping urban flooding, extreme heat, and biodiversity needs

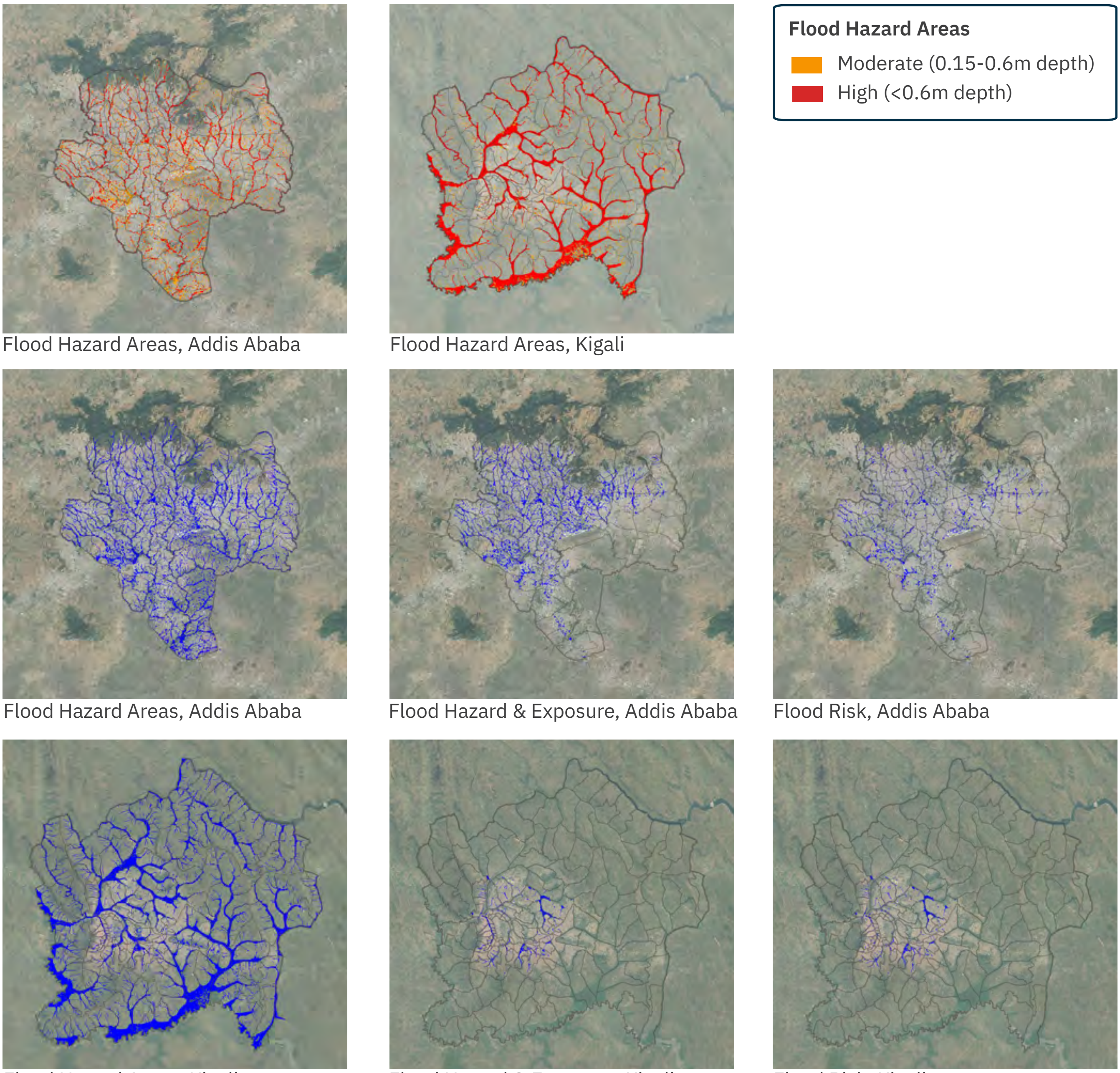


Urban Flooding

This analysis integrates information about the likelihood of flooding (hazard), what is at risk in the area (exposure), and the susceptibility of people and assets to flood-related damages (vulnerability) (Figure 10). For citywide planning purposes, the urban flood model shows the areas that are likely to face inundation and flooding in an extreme climate event based on the inundation levels for a 100-year return period storm.

A hydrologic model is developed based on a Digital Terrain Model (DTM that calculates hydrological flow depending on rainfall levels, selection of the terrain,, percolation rates and flows to drainage networks. The flood hazard map is categorized by inundation level categories of medium risk between 0.15m and 0.6m and high risk of more than 0.6m. The maps in Figure 10 show the spatial extents of the flood hazard areas that are exposed to medium and high levels of flooding in a 100-year return period storm, then hazard areas with exposure based on population data from WorldPop, and the flood risk are that also screens for vulnerability.

Figure 10 | **Mapping of urban flooding for a 100-year Return Period in Addis Ababa, Ethiopia and Kigali, Rwanda**

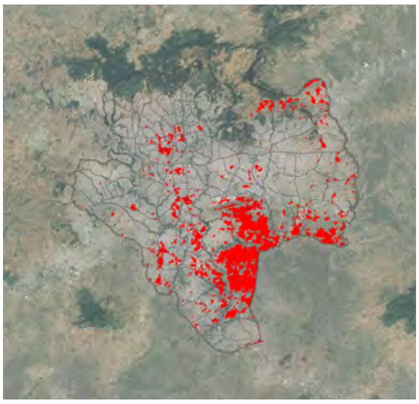


Extreme Heat

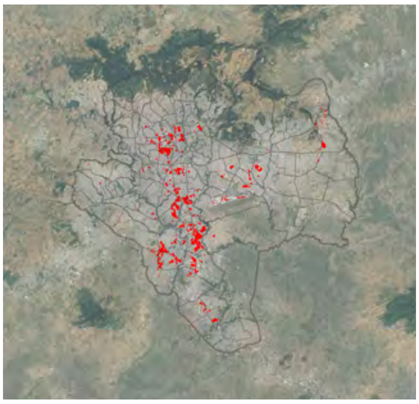
Similar to the methods for urban flooding, this extreme heat analysis integrates information about the likelihood of extreme (hazard), what is at risk in the area (exposure), and the susceptibility of people and assets to extreme heat-related damages (vulnerability) (Figure 11).

Heat hazard areas that are exposed to high land surface temperatures (compared to whole city) were identified from Landsat remote sensing using Google Earth Engine. Building on the heat hazard maps, the heat exposure and vulnerability maps overlay demographic, land use, and other relevant data (on the heat hazard maps) to identify and assess at-risk locations and populations in the extreme heat risk map. The maps in Figure 11 show the spatial extents of the heat hazard areas, the areas with exposure based on population density data from WorldPop, and the areas of heat risk correlated with vulnerability.

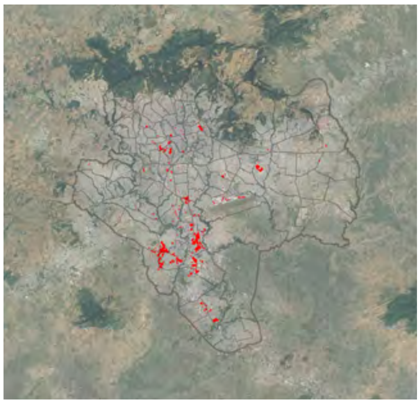
Figure 11 | **Mapping of extreme heat in Addis Ababa, Ethiopia and Kigali, Rwanda**



Heat Hazard Areas, Addis Ababa



Heat Hazard & Exposure, Addis Ababa



Heat Risk, Addis Ababa

Heat Hazard Areas, Kigali

Heat Hazard & Exposure, Kigali

Heat Risk, Kigali

Biodiversity

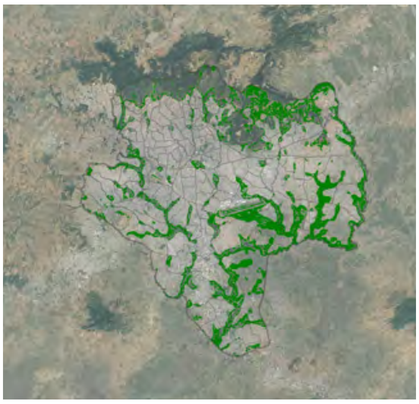
Data on current land cover, riparian zones, and the potential to improve habitat connectivity were combined to identify opportunity areas to improve and restore land in ways that would support biodiversity. This analysis identifies areas adjacent to existing habitat that can improve the extent of those areas and new areas across the city that could provide habitat linkages between two or more existing habitat areas.

The existing land cover is used to assess the habitat potential, habitat connectivity opportunities to connect existing habitat, and riparian buffer zones were combined into an index density map that represents areas of biodiversity opportunity.

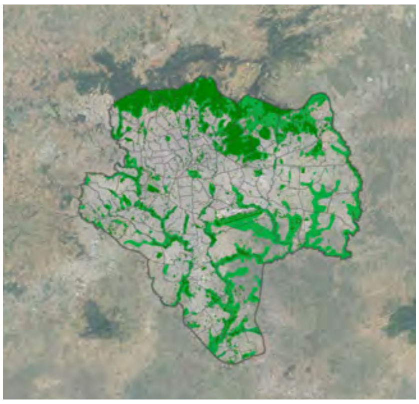
Figure 12 | **Mapping of biodiversity in Addis Ababa, Ethiopia and Kigali, Rwanda**

Biodiversity Opportunities

- Opportunity Areas for Habitat
- Existing Natural Areas



Biodiversity Opportunity Areas, Addis Ababa



Existing and Opportunity Biodiversity Areas, Addis Ababa

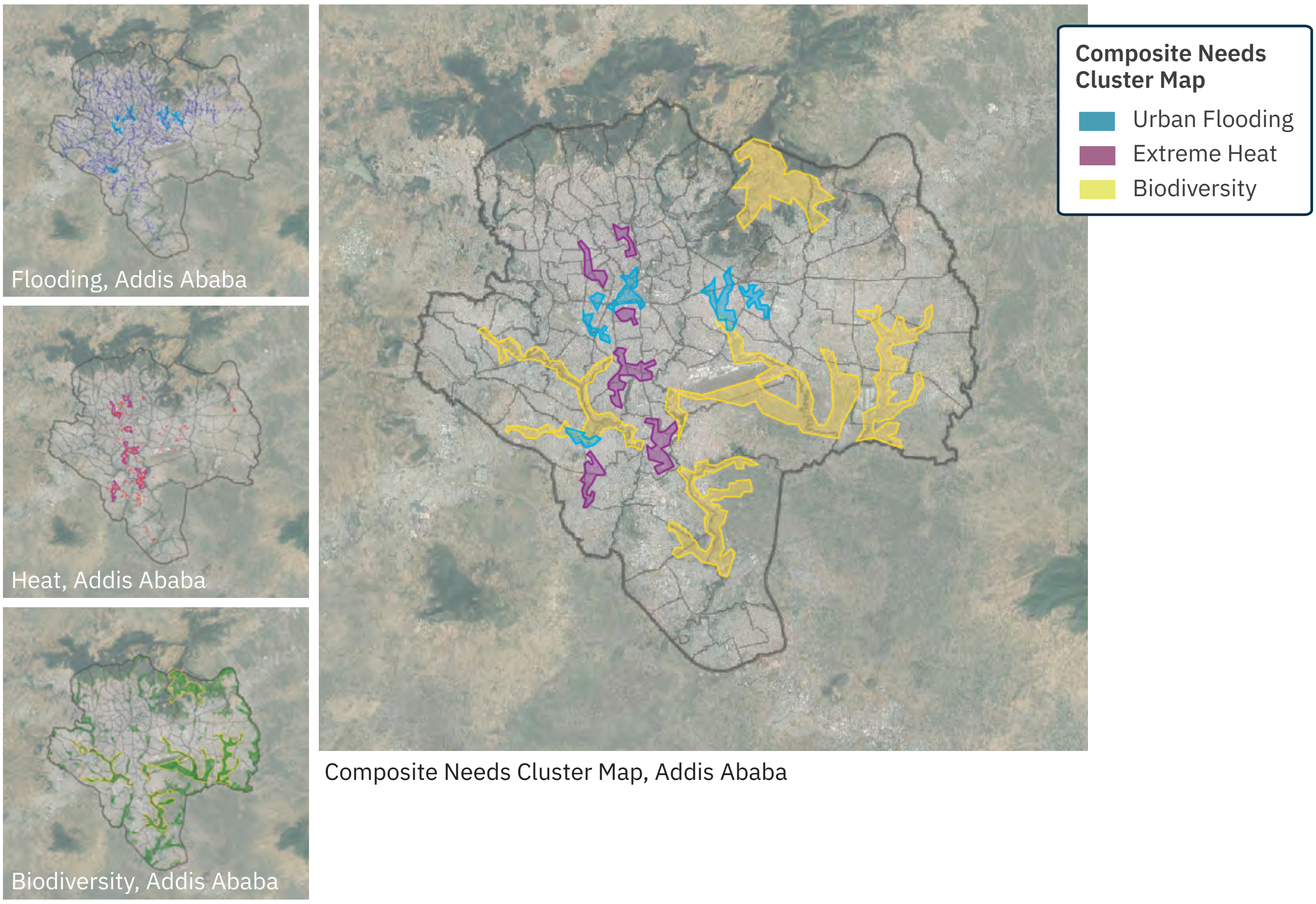
Biodiversity Opportunity Areas, Kigali

Existing and Opportunity Biodiversity Areas, Kigali

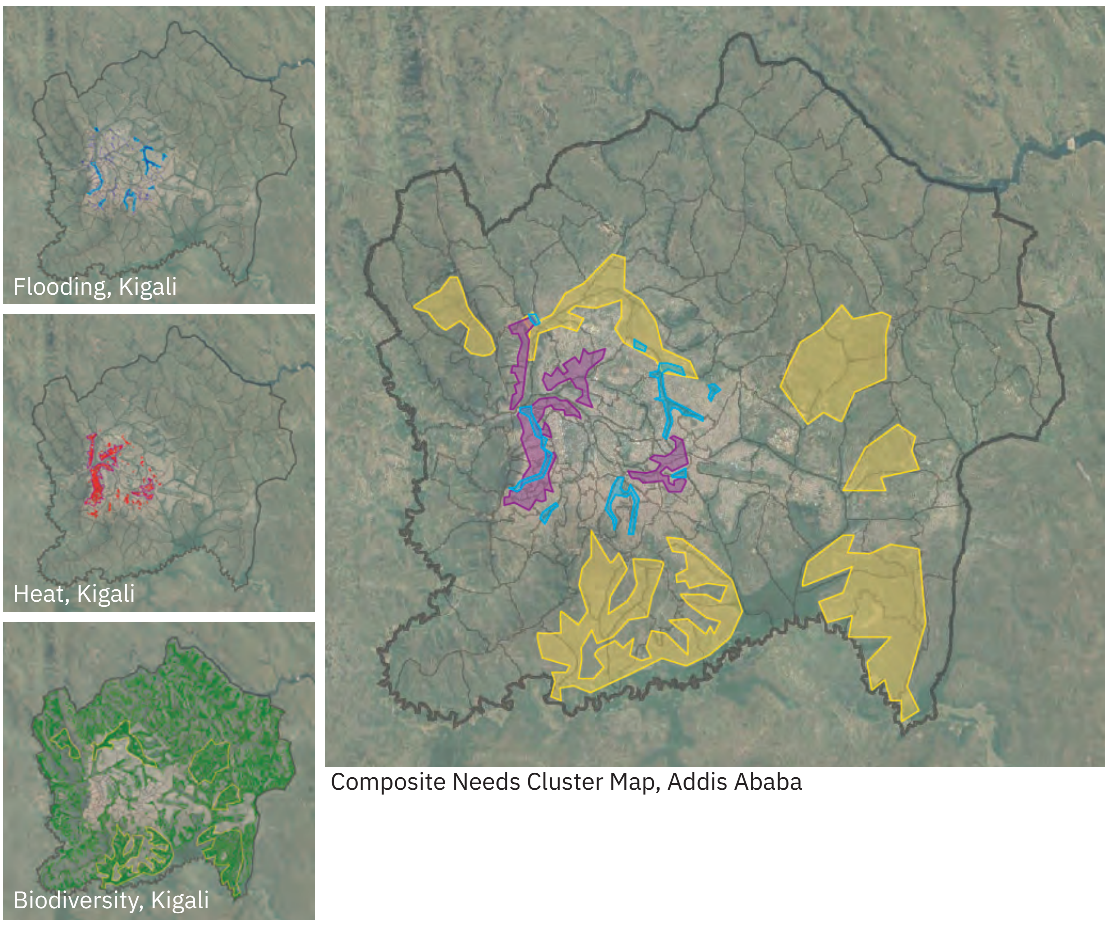
Step 2: Composite Needs Mapping

The next step in the assessment process is to combine the results of the needs analysis to support identification of priority areas for NBS interventions that address multiple needs. The composite needs mapping identifies clusters for each of the three needs (flood, heat, biodiversity) individually and then overlays the three needs clusters to identify adjacencies and overlaps across the city. Each of the three needs maps, (1) flood hazard and exposure, (2) heat hazard and exposure, and (3) biodiversity opportunities, are visually analyzed to select 3-6 of the largest/most dense clusters. These clusters are selected by visual inspection and the shapes are outlined by hand. The selected clusters are then overlaid onto a single map to show adjacencies and overlaps (See Figure 13). These maps serve as the basis for stakeholder review and selection of priority areas for NbS intervention. This composite mapping helps stakeholders that focus on one of the three needs to see their priorities represented alongside others that might be focused on one of the other needs. There is also flexibility in this approach to incorporate additional needs that may be a priority in addition to flooding, heat, and biodiversity.

Figure 13 | **Composite needs mapping in Addis Ababa, Ethiopia and Kigali, Rwanda**



Composite Needs Cluster Map, Addis Ababa



Composite Needs Cluster Map, Addis Ababa

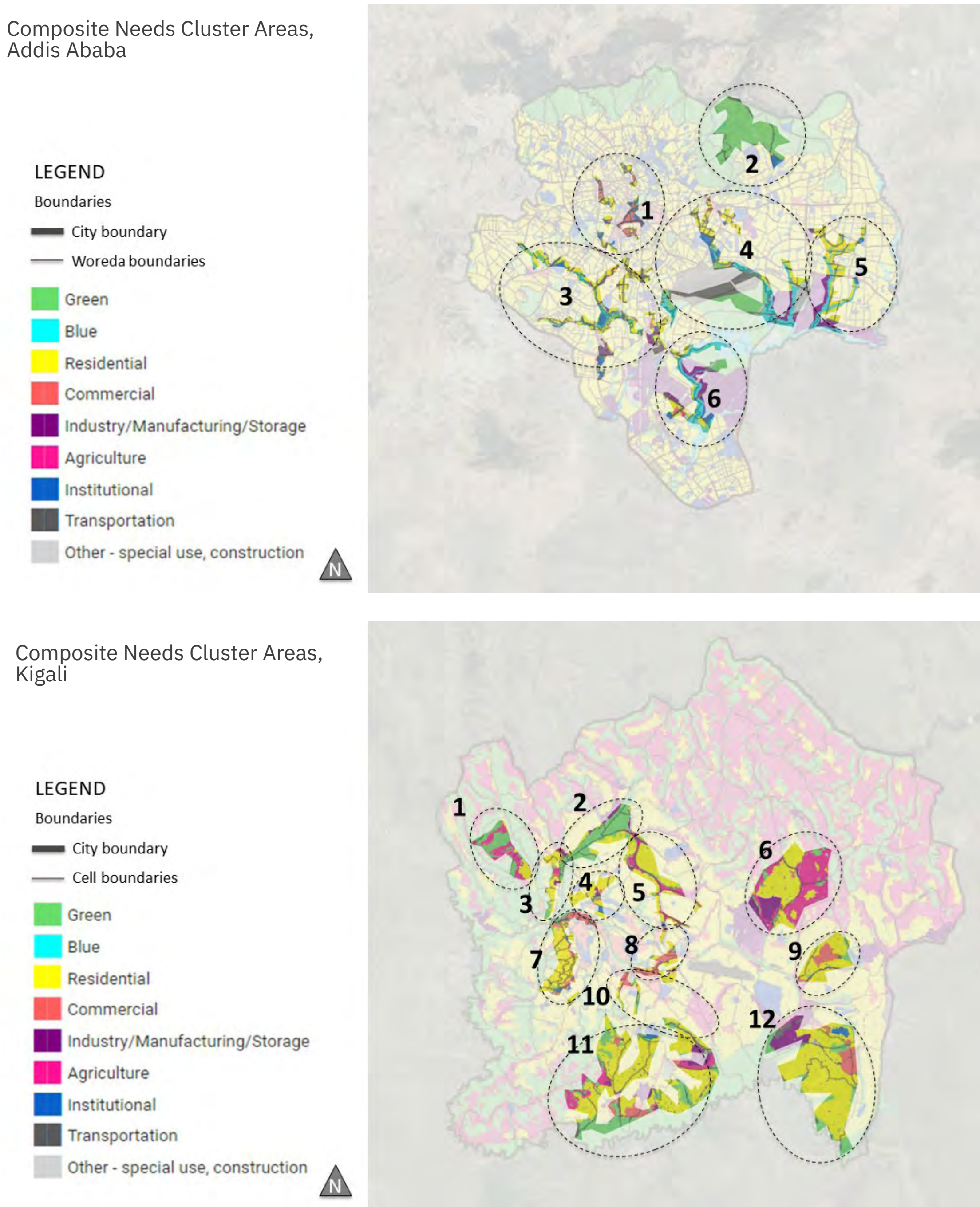
NbS Opportunities

Once the composite cluster areas are defined through the spatial mapping of needs, the cluster needs results from the composite mapping are overlaid with the urban typologies to support the identification of suitable NbS opportunities for further analysis. The priority cluster needs areas are mapped with their urban typologies, which correlate to NbS tools that are most suited for those land use types.

Step 1: Matching Urban Typologies for NbS to Composite Clusters

The composite needs areas are grouped into clusters considering the administrative boundaries, the urban transitions, and natural landforms. Each typology includes NbS tools that are most suited to address urban water, heat, and biodiversity needs. A suite of options can be developed by matching the priority risk area with the urban typology appropriate NbS tools.

Figure 14 | **Cluster needs priority mapping by urban typologies in Addis Ababa, Ethiopia and Kigali, Rwanda**



Step 2: NbS Opportunities Matrix

The opportunities screening matches the composite need areas to their urban typologies within their micro-catchment, which include NbS tools that are most suited for those land use types. These alternatives will be assessed for effectiveness based on the hazard risk focus (e.g., the potential for flood risk reduction, heat island mitigation and ecological habitat protection and restoration) as well as suitability for the localized geography and climate (e.g., soil type, hydrology, natural and built environment context). This opportunities screening matrix identifies the most appropriate NbS to enhance urban water resilience with infiltration, evaporation, detention, conveyance, and reuse, to mitigate extreme heat with shade, vegetated and high albedo surfaces, and the potential of existing natural areas where the city can prioritize protection and restoration of landscape function and healthy habitats and contribute to the region's overall habitat connectivity.

This matrix is the starting place to consider the types of NbS that can be used to address flooding, heat, and biodiversity in the priority areas. The analysis highlights locations within the cluster needs areas where NbS and greening could be critical to create urban flood and heat resilience and protect biodiversity. In addition, current and planned NbS projects are included in the matrix to highlight the potential for leveraging existing city priorities and to draw attention to the types of NbS that have been prioritized, as well as the stakeholders involved.

NBS SUITABILITY

NbS tools can help mitigate the impacts of urban flooding, riverine flooding, coastal flooding, water availability, water quality, extreme heat, and biodiversity. All tools are not appropriate for all challenges and urban contexts. The table below shows the NbS tools that can be used to address these urban resilience risks, as well as their functions, compatible urban typologies, and implementation mechanisms. Table 4 shows the NbS tools included in this guide that address water, heat, and biodiversity challenges, and Table 5 shows compatible urban typologies, examples and implementation mechanisms.

Table 4 | Urban NbS tools suitability to address water, heat and biodiversity challenges

NBS TOOLS	Urban Flooding	Riverine Flooding	Coastal Flooding	Water Availability	Water Quality	Extreme Heat	Biodiversity
Natural lands/ forests	+	+		+	+	+	+
Tree plantings	+	+		+	+	+	+
Sustainable agriculture				+	+	+	+
Open space/ parks	+	+	+	+	+	+	+
Greenways	+				+	+	+
Riparian floodplain	+	+		+	+	+	+
Creek daylighting	+	+			+	+	+
Rain gardens	+				+	+	+
Rainwater harvesting	+			+	+		
Green roofs and green walls	+				+	+	+
Wetlands	+	+	+	+	+	+	+
Coastal habitats			+		+		+
Beaches and Dunes			+		+		+

- **Urban flooding:** NbS absorbs water, allowing greater infiltration into the soils, or relocates water to other sites.
- **Riverine flooding:** NbS located within or adjacent to streams, rivers, and other water bodies help absorb and slow down the water flow.
- **Coastal flooding:** NbS located within or adjacent to coastal areas, such as shorelines and beaches, serve as a barrier between the land and the sea, helping absorb and slow down water flows.
- **Water availability:** NbS conserves water or recharges source water reservoirs.
- **Water quality:** NbS improves water quality in cities by preventing the release, capturing or treating pollutants present in water.
- **Extreme heat:** NbS mitigates extreme heat by providing shade, absorbing heat through the process of evapotranspiration, increasing albedo to promote light reflection or creating spaces for people to access shade.
- **Biodiversity:** NbS increases areas for habitat diversity, protect or enhance existing natural areas, and support habitat connections for multiple species living in cities.

Table 5 | **NbS Opportunities linking urban typologies to NbS tools, examples, mechanisms, and functions**

URBAN TYPOLOGIES	NBS TOOL	EXAMPLES	MECHANISMS	WATER FUNCTION	HEAT FUNCTION	BIODIVERSITY FUNCTION
Green Landscapes	Natural lands/ forests	Urban forests, upland/upper-watershed/riparian forests, shrublands, grasslands	Protect/ enhance/ restore/ build	Sink t, Slow it, Clean it	Lighten it, Cover it, Access it, Cool it	Safeguard it, Diversify it, Buffer it, Connect it
Green landscapes / Institutional/ Commercial/ Residential/ Transportation	Tree plantings	Street trees, Park trees, Private property trees	Build	Sink it, Slow it, Clean it	Lighten it, Cover it, Access it, Cool it	Safeguard it, Diversify it, Connect it
Green landscapes / Commercial	Sustainable agriculture	Agroforestry and Silvopasture, Farmland Best Practices	Enhance existing practices/ restore parts of land to natural condition	Reuse it, Clean it	Lighten it, Cover it, Cool it	Safeguard it, Diversify it, Buffer it
Green landscapes / Blue landscapes Institutional/ Commercial/ Residential/ Transportation	Open space/ parks	Open spaces, Neighborhood parks, Pocket parks, Stormwater parks, Waterfront parks	Protect/ enhance/ build	Sink it , Slow it, Reuse it, Clean it	Lighten it, Cover it, Access it, Cool it	Safeguard it, Diversify it, Buffer it, Connect it
Green landscapes / Transportation	Greenways	Tree Corridors, Bioswales	Protect/ enhance/ build	Sink it, Slow it, Move It, Clean it	Cover it, Access it, Cool it	Safeguard it, Diversify it, Connect it
Green/ blue landscapes	Riparian floodplain	Floodplain management, Floodplain/channel reconnections	Protect/ enhance/ restore	Sink it, Slow it, Clean it	Cover it, Cool it	Safeguard it, Diversify it, Buffer it
Green landscapes/ blue landscapes/ Commercial	Creek daylighting	Channelized urban creek, natural open space creek	Restore	Sink it, Slow it, Move It, Clean it	Cool it	Safeguard it, Diversify it, Connect it
Green landscapes / Institutional/ Commercial/ Residential/ Transportation	Rain gardens	Retention rain gardens, detention rain gardens, bioswales	Build	Sink it , Slow it, Clean it	Cool it	Diversify it, Buffer it, Connect it
Green landscapes / Blue Landscapes/ Institutional/ Commercial/ Residential	Rainwater harvesting	Cisterns, Rain Barrels, Detention Ponds, aquifer recharge with infiltration ponds/fields	Build	Slow it, Reuse it, Clean it	N/A	N/A
Institutional/ Commercial/ Residential	Green roofs and green walls	Green roofs (intensive and extensive), green walls	Build	Sink it, Slow it, Clean it	Lighten it, Cool it	Diversify it, Connect it
Green/ blue landscapes	Wetlands	Inland wetlands (e.g., wastewater treatment wetlands), estuarine wetlands	Protect/ enhance/ build	Sink it, Slow it, Reuse it, Clean it	Lighten it, Cool it	Safeguard it, Diversify it, Buffer it, Connect it
Green/ blue landscapes	Coastal habitats	Mangroves, Salt Marshes, Reefs, Seagrass	Protect/ enhance/ restore	Sink it, Slow it, Clean it	N/A	Safeguard it, Diversify it, Buffer it, Connect it
Green/ blue landscapes	Beaches and Dunes	Beaches, Dunes	Protect/ enhance/ restore	Sink it, Slow it, Clean it	Access it	Safeguard it, Diversify it, Buffer it, Connect it

Step 3: Stakeholder Validation and Prioritization

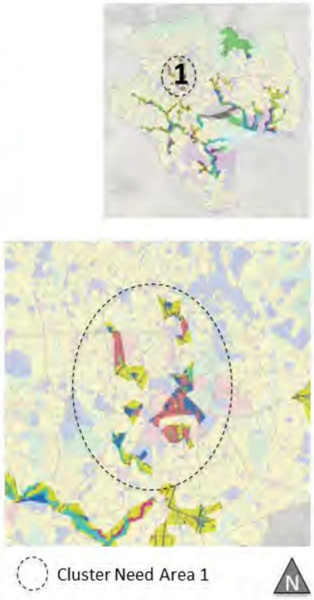
The NbS selection framework is performed in collaboration with the local authorities so that decisions about priority locations are driven both by the spatial location of the risk and integration with local planning and development policy, plans and development. The stakeholder validation and prioritization will identify the key locations to define the NbS tools best suited to address the risks and integrate with the urban typology. This stage involves working closely with the city stakeholders to refine NbS opportunities, preferences for NbS tools, and identification of key areas of need. A set of priority areas are selected to further assess NbS potential (See Figure 14) and advance concept development as a model for citywide action in the next step of NbS Recommendations.

Workshops should be designed to integrate city development goals and NbS potential for addressing current and future risks. The validation of current conditions, changes over the last decade and current and future development proposals will support the finalization of priority areas for consideration of NbS recommendations. In addition to project concepts, policy and regulations to support integration of NBS into public infrastructure, current built areas, and future development should be included in these discussions.

Figure 14 | **Cluster needs priority mapping by urban typologies in Addis Ababa, Ethiopia and Kigali, Rwanda**

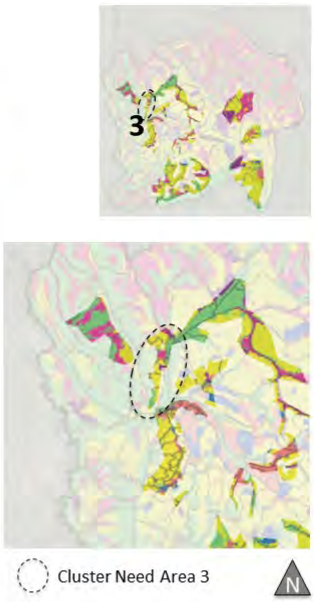
ADDIS ABABA NBS Opportunities

Cluster Area	Urban Typologies	Needs Cluster: Urban Flooding	Needs Cluster: Extreme Heat	Needs Cluster: Biodiversity	NBS Opportunities
AREA 1					
ADDIS KETEMA SUB CITY W6/8/1 + LIDETA SUB CITY W5					
Addis Ketema Secondary School, Merkato Enchet Tera, Mola Maru, Chid Tera, Minalesh Tera and Shema Tera	Residential		✓		Streets trees, neighborhood parks, rain gardens, rainwater harvesting, green roofs
	Commerical		✓		Tree plantings, pocket parks, rain gardens, rainwater harcesting, green roofs
	Institutional		✓		Tree plantings, open space and parks, rain gardens, rainwater harvesting, and green buildings (roofs and walls)
LIDETA SUB CITY W9					
Balcha Hospital	Residential	✓			Streets trees, neighborhood parks, rain gardens, rainwater harvesting, green roofs
	Commerical	✓			Tree plantings, pocket parks, rain gardens, rainwater harcesting, green roofs
	Institutional	✓			Tree plantings, open space and parks, rain gardens, rainwater harvesting, and green buildings (roofs and walls)
ARADA SUB CITY W5					
Serategna Sefer, Mamo Kacha, Addis Ababa Restaurant, Afencho Ber Health Center	Residential		✓		Streets trees, neighborhood parks, rain gardens, rainwater harvesting, green roofs
	Commerical		✓		Tree plantings, pocket parks, rain gardens, rainwater harcesting, green roofs
	Institutional		✓		Tree plantings, open space and parks, rain gardens, rainwater harvesting, and green buildings (roofs and walls)
LIDETA SUB CITY W10 + KIRKOS SUB CITY W5					
Bisrat FM 101.1 Radio Station up to Dessie Hotel; Bulgaria Saint Michael Church	Residential	✓			Streets trees, neighborhood parks, rain gardens, rainwater harvesting, green roofs
	Institutional	✓			Tree plantings, open space and parks, rain gardens, rainwater harvesting, and green buildings (roofs and walls)
KIRKOS SUB CITY W7/W10					
La Gare, Churchill Street, Ambassador Park	Green Landscapes	✓			Upland forests, tree plantings, stormwater parks, greenways
	Commerical	✓			Tree plantings, pocket parks, rain gardens, rainwater harcesting, green roofs
	Institutional	✓			Tree plantings, open space and parks, rain gardens, rainwater harvesting, and green buildings (roofs and walls)
Cherkos Sefer	Commerical		✓		Tree plantings, pocket parks, rain gardens, rainwater harcesting, green roofs
	Residential		✓		Streets trees, neighborhood parks, rain gardens, rainwater harvesting, green roofs



KIGALI NBS Opportunities Matrix

Cluster Area	Urban Typologies	Needs Cluster: Urban Flooding	Needs Cluster: Extreme Heat	Needs Cluster: Biodiversity	NBS Opportunities
AREA 3					
AGATEKA	Industrial	✓	✓	✓	Rainwater harvesting, green roofs, green walls
	Agricultural	✓	✓	✓	Urban Agriculture, tree plantings, rainwater harvesting
	Residential		✓	✓	Streets trees, neighborhood parks, rain gardens, rainwater harvesting, green roofs
KARURUMA	Industrial		✓		Rainwater harvesting, green roofs, green walls
	Agricultural		✓		Urban Agriculture, tree plantings, rainwater harvesting
	Commerical		✓		Tree plantings, pocket parks, rain gardens, rainwater harcesting, green roofs
	Residential		✓		Streets trees, neighborhood parks, rain gardens, rainwater harvesting, green roofs
NYAMUGARI	Residential		✓		Streets trees, neighborhood parks, rain gardens, rainwater harvesting, green roofs
NYAMABUYE	Green Landscapes		✓		Upland forests, tree plantings, stormwater parks, greenways
	Residential		✓		Streets trees, neighborhood parks, rain gardens, rainwater harvesting, green roofs



NbS Recommendations

The goal is for NBS to be integrated into the urban built and natural ecosystems. Once the composite needs and NbS opportunities have been discussed with stakeholder and a set of priority areas are selected, the final step is developing NbS recommendations.

Step 1: NbS Project Concepts for Priority Areas

A key goal for city partners and stakeholders is to identify groundwork projects at the community and site level for early implementation to build knowledge about NbS. Based on stakeholder preferences, the project team now moves into site assessment and NbS concept development for a set of selected priority cluster need areas. This stage involves local site assessments through desktop analysis, field visits, concept development, and engagement with community stakeholders. In this stage, site assessments are prepared to understand on-the-ground conditions for the priority areas, such as impervious surfaces, land cover and buildings, street network. The assessments should include mapping of watershed and hydrological conditions, land use and vegetation, and riparian zones. The site visits aim was to jointly assess the current state of the selected priority areas, obtain insights and come up with site specific recommendations (See Figure 15 and 16). The results should be discussed with stakeholder to ensure their needs and preferences are considered in the development of NbS concepts.

With the detailed site assessments, potential NbS concepts are developed to support flood, heat and ecological resilience, while supporting community health. Design teams should include landscape architects, civil engineers, hydrologic engineers, ecologist, biologist, water resources experts, climate scientists. Together these disciplines can advance NbS project concepts to further refine in partnership with stakeholders in the Action Plan Workshops.

Hydrologic Assessment:

- Evaluate water features, flood-prone areas, water source quality, and feasibility of NBS solutions
- Assess and collect hydrological data and natural drainage systems, flood-prone areas, and water quality.
- Consider the feasibility of water-related NBS solutions.

Biodiversity Evaluation:

- Document local plant and animal species and assess vegetation health and diversity
- Identify signs of wildlife activity and water bodies, crucial for biodiversity conservation

Urban Typology Analysis:

- Identify existing infrastructure and impervious surfaces
- Evaluate drainage systems,
- Explore nature-based solution opportunities to tackle urban challenges

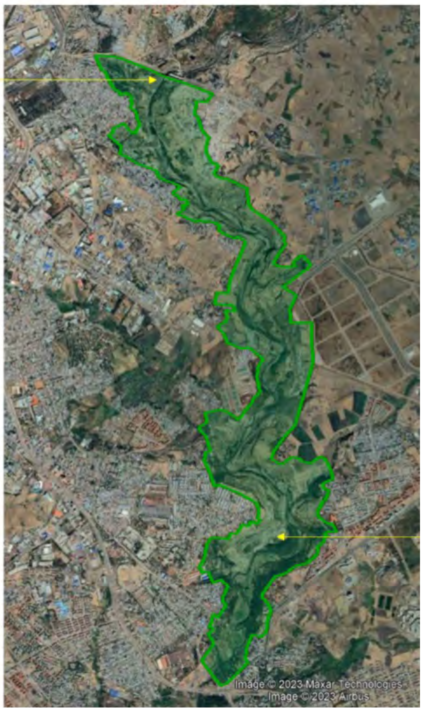
Figure 15 | **Site Assessment and NbS Concepts in Addis Ababa, Ethiopia**

Cluster Need Area: Kebena-Akaki Rivers Confluence to Kilinto River

Addis Ababa

Images: EiABC

Bulbula River and Akaki river confluence, characterized by degraded hills, informal encroachment, housing, and urban agricultural practices.



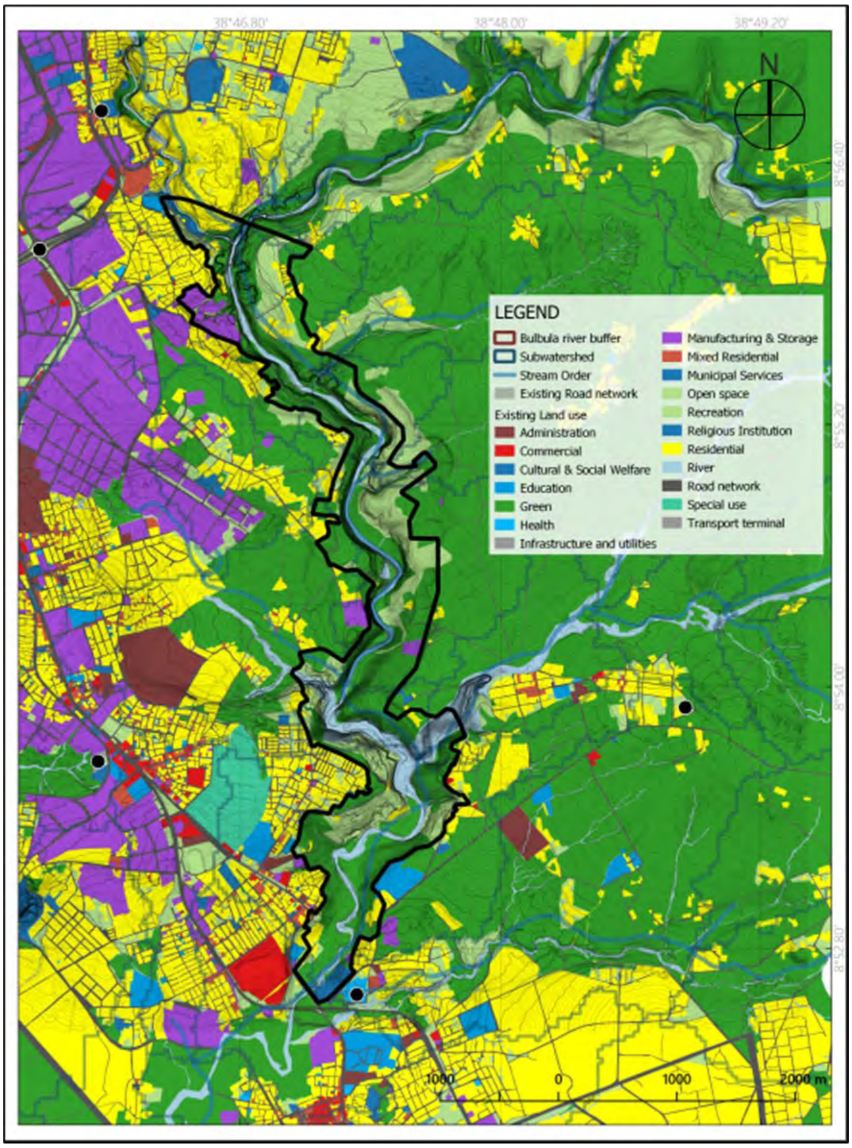


Figure 16 | Site Assessment and NbS Concepts in Kigali, Rwanda

Cluster Need Area: Gatsata- Karuruma Sub-catchment, Kigali (*Images: RYWP)*

Description	Coordinates	Photos

PHYSICAL CHARACTERISTICS

- **Urban Typology**: The dominant land cover of the sub catchment is the residential part. It covers 60% of the sub catchment. Other landscape features include agricultural, industrial, forests and wetlands which cover the remaining 40%.
- **Landscape Features**: Distinctive natural landscape features are hills, forests, and watershed and open spaces.
- **Water Features**: There are water streams such as Murongozi, Kagorogoro, Kanyonyomba which draw from Nyabarongo river.
- **Impervious/Pervious:** The big ratio (60%) of the sub catchment is pervious since there are a lot agricultural activities. The asphalt and cobblestone roads which make up the remaining 40% are found mainly on the principle roads and a few secondary roads.
- **Settlement pattern:** Two distinctive settlement patterns in the sub catchment are informal scattered settlement that are found in Jali and Jabana and informal dense settlement in Gatsata. But there are many areas that are still under development in Buhiza and Bweramvura cell.

WATERSHED AND HYDROLOGY

Rivers and Streams: The largest streams in the subcatchment is Murongozi. Murongozi is not protected in some areas. Other streams identified aew Kagorogoro and Kanyonyomba (flows into Nyabarongo) which are not protected in some areas. Rivers like Karuruma river (Nyabugogo river tributary) have protected buffer zone with bamboo in some parts.

DEGRADATION SOURCES

Key Degradation Features: stream banks degradation due to disrespected buffer zone and informal settlements.
Source of pollution and their drivers: Main source of pollution are the mining residues and agricultural effluents seeping into the stream. The respective drivers are the presence of multiple mining queries in the buffer area of the streams as well as agricultural activities.

Degradation	LATITUDE	LONGITUDE
degraded stream banks due to mining queries	1.87874880	30.03557671
degraded stream banks due to agricultural activities	1.89069861	30.04147958

POTENTIAL NBS

Stream or river buffer zone protection: These are areas identified for bamboo tree plantation and buffer zone protection. (these were proposed on Murongozi, Kagorogoro and Kanyonyomba)

Open space that need greening: there are potential area with natural grasses that were identified with a need to be enhanced with planting strip grasses to improve greening as well as recreational areas. (it was identified in Agateko and Nyakabungo)

POTENTIAL NBS TO BE ENHANCED	LATITUDE	LONGITUDE
agroforestry	1.86942976	30.01856346
proposed area for afforestation	1.87794892	30.01789175
proposed green spaces	1.88397595	30.04055087
proposed green Road buffer	1.89456324	30.05121902

Step 2: Action Plan Workshop

The Action Plan Workshop gathers local stakeholders to review the priority areas NbS Concepts, draft NbS recommendations for projects, programs, and policies, and present and discuss immediate-, mid-, and long-term actions towards implementation.

This is an important touch point in the project to ensure that the NbS project ideas and citywide NbS recommendations are aligned with key stakeholders, as well as discussing key roles and responsibilities for implementation.

Step 3: Final Recommendations

The culmination of the Strategic NbS Framework is a planning roadmap for NbS implementation - the Citywide NbS Recommendations Report. This report should include citywide recommendations for NBS implementation strategies and detailed project, program, and policy recommendations for selected priority risk areas. Recommendations will outline the roles and responsibilities for implementation, operations and maintenance, costs, and steps to move from selection towards project preparation, including additional studies, design, and commitments by city partners and other local stakeholders.

Citywide NbS Recommendations Report

i. Introduction - Describes the project, team, approach, and contents of the report
ii. Needs Assessment - Summary of the climate risk analysis methods and results
iii. NBS Opportunities - Summary of the Urban Typologies and NBS Opportunities
iv. Stakeholder Engagement - Summary of the roundtable, validation workshops, and action plan engagement
v. Project Concepts for Priority Areas - Describe the recommended solutions for the priority areas, including projects, programs, and policy with rough costs
vi. Recommended Actions - Steps to move from selection towards project preparation, including additional studies, design, and commitments by city partners and other local stakeholders. Including recommended groundwork projects at the community and site level for early implementation..

This report is the start of long term citywide action towards NbS implementation for climate resilience. The rapid needs assessment and recommendations development in partnership with city stakeholders creates shared vision and ownership to pursue NbS projects, policies and programs that address multiple goals and improve urban resilience.

SECTION 3: NBS CATALOG

The following pages contain fact sheets for each of the NbS tools. Each fact sheet contains the following information:

1. **Description**
2. **Suitability characteristics**
   i. Technical
   ii. Institutional
   iii. Social
3. **Co-benefits:** Environmental, Social & Economic
4. **Project considerations**
   i. Project mechanisms (enhance, protect....)
   ii. Scale of the project (size) and location
   iii. Implementation strategies and partners
5. **Cost considerations**

Co-benefits

In the context of this guide, co-benefits are benefits from NbS interventions other than the mitigation of the three assessed risks: urban flooding, extreme heat, and biodiversity. To facilitate comparison between different NbS tools, the following list of 12 co-benefits was selected representing environmental, social and economic co-benefits:

- **Environmental:** (1) carbon sequestration, (2) enhancing biodiversity and wildlife habitat, (3) erosion control, (4) air quality improvements
- **Social:** (1) Provide recreational opportunities, (2) strengthen community ties through shared natural spaces, (3) improve physical and mental health, (4) Aesthetic benefits
- **Economic:** (1) reduced utility costs (2) green job creation, (3) food production, (4) tourism

The table below shows the potential environmental, social, and economic co-benefits for each NbS Tool, each represented by a star (*). Those with potential to deliver all four of the co-benefits identified in a category are shown in darker green (****) and those with less in lighter green (*).

Table 6 | **Potential environmental, social and economic co-benefits for NbS tools to address flooding, extreme heat, and biodiversity. The number of potential co-benefits are shown by number of stars (* to ****), based on list above.**

NBS TOOL	ENVIRONMENTAL	SOCIAL	ECONOMIC
Natural lands/ forests	****	****	**
Tree plantings	***	***	**
Sustainable agriculture	****		**
Open space/ parks	****	****	**
Greenways	***	****	**
Riparian floodplain	**	***	*
Creek daylighting	**	***	**
Rain gardens	*	*	**
Rainwater harvesting	*		*
Green roofs and green walls	**	**	**
Wetlands	***	***	*
Coastal habitats	***	**	*
Beaches and Dunes	**	****	**

Fact sheets

Conventions

To facilitate the reading of the fact sheets, the needs addressed and urban typologies are coded as follows:

RISK ADDRESSED

UF	Urban flooding
RF	Riverine flooding
CF	Coastal flooding
WA	Water Availability
AQ	Water quality
EH	Extreme heat
BD	Biodiversity

URBAN TYPOLOGIES

GL	Green landscapes
BL	Blue landscapes
R	Residential
C	Commercial
N	Industrial
A	Agricultural
I	Institutional
T	Transportation

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Endnotes

1 https://www.wri.org/our-work/project/cities4forests

2 https://www.wri.org/initiatives/urban-water-resilience-africa

3 This is not an exhaustive list. This is meant for illustrative purposes.

4 This includes practices such as rotational livestock grazing, farmer-managed natural regeneration, furrow diking, landscape buffers, soil enhancement, plant diversity, terraced fields, cover crops.

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Developed by the World Resources Institute, this Guide is a work in progress and is undergoing user testing by the Urban Water Resilience and Cities4Forests initiatives with stakeholders in Addis Ababa, Ethiopia and Kigali, Rwanda.

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URBAN NBS TOOL 1:

Natural Lands/ Forests

RISK(S) ADDRESSED

URBAN TYPOLOGIES

Description

Natural lands and forests absorb rainfall, slow the velocity of runoff thereby reducing erosion, mitigate flooding by promoting higher infiltration in comparison to impervious built-up areas capture pollutants and store carbon (Pregitzer, C.C, et al. 2019) (Wilson et al. Forthcoming, p. 6). Additionally, they cool cities by providing shade and increasing evapotranspiration (US EPA 2014). They also act as natural water filters, provide habitat and enhance biodiversity (FAO 2019, p. 4). Additionally, forests provide important materials for cities such as wood and fiber (Brill et al. 2021, p. 46).

Natural lands and forests include the following types:

- Forests, continuous stands of trees (Brill et al. 2021, p. 92), which may be located in urban or upland / upper watershed /riparian areas;
- Shrublands, landscapes dominated by shrubs; and
- Grasslands, areas with predominately grass understories (Brill et al. 2021, p. 92).
- Refer to Urban NBS Tool 2: Tree Planting for more information.

Natural lands and forests occur where the historical ecology of the area has been preserved in cities or in upstream areas in the city's watersheds. Where they have been lost, they can be restored within urban development projects and at the edges of built-up areas of cities.

FUNCTIONS

Water Management

Sink It | Slow It | Move It | Reuse It | Clean It

Heat Management

Lighten It | Cover It | Access It | Cool It

Biodiversity Management

Safeguard It | Diversify It | Buffer It | Connect It

Suitability characteristics

TECHNICAL:

- ☐ Siting – These projects should be sited in existing or degraded natural lands or forests, and in some cases, adjacent properties to these historical natural areas,
- ☐ Biophysical factors – Native and non-invasive vegetation should be prioritized in restoration and enhancement projects and based on the project's goals.
- ☐ Design requirements - The design of natural lands or forest interventions l is intended to enhance or restore the natural ecology. In the cases where new interventions are built, it will be necessary to consider soils, slopes, access to water for vegetation selection and access points based on adjacent land uses.

INSTITUTIONAL:

- ☐ Land use jurisdiction – Depending on the location of natural lands or forests, they may fall into the jurisdiction of different municipal or regional authorities, and these stakeholders will be critical for implementation.
- ☐ Ownership – Suitable lands for natural lands or forests may be publicly or privately owned, and therefore interventions may require acquisition or authorization by the landowner, and in the case of private land incentivization alongside government requests.
- ☐ Operations/ stewardship - For public natural lands, one or more agencies, such as natural land managers, parks, or forestry agencies should budget for and perform regular maintenance and monitoring to ensure healthy landscapes and habitat. For privately managed natural lands, the City may provide incentives for protection and management by a private landowner, or regulate management of acreage of landscape coverage, which should be inspected annually.

SOCIAL:

- ☐ Access - These lands provide important aesthetic and recreational benefits, and therefore it is important that public access be properly planned and designed so as to protect the resource while providing access.
- ☐ Benefits - Natural lands are important for ecosystem services, as well as supporting healthy communities with mental and physical health and habitat for animals and plants. Balancing the needs of all users should be considered for these areas.
- ☐ Challenges - Natural lands or forests may be desired for other land uses, such as commercial or residential buildings, and may be exploited (for timber harvesting or unauthorized informal expansion) more easily due to their location and size.

Project considerations

Natural lands and forests can be protected, enhanced, restored or built. In areas where these types of land cover are already present, the focus should be on protection and enhancement. In the case that these are significantly degraded, restoration should be considered as an alternative.

In the case where these areas are not present, forests, shrublands, and grasslands can be built by converting an existing open or built space into these ecosystems. The suitability characteristics should be taken into consideration when selecting a site.

In many cities, natural lands and forests are managed by the city Forestry department. In some cases, these areas are managed by the parks agency at the city, regional or national level.

Natural lands and forests occur at the site or network scale. Implementation strategies will depend on land ownership:

- ☐ In **public lands**, capital projects or partnerships will be the most adequate implementation options. The city or regional **parks** and/or **environmental** department may be relevant stakeholders. For example, the city forest department may invest in the restoration of a deforested area within a public forest.
- ☐ In **private lands,** policy interventions or partnerships will be the most relevant strategies for natural lands and forests implementation strategies. Besides the relevant local or regional authorities, some **private stakeholders** will be important for project success. For example, a change in policy may require that a certain percentage of private lands remain undeveloped.

Protecting existing natural lands and forests provide the most immediate benefits, because they are established in the landscape. New forests will begin providing some benefits in the short term, but require decades of maturing to reach their full potential (Browder et al., 2019, p. 32).

Co-benefits

ENVIRONMENTAL	SOCIAL	ECONOMIC
****	****	**
Carbon sequestration	Provide recreational opportunities	Reduced utility costs
Enhancing biodiversity and wildlife habitat	Strengthen community ties through shared natural spaces	Green job creation
Erosion control	Improve physical and mental health	Food production
Air quality improvements	Aesthetic benefits	Tourism

Cost considerations

- **Cost:** The cost of this NBS tool varies depending on the type of forest activity carried out. Some examples are listed below.
    - *Forest restoration:* variable, but on average 2,000-3,500 USD/ha [2,120-3,710 in 2021 dollars] excluding land purchase costs (Ozment, Ellison, and Jongman 2019, p. 10)
    - *Sustainable Land Management Maintenance:* median costs equal to $100 per hectare per year [$124.27 in 2021 dollars] (Ginger, et al 2015, p. 966).
- Every dollar invested in restoring degraded forests would create between **$7–$30** in benefits (Verdone and Seidl 2017).

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CASE STUDY:
Forest Protection for Drinking Water Quality in Augsburg, Germany

RELEVANCE:

This case study illustrates how the government can partner with local landowners to protect watershed lands that ensure high source water quality and how policies can restrict destructive land uses in close proximity to water sources.

BACKGROUND AND KEY CONCERNS:

The Siebentisch forest and the Lechau-meadows provide a high-quality source for drinking water for the city of Augsburg, Germany. The water comes from the Alps mountains and then is filtered through the Siebentisch forest located just southeast of the city before being pumped, untreated, to Augsburg and used for drinking. In 1962 the European Union passed the Common Agricultural Policy that provided subsidies to increase agricultural output, which by the 1980's resulted in more production and overuse of fertilizers and pesticides that reduced water quality.

TECHNICAL IMPLEMENTATION OF NBS:

In 1986, in order to reduce treatment costs, the Water Utility (SWA) launched a three-prong approach to address water quality that included 1) the purchase of land in the water supply catchment and conversion to green space, 2) advisory support and performance-based contracts with farmers, and 3) regulations based on the water management zones defined by the proximity to water withdrawal.

INSTITUTIONAL AND LEGAL ARRANGEMENTS:

SWA is publicly owned and privately run. SWA and the city purchased much of the land in the water catchment area and SWA is responsible for managing these lands and protecting drinking water supply. SWA partners with the Forestry Administration for the management of the forested lands and with farmers on agricultural and pasturelands in the catchment. SWA implemented regulations on agricultural practices in the nearby catchment area where infiltration influences the drinking water capture. SWA worked with the German Ministry for Research and Technology to open a dialogue with the local farmers and develop a voluntary program that provides performance-based payments for nitrogen reductions in farm practices. These contracts pay farmers for meeting certain targets and fine them for negative effects. In addition to these contracts, SWA provides advisory services through a consultant to farmers with guidance for best practices.

ECONOMIC VALUATION:

SWA invests 15 percent of water fees on their program to protect water at the source. A 2013 cost benefit analysis showed the program costs for source water protection to be five percent lower than water treatment. Social considerations: The utility invests directly in the landowners through a voluntary program that provides technical guidance and financial benefits to partner in achieving water quality goals. The combination of regulations, voluntary contracts, and technical support allows for landowners to take part in the effort and benefit from their participation at any level. Drinking water costs remained low throughout the program, while SWA invested approximately 15% of collected water management payments for land acquisition, performance contract payments and technical support for farmers, and monitoring

MAJOR TAKEAWAYS:

The voluntary public-private partnership between the government and local farmers took time to implement, but within 20 years (1991-2011), the program partnered with 75% of the farmers in the management zones and achieved the nitrogen reductions and water quality goals Institutional partnership with the German Ministry for Research and Technology was key in developing the dialogues between the farmers and water resource experts to define the program.

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Developed by the World Resources Institute, this factsheet and case study forms part of Nature Based Solutions Selection Guide and is a work in progress undergoing user testing by the Urban Water Resilience and Cities4Forests initiatives with stakeholders in Addis Ababa, Ethiopia and Kigali, Rwanda


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URBAN NBS TOOL 2:

Tree Plantings

RISK(S) ADDRESSED

URBAN TYPOLOGIES

Description

Trees reduce flooding by intercepting rainfall and increasing infiltration (UNEP 2014, p. 20). Trees also improve air quality in cities (Beatley and Newman 2013, p. 7) and reduce local temperatures by providing shade and increasing evapotranspiration (Glick, P. et al. 2020, p. 21). Additionally, they provide aesthetic benefits as they beautify streets and parks.

Trees can be classified based on their location:

- Street trees, located alongside public or private roads;
- Park trees, located inside publicly accessible green spaces; and
- Private property trees, located within private property.

Within cities, trees can be found lining street corridors or in groupings within local parks or on private property (Wilson et al. Forthcoming, p. 4). Large groupings of trees make up the urban forest in remnant patches of native woodland, forested ravines and corridors, open spaces and parks, among other landscapes (Wilson et al. Forthcoming, p. 4).

FUNCTIONS

Water Management

Sink It | Slow It | Move It | Reuse It | Clean It

Heat Management

Lighten It | Cover It | Access It | Cool It

Biodiversity Management

Safeguard It | Diversify It | Buffer It | Connect It

Suitability characteristics

TECHNICAL:

- ☐ Siting - Tree species canopy size, shape and height should be considered when placing trees or groups of trees in the urban landscape, along with consideration for leaf litter, fruits, and odors. Before selecting a new tree for a site, the existing landscape must be compatible with the new species in terms of sun/shade requirements, and proposed use
- ☐ Biophysical factors – Ensure that the selected site has characteristics compatible with the selected tree species, such as annual rainfall, water table depth, slopes, and soil type. Selection of native trees and ensuring a diversity of tree species will ensure long term health of the urban forest in a changing climate.
- ☐ Design requirements – Tree location and spacing should be determined by an arborist or landscape architect and will depend on the site type (streets, property, etc.). Plantings should be designed to allow easy access for monitoring and maintenance (pruning, irrigation, pest control, etc.).

INSTITUTIONAL:

- ☐ Land use jurisdiction – Tree planting sites may be under the jurisdiction of various municipal or regional authorities, and these partners will be critical for the implementation of these interventions.
- ☐ Ownership – Tree planting sites may be publicly or privately owned, and therefore interventions may require acquisition or authorization by the landowner. Decisions about tree care should be determined before planting.
- ☐ Operations/ stewardship - Trees require continuous monitoring and care to ensure their survival, and therefore an appropriate stakeholder should be assigned this task as a part of the planning process.

SOCIAL:

- ☐ Access - Trees provide important aesthetic and health benefits to communities, and therefore it is important that they are equitably distributed across urban areas to ensure access by all.
- ☐ Benefits - Careful consideration should be given to tree location to address potential equity concerns related to the distribution of project benefits.
- ☐ Challenges - Concerns over lack of maintenance, dangers of limbs falling from trees not cared for, and leaf and fruit litter should be addressed up front. Maintenance funding and staffing is critical for a healthy urban forest.

Project considerations

There are several locations for tree planting:

- **Public Right of Way**, on public property on or adjacent to streets and alleyways,
- **Parks and Open Space,** which can be public or privately owned,
- **Watershed/Riparian Lands,** enabling urban water resilience risks to be addressed upstream, and
- **Private Lands,** which may be located in residential, commercial or agricultural areas.

There are **three** relevant project scales:

☐ **Citywide Program**

City-wide tree plantings are generally led by the local **Urban Forestry Manager**. Some relevant implementation strategies are **capital projects,** where public funds are used to develop the tree planting interventions, or **policy** measures, such as the setting of an Urban Tree Canopy Cover target of 30%.

Another alternative for implementation is a **residential tree planting program,** which can be implemented with the leadership of the city's **Open Space** and **Water Resources** Managers in partnership with **private stakeholders.** Similarly, public agencies may choose to carry out a **Street Tree Planting** project at the city scale, which may be fully publicly funded or incorporate private funds as well.

☐ **Project Level**

Tree plantings are often implemented at the project level, whether a public streetscape, public park, or private development site. These may be in the form of **tree corridors** and **green streets** that are designed to manage stormwater runoff (FEMA 2021, p. 7), and replacing impervious cover with tree plantings. Key stakeholders include the city **Urban Forestry** and **Public Property** Managers.

☐ **Neighborhood scale/ Community Based Projects**

Community-based tree planting projects can occur through **partnerships** between the community, public agencies and other private partners. These involve street tree plantings or tree planting projects at a local school or neighborhood park to increase shade, address localized flooding, and beautify the neighborhood. Alternatively, projects at the neighborhood scale can be incentivized through policy reforms, such as **redevelopment regulations** to reduce impervious cover.

When carrying out these interventions, it is important to consider that trees require time to mature in order to reach their full potential (UNEP 2014, p. 21).

Co-benefits

ENVIRONMENTAL	SOCIAL	ECONOMIC
***	***	**
Carbon sequestration	Provide recreational opportunities	Reduced utility costs
Enhancing biodiversity and wildlife habitat	Strengthen community ties through shared natural spaces	Green job creation
Erosion control	Improve physical and mental health	Food production
Air quality improvements	Aesthetic benefits	Tourism

Cost considerations

- **Cost:** The cost of tree planting interventions can be divided into the costs of land acquisition, materials and tree planting costs (UNEP 2014, p. 21). Below are some considerations for each of them.
    - Materials/ tree planting costs considerations.
    - Lands in the proximity of or within major cities are likely to be more costly, but they may also provide larger benefits (UNEP 2014, p. 21).

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CASE STUDY:
Forest restoration and conservation in Telangana state, India

RELEVANCE:

The Indian state of Telangana has received much global attention due to its efforts to promote afforestation, restoration and conservation of forests. The initiative, Telangana Ku Haritha Haram (Green Garland of Telangana), which began in 2015, has the goal of increasing green cover from 24% to 33% and tackling declining levels of forest cover.

BACKGROUND AND KEY CONCERNS:

Nearly 40% of India's forests suffer from degradation. In order safeguard forests, improve food security, combat extreme heat, reverse biodiversity loss and boost local economies, the Green Garland of Telangana project envisioned the goal of planting 1.3 billion trees in outside forest lands and one billion trees in existing forests.

TECHNICAL IMPLEMENTATION OF NBS:

Since the program's inception in 2015, over 2 billion seedlings have already been planted, with 1.42 billion trees outside of existing forest areas and nearly a billion trees in existing forests. As part of the project, 238 forest blocks are under development in and around cities covering an area of nearly 71,000 hectares. Moreover, the project has led to the opening of 35 urban forests and the designation of 70 forest blocks as Conservation Blocks protected against negative anthropogenic influences. Under the project's "Jungle Bachao" area-specific approach, Telangana has restored 390,000 hectares of forest land from biotic interferences and other forms of degradation.

INSTITUTIONAL AND LEGAL ARRANGEMENTS:

The project was implemented by the Telangana Government under the flagship program "Telangana Ku Haritha Haram" and monitored by public representatives and field functionaries.

ECONOMIC VALUATION:

The project has enjoyed strong public support, primarily because it has been directly linked to the creation of new jobs and as a source of income for the state's residents. With a total cost of nearly US $700 million, the program has been instrumental in restoring 245,000 hectares of degraded forests.

TAKEAWAYS:

- Through the Haritha Haram initiative, Telangana has been able to increase green cover by planting over 2 billion trees in existing forests and outside them
- The project's "Jungle Bachao" area-specific approach has led to the restoration of 390,000 hectares of forest land from biotic interferences and other forms of degradation

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URBAN NBS TOOL 3:

Sustainable Argiculture

RISK(S) ADDRESSED

URBAN TYPOLOGIES

Description

Sustainable agricultural practices protect the land and water, promote water conservation, and can improve farmer yields (Chartzoulakis,2015). They also contribute to heat mitigation with higher albedo surface cover crops (Carrer et al. 2018, p. 1) and through the incorporation of trees into the landscape (Glick, P. et al. 2020, p. 21).

Sustainable agricultural practices include:

- Agroforestry, growing trees in association with agricultural crops (UNESCO World Water Assessment Programme 2018, p. 42);
- Silvopasture, combining trees with forage pasture and livestock (UNESCO World Water Assessment Programme 2018, p. 55); and
- Farmland Best Practices, which involves practices that mitigate the negative environmental impacts of farming (Chartzoulakis,2015). Some examples are rotational livestock grazing, farmer-managed natural regeneration (FMNR), furrow diking, landscape buffers, soil enhancement, plant diversity, terraced fields and cover crops.

Sustainable agriculture consists of good stewardship of the natural systems and resources that farms rely on (Union of Concerned Scientists 2021).

FUNCTIONS

Water Management

Sink It
Slow It
Move It
Reuse It
Clean It

Heat Management

Lighten It
Cover It
Access It
Cool It

Biodiversity Management

Safeguard It
Diversify It
Buffer It
Connect It

Suitability characteristics

TECHNICAL:

- ☐ Siting – Silvopasture projects require a site capable of simultaneously supporting trees and forage (Hamilton 2008, p. 11). Farmland best practices typically will occur on existing agricultural lands.
- ☐ Biophysical factors – Sustainable agricultural practices are designed to address the local site conditions for various farming practices.
- ☐ Design requirements - The practices should be selected depending on characteristics of the agricultural site, such as soil type, crops and/or livestock types, water sources, and desired outcomes, like water availability or quality improvements and stormwater management.

INSTITUTIONAL:

- ☐ Land use jurisdiction – Given that agriculture is a commercial practice and that it often has a specialized authority for its regulation, collaboration between the authorities controlling commercial, agricultural, and environmental issues may be necessary for project implementation.
- ☐ Ownership – Most agricultural lands are owned or operated from the private sector and therefore may require incentives to implement sustainable agriculture best practices.
- ☐ Operations/ stewardship – Sustainable practices may require additional labor to maintain and operate, which needs to be incorporated into the regular operation of agricultural lands. These new practices may require capacity building for operations and maintenance workers.

SOCIAL:

- ☐ Access – Given that these projects are predominantly located on private lands, public access may not be feasible. However, designs could maximize benefits for the community by placing trees close to roads or in the farm areas closest to populated centers to share the local cooling benefits for interventions that involve tree planting.
- ☐ Benefits – Improved water quality and access to farmed fruits and vegetables can support communities. Successful agricultural businesses also provide jobs.
- ☐ Challenges - Farmers may face budget constraints for the implementation of sustainable agricultural practices, which may cause low support. This can be addressed by implementing incentives for the uptake of these practices. Farmers may not be familiar with the new technologies and practices and may prefer to maintain their current procedures. This can be addressed through education and training, as well as pilot projects.

Project considerations

Sustainable agriculture can be implemented in most agricultural lands. The specific **practices** will depend on the type of crops present and budget constraints for the selected site.

Sustainable agricultural practices can be implemented in a variety of **scales**, ranging from a specific site to the watershed basin or citywide level.

Likewise, there are various available implementation strategies, including **subsidies, policies and education campaigns**. For example, the local environmental department may **subsidize** specific technologies related to sustainable agriculture, increasing the cost-effectiveness of their uptake for farmers. On the other hand, for sustainable agricultural practices that lead to increased yields, local public agencies may decide to lead an **education campaign** to socialize these benefits and thereby promote the adoption of the related technologies by farmers. Another alternative is incorporating some **requirements** related to sustainable agriculture into the **legal framework**, so that these are adopted in the city-wide or watershed scale.

Relevant **partners** include the city environmental department, authorities related to commercial and agricultural activities, water utilities, and private stakeholders and farm holders associated to agricultural activities. In some cases, the city **environmental department** may be in charge of the regulation of farming activities, but in other cases there may be a specific agency in charge of **agricultural activities.** This responsibility may also fall to the commercial department, or the responsibilities can be shared by multiple public agencies. The responsible agency or agencies will play an important role in the implementation of this NBS Tool.

Co-benefits

ENVIRONMENTAL	SOCIAL	ECONOMIC
****		***
Carbon sequestration	Provide recreational opportunities	Reduced utility costs
Enhancing biodiversity and wildlife habitat	Strengthen community ties through shared natural spaces	Green job creation
Erosion control	Improve physical and mental health	Food production
Air quality improvements	Aesthetic benefits	Tourism

Cost considerations

Cost: The cost will depend on various factors, such as the scale of the agricultural activity, the types of practices employed, and site-specific characteristics such as soil type. Below are some reference costs for each of the types of this NBS tool.

- *Silvopasture:* $100-150 dollars per acre in existing pasture sites that do not involve extensive preparation (Hamilton 2008, p. 13).
- *Urban Agriculture*: Expected net income per acre $5,600-$6,600, varies widely per site and practices (Rangarajan and Riordan 2019, p. 47).

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CASE STUDY:
Community-led Watershed Restoration in Kumbharwadi, India

RELEVANCE:

This case study shows the importance of involving local communities in the stewardship of their lands and measurable results from small scale NBS.

BACKGROUND AND KEY CONCERNS:

A participatory watershed development (WSD) program improved water access, agricultural yields and income generation for poor rural villagers by restoring degraded landscapes of the Kumbharwadi watershed, increasing rainwater capture, storage capacity, soil fertility, and reducing soil erosion. Degraded lands and water scarcity for long periods are common in the villages in Kumbharwadi. Erratic, deficient, and delayed rainfall patterns, deforestation and unsustainable agriculture and livestock practices – required women to travel for water and reduced agriculture to half of the year.

TECHNICAL IMPLEMENTATION OF NBS:

A participatory watershed development (WSD) program improved water access, agricultural yields and income generation for poor rural villages by restoring degraded landscapes of the Kumbharwadi watershed, increasing rainwater capture, storage capacity, soil fertility and reducing soil erosion. The program enabled equitable decision-making through their requirement for the establishment of a village committee to participate and involvement with local youth training.

INSTITUTIONAL AND LEGAL ARRANGEMENTS:

The Watershed Organization Trust (WOTR) implemented the participatory WSD project from 1998 to 2002, financed by the German Bank for Development and the German Agency for Technical Cooperation, and funds granted through the National Bank for Agriculture and Rural Development (NABARD) and WOTR (Gray and Srinidhi 2013).

WOTR worked with landowners to implement natural and build infrastructure for water management:

- Natural infrastructure, like afforestation, reforestation, agroforestry, and on-farm contour trenching, which regenerated the landscape and helped retain soil and its moisture, improving fertility for cultivation.
- Built structures, like check dams, farm bunding, and loose boulder structures, which helped slow the velocity of water runoff, increase infiltration into groundwater reserves, and regulate the timing and flows of water throughout the seasons.
- Analysis of the program results show, “multiple benefits by reducing runoff (by 45%, on average) and soil loss, augmenting groundwater storage, boosting crop yields, increasing cropping intensity (by 36%, on average), enhancing income, generating rural employment, building social capital and reducing poverty” (Sikka, A, IWMI, 2018).

ECONOMIC VALUATION:

The program increased groundwater levels, improved soil fertility, and marked gains in agricultural productivity. Net agricultural income increased from $69,000/year to almost $625,000/ year for the watershed. Villagers no longer need to rely on supplemental water supplies from the government. Cumulative benefits of the WSD program from 1998 to 2012 were three times the cumulative costs of the program. In 2014, WOTR introduced the Water Stewardship Initiative in 106 villages, including Kumbharwadi, to empower locals to actively manage their watersheds over time.

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FarmersGov/Flickr

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URBAN NBS TOOL 4:

Open Space/ Parks

RISK(S) ADDRESSED

URBAN TYPOLOGIES

Description

Open spaces and parks provide communities with space to relax and recreate. Landscaped areas support stormwater management by allowing water infiltration and filtering (Harnik, 2006). Additionally, parks can improve air quality and mitigate the urban heat island effect (Browder et al. 2019, p. 45).

Open space and parks can be classified into various types:

- Open spaces, publicly accessible sites of undeveloped land (US EPA 2017);
- Pocket Parks, small outdoor spaces often surrounded by buildings (National Recreation and Parks Association n.d., p. 1);
- Neighborhood parks, larger parks with more facilities intended for the use of neighborhood residents (Cohen et al. 2016, p. 420);
- Stormwater parks, recreational sites designed to mitigate urban flooding during extreme events (FEMA 2021, p. 6); and
- Waterfront parks, parks designed to absorb tidal and storm flooding (FEMA 2021, p. 8).

Open spaces may be green spaces that are covered in different types of vegetation, such as grass, trees or shrubs, or sports fields, sports courts, public plazas schoolyards, playgrounds, public seating areas, and vacant lots (US EPA 2017).

FUNCTIONS

Water Management

Sink It | Slow It | Move It | Reuse It | Clean It

Heat Management

Lighten It | Cover It | Access It | Cool It

Biodiversity Management

Safeguard It | Diversify It | Buffer It | Connect It

Suitability characteristics

TECHNICAL:

- ☐ Siting – Due to the variability of open space design uses, there are many different suitable sites. Tiny pocket parks to large open spaces provide benefits for residents.
- ☐ Biophysical factors – Consideration of the water and heat management strategies in selecting sites will determine the needs, such as planting palettes and soils.
- ☐ Design requirements - Again, the design will be driven by meeting the specific needs of the water and heat management strategies and the site constraints. Considerations of native species and habitat that safely coexist with people should be prioritized.

INSTITUTIONAL:

- ☐ Land use jurisdiction – In order to provide greater access to parks and open spaces, cities may want to partner with private landowners to allow residents to access and enjoy privately held parks,
- ☐ Ownership – Open spaces and parks are located in private and publicly owned lands. Multiple agencies own, operate, and maintain a portion of a city's open space network, recreation and parks departments, natural land managers, utility managers.
- ☐ Operations/ stewardship – Green spaces and parks require regular inspections and routine maintenance to preserve their benefits.

SOCIAL:

- ☐ Access – Parks should be easily accessed from every neighborhood and for all ages and abilities. Ideally every resident should be no more than half a mile from a park or open space (Harnik, 2006).
- ☐ Benefits - Parks provide important recreational amenities to support physical and mental health, they provide gathering spaces to connect with community, and nature.
- ☐ Challenges – Local communities should be involved in the planning and design of local parks, as well as continued stewardship to ensure safety and open access for all.

Project considerations

In areas with existing open spaces or parks, these can be **protected** or **enhanced** to address urban resilience risks. In areas where these features are not yet present, they can be **built** in suitable areas.

Open space interventions generally consist of protecting or enhancing existing **green areas** within cities. Park interventions, the park type will depend on space availability and on priorities of the stakeholders carrying out the project. **Waterfront parks** can be designed to mitigate coastal flooding and **stormwater** parks can be designed to address urban flooding (FEMA 2021, p. 6-8). P**ocket** or **neighborhood parks** provide passive and active recreational amenities for communities.

There are **three** relevant scales for the implementation of this NBS Tool:

1. **Citywide Program**

Parks and open space interventions can be done at the city-scale. The city **Development** and **Open Space Managers** will be relevant stakeholders. One potential implementation strategy is establishing an **Open Space Access Policy,** where at open space is required to be at a certain maximum distance (e.g., ¼ mile) from all residential buildings in the city. Legislation may require **reductions in impervious cover** throughout the city, such as the establishment of **Redevelopment Regulations to Manage On-Site Stormwater,** through which private stakeholders may be required to incorporate green open spaces within constructed sites. This kind of policy would lead to more investment in this NBS tool, in order to comply with legal requirements.

2. **Project Level**

Interventions can also be carried out at the project level. In this case, the suitable implementation strategies will depend on land ownership:

- ☐ For public **lands**, a site or group of sites can be protected, enhanced or constructed through **capital** investments or **partnerships** with industrial or commercial partners. For example, **Park Greening Improvements** can be carried out to enhance existing public parks.
- ☐ For private **lands**, implementation can be done through **policy** changes or **public-private partnerships**. Another alternative is **acquisition** of the desired lands by public authorities.

3. **Neighborhood scale/ Community Based Projects**

Interventions can also be carried out at the neighborhood scale. **Community-based projects allow** local communities to partner with public and private stakeholders to increase green spaces in their neighborhood.

Relevant **partners** for these projects are the city parks and environmental departments. The management of open space and parks may require **collaboration** between the local and regional authorities responsible for open space management and environmental issues.

Co-benefits

ENVIRONMENTAL	SOCIAL	ECONOMIC
****	****	**
Carbon sequestration	Provide recreational opportunities	Reduced utility costs
Enhancing biodiversity and wildlife habitat	Strengthen community ties through shared natural spaces	Green job creation
Erosion control	Improve physical and mental health	Food production
Air quality improvements	Aesthetic benefits	Tourism

Cost considerations

- **Cost:**
  - *Open spaces:* Highly variable, depends on land prices (Ozment, Ellison, and Jongman 2019, p. 8).

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CASE STUDY:

Gorla Maggiore Water Park, Milan

RELEVANCE:

The Gorka Water Park in Milan addresses flood prevention and water pollution reduction with a new multi-purpose open space park for treating stormwater and passive and active recreation.

BACKGROUND AND KEY CONCERNS:

Water overflows are a common problem in Gorla Maggiore. Just between March and August 2014, 70 instances of sewer overflows were recorded. The overflows not only contain excess storm water, but also human waste, debris and toxic substances, ultimately leading to local flooding. To address this issue, the Gorla Maggiore Water Park was inaugurated in March 2013. Located in the Gorla Maggiore municipality in the Italian region of Lombardy about 30 kilometers northwest of Milan, the park consists of a constructed wetland built on the Olona river banks and includes a grid area for water pollutant removal, four vertical sub-surface flow constructed wetlands and a sedimentation tank. The park runs a combined sewer system that collects rainwater runoff, local sewage, and industrial wastewater all in the same pipe network. The sewer system sends the sewage to a wastewater treatment plant situated within 5 miles of distance from Gorla Maggiore, where it is treated and ultimately discharged in the Olana River.[1] The park also features walking and cycling paths and green open space with riparian trees. [2]

TECHNICAL IMPLEMENTATION OF NBS:

The Gorla Water Park has a surface area of about 6.5 ha. It consists of a flood prevention area spanning one hectare, another area for water pollutant removal and treating wastewater, and 1.3 ha of a leisure and recreational area. The water park is composed of four sand filter vertical beds designed for managing the first flush from the combined sewer overflow and an additional retention basin for the accumulation and controlled release of the second flush into the river. The project also includes a recreational space for activities, such as biking, running, picnicking and animal-watching.

INSTITUTIONAL AND LEGAL ARRANGEMENTS:

The Gorla Water Park was sponsored and managed by the Lombardia Regional Authority and created and monitored by the IRIDRA, an engineering company with expertise in wetland construction.

1. https://www.researchgate.net/publication/320358119_Going_green_Ex-post_valuation_of_a_multipurpose_water_infrastructure_in_Northern_Italy
2. https://www.researchgate.net/publication/320358119_Going_green_Ex-post_valuation_of_a_multipurpose_water_infrastructure_in_Northern_Italy

ECONOMIC VALUATION:

The park was funded by the regional government and Fondazione Cariplo, a charitable foundation in Milan. The project cost approximately €2 million.

SOCIAL CONSIDERATIONS:

The project supported educational and scientific research and has increased recreational activities for the general public.

TAKEAWAYS:

- ❒ The construction of the Gorla Water Park has been instrumental in protecting against floods and improving water management.
- ❒ The park has improved local habitats for a range of species and reduced biodiversity loss.
- ❒ The project has also contributed to reduced levels of air and water pollutants.

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URBAN NBS TOOL 5:

Greenways

RISK(S) ADDRESSED

URBAN TYPOLOGIES

Description

Greenways provide cooling and connectivity and can also capture stormwater, thereby reducing flooding (Lambert 2019). Additionally, they provide aesthetic benefits and opportunities for active personal transportation and recreation, which can lead to improved physical and mental health (FEMA 2021, p. 12).

There are two main types of greenways:

- Tree Corridors: linear green spaces with trees and other vegetation that connect to existing open spaces forming a green network, provide spaces for walking and biking and habitat for species (Lambert 2019); and
- Bioswales: shallow vegetated depressions that capture, treat and slowly infiltrate stormwater back into the ground or landscape (National Association of City Transportation Officials 2013), and also provide habitat for local biodiversity (Naturally Resilient Communities 2017).

Greenways are corridors of protected open and vegetated space (FEMA 2021, p. 6). They create connections between neighborhoods and destinations for people and animals in cities, aligning with existing roadways, linear transportation corridors or waterways.

FUNCTIONS

Water Management

Sink It
Slow It
Move It
Reuse It
Clean It

Heat Management

Lighten It
Cover It
Access It
Cool It

Biodiversity Management

Safeguard It
Diversify It
Buffer It
Connect It

Suitability characteristics

TECHNICAL:

- ☐ Siting -
  - ☐ Tree corridors should consider available soil types and space to allow full maturity of trees, as well as sun and wind conditions appropriate for the tree type, and water availability. Rows of tightly planted trees can also trap pollutants from vehicle emissions, it is important to allow air flow to move pollutants.
  - ☐ Bioswales are intended to capture stormwater runoff and treat flows before infiltrating or returning to the storm water capture system. It is best to locate these adjacent to large impervious areas, like a roadway, parking lot or roof area to make use of the treatment (UNEP 2014, p. 39).
- ☐ Biophysical factors –
  - ☐ Tree corridor species can be selected to accommodate local conditions.
  - ☐ Bioswales are best suited for low slope areas, in order to mitigate the risk of erosion (Naturally Resilient Communities 2017).
- ☐ Design requirements - Bioswales are typically sized to capture the "first flush" rain event, which tends to carry higher pollutant loads (National Association of City Transportation Officials 2013).

INSTITUTIONAL:

- ☐ Land use jurisdiction – Tree corridor and bioswale networks often are located with public rights-of-ways, which serve transportation and infrastructure purposes and may require interagency collaboration. Long corridors may also cross private property and require easements or agreements for access.
- ☐ Ownership – Project sites can be owned by public or private stakeholders, which will significantly impact project feasibility, cost, and implementation strategies.
- ☐ Operations/ stewardship – Maintenance and operation responsibilities should be designated as part of the project planning process, as greenways require continuous maintenance to ensure long-term benefits for cities.

SOCIAL:

- ☐ Access – Due to their importance for connectivity, greenway design must ensure that there are access points for city residents to enter these corridors.
- ☐ Benefits – Greenways provide communities with important amenities, such as cooling, mental health, and aesthetics, and therefore siting should ensure that benefits reach the greatest number of residents possible, especially vulnerable communities.
- ☐ Challenges – Areas suitable for greenway implementation may be desired for other land use types, and this may lead to opposition to project implementation.

Project considerations

There are three main implementation options:

- ☐ **Protect** existing tree corridors or bioswales to prevent their degradation,
- ☐ **Enhance** existing tree corridors or bioswales through investment or policy instruments, or
- ☐ **Build** new tree corridors or construct new bioswales.

Greenways can be implemented at the **corridor** or **network** scale. The size depends on the availability of space and on the scale of the risk to be addressed. They can be located alongside **roads** or other linear transportation infrastructure or waterways, which can be public or private depending on land tenure of the selected site(s).

For public lands, the implementation can be carried out through capital projects with the leadership of the city **Streets, Open Space** and **Urban Forestry** Managers. For example, it is possible to integrate greenway enhancement into city master plans or other urban development strategies (Natural Walking Cities 2019).

For private lands, this NBS tool can be implemented through **partnerships,** where public agencies co-lead projects with commercial or industrial partners. Potential private partners are landowners, land managers or project investors. Alternatively, public agencies may use **acquisition** as a tool to purchase and carry out greenway projects in the selected private lands, although these interventions may be limited by budget constraints.

Co-benefits

ENVIRONMENTAL	SOCIAL	ECONOMIC
***	****	**
Carbon sequestration	Provide recreational opportunities	Reduced utility costs
Enhancing biodiversity and wildlife habitat	Strengthen community ties through shared natural spaces	Green job creation
Erosion control	Improve physical and mental health	Food production
Air quality improvements	Aesthetic benefits	Tourism

Cost considerations

- **Cost**
  - ❑ *Bioswales:*
    - Installation:
      - ❑ Industrial bioswales: $110 - $430/m2 (Ozment, Ellison, and Jongman 2019, p. 8).
      - ❑ In an alley: $24 - 100/m2 (UNEP 2014, p. 41).
    - Maintenance: varying costs (some very low (UNEP 2014, p. 41) and some very high (REF)) to maintain trees in corridors once vegetation has grown. Maintenance costs increase with jurisdictional complexity (between government agencies, public and private property etc.)

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CASE STUDY:
Medellin Green Corridors, Columbia

RELEVANCE:

The Medellin Green Corridors project is a culmination of the city's efforts to combat extreme temperatures and the heat island effect. The project won the Ashden Award for Cooling in 2019 from Nature Award.[1]

BACKGROUND AND KEY CONCERNS:

Following several decades of rapid urban development, the urban heat island effect was becoming more and more extreme in Medellin. To combat this challenge, Medellin began its three-year-long program, "Greener Medellin for You" to chart a new path and a more resilient development paradigm.

TECHNICAL IMPLEMENTATION OF NBS:

To achieve its goal of combating the heat island effect, the Medellin Green Corridors project transformed 12 waterways and 18 roads into 30 green corridors by planting 8,800 trees and palms, covering an area of 65 hectares. The 30 green corridors offer an interconnected 12.4-mile set of shady routes including bike lanes and walkways across the city. The city has also planted 596 additional palms and trees in busy traffic thoroughfares, alongside over 90,000 non-tree plants.

"When we made the decision to plant the 30 green corridors, we focused on areas which most lacked green spaces," according to Mayor Federico Gutiérrez.[2] "With this intervention we have managed to reduce temperature by more than 2°C and already citizens feel it". One study of just one corridor has estimated that it would absorb as much as 160,787 kg of CO2 per year, the equivalent of emissions from 18,000 gallons of gasoline. The study has projected that roughly 2,308,505 kg of CO2 would be eventually absorbed by the plants' biomass -- the equivalent of removing 500 passenger vehicles off the road in one year.

INSTITUTIONAL AND LEGAL ARRANGEMENTS:

The Medellin Green Corridors project was supported by the Kigali Cooling Efficiency Program, an initiative by the ClimateWorks Foundation that seeks to improve access to climate-friendly cooling and implemented by the city administration. The project's implementation was overseen by the city administration.

ECONOMIC VALUATION:

The project cost a total of US $16.3 million, with maintenance costing about $1.50 per square meter based on work done by 150 gardeners every two to three months.

1. https://www.unep.org/pt-br/node/25230
2. https://www.unep.org/pt-br/node/25230

SOCIAL CONSIDERATIONS:

Medellín's Joaquin Antonio Uribe Botanical Garden trained 75 locals from low-income backgrounds to become city gardeners and planting technicians for the purpose of monitoring and maintaining the 30 Green Corridors as part of their full-time employment.

TAKEAWAYS:

- ☐ Medellin's 30 Green Corridors have considerably mitigated the urban heat island effect, with an estimated reduction of 2°C in temperature in some parts of the city.
- ☐ City authorities expect even more decrease in extreme temperatures by 4-5°C in 28 years' time.
- ☐ Just one of the 30 corridors is able to absorb as much as 160,787 kg of CO2 per year.

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Reg Natarajan/Flickr

Developed by the World Resources Institute, this factsheet and case study forms part of Nature Based Solutions Selection Guide and is a work in progress undergoing user testing by the Urban Water Resilience and Cities4Forests initiatives with stakeholders in Addis Ababa, Ethiopia and Kigali, Rwanda


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URBAN NBS TOOL 6:

Riparian Floodplain

RISK(S) ADDRESSED

URBAN TYPOLOGIES

Description

Riparian floodplains prevent flooding by retaining excess water and slowing runoff flows (EiBAC and University of Copenhagen 2017, p. 26), while also reducing erosion and improving water quality (FEMA 2021, p. 6). Riparian areas help cool surface temperatures due to the presence of vegetation and provide habitat for species (UNESCO World Water Assessment Programme 2018, p. 55).

Riparian floodplain interventions can be classified into three types:

- Riparian management, where existing riparian floodplains are protected or enhanced;
- Channel reconnections, where a former riparian floodplain area is reconnected to the waterway to recover some of its natural functions (FEMA 2021, p. 6); and
- Floodplain Restoration, where new land is identified and established alongside rivers and existing floodplain areas to manage higher water levels in rivers and to protect priority areas from the impacts of flooding.

Riparian floodplains cover the area adjacent to rivers or streams where the inundation level fluctuates. This is the portion of the river buffer where the water table is at the surface (EiBAC and University of Copenhagen 2017, p. 26). Healthy riparian areas support deep-rooted trees and a diversity of grasses and shrubs (UNESCO World Water Assessment Programme 2018, p. 55) which help to infiltrate, slow, and clean the water, and support local biodiversity.

FUNCTIONS

Water Management

Sink It | Slow It | Move It | Reuse It | Clean It

Heat Management

Lighten It | Cover It | Access It | Cool It

Biodiversity Management

Safeguard It | Diversify It | Buffer It | Connect It

Suitability characteristics

TECHNICAL:

- ☐ Siting – Interventions should be carried out in existing or former floodplain areas, in order to approximate natural hydrological conditions.
- ☐ Biophysical factors – Depth to groundwater, slopes, and spatial location in the floodplain will determine project boundaries and planting palettes.
- ☐ Design requirements – Interventions should make use of natural components, such as local soils and native vegetation, and designate areas for access to avoid disruption of ecosystem processes and plant health.

INSTITUTIONAL:

- ☐ Land use jurisdiction – Riparian floodplains do not follow administrative boundaries and in some cases will require multi-jurisdiction partnerships to restore and maintain flood management.
- ☐ Ownership – As rivers and streams cross neighborhoods and cities, so too their floodplains will cross public and private properties with a variety of land uses. Public agencies may consider acquisition or easements to reclaim the floodplain for natural flood management. Sometimes floodplains will be sited away (upstream) from the area that is to be protected (downstream) which requires up front agreements on the roles and responsibilities of different jurisdictions in maintenance.
- ☐ Operations/ stewardship - Healthy riparian areas require landscape maintenance, especially post rain events where the landscape experiences periods of inundation. These lands often have trails for recreation that need regular maintenance and annual inspections and repair. Protection of the habitat may require fencing and regular observation.

SOCIAL:

- ☐ Access – Entrance points should be part of project design in order for local communities to take advantage of the recreational opportunities offered by riparian areas.
- ☐ Benefits – Healthy riparian areas reduce flood waters entering neighborhoods and homes. Education about the ecosystem services provided by these ecological areas can help residents better understand their value and help care for these spaces. Local communities will be important stakeholders in the planning process to determine access and use in these riverside areas.
- ☐ Challenges - For the case of floodplain enhancement or restoration, it may be necessary to remove the present land use in the floodplain area, which may cause potential conflicts with current landowners and stakeholders. In some cases, existing floodplain areas became home to vulnerable populations and support for relocation must be part of any floodplain development with informal settlements

Project considerations

Riparian floodplain projects take one of three approaches:

- ☐ **Protect** existing riparian floodplains, by avoiding their conversion to other land uses,
- ☐ **Enhance** existing riparian floodplains, and
- ☐ **Restore** the floodplain in areas where it has been degraded or occupied by other land uses.

Generally, interventions related to the protection, enhancement or restoration of the riparian floodplain are done at the watershed or sub-watershed scale, but they can also be carried out at the site or network level. The local or regional **natural lands manager** in the parks or utility agencies will be a key stakeholder for the implementation of these interventions.

Some potential implementation strategies are:

- ☐ The **acquisition** of areas for floodplain expansion by public agencies.
- ☐ The enhancement of the existing floodplain through **Capital Projects on Public Lands** or **partnerships** with industrial, or commercial or residential partners.
- ☐ **Regulatory changes** that promote floodplain protection, enhancement, or restoration. For example, the local open space planning agency may establish a no-development zone around existing rivers (FEMA 2021, p. 18).

Co-benefits

ENVIRONMENTAL	SOCIAL	ECONOMIC
**	***	*
Carbon sequestration	Provide recreational opportunities	Reduced utility costs
Enhancing biodiversity and wildlife habitat	Strengthen community ties through shared natural spaces	Green job creation
Erosion control	Improve physical and mental health	Food production
Air quality improvements	Aesthetic benefits	Tourism

Cost considerations

- **Cost:** The cost will vary based on the intervention type. Some examples are included below.
  - *Channel rehabilitation:* $16,000 -$53,000/km of river (Ozment, Ellison, and Jongman 2019, p. 10).

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CASE STUDY:

Restoring the Iguazu Floodplain, Brazil

RELEVANCE:

Located in the State of Paraná, Brazil, the Metropolitan Area of Curitiba was developed in the Upper Iguaçu River Basin, which is 1000 square kilometers in size, to address the river's flooding. There are several tributaries, with areas of 100 square kilometers each. The Metropolitan Area of Curitiba has a population of 2.5 million inhabitants, with most of the residents living in the Belem Basin and other neighboring basins.

BACKGROUND AND KEY CONCERNS:

The river in the Iguazu Floodplain commonly floods. Constant growth pressures due to urbanization were causing the unauthorized occupation of the floodplain, with impermeable surfaces and poorly functioning urban drainage systems ultimately leading to a six-fold increase in basin flooding. In 1995, flood damages cost Curitiba over $40 million. Floods would also happen due to urban infrastructure such as bridges and landfill obstructing the flow of water and inefficient drainage systems. In order to address flooding of the Iguacu River, the Flood Management Project was undertaken in 1996 by the Metropolitan Area of Curitiba and funded by the World Bank.[1]

TECHNICAL IMPLEMENTATION OF NBS:

The project included creating a place for flow and storage in the flood plain of the Iguacu River, developing a strategy to discourage unauthorized population living in the flood plain and creating the Urban Drainage Master Plan, as part of which urban parks would be established on the tributaries to damp the increase in the peak flow of the uncontrolled upstream area.[2]The project also set aside sections of the land for wetlands in order to deliver water quality benefits.

INSTITUTIONAL AND LEGAL ARRANGEMENTS:

The city and the World Bank jointly constructed a large public park around the river in the Iguazu Floodplain, with the state purchasing the land and resettling local residents. In order to curb unauthorized occupation of the flood plain, the land is monitored and regulated by law enforcement.

1. https://commons.wikimedia.org/wiki/File:Cataratas_do_Igua%C3%A7u_-_panoramio_(41).jpg

2. https://www.floodmanagement.info/publications/casestudies/cs_brazil_sum.pdf

TAKEAWAYS:

- ☐ Integrated urban drainage systems represent an environmentally and economically sustainable method of addressing urban flooding.
- ☐ Rapid urbanization and growth pressures require strategies that take into account land use as it relates to flooding, sanitation and waste management.

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URBAN NBS TOOL 7:

Creek Daylighting

RISK(S) ADDRESSED

URBAN TYPOLOGIES

Description

Creek daylighting improves urban hydrology, expanding the floodplain, increasing storage capacity, and in naturalized settings filtering polluted runoff. Creek daylighting can reduce flooding by allowing more stormwater runoff to pass through designed waterways (Naturally Resilient Communities 2017). These interventions also create habitat and help people reconnect with nature by creating new and desirable recreation spaces (Pinkham 2000, p. iv-v).

There are two main types of Creek daylighting:

- ☐ Natural open space creek, where the objective is to restore a degraded or buried waterway to its former ecological function.
- ☐ Channelized urban creek, where an artificial channel is constructed in a former waterway site to restore water flow; and

Reintroducing historic creeks and streams in urban areas brings water features, landscaping and sometimes hardscape into open space, commercial areas, or residential areas along former creek alignments. Creek daylighting may have natural, soft bank and vegetated edges, which is preferable because it provides the most benefits, or a channelized hard edge (Trice 2016, p. 8).

FUNCTIONS

Water Management

Sink It | Slow It | Move It | Reuse It | Clean It

Heat Management

Lighten It | Cover It | Access It | Cool It

Biodiversity Management

Safeguard It | Diversify It | Buffer It | Connect It

Suitability characteristics

TECHNICAL:

- ☐ Siting - Creek daylighting interventions require long linear continuous corridors (Naturally Resilient Communities 2017), which poses a significant constraint for project siting. Creek daylighting projects most often are sited in former or current (but covered) river, creek, or streambeds, as well as sites with redesigned grading to create low lying channelization.
- ☐ Biophysical factors – Consideration of the soil and channel material for function along with available space for the channel path and gently sloping banks for vegetation. These projects require hydrologic modeling to ensure flows will move through the system using gravity and other design tools (Naturally Resilient Communities 2017).
- ☐ Design requirements – Channel design and flow design are critical to ensure positive drainage and adequate storage in the designed creek, as well as adequate floodplain banks to avoid damage to nearby infrastructure and development. Planting design should be considered for the various depths of the creek and to maximize water treatment and biodiversity and habitat. require major excavation (Trice 2016, p. 13).

INSTITUTIONAL:

- ☐ Land use jurisdiction – These projects will often involve cooperation between the public agencies due to issues around the ownership of the new waterway and the existence of multiple legal and planning requirements (Naturally Resilient Communities 2017)
- ☐ Ownership – Creek daylighting impacts a linear stretch in urban areas that may cross multiple parcels with differing ownership. The coordination of multiple agencies may be necessary for project implementation and permitting (Pinkham 2000, p. v).
- ☐ Operations/ stewardship – Monitoring and maintenance in the first few years are important to ensure a successful long term infrastructure asset. Close monitoring of the stability of the channel and the establishment of the plantings early will be followed by regular landscape maintenance as well as water quality monitoring (Naturally Resilient Communities 2017).

SOCIAL:

- ☐ Access – Consider impacts of public access and determine which activities are appropriate for ensuring water quality,
- ☐ Benefits – Creek Daylighting projects can be transformative for communities. In addition to flood management and increased neighborhood cooling, they provide physical and mental health benefits and can simultaneously serve as safe active transport corridors for pedestrians and bicyclists.
- ☐ Challenges – One potential challenge is the lack of public awareness of buried waterways, which may lead to resistance towards the daylighting project. There may also be potential concerns around child safety and disease vectors (Pinkham 2000, p. v).

Project considerations

Creek daylighting projects are large scale interventions that often bring together multiple stakeholders from government institutions, businesses, and neighbors. One potential implementation strategy is **capital projects on public lands** with the leadership of the Natural Lands Manager, Parks and Open Space Authority or Water Utility for stormwater management. Implementation mechanisms may include **partnerships** or **acquisition** to complete these long linear projects and integrate them into the urban fabric.

Successful creek daylighting projects employ technical consultants specialized in stream restoration and emphasize public education and participation (Pinkham 2000, p. 1).

Co-benefits

ENVIRONMENTAL	SOCIAL	ECONOMIC
**	***	**
Carbon sequestration	Provide recreational opportunities	Reduced utility costs
Enhancing biodiversity and wildlife habitat	Strengthen community ties through shared natural spaces	Green job creation
Erosion control	Improve physical and mental health	Food production
Air quality improvements	Aesthetic benefits	Tourism

Cost considerations

- **Cost:**
  - $1,000 per linear foot of daylighted stream (Naturally Resilient Communities 2017; Trice 2016, p. 16; Pinkham 2000, p. 10).
  - According to Trice (2016), the cost of projects depends on various factors, including:
    - the extent of urbanization and adjacent infrastructure;
    - whether volunteers or in-kind donations are used;
    - whether the stream is on public or private land;
    - if property must be purchased; and
    - whether there are additional community amenities (e.g., Parks or greenways).

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Jimmy Tan/Flickr

CASE STUDY:
Kallang River Restoration in Bishan Mo Park, Singapore

RELEVANCE:

In 2006, Singapore's National Water Agency, the Public Utilities Board (PUB), inaugurated a new project named as the Active, Beautiful, Clean Waters Programme (ABC Waters). The program seeks to integrate water as a core element of urban design around water infrastructure, landscaping and city buildings.

BACKGROUND AND KEY CONCERNS:

Singapore has one of the highest population densities in the world and lacks the natural water resources required to meet the demand of its residents. Since 1961, Singapore has imported nearly 250 million gallons of water each day from the Johor River in Malaysia to meet just half of its 430 million gallons per day demand for water. With two monsoon seasons per year which pose flood risks, Singapore needed to manage its water resources using blue-green infrastructure combining vegetation and natural waterflows. This strategy has helped reduce pollutant runoff into waterways, improved sanitation, and created new city greenspace. Using blue-green infrastructure has also transformed the island into an urban water catchment area, thus helping reduce flood risk and increase water supply. [1]

TECHNICAL IMPLEMENTATION OF NBS:

The ABC Waters project consists of three main goals: (1) creating recreational spaces for residents, (2) building urban resilience against flooding and (3) systematically managing water before it finds its way to nearby catchments.[2] Under the ABC program, from 2010 until 2018, 75 related projects were authorized toward achieving these goals. Studies done on the effectiveness of these projects suggest a 33% reduction in peak flow for 10-year design storm. One such project, the Bishan Ang Mo Kio Park is a community park that was built to act as a green buffer between the towns of Bishan and Ang Mo Kio in Singapore. A naturalized river that imitates the concept of a flood plain operates across the center of the park and connects with the Kallang River. The river was transformed in 2012 into a network of constructed wetlands, rain gardens, and vegetated bioswales, not only for the purpose of regulating flood, but also for supporting recreational use and local biodiversity. The park is also frequently used by people in the vicinity and from around the city.

INSTITUTIONAL AND LEGAL ARRANGEMENTS:

The ABC Waters program was launched by Singapore's Public Utilities Board in 2006.The Kallang River Restoration project was a partnership between the National Parks Board (NParks) and National Water Agency, the Public Utilities Board (PUB), who co funded the design and implementation.

1. https://www.mdpi.com/2071-1050/13/18/10427/pdf
2. file:///Users/basitmuhammadi/Downloads/sustainability-13-10427-v2%20(1).pdf

ECONOMIC VALUATION:

By adopting blue-green infrastructure, Singapore's operational and maintenance costs of the naturalized river are 75 percent lower than the previous concrete canal that served as the city's stormwater infrastructure. The overall economic valuation of benefits associated with the park and the recreational space amount to $73 million per year, over twice as much as the value of the park estimated without using blue-green infrastructure at only $34.5 million per year. So far, 28 blue-green infrastructure projects have been launched in the city. In aggregate terms, they save Singapore $390 million per year in costs associated with water by reducing the need to import water, mitigating flood and water treatment costs, and improving water supply.

SOCIAL:

Prior to redevelopment, Kallang River was a clear dividing line between the park and community as a straight fenced concrete canal in dire need of an upgrade. The design team worked together with the park and water authorities to rethink traditional infrastructural approaches in order to maximize land, financial and human resources.

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Montgomery County Planning Commission/Flickr

URBAN NBS TOOL 8:

Rain Gardens

RISK(S) ADDRESSED

URBAN TYPOLOGIES

DESCRIPTION

Rain gardens capture stormwater runoff from adjacent impervious surfaces, address nuisance flooding, and improve water quality by collecting, slowing, absorbing, filtering pollution, and storing water (Browder et al. 2019, p. 104). They also cool cities by promoting evapotranspiration and can provide aesthetic benefits (UNEP 2014, p. 40).

Rain gardens can be classified into 2 types based on their objective:

- Retention rain gardens, which capture stormwater runoff, allow infiltration into subsurface soils and evapotranspiration; and
- Detention rain gardens, which detain stormwater runoff in the peak of the storm and, once full, slowly release excess water back into the stormwater system through overflow pipes or a surface swale.

Rain gardens are depressions in the landscape that are filled with bio-filtration soils, native shrubs, perennials, and flowers. (The Groundwater Foundation 2021). They are located next to impervious surfaces, like parking lots, sidewalks, or streets (Browder et al. 2019, p. 107), or around homes and businesses to manage roof runoff (FEMA 2021, p. 7).

FUNCTIONS

Water Management

Sink It | Slow It | Move It | Reuse It | Clean It

Heat Management

Lighten It | Cover It | Access It | Cool It

Biodiversity Management

Safeguard It | Diversify It | Buffer It | Connect It

Suitability characteristics

TECHNICAL:

- ☐ Siting - Rain gardens are designed to collect stormwater before it enters a water body or storm-sewer system, and so they are generally located in the low end of a site, because stormwater flows to these areas (UNEP 2014, p. 39). It is important to consider the local hydrology in site selection to ensure that the rain gardens don't cause negative downstream impacts (UNEP 2014, p. 41).
- ☐ Biophysical factors – Soil types will determine whether the rain garden can infiltrate runoff or detain and slowly release runoff back into the stormwater management system. The selected vegetation should have high tolerance for wet and dry wet conditions and potentially high levels of urban and industrial pollutants present in stormwater runoff (UNEP 2014, p. 39).
- ☐ Design requirements – Rain Garden sizing will depend on space availability, the impervious drainage management area and on the size of the target rain event. A safe sizing ratio will design the garden footprint at 10% the size of the drainage area. They can be professionally built or self-installed.

INSTITUTIONAL:

- ☐ Land use jurisdiction – Often implemented on single properties by the owners (institutional, residential, commercial, public open space,) reducing conflicts of jurisdiction.
- ☐ Ownership – Depending on the owner and their maintenance program, rain gardens effectiveness will be tested. Sites suitable for rain garden construction can be located in public and private lands. In both scenarios, the stakeholder with ownership of the land will be critical for project design and implementation.
- ☐ Operations/ stewardship - Rain gardens require regular inspections to monitor vegetation cover, mulching, and infiltration capacity (UNEP 2014, p. 41). In addition, these should be regularly cleaned of trash that may collect in the runoff that enters the system.

SOCIAL:

- ☐ Access – Rain gardens are small scale distributed green infrastructure and most often incorporated into the public realm, in open space, and streets, as well as private spaces like residential or commercial properties.
- ☐ Benefits – Rain gardens provide stormwater runoff mitigation and greening. The distribution of these benefits should be considered when selecting a project site or group of sites.
- ☐ Challenges - Concerns from residents regarding vector borne disease from mosquitos and different preferences about garden aesthetics must be considered.

Project considerations

The selection of the rain garden type will depend on the characteristics of the selected site. If the soil present in the selected area has significant **infiltrative capacity**, the system can be designed with this objective in mind as a retention rain garden. Alternatively, if this is not possible the system can be designed to temporarily capture stormwater and slowly release flows as a detention rain garden.

Rain gardens provide the most benefit when they are located at the downstream point of an impervious surface, like a parking lot, large roof area, or street. These are often a mix of public and private sites.

Relevant implementation strategies are **capital projects** for the case of public roads, open space, and other public properties or **Partnerships** with commercial or industrial sectors or **incentives** for private properties, including residential, commercial, and industrial. An example implementation strategy for residential land uses is **residential rain garden incentive program**, where those who decide to implement this tool, reducing the stormwater load for the city, receive a financial benefit in the form of a rebate or credit.

Co-benefits

ENVIRONMENTAL	SOCIAL	ECONOMIC
*	*	**
Carbon sequestration	Provide recreational opportunities	Reduced utility costs
Enhancing biodiversity and wildlife habitat	Strengthen community ties through shared natural spaces	Green job creation
Erosion control	Improve physical and mental health	Food production
Air quality improvements	Aesthetic benefits	Tourism

Cost considerations

- **Cost:** Between 32 and 65 dollars/ m2 for construction, and low operation and maintenance costs once the vegetation has been established (UNEP 2014, p. 41).

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La Citta Vita/Flickr

CASE STUDY:
Rain Gardens in Kviberg, Sweden

RELEVANCE:

The main goal of the intervention was to create rain gardens near Kviberg's multisport arena, a city property in northeastern Göteborg, to handle the rainwater flowing from the arena's parking area. The intervention has also helped protect nearby Säveån, an area designated as Natura 2000, a network of natural sites containing rare and threatened species in the European Union and requiring care and protection.

BACKGROUND AND KEY CONCERNS:

Floods are a common problem in Göteborg, with excess rainwater after heavy rain events often flowing into wastewater systems and overloading them, resulting in untreated wastewater polluting the city's watercourses. Due to the nearby location of Säveån, a Natura 2000 area, it is imperative that the water flowing from the Kviberg's multisport arena is clean.

TECHNICAL IMPLEMENTATION OF NBS:

In June 2015, Göteborg undertook constructing of Sweden's first rain gardens. The rain garden, which is 700 square meters in size, filters pollutants from the parking area and manages stormwater runoff resulting from heavy rainfall.[1] The raingardens have helped improve water quality, protection against flooding, stormwater management and preserving biodiversity in the area.

INSTITUTIONAL AND LEGAL ARRANGEMENTS:

The intervention was led by the city administration and its parking company, Göteborgs Stads Parkeringsaktiebolag. The project was funded using local funding from the public budget.

ECONOMIC VALUATION:

In terms of overall economic benefits, the construction of the rain garden has led to reduced costs associated with urban water management. The program cost nearly 5 million euros.[1]

SOCIAL CONSIDERATIONS:

The project represents the city's commitment to protect Säveån, which is designated as Natura 2000, and its willingness to make Göteborg more livable and resilient to erratic water conditions.

1. https://una.city/nbs/goteborg/rain-gardens-kviberg

TAKEAWAYS:

- ☐ The construction of the raingarden has helped manage stormwater and protect nearby areas against heavy flooding.
- ☐ With 700 square meters (0.07 ha) in size, the raingarden has been influential in filtering water pollutants coming from the parking area and improve air quality
- ☐ Ultimately, the raingarden has led to reduced costs associated with urban water management

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URBAN NBS TOOL 9:

Rainwater Harvesting

RISK(S) ADDRESSED

URBAN TYPOLOGIES

Description

Rainwater harvesting systems capture and store rainfall for future reuse. Harvested rainwater can be used for landscaping, watering crops, wildlife watering, livestock, and groundwater recharge, among other uses (Mechell et al. 2009, p. 1).

There are 4 main types of rainwater harvesting systems:

- ☐ Detention ponds, ponds constructed to temporarily store water after a rainfall event (Trémolet et al. 2019, p. 64); and
- ☐ Aquifer recharge, served by infiltration ponds/fields, or large land areas that are dedicated to capturing and infiltrating rainwater;
- ☐ Cisterns, which can store hundreds or thousands of gallons of rainwater (FEMA 2021);
- ☐ Rain Barrels, which can store tens of gallons of rainwater (FEMA 2021).

Rainwater harvesting systems range in size and complexity. They can be used in small-scale residential landscapes or in large-scale landscapes, such as parks, schools, commercial sites, parking lots, and apartment complexes (Mechell et al. 2009, p. 1). They involve varying levels of water treatment depending on the planned use of the harvested water.

FUNCTIONS

Water Management

Sink It | Slow It | Move It

Reuse It | Clean It

Heat Management

Lighten It | Cover It | Access It | Cool It

Biodiversity Management

Safeguard It | Diversify It | Buffer It | Connect It

Suitability characteristics

TECHNICAL:

- ☐ Siting – The selection of a system will depend on the drainage area contributing to the rainwater capture and the post capture uses. The space requirements will depend on the type of rainwater system selected. The simpler systems, such as rain barrels, can be installed in almost any sites, whereas larger solutions such as cisterns or detention ponds have larger space requirements.
- ☐ Biophysical factors – Rainwater harvesting systems should be located in areas with sufficient rainfall to collect and water demand for use.
- ☐ Design requirements – An appropriate project design can be selected based on three main factors: (1) the quantity of rainfall, (2) water demand, and (3) space availability.

INSTITUTIONAL:

- ☐ Land use jurisdiction – There may be some regulatory barriers for rainwater harvesting stemming from local regulations on drinking and non-drinking water quality and access.
- ☐ Ownership – Sites suitable for rainwater harvesting may be publicly or privately owned, which will determine the ownership of the obtained water resources.
- ☐ Operations/ stewardship – Rainwater harvesting systems require proper maintenance to ensure the quality and continuity of the water supply. The maintenance operation will vary based on the end use of the collected water.

SOCIAL:

- ☐ Access – N/A.
- ☐ Benefits – Rainwater harvesting can fulfill or supplement water supply needs for many different purposes. The need and supply should be matched to the location and system.
- ☐ Challenges - There may be stigma surrounding the use of harvested rainwater, so it may be necessary to provide information to the public about the safety of this practice.

Project considerations

Land based rainwater harvesting with detention ponds and recharge fields are most often used on large properties, like farm holdings, commercial parking lots, campuses, where runoff must be captured and treated before discharging and locations that rely on groundwater as a key water source.

Rainwater harvesting captures the runoff falling on a roof system through drainage pipes and is influenced by the roof style, slope and existing drainage. Small building roofs, such as residential homes or small structures like a storage shed, will commonly use a rain barrel to collect roof runoff from existing roof gutters and use the water for landscaping needs. This is a low cost option for increasing water access.

Large building roofs, such as commercial buildings, schools, or warehouses, will commonly use a cistern to hold larger volumes of runoff and allow use over a longer period.

Co-benefits

ENVIRONMENTAL	SOCIAL	ECONOMIC
*		*
Carbon sequestration	Provide recreational opportunities	Reduced utility costs
Enhancing biodiversity and wildlife habitat	Strengthen community ties through shared natural spaces	Green job creation
Erosion control	Improve physical and mental health	Food production
Air quality improvements	Aesthetic benefits	Tourism

Cost considerations

- **Cost:**
  - *Wet detention ponds:* \$17.5 -\$35 per cubic meter of storage area. (Naturally Resilient Communities 2017)
  - *Dry detention basins:* \$10 per square meter for smaller basins and \$5 per square meter for larger basins (Naturally Resilient Communities 2017)
- The average cost for water supplied to a home in the U.S. is about \$2.00 for 1,000 gallons, which equals about 5 gallons for a penny (Mechell et al. 2009, p. 9).

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. Ray in Manila/Flickr

CASE STUDY:
China's Sponge Cities

RELEVANCE:

A sponge city is an innovative approach to design sustainable water cities that integrates Nature-based Solutions to capture, store, filter, and purify rainwater for reusability. This case study shows how the Chinese government has supported the development of sponge cities.

BACKGROUND AND KEY CONCERNS:

Due to rapid increase in urban population, China faces water challenges attributable to insufficient water infrastructure, waterway degradation, erratic storms, and flooding. In fact, half of Chinese cities can be classified as water scarce.[1] In order to address these challenges, China supported construction of green roofs, permeable pavements, and wetland restoration in 30 cities between 2015-2016. [2]

TECHNICAL IMPLEMENTATION OF NBS:

"The city-wide deployment of nature-based solutions such as green roofs, pervious pavements and bioremediation along with the restoration of urban and peri-urban wetlands and rivers lie at the heart of the national initiative" (Xu and Horn, 2017). The installation of green roofs, walls and permeable pavement alongside the revitalization of degraded lakes and wetlands facilitate the absorption of excess water. This excess water is then collected by raingardens and bioretention swales and transferred back to the natural system. Some of the water is also stored to support irrigation during drought periods.

ECONOMIC VALUATION:

The Chinese government has directly funded each of the 30 cities with $59 to $88 million per year as part of public-private partnerships. This was part of a strategy created by China's Ministry of Finance enabling private investment in the construction of various NBS projects. Recent cost estimates show that scaling these NbS to meet the country's goals of 80% of cites equipped with sponge city projects would amount to $1 trillion USD. The cost for implementaiton is estimated between $15 to $22 million per square kilometer.

1. https://documents1.worldbank.org/curated/en/253401551126252092/pdf/134847-NBS-for-DRM-booklet.pdf

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URBAN NBS TOOL 10:

Green Roofs and Green Walls

RISK(S) ADDRESSED

URBAN TYPOLOGIES

FUNCTIONS

Water Management

Sink It | Slow It | Move It | Reuse It | Clean It

Heat Management

Lighten It | Cover It | Access It | Cool It

Biodiversity Management

Safeguard It | Diversify It | Buffer It | Connect It

Description

Green roofs and walls capture excess stormwater, preventing flooding (FEMA 2021, p. 7), while also improving water quality (UNEP 2014, p. 36) and in some cases can improve air quality by capturing airborne pollutants. Green roofs also mitigate the urban heat island effect (Glick, P. et al. 2020, p. 21), which can reduce energy costs.

There are two main types of green roofs:

- Extensive green roofs, a vegetation layer planted over a waterproofing system on top of a roof (Technical Preservation Services, National Park Service n.d.), with shallow soil depth, which may be installed as part of the building construction or retrofitted post construction; and
- Intensive green roofs, with deep soil depth allowing for shrubs and trees in the vegetation palette. (FEMA 2021, p. 7), which are often integrated into the initial design and construction of a building, rather than retrofits; and

In addition to green roofs, buildings may incorporate:

- Green walls, vegetated wall surfaces, including green facades, living walls and retaining living walls (Green Roofs for Healthy Cities n.d.).

Green roofs consist of a planting medium and vegetation (FEMA 2021, p. 7). Commercial buildings with large flat roofs and sufficient structural support for additional weight on the roof can be designed to incorporate intensive green roofs with deeper soil and diverse plantings. Individual homes may incorporate smaller areas with extensive green roofs that utilize small succulents with porous lightweight soils (FEMA 2021, p. 7). Green roofs can support biodiversity, with the type and amount of biodiversity dependent on the type and extent of the green roof installed (Living Roofs, n.d.).

Suitability characteristics

TECHNICAL:

- ☐ Siting – The structural integrity of the building is a key criterion for considering a green roof or green wall. With sufficient support, green roofs and walls can provide natural insultation, capture and filter rainwater, clean the surrounding air and support biodiversity. They are often in competition for space with solar and other mechanical requirements for the roof area.
- ☐ Biophysical factors – The vegetation should be selected to be suitable for local conditions (UNEP 2014, p. 35) and biodiversity.
- ☐ Design requirements - Roof and/or wall retrofitting may pose a significant logistical challenge, because often these places can be difficult to access. Depth is an important design factor that will depend on roof structure, the selected vegetation, annual rainfall, and stormwater performance requirements (Technical Preservation Services, National Park Service n.d.).

INSTITUTIONAL:

- ☐ Land use jurisdiction – Existing regulatory requirements for roofs or walls may not be compatible with this type of infrastructure, so regulatory changes could be necessary for the implementation of this NBS tool.
- ☐ Ownership – Similarly to many other urban NBS tools, green roof and wall interventions may be located in public and private sites.
- ☐ Operations/ stewardship – Green roofs and walls will require more maintenance during the first five years. Maintenance activities can include weeding, plant replacement, fertilization, and soil tests (Minnesota Pollution Control Agency 2021). Often, green roofs will extend the life of a roof, by providing a protective layer over the waterproofing and structure.

SOCIAL:

- ☐ Access - When possible, the incorporation of accessible roof decks to allow building users to enjoy the view is desirable. These systems may not have direct access on them but viewing landscaping can support mental health.
- ☐ Benefits – Vegetative covering of building surfaces can support better insulation and temperature regulation, as well as reduce heating and cooling costs. Providing views of the vegetated surfaces supports mental health.
- ☐ Challenges - Given the high construction costs and logistical maintenance considerations of green roofs, it may be difficult to convince private actors to invest in this NBS tool without the appropriate incentives.

Project considerations

For a selected location, the implementation of this tool can be either through (1) green roofs, (2) green walls, or (3) both. Green roofs are easier to build due to their location in horizontal surfaces, but green walls may be used to provide the same function in places where there is no available space on roofs and/or the retrofitting process is especially challenging. Additionally, in neighborhoods where water and heat risks are high, it may be desirable to incorporate green roofs and green walls in suitable buildings.

Green roofs and walls are generally implemented at the **site** scale, but they can be implemented programmatically at a larger scale. They can be installed on **public** or **private** buildings.

- ☐ For the case of **public buildings,** the recommended implementation strategy is capital investment, and the leadership of **Public Property Managers** will be required.
- ☐ For **private buildings,** the building owner and managers will have to be engaged in the process. The NBS intervention could be carried out through changes in **policy** (for example, requiring green roofs or walls for certain building types) or through **partnerships** between commercial or industrial stakeholders and the city environmental department. Another feasible alternative is an **incentive program** where benefits are offered to those who install these structures in their buildings**.**

Co-benefits

ENVIRONMENTAL	SOCIAL	ECONOMIC
**	**	**
Carbon sequestration	Provide recreational opportunities	Reduced utility costs
Enhancing biodiversity and wildlife habitat	Strengthen community ties through shared natural spaces	Green job creation
Erosion control	Improve physical and mental health	Food production
Air quality improvements	Aesthetic benefits	Tourism

Cost considerations

- **Cost**
  - *Green roofs:* $110 to $270/m2 (Ozment, Ellison, and Jongman 2019, p. 8).
  - *Intensive green roofs:* construction costs of between USD 200 to USD 900 m2, annual maintenance cost of 2 to 3 per cent of the initial investment (UNEP 2014, p. 36).
  - *Extensive green roofs:* construction costs of between USD 65 to USD 450 m2, annual maintenance cost of 2 to 3 per cent of the initial investment (UNEP 2014, p. 36).
- Green roofs are more than 2 to 5 times more expensive to install than traditional roofs, but their cost is comparable over the life cycle due to a longer lifespan and their provision of building insulation, which lowers utility bills (Ozment, Ellison, and Jongman 2019, p. 8).

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CASE STUDY:
Sherway Gardens Shopping Centre, Toronto, Canada

RELEVANCE:

This case study demonstrates how green roofs have been used in Toronto, Canada atop a shopping centre to combat stormwater runoff and combat the city's heat island effect during the summer.

BACKGROUND AND KEY CONCERNS:

Sherway Gardens is a large shopping mall in Toronto, Ontario. It opened in 1971 and underwent redevelopment in 2015. To address environmental concerns including stormwater and the heat island effect, Sherway Gardens installed a 9,500-square-meter (102,000 square feet) green roof on a free-standing commercial structure. The highly visible green roof has been crucial in managing the facility's stormwater concerns. By slowing the release of stormwater into the city's sewer system, the green roof plays an integral role in sustainably managing stormwater.

TECHNICAL IMPLEMENTATION OF NBS:

The green roof atop Sherway Gardens is very light in weight (12 pounds per square foot, fully saturated) and has the capacity to retain 33.9 L of water or 1.3 inches of rainfall fully saturated. In technical terms, this system is classified as the XF301 Sedum Standard comprising a root barrier, a drainage mat, two layers of recycled polymeric water retention fleeces and a pre-cultivated sedum mat.

INSTITUTIONAL AND LEGAL ARRANGEMENTS:

The project was undertaken by the owner of Sherway Gardens, Cadillac Fairview, and constructed and monitored by the architecture company, DIALOG.

ECONOMIC VALUATION:

The construction of the roof was part of a broader redevelopment plan of the shopping mall, costing Sherway Gardens a total of CAN $550 million. Toronto's Green Roof Bylaw "sets out a graduated green roof requirement for new development or additions that are greater than 2,000 m^2 in gross floor area," thus motivating the construction of the Sherway Gardens green roof. Moreover, the Eco Roof Incentive Program also offers grants to companies and commercial businesses to construct green roofs in light of the NBS benefits they offer.

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URBAN NBS TOOL 11:

Wetlands

RISK(S) ADDRESSED

URBAN TYPOLOGIES

Description

Wetlands capture and purify water (FEMA 2021, p. 6) and produce a cooling effect through evapotranspiration (Hesslerova et al. 2019). They also contribute to groundwater recharge and provide wildlife habitat (FEMA 2021, p. 6). Additionally, wetlands act as natural water filters, improving water quality (UNEP 2014, p. 25).

There are two main types of wetlands:

- Inland wetlands, located within continental urban or rural areas. One subtype is wastewater treatment wetlands, constructed to serve as a form of biological wastewater treatment (UNEP 2014, p. 28); and
- Estuarine wetlands, located where the water meets the sea.

Wetlands occupy the transitional zone between wet and dry environments, and they range from permanently or intermittently wet land to shallow water and land-water margins (Shine and de Klemm 1999, p. 3). As a NBS intervention, they can be implemented in areas already containing this type of ecosystem or be designed and built in suitable open spaces.

FUNCTIONS

Water Management

Sink It | Slow It | Move It | Reuse It | Clean It

Heat Management

Lighten It | Cover It | Access It | Cool It

Biodiversity Management

Safeguard It | Diversify It | Buffer It | Connect It

Suitability characteristics

TECHNICAL:

- ☐ Siting – Wetland siting differs between existing and constructed wetlands. Constructed wetland protection, enhancement or restoration should take place where existing wetlands are located or where they have been degraded. For constructed wetlands, large open spaces are suitable sites (Biswas et al. 2019, p. 42).
- ☐ Biophysical factors – For constructed wetlands, characteristics such as soil type, hydrology, vegetation, and species should be considered for the selection of the project location (EPA Office of Water 2004, p. 2).
- ☐ Design requirements – Constructed wetland design will depend on the objectives of the project. For example, if the objective is only flooding mitigation, the wetlands should be sized to capture a certain amount of rainfall. On the other hand, sometimes water quality may be considered a priority, and this will be an important factor for wetland design.

INSTITUTIONAL:

- ☐ Land use jurisdiction – Wetland areas may fall into the jurisdiction of different local or regional authorities, and therefore this type of NBS intervention will often require collaboration between entities.
- ☐ Ownership – Wetland ownership considerations will depend on project location.
- ☐ Operations/ stewardship – Constructed wetlands may require regular inspections, monitoring and maintenance (EPA Office of Water 2004, p. 2) to ensure they are delivering on their intended use.

SOCIAL:

- ☐ Access – Wetland projects should include sites for public access, to ensure that the recreational and community-building opportunities associated to the project can take place.
- ☐ Benefits – The costs and benefits of the project for different communities and stakeholders should be considered as one of the factors for project site selection.
- ☐ Challenges - Careful operation and management of projects will be necessary to avoid potential public concerns around safety considerations, mosquitoes, smells and other factors.

Project considerations

In areas with **existing wetlands**, the most relevant NBS intervention will be to **protect** or **enhance** them. The first step in this process is to identify where wetlands are located and determine their current health status. Based on this assessment and on other constraints such as the available budget and land ownership, the next step will be to identify the specific areas to be protected, enhanced or restored.

For areas **without existing wetlands**, a viable alternative could be a constructed wetland. The first step will be to identify available areas suitable for their construction – based on land use, soil type, hydrology and topography – and carry out the design of the wetland. This will be followed by the construction of the wetland, and subsequently by the operation and management stage.

Wetlands can be built at the **parcel**, **corridor** or **programmatic** level. They can be built in riparian lands, coastal areas, parks and open space, vacant lands, among other locations. Wetland size ranges from half an acre to upwards of 5 acres.

The city **Natural Lands Manager** and **Environmental Department** will be key stakeholders, but additional partners will have to be engaged depending on the intervention type (protection, enhancing or building) and the location of the wetland (in public lands, private lands, protected lands, etc.).

If the existing wetland or selected area for wetland construction is located on **public lands**, city government can pursue implementation through their capital project program.

Co-benefits

ENVIRONMENTAL	SOCIAL	ECONOMIC
***	***	*
Carbon sequestration	Provide recreational opportunities	Reduced utility costs
Enhancing biodiversity and wildlife habitat	Strengthen community ties through shared natural spaces	Green job creation
Erosion control	Improve physical and mental health	Food production
Air quality improvements	Aesthetic benefits	Tourism

Cost considerations

- ☐ **Cost:**
  - *Constructed wetlands*: $7 to $15/m2 (Ozment, Ellison, and Jongman 2019, p. 8), maintenace costs are generally low (UNEP 2014, p. 28).
  - *Wetland restoration*: $33,000/ha (Ozment, Ellison, and Jongman 2019, p. 10).
- ☐ Wetlands often have lower construction, operation and maintenance costs than traditional wastewater treatment options (EPA Office of Water 2004, p. 1).

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CASE STUDY:

Metro Colombo Urban Development Project

RELEVANCE:

This case study shows how urban wetlands can be used to address flooding risks.

BACKGROUND AND KEY CONCERNS:

The city of Colombo, Sri Lanka is surrounded by wetlands, but they had suffered significant degradation, leading to the loss of a significant portion of their water-holding capacity. The city experienced record-breaking flooding events in 2010. To address this issue, the government implemented the Metro Colombo Urban Development Project, combining green and grey infrastructure to reduce flooding risk. This project included wetland conservation as one of its key actions (GFDRR et al. 2018).

TECHNICAL IMPLEMENTATION OF NBS:

The Columbo Wetland Complex, covering 20 square kilometers, is integrated into the City of Columbo. These wetland areas were degraded due to improper dumping and unsustainable farming practices. To address this, a long-term program to protect and restore these wetlands is underway with support from the World Bank and other international partners to support Sri Lanka's Columbo Wetland Complex.

INSTITUTIONAL AND LEGAL ARRANGEMENTS:

The project was financed by the Global Facility for Disaster Reduction and Recovery, the Multi-Donor Trust Fund for Sustainable Urban Development and the Korean Green Growth Trust Fund (Rozenberg et al. 2015)

ECONOMIC VALUATION:

Economic analysis of selected wetland benefits including carbon sequestration, climate regulation through reduced use of air conditioning near wetland areas, and wastewater treatment has demonstrated that annually the economic value of the wetlands far exceeds the economic benefits of lakes (Rozenberg et al. 2015).

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URBAN NBS TOOL 12:

Coastal Habitats

RISK(S) ADDRESSED

URBAN TYPOLOGIES

Description

Coastal habitats protect coasts from the impacts of floods and storms and provide habitat for species. They also store carbon, thereby mitigating climate change (Reddy 2019).

There are 4 main types:

- Mangroves, tropical and subtropical coastal wetlands characterized by the presence of mangrove trees (US EPA 2015). Mangroves can tolerate extreme environments, including those with high salinity, high temperature, and extreme tides and muddy organic sediments devoid of oxygen (Alongi 2009);
- Salt Marshes (also known as coastal marshes), tide dominated saline wetlands, covered in saltwater tolerant grasses, shrubs and other vegetation (UNEP 2014, p. 45) Salt marshes are often referred to as “sponges” because of their ability to absorb wave energy during coastal storms or normal tide cycles (Naturally Resilient Communities 2017);
- Reefs, ecosystems formed by colonies of coral or oysters; and
- Seagrasses, underwater ecosystems covered in species with grass-like leaves (Reynolds and Knowlton 2018, p. 1).

These ecosystems are found along and close to marine shorelines (Reddy 2019). They are often threatened by human activities such as agriculture and land and water development, so interventions can either remove these pressures or restore ecosystems where they have been significantly degraded (UNEP 2014, p. 46).

FUNCTIONS

Water Management

Sink It | Slow It | Move It | Reuse It | Clean It

Heat Management

Lighten It | Cover It | Access It | Cool It

Biodiversity Management

Safeguard It | Diversify It | Buffer It | Connect It

Suitability characteristics

TECHNICAL:

- ☐ Siting – The siting of coastal habitats depends directly on the type of habitat to be used. Mangroves and salt marshes typically require larger amounts of space in order to function well and provide the desired flood and stormwater hazard mitigation benefits, than reefs and seagrasses, which can occupy smaller areas.
- ☐ Biophysical factors – Coastal habitats are all impacted by factors directly linked to urbanization and development. Mangroves, seagrasses and reefs are all sensitive to water quality and temperature, and severely impacted by land-based pollution from runoff, nutrients and sedimentation (Naturally Resilient Communities 2017). Physical impacts from fishing and boating may also have severe impacts on the health and growth of coastal habitats.
- ☐ Design requirements - Coastal habitats should be designed and sited with careful consideration to current land use and forecasted future land cover. The size of the systems should be proportionate to the scope and extend of flood and storm benefits envisioned. Regarding reefs, restoring coral reefs can be expensive and technologically complex. The critical design features that make coral reefs effective protection barriers are the size, height, hardness and structural complexity of the reefs (UNEP 2014).

INSTITUTIONAL:

- ☐ Land use jurisdiction – Coastal habitats are often located on public land, but may also be found in community-managed concessions. Their management may require inter-agency cooperation.
- ☐ Ownership – Project sites – especially for mangroves and salt marshes – can be owned by public and community stakeholders, which will significantly impact the project's extent, feasibility, cost and implementation options.

SOCIAL:

- ☐ Access – Coastal habitats should include opportunities for public access and recreation, meaning that access sites should be considered during the design phase. Most importantly, there should be mechanisms in place to control public access – and limit it if necessary – given how sensitive these systems are to human impact.
- ☐ Benefits – Coastal habitats are also source of income and support to livelihoods of millions of people (UNEP 2014). Salt marsh soils are often deep mud and peat, containing large amount of plant matter and acting as rich habitats for biodiversity (UNEP 2014).
- ☐ Challenges – The danger to coastal ecosystems from people and development has increased rapidly in recent decades. The most efficient way to maintain water-related ecosystem services of these coastal wetlands is elimination of existing pressures, e.g., limiting coastal deforestation, land development and pollution (UNEP 2014). While seagrasses rely on clean and clear water to survive and thrive, they can also play a role in improving water quality and clarity. Seagrasses help trap fine sediments and particles that are suspended in the water column, which increases water clarity. Seagrasses are also able to filter, to a degree, nutrients that come from land-based pollution and stormwater runoff before these nutrients are washed out to sea and to other sensitive habitats such as coral reefs (Naturally Resilient Communities 2017). The accelerated rate of global climate change requires particular consideration in relation to the long-term fate of restored reefs (UNEP 2014).

Project considerations

Coastal habitats can be implemented using four approaches:

- ☐ **Protect** existing ecosystems;
- ☐ **Enhance** existing ecosystems;
- ☐ **Restore** ecosystems in areas where they have been degraded; and
- ☐ **Build** new reef or seagrass systems

The type of intervention will depend on the ecosystems present in the project area and on the risks targeted by the project. For example, coral and oyster reefs are very effective in mitigating coastal erosion (Glick, P. et al. 2020, p. 16), but they do not have significant benefits for water quality.

Another important consideration is the timescale of interventions, since different alternatives will produce benefits at different speeds. For coral reefs, two to five years are required for growth and reproduction (Browder et al. 2019, p. 32). In comparison, mangroves require more time to mature and accrue benefits.

Co-benefits

SHARED BY ALL:

ENVIRONMENTAL	SOCIAL	ECONOMIC
**	*	
Carbon sequestration	Provide recreational opportunities	Reduced utility costs
Enhancing biodiversity and wildlife habitat	Strengthen community ties through shared natural spaces	Green job creation
Erosion control	Improve physical and mental health	Food production
Air quality improvements	Aesthetic benefits	Tourism

PROVIDED BY AT LEAST ONE SUB-TYPE:

ENVIRONMENTAL	SOCIAL	ECONOMIC
***	**	*
Carbon sequestration	Provide recreational opportunities	Reduced utility costs
Enhancing biodiversity and wildlife habitat	Strengthen community ties through shared natural spaces	Green job creation
Erosion control	Improve physical and mental health	Food production
Air quality improvements	Aesthetic benefits	Tourism

Cost considerations

- **Cost:** The cost will depend on the intervention type. Some examples are included below.
    - *Mangrove restoration:* $0.1/ m2 (ranging from $0.05 to $6.50) (Ozment, Ellison, and Jongman 2019, p. 6).
    - *Salt marsh restoration:* $1.11/m2 (ranging from $0.01 to $33.00) (Ozment, Ellison, and Jongman 2019, p. 6).
    - *Coral reef restoration:* $166/m2 (ranging from $2 to $7,500) (Ozment, Ellison, and Jongman 2019, p. 6).
    - *Oyster reef restoration:* $107 to $316/m2. (Ozment, Ellison, and Jongman 2019, p. 6).
    - *Seagrass restoration:* $11/m2 (ranging from $0.20 to $410) (Ozment, Ellison, and Jongman 2019, p. 6).

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CASE STUDY:
Mangrove Restoration for Coastal Resilience in Demak, Central Java, Indonesia

RELEVANCE:

A coalition of partners supported shoreline adaptation to address erosion and coastal flooding with permeable structures that allowed large scale mangrove restoration along the coast of Indonesia.

BACKGROUND AND KEY CONCERNS:

The North Java coastline of Indonesia has experienced significant erosion and resulting coastal flooding. The mangrove belts have been removed for other shoreline uses and no longer provide natural protection from wave pressures. "30 million people suffer from coastal flooding and erosion hazards in Northern Java, affecting 3000 villages." (Wetlands International) In order to address this risk, a consortium of partners came together to pilot natural infrastructure restoration in Demak along the central coast to protect the village from sea level rise and flooding, as well as safeguard the aquaculture practices that many in the village rely on for income.

NBS TECHNICAL IMPLEMENTATION:

The project team started the restoration process by placing permeable structures made of brush and local wood in the near shore to support sediment capture that raised the shore bed and created the optimal conditions for mangrove restoration. The installation was done in partnership with the local communities to build capacity for stewardship and expansion along the coastline to other communities. The permeable structures must be continually maintained and repaired to ensure sediment capture maintains the optimal shore bed levels. Mangroves naturally repopulate in these improved shore condition and communities enhanced this with additional plantings.

INSTITUTIONAL AND LEGAL ARRANGEMENTS:

The Building with Nature Indonesia programme (2015-2020) is supported by a multi-partner coalition that includes: Ecoshape, Wetlands International, the Indonesian Ministry of Marine Affairs and Fisheries (MMAF), the Indonesian Ministry of Public Works and Housing (PUPR), Witteveen+Bos, Deltares, Wageningen University & Research, UNESCO-IHE, TU Delft, Von Lieberman, Blue Forests, Kota Kita, Diponegoro University, and local communities. Their long-term commitment has enabled the program to test, monitor and improve practices for mangrove restoration, aquaculture farming practices and capacity building.

ECONOMIC VALUATION:

The programme and pilot project are financially supported by The Dutch Sustainable Water Fund, The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) as part of the International Climate Initiative (IKI), Waterloo Foundation, Otter Foundation, Topconsortia for Knowledge and Innovation Mangroves for the Future.

SOCIAL CONSIDERATIONS:

As part of the programme, the coalition helped to set up Coastal Field Schools where community members could engage in experiential learning about the protection of the coastline, sustainable aquaculture farming practices, and the importance of monitoring and evaluation. These training resources empowered residents to engage directly in their community resilience.

KEY TAKEAWAYS:

- ☐ Long term commitment by the partners, their funders, and the people in the community was key to ensuring that the effort survived beyond the pilot and knowledge was transferred to the community.
- ☐ Nature-based solutions require time to implement and time for establishment of the natural elements. This project showed how the placement of the permeable structures was a key first step before the mangroves could return and again protect the shoreline.

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Developed by the World Resources Institute, this factsheet and case study forms part of Nature Based Solutions Selection Guide and is a work in progress undergoing user testing by the Urban Water Resilience and Cities4Forests initiatives with stakeholders in Addis Ababa, Ethiopia and Kigali, Rwanda

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URBAN NBS TOOL 13:

Beaches and Dunes

RISK(S) ADDRESSED

URBAN TYPOLOGIES

Description

Beaches and dune provide a buffer area between the land and the sea, thereby reducing coastal flooding (FEMA 2021). They also prevent erosion (Ozment, Ellison, and Jongman 2019, p. 6) and have aesthetic and recreational benefits.

There are two main types:

- Beaches, stretches of sand or smaller loose particles that exist between the water and the land (Naturally Resilient Communities 2017); and
- Dunes, landforms where blown sand is accumulated (Naturally Resilient Communities 2017).

Beaches can prevent coastal erosion caused by strong winds, waves, and tides, and can stop waves and storm surges from reaching inland areas. Dunes often feature dune grasses or other vegetation, which helps them maintain their shape (FEMA 2021, p. 8). The natural services that beaches and dunes provide can be enhanced through artificial sand nourishment. Healthy dune systems can serve as a repository for sand to naturally replenish beaches that have experienced significant erosion from coastal storms.

FUNCTIONS

Water Management

Sink It | Slow It | Move It | Reuse It | Clean It

Heat Management

Lighten It | Cover It | Access It | Cool It

Biodiversity Management

Safeguard It | Diversify It | Buffer It | Connect It

Suitability characteristics

TECHNICAL:

- ☐ Siting – Beaches and dunes should be sited in areas where they already occur or where they have been degraded or reduced in size. The wider a beach or dune system is, and the more space between the sea and any developed or populated areas, the more effective and efficient the system will be at mitigating damage (Naturally Resilient Communities 2017).
- ☐ Design requirements - The size, width, slope, shape, and sand volume of beaches and dunes determine how well they can protect developed areas during storm events. Beaches are capable of reducing impacts from coastal storms by acting like a buffer whilst dunes serve as more of a barrier between the water and inland areas. (Naturally Resilient Communities 2017). Intentional design of beaches and dunes to work in combination with gray infrastructure can achieve coastal resilience.

INSTITUTIONAL:

- ☐ Land use jurisdiction – Beaches and dunes may fall under the jurisdiction of multiple authorities, and sometimes even private landowners, necessitating collaboration between entities for due planning and management.
- ☐ Ownership – Beach and dune ownership considerations depend on project location and could involve multiple government agencies and/or private landowners.
- ☐ Operations/ stewardship – Because beaches and dunes are highly dynamic in their natural state, changing in response to changing wind and water levels (Linham and Nicholls 2010), they require constant monitoring to make sure they are maintaining their structure and intended benefits. Maintenance may be required, which could include sand nourishment and plantings (Glick et al. 2020, p. 16).

SOCIAL:

- ☐ Access – Beaches provide communities with important recreational amenities, and therefore it is important to include access points as a part of project design.
- ☐ Benefits - In addition to protecting coastlines from flooding and erosion, beaches and dunes can generate income for local communities by underpinning fisheries, tourism, and recreation. Some beaches and dunes can improve water quality and also enhance habitat and biodiversity (Ozment, Ellison, and Jongman 2019, p. 6).
- ☐ Challenges – Dune projects may face significant costs related to land costs, foregone investment and land development limitations (UNEP 2014, p. 48). Beaches and dunes are naturally dynamic environments and will fluctuate in size and shape year to year based on the impact of wind, waves, tides, and storm events. These processes are essential to the ongoing maintenance of beaches and dunes, and if interrupted or suspended, can have negative impacts on the size and shape of the coastline and the ability of the system to provide flooding and erosion control benefits (Naturally Resilient Communities 2017).

Project considerations

There are 3 main alternatives for the implementation of this NBS tool:

- ☐ **Protect** existing beaches and dunes to prevent their degradation;
- ☐ **Enhance** existing beaches and dunes to increase the desired benefits; or
- ☐ **Restore** beaches and dunes where they have been degraded.

The implementation strategies depend on the type of land where the project is located:

- ☐ If the intervention is in **public lands,** the most relevant implementation strategies will be capital projects, where the project can be implemented using public funds. Generally, this will involve the leadership of the environmental department.
- ☐ If the intervention is in **private lands,** some possible implementation strategies will be **acquisition,** for example through the purchase of the project area by a public agency, or **partnerships,** where the projects can be co-led with commercial or industrial partners. Another alternative is the use of **policy interventions** to require the protection of some percentage of existing beaches or dunes.

Co-benefits

ENVIRONMENTAL	SOCIAL	ECONOMIC
**	****	**
Carbon sequestration	Provide recreational opportunities	Reduced utility costs
Enhancing biodiversity and wildlife habitat	Strengthen community ties through shared natural spaces	Green job creation
Erosion control	Improve physical and mental health	Food production
Air quality improvements	Aesthetic benefits	Tourism

Cost considerations

- **Cost:** The cost will depend on the type of intervention. Some examples are presented below.
  - *Artificial sand nourishment:* $6,500 - $16,400/m (Ozment, Ellison, and Jongman 2019, p. 6).
  - *Revegetating and restoring sand dunes:* $100 - $16,400/m (Ozment, Ellison, and Jongman 2019, p. 6).

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CASE STUDY: Natural Water Filtration through a Sand Dunes System in Amsterdam

RELEVANCE:

This case study shows Amsterdam uses the sand dune filtering system and artificial groundwater recharge for its drinking water.

BACKGROUND AND KEY CONCERNS:

Since 1847, Amsterdam and its surroundings have sourced water through pipes from the dune area of Haarlem. Beginning in the 1930s, however, over-abstraction was causing the penetration of saltwater in the dune area, leading to adverse ecological consequences. To address this, the municipality of Amsterdam initiated a large-scale artificial recharge in the 1950s. Presently, the sand dune filtering mechanism alongside the artificial groundwater recharge system constitutes a core aspect of Amsterdam's green infrastructure involving drinking water. Similar projects have been undertaken over the last several decades to support the management of this NBS tool.

NBS TECHNICAL IMPLEMENTATION:

The Amsterdam Water Dunes System, which is also run by Waternet, produces 90 million cubic meters of drinking water per year. It spans an area of around 3,500 hectares in the Noord-Holland province. The water is primarily sourced from the Lek Canal, located 55 kilometers away. Once the water has been pretreated near the intake in Nieuwegein, it is sent away to the Amsterdam Water Supply Dunes situated in Vogelenzang. After the water has percolated in the dunes' shallow groundwater system, it undergoes post-treatment in the Leiduin water treatment plant. The process of producing drinking water eventually involves 14 various steps, as part of which the dune sand serves as a natural filter for suspended particles. The dune sand also contains a rich environment of bacteria, thus facilitating the decomposition of pathogenic and pesticidal substances. The recharge system plays an integral role in preventing the water's pollution, ensuring water quality in the catchment area.

LEGAL ARRANGEMENTS:

The artificial recharge system is managed and monitored by Waternet, a non-profit water company that provides water-related services to 1.3 million people in Amsterdam and its surrounding regions. Waternet is jointly owned by the city of Amsterdam and the Regional Public Water Authority. As such, the company oversees all aspects of the recharge and drainage system.

ECONOMIC VALUATION:

The overall cost of water production is under €1 per square meter, entirely paid by consumers.

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Developed by the World Resources Institute, this factsheet and case study forms part of Nature Based Solutions Selection Guide and is a work in progress undergoing user testing by the Urban Water Resilience and Cities4Forests initiatives with stakeholders in Addis Ababa, Ethiopia and Kigali, Rwanda