Enhancing Biodiversity Co-Benefits From Nature-Based Solutions for Adaptation in Practice

A compendium of case studies

NCAI REPORT

IISD | Nature for Climate Adaptation Initiative

In partnership with Canada

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Nature for Climate Adaptation Initiative

The Nature for Climate Adaptation Initiative (NCAI) seeks to increase the knowledge and capacity of civil society to design and deliver nature-based climate solutions (NBCS) that are socially inclusive, gender responsive, and that enhance biodiversity and ecosystem resilience to change.

Enhancing Biodiversity Co-Benefits From Nature-Based Solutions for Adaptation in Practice: A compendium of case studies

November 2023

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Introduction

Nature-based solutions (NbS) for adaptation projects are increasing in focus across the world as a means of helping communities and ecosystems adapt to climate change. When implemented with environmental and social safeguards, NbS for adaptation can provide multiple benefits to society and biodiversity (Lo & Rawluk, 2023). And while an increased uptake of NbS for adaptation projects in the international development field is apparent, a gap in evidence exists on how such projects achieve biodiversity co-benefits—that is, the net gains to biodiversity and ecosystem functioning and services that can be attained from the implementation of NbS for adaptation. Protecting and supporting biodiversity and ecosystems in NbS for adaptation projects is important because they provide ecosystem services to communities, such as wetlands absorbing floodwaters, which, in turn, help to sustain livelihoods and support community adaptation to climate change (Lo & Rawluk, 2023).

Box 1. What are NbS for adaptation?

A suite of actions to protect, conserve, restore, sustainably use, and manage natural ecosystems to strengthen the resilience of ecosystems, biodiversity, and communities to the impacts of climate change.

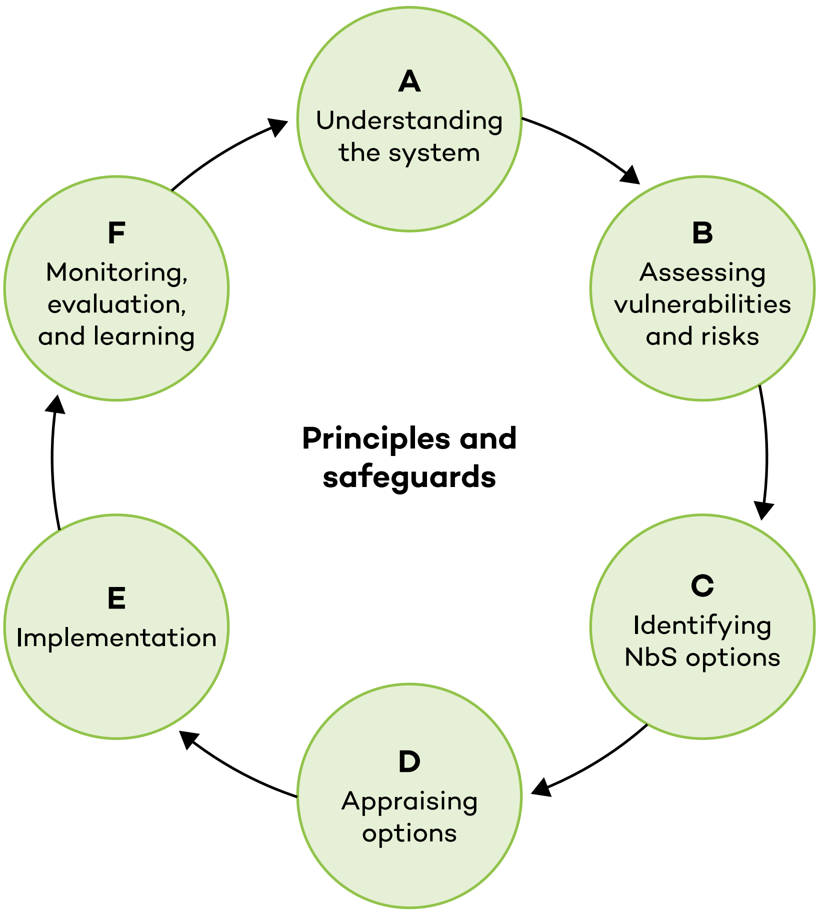
- They are specifically oriented toward managing current and future climate risks and enhancing biodiversity and ecological resilience.
- They target and benefit particular groups and their livelihoods based on risk or vulnerability assessments.
- They include "nature-based" measures integrating ecosystem processes, e.g., flood water storage through wetlands.
- They take into consideration local, environmental, economic, and social contexts, including traditions and culture.

About the Case Studies

To address the gap in evidence, two case studies have been developed as a supplement to a technical brief, *Enhancing Biodiversity Co-Benefits From Nature-based Solutions* (Lo & Rawluk, 2023) developed under the Nature for Climate Adaptation Initiative (NCAI) (Box 2). The technical brief provides a set of recommendations to help plan, design, and implement NbS for adaptation that enhance biodiversity and ecosystem integrity. It also provides step-by-step guidance on implementation that emphasizes biodiversity considerations at each step (Figure 1).

The supporting case studies presented here provide practical examples of enhancing biodiversity co-benefits at various stages of implementing NbS for adaptation.

Figure 1. NbS project implementation cycle



Source: Lo & Rawluk, 2023.

Case Study 1 provides a practical example of understanding baseline conditions (Step A) and monitoring and documenting biodiversity co-benefits (Step F) as part of a mangrove protection and restoration project in Grenada to strengthen its resilience to climate change.

Case Study 2 examines the role of biological corridors in urban areas in Costa Rica to connect animal habitats and enhance ecosystem services for adaptation. The case study illustrates considerations for assessing ecosystem services and biodiversity in a target system for NbS (Step A) and provides examples of indicators and participatory monitoring techniques (Step F).

Each case study includes an overview of the local context and climate risks, how the project adapted to climate change and integrated biodiversity in practice, and lessons learned. The case studies were developed through interviews with project implementers and by reviewing relevant reports and documents.

Box 2. About the NCAI

The NCAI strengthens the knowledge and capacity of civil society organizations to design and implement NbS for climate change adaptation through three key tools:

- a self-paced, accessible e-learning course developed in partnership with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the International Union for Conservation of Nature;
- an online learning space with technical guidance, resources, case studies, and events focused on gender equality, social inclusion, and biodiversity co-benefits; and
- targeted virtual and in-person learning exchange opportunities that foster a community of practice around NbS for adaptation.

Through the sharing of promising practices and lessons learned, the case studies seek to inform and inspire adaptation practitioners and planners to help ensure that biodiversity co-benefits are captured throughout the lifetime of a project. These practitioners and planners include technical support staff, civil society organizations, and researchers who are (or will be) directly involved in the design and implementation of NbS for climate adaptation projects, such as those under Global Affairs Canada's Partnering for Climate program.

Case Study 1: Mangrove restoration in Grenada

Anika Terton and Nicole Jang

The authors are grateful and would like to extend our sincere thanks to Jody Daniel and Zoya Buckmire for their guidance, time, and collaboration in the development of this case study.

Project at a Glance	
Implementing organizations	Grenada Fund for Conservation and GAEA Conservation Network
Funder	Environment and Climate Change Canada; Green Climate Fund
Project focal areas	Mangrove forests and coastal areas in Grenada
Climate stressors	Sea level rise, storm surges, high-intensity hurricanes, increasing temperatures, and reduced precipitation
Ecosystem	Mangrove forests
Ecosystem services	Protection and restoration of mangrove ecosystem services, including coastal protection, water filtration, fish and marine habitat protection, and carbon sequestration
Timeline	2019–2022

Figure 2. Map of Grenada

Climate Change Risks and Impacts in Grenada

Grenada is a Small Island Developing State (SIDS) in the southeastern Caribbean. The country, made up of the main islands of Grenada, Carriacou, and Petite Martinique, possesses a high degree of biodiversity that is particularly fragile and vulnerable to external shocks. As a SIDS, Grenada is already experiencing the impacts of climate variability and change, with serious socio-economic and ecological consequences. Future climatic risks associated with reduced precipitation, increasing temperatures, sea level rise, storm surges, and high-intensity hurricanes and storms are predicted to aggravate existing vulnerabilities and undermine the pursuit of key development targets (Government of Grenada, 2017; Taylor et al., 2020). Sea level rise is particularly concerning, as much of the ecosystem services provided by mangroves (Friess et al., 2012; Sasmito et al., 2018; Ward et al., 2016), seagrass beds (Keyzer et al., 2020), and coral reefs (Perry et al., 2016) are under threat. Climate forecasts suggest that sea levels for the islands may increase by a minimum of 1 metre by 2100 (Mimura et al., 2007; Taylor et al., 2020). This means that a key climate risk the population is experiencing is gradual but persistent coastal erosion, driven largely by the effects of climate change and compounded by anthropogenic factors, such as tourism development and sand mining (Ministry of Climate Resilience, the Environment, Forestry, Fisheries, Disaster Management and Information, 2017b). Expected increases in the frequency and intensity of storms and hurricanes are also of particular concern; in 2004, Hurricane Ivan devastated the tri-island state, claiming the lives of 34 people, destroying 95% of Grenada's forest, decimating wildlife populations, and causing damages worth twice the nation's annual economic output (Government of Grenada, 2016; Jimenez, 2004).

The increased frequency of hazards along Grenada's coastlines has resulted in significant loss of fertile land and coastal forest and vegetation cover, including mangroves. This growing problem requires immediate and appropriate adaptation response measures to reduce the vulnerability of these islands to the impacts of climate change.

Mangroves as a Last Line of Defence Against Sea Level Rise and Storm Events

Mangroves are tropical flowering plants found in coastal regions that have evolved to survive in saline and tidal environments through unique adaptations to their reproductive and root systems. Their root systems, which lie partially above the water line, not only help the plants deal with daily tidal changes but also offer protection to coastal habitats and communities in the face of climate change. Their role in protecting coasts against natural hazards, such as storms and coastal erosion, has been widely recognized, and the ecosystem services they provide are extensive and well documented: mangroves can reduce coastal erosion, filter pollutants and absorb excess nutrients, protect coastal areas during hurricanes and storm surges, mitigate the impacts of sea level rise, and provide habitats and nurseries for fish and marine invertebrates (Jakovac et al., 2020). The protection and restoration of mangrove ecosystems is an effective form of NbS for climate adaptation. There are mitigation benefits as well; mangroves also act as major carbon sinks, sequestering four to five times more carbon than tropical forests (Twilley et al., 2017).

Despite their importance, mangroves are under threat. Mangroves have declined by as much as 30%–50% globally in the last century (Feller et al., 2017), and many mangrove restoration projects have experienced mixed success, often carrying with them high seedling loss rates (Lovelock et al., 2022). In most cases, the failure of these efforts is a result of the environmental requirements of mangrove seedlings not being met where they are replanted because planting is done without proper site assessment and inappropriate species selection (Chan & Baba, 2010; Lewis & Brown, 2014; Trench & Webber, 2012). This is compounded by an emphasis on area-based targets, rather than on the quality of restoration procedures (Lovelock et al., 2022). These poor success rates are a global problem, not unique to Grenada (Daniel et al., 2022).

NbS for Adaptation: Improving mangrove restoration rates and maximizing success in Grenada

To address these challenges in Grenada, two local civil society organizations, the Grenada Fund for Conservation and Gaea Conservation Network, undertook a project to develop a mangrove restoration protocol for Grenada to test and improve techniques on mangrove protection and restoration with the goal of increasing restoration success rates in the Caribbean and to strengthen coastal resilience to climate change in Grenada (Buckmire et al., 2022). The protocol provides insights into the biophysical needs of mangrove species to protect existing mangroves, increase restoration success rates, and provide a better understanding of the environmental conditions in which the plants thrive and in which they are more likely to survive. The protocol was then applied in the Lauriston Beach Mangrove Restoration and Rehabilitation Project (Box 3).

The project team started by establishing reference conditions for mangrove forests in Grenada by surveying environmental conditions and biodiversity at identified sites. Data collection and surveys were supported by university and college students as well as community volunteers. To inform future restoration efforts, the data derived from these surveys was used to determine in what conditions specific mangrove species thrive. In parallel, the project team undertook pilot growth experiments to determine optimal biological conditions for mangrove seedlings in coastal areas to better understand, inform, and expand restoration efforts to include more species. The experimental plots were placed at various locations with differing water sources and elevations but sheltered by natural mangrove forests. The lessons learned from using mangrove ecology to guide restoration efforts were used to develop Grenada's mangrove restoration protocol to help boost the country's overall restoration success rates (Buckmire et al., 2022).

Box 3. Lauriston Beach Mangrove Restoration and Rehabilitation Project

The Lauriston Beach Mangrove Restoration and Rehabilitation Project was informed by the new mangrove restoration protocol to maximize success. Mangrove ecology was used to inform species selection, planting zones, and approaches.

Despite its natural beauty, the coast along Lauriston Beach on Carriacou sees severe erosion. The erosion is worsened by climate change impacts, like sea level rise and flooding, and the deforestation of the coasts, with locals cutting wood, primarily for charcoal production. The local government and community members now work to tackle climate change threats and reduce vulnerabilities through engagement with the Grenada Fund for Conservation to restore the area with mangroves.

The project team established a mangrove nursery to cultivate saplings of red and white mangroves. The newly planted saplings will take several years to take firm hold in the sand and soil. The project team installed fencing, pens, and bamboo casings to boost the saplings' chances of survival, adding protection from the wind, waves, and animals. Signs were also placed to alert and educate hikers to avoid treading on mangroves. As the saplings take root, Lauriston locals will continue tending to them to cultivate a healthier, more resilient coastline (J. Daniel and Z. Buckmire, personal communication, May 10, 2023).

Through this project, the team applied several tools and methods to assess baselines and monitor the conditions in which different mangrove species thrive and to assess the intended biodiversity co-benefits they deliver. Several types of biodiversity, ecosystem, and wildlife surveys were used by the project team to create baseline data and assess the delivery of biodiversity benefits:

- **Bird Surveys:** Undertaking bird surveys at project sites on a regular basis throughout the lifetime of a project can provide important information about species diversity and overall ecosystem health, such as in a forest or wetland (Mekonen, 2017). Mangrove forests provide a primary habitat for many native and migratory birds. Measuring species richness or the presence of specific bird species is a valuable approach to establishing a baseline and informing ecosystem health over time. Bird surveys are usually undertaken between sunrise and late mornings, with trained volunteers or technicians conducting counts based on sightings and birdsongs.

- **Vegetation and Flora Surveys:** These kinds of surveys ascertain the presence of significant flora, vegetation, or ecological communities. Surveying usually includes measuring the average height and coverage of seedlings planted as part of any restoration project, the presence of native and invasive species, and the presence of significant plants or trees. Photo-monitoring can be an important tool to help visualize changes in vegetative cover or species at small sites. For example, photos can provide insight into conditions such as improved vegetation along streambanks.
- **Water Sampling:** Water sampling surveys can examine water conditions in nearshore environments. Samples are usually taken at different locations along the shore. Project teams can use water quality parameters to help gauge the health of a water body by assessing factors such as dissolved oxygen, pH, nutrient levels, bacteria count, or alkalinity. These can be used to inform a project's interventions based on data collected.
- **Fish Surveys:** Fish surveys help quantify the health of fish populations in coastal waters near mangroves. Methods usually include visual observation and catch and release. Catch and release methods involve recording the identity, weight, and length of the fish caught. This kind of data (e.g., the presence of juvenile fish) can act as indicators of the importance of mangroves as a nursery for local fish species.
- **Mammalian Predator Surveys:** Accounting for mammalian predators can provide insight into the current and future resilience of an ecosystem. For example, invasive predators (e.g., cats and rats) can cause declines in native wildlife. Observing the occurrence of invasive and endemic mammals within a specific ecosystem can provide insight into potential future threats and conservation management needs for protecting ecosystem resilience and controlling predator access. Methods include installing baited camera traps over a specific period of time (e.g., two weeks) to capture native and invasive small to medium-sized mammals.

Lessons Learned

Several lessons can be learned from mangrove restoration and rehabilitation projects in Grenada that can apply to a wide range of NbS for adaptation projects (J. Daniel and Z. Buckmire, personal communication, May 10, 2023):

Appropriate Indicators and Methods

The level of technical expertise required to monitor and measure ecosystem health and biodiversity co-benefits can be a constraint for project implementers. NbS for adaptation projects should involve communities and respect free, prior, and informed consent; hence, project teams should consider choosing indicators that can be monitored and assessed by local communities with minimal technical expertise or where community members can easily be trained in collecting data. Engaging directly with local communities and understanding the ecosystem services they rely on helps identify the most locally appropriate metrics and ensures that the data collected is useful to them. Traditional knowledge and local and Indigenous knowledge should be considered and included when selecting suitable indicators and methods to collect data.

Capacity Building and Expert Advice

During the design phase of the project, consider engaging an advisor or expert with the appropriate ecological expertise relevant to your project site. Involving them may help project teams understand existing ecological data, indicators most appropriate for understanding ecosystem health (depending on the geographical scope), and time frames for interventions.

Citizen Science

Citizen science is well developed for biodiversity monitoring and could be used to monitor the ecosystem health co-benefits of NbS for adaptation and enable subsequent knowledge sharing. Consider engaging local conservation organizations or university students in data collection for the project and providing appropriate training in ecological research techniques.

Set a Baseline

When trying to understand changes in ecosystem health and biodiversity co-benefits, it is crucial to consider the baseline before any intervention is implemented. This can be done by using the same methods and approaches used to monitor ecosystem health and biodiversity co-benefits over the lifetime of the project or through existing species and ecosystem assessments of the area.

Case Study 2: Interurban biological corridors in Costa Rica

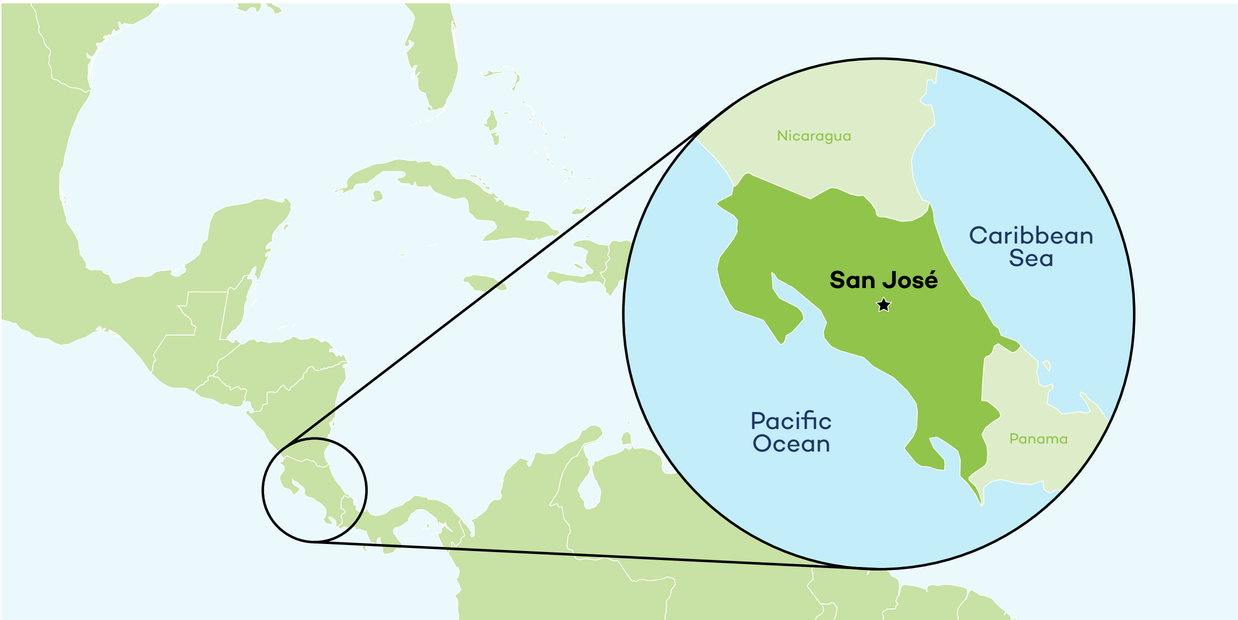
Veronica Lo and Jairo Sancho Rodríguez

Photo: Jairo Sancho Rodríguez

The authors are grateful to Mauricio Luna Rodriguez for reviewing this case study.

Project at a Glance	
Implementing organizations	Ministry of Environment and Energy of Costa Rica (MINAE), National System of Conservation Areas (Sistema Nacional de Areas de Conservation, or SINAC) within the National Program of Biological Corridors
Partners	Local governments, ministries, non-governmental organizations, the private sector, civil society, and academia
Funder	The Federal Ministry of the Environment, Nature Protection and Nuclear Safety, Germany
Project focal areas	Strengthening the capacity of different levels of government and other actors to plan and manage interurban biological corridors; communications and knowledge management; participatory management of biodiversity; strategic alliances
Climate stressors	Urban heat island effect, flooding
Ecosystem	Urban ecosystems within the greater metropolitan area of San José, Costa Rica (rivers, watersheds, forests), with a focus on protected river basins
Ecosystem services	Climate regulation, air quality, drinking water, prevention of erosion, pest control, energy, food, feeling of belonging, recreation, and transit area for wildlife
Beneficiaries	Population in the greater metropolitan area of San José and inhabitants of the interurban biological corridors who depend on their ecosystem services
Timeline	Project initiated in 2018 and will continue until 2023

Figure 3. Map of Costa Rica



Climate Change Risks and Impacts in Costa Rica

With its mountainous landscapes, tropical rainforests, and coastlines, Costa Rica is renowned as a global biodiversity hotspot, hosting 5% of the planet's biodiversity. The country has long prioritized the conservation of its biological wealth, recognizing that the resilience of the nation and its inhabitants depends on the health of its ecosystems and biodiversity. However, Costa Rica and its neighbouring countries are also vulnerable to climate change impacts. Shorter-term impacts include changing intensity and frequency of droughts, hurricanes, and tropical storms, extreme temperatures, and intense rainfall over short periods of time. Slow-onset impacts include higher temperatures, loss of biodiversity, forest and land degradation, ocean acidification, sea level rise, and saltwater intrusion into freshwater sources (MINAE, 2021). Extreme events, such as the drought linked to El Niño conditions between 2014 and 2016, tropical storm Nate in 2017, and hurricanes Eta and Lota in 2019, have impacted the country's infrastructure and public services, resulting in the loss of millions of dollars. Sectors impacted include biodiversity, water resources, health, agriculture and fisheries, infrastructure, and urban development and tourism.

Approximately half of the population of Costa Rica, or approximately 2.6 million people, is concentrated in the greater metropolitan area of the capital, San José (Gran Área Metropolitana, or GAM), which makes up only about 4% of the country's territory. Climate change impacts in this urban area include high temperatures and increased flooding, compounded by air and noise pollution and uncontrolled dumping of wastewater (SINAC, n.d.).

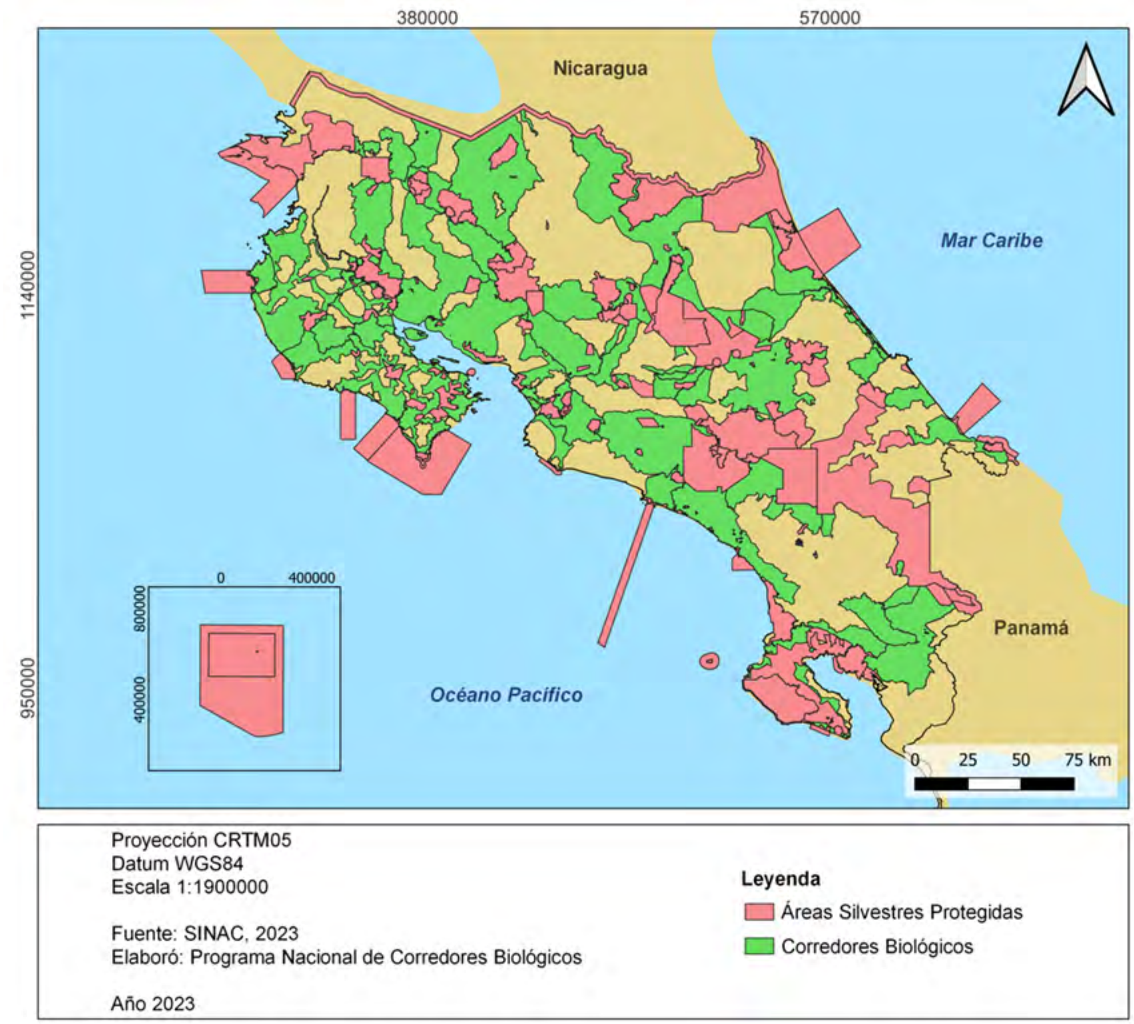
In April 2022, the Government of Costa Rica launched its first national adaptation plan (NAP), which sets out priority axes for enhancing climate resilience. These axes include strengthening conditions for the resilience of human and natural systems through planning of terrestrial, coastal, and marine areas (Axis 2) and managing biodiversity and ecosystems for adaptation and the well-being of local communities, including through ecosystem-based adaptation (Axis 3) (Dirección de Cambio Climático; Ministerio de Ambiente y Energía, 2022). Aside from climate impacts such as warming air temperatures and increased flooding events, the growing city is challenged by air pollution, uncontrolled dumping of wastewater, and noise pollution.

The Role of Biological Corridors in Responding to Climate Change

A biological corridor (also known as an ecological or wildlife corridor) is an area of land, coast, or sea that connects protected areas across landscapes, ecosystems, and habitats, enabling the movement of wildlife and the flow of ecological processes (Palmeri et al., 2017). Biological corridors have proved to be successful at increasing movement between fragmented wildlife populations, providing space for flora and fauna to adapt to climate change and reducing human–wildlife conflicts (Resasco, 2019; Zellmer & Goto, 2022). However, implementing wildlife corridors in cities is difficult due to high levels of habitat fragmentation: that is, wildlife habitat is broken up by multiple roads, land parcels, and jurisdictions. Other challenges include the changing land ownership and difficulties in reconciling competing stakes in conservation initiatives, given the diverse number of actors in urban areas (Zellmer & Goto, 2022).

Biological corridors are important conservation strategies in Costa Rica, maintaining biodiversity and ecosystem processes that contribute to adaptation and promoting investments in conservation efforts (SINAC, n.d.). They are managed by SINAC, an agency of the Ministry of Environment and Energy, through the National Program of Biological Corridors. The program's mandate is to create, consolidate, and manage interurban biological corridors, coordinating with other institutions, civil society, and the private sector to raise awareness of the role of the corridors in enhancing biodiversity while contributing to sustainable urban development and a higher quality of life and human well-being for the inhabitants of the GAM. The program places a heavy emphasis on participatory processes, including local management committees with stakeholder representatives. Currently, there are 52 biological corridors in Costa Rica, representing 38% of the country's land, of which seven are interurban corridors (Figure 4). These corridors are currently being assessed for progress in promoting ecological connectivity.

Figure 4. Protected areas and biological corridors, Costa Rica



Source: SINAC, 2023, reproduced with permission.

Box 4. Costa Rica's Biological Corridors

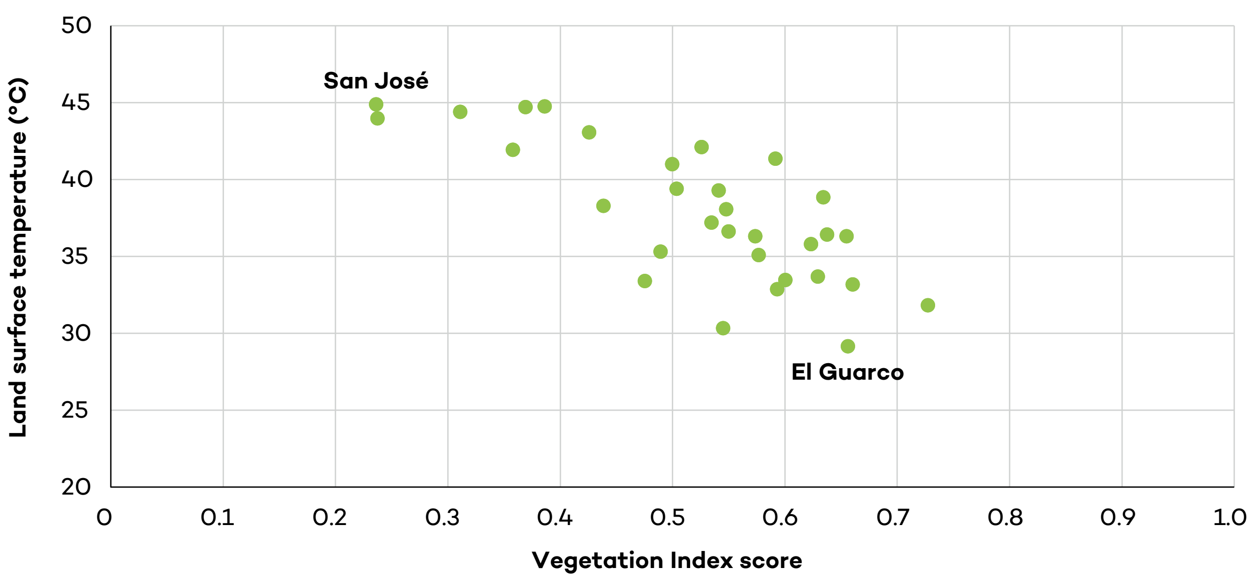
Biological corridors are a key component of Costa Rica's NAP, which calls for the establishment and management of these corridors to conserve biodiversity outside of protected areas and support the provisioning of ecosystem services that are important for climate adaptation. Twelve potential new bio-corridors have been identified in the NAP, of which three have been established: 1. Amistosa, in the Pacific Ocean; 2. Parismina, in the northern Caribbean Sea; and 3. Mono Aullador, in the Cuenca del Río Tempisque. The NAP also calls for the restoration of 200 hectares of land as interurban biological corridors in the greater metropolitan area of GAM.

The Biodiver_City Project

San José is the largest city in Costa Rica. It is prone to flooding due to altered river channels, mountainous terrain, and the lack of permeable natural surface areas for water infiltration, which have been replaced by roads, buildings, and other infrastructure as the city has grown. In addition, the paved and built surfaces contribute to the urban heat island effect, as these artificial surfaces absorb and retain more heat than natural areas (see Figure 5). In response, MINAE and SINAC are working with the GAM municipalities to implement a program for the sustainable management of watersheds, supported by GIZ.

The Biodiver_City project aims to establish two interurban biological corridors along the María Aguilar and Río Torres river watersheds, connecting these corridors to a large network of natural areas as part of the National Program of Biological Corridors. The project aims for public institutions (MINAE, SINAC, and municipal administrations) and key stakeholders (including private sector actors, non-governmental organizations, and academia) to incorporate urban ecosystem services and the establishment and management of interurban biological corridors as part of urban development planning. SINAC works with partners to create and support the interurban biodiversity corridors, while their management is directed by the municipalities. Overall, the team and partners are comprised of MINAE, SINAC, GAM municipalities, and GIZ, working in close cooperation with civil society organizations, academic institutes, and the private sector.

Figure 5. Relationship between surface temperature and vegetation index for different cantons in the greater metropolitan area of San José



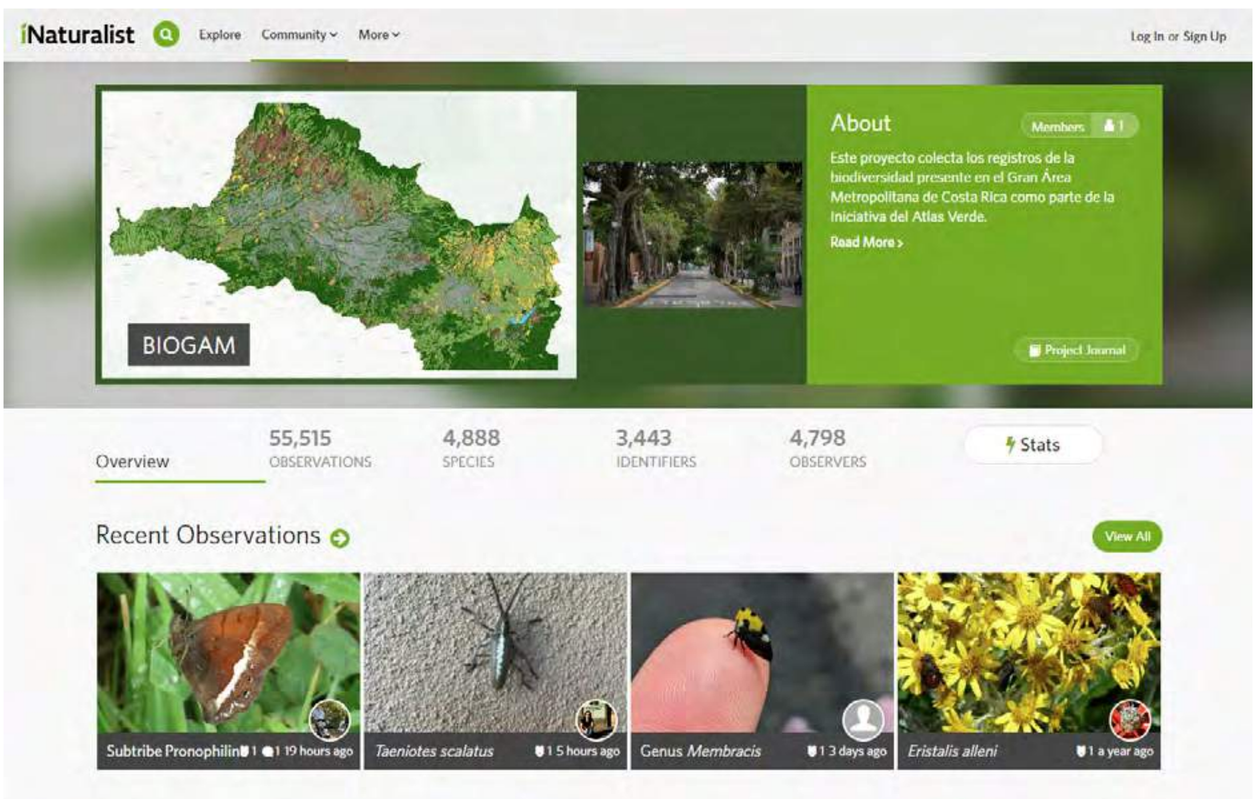
Source: Atlas Verde, 2021.

The Biodiver_City project illustrates the biodiversity considerations that are needed for implementing NbS for adaptation, as described in the NCAI biodiversity technical brief, particularly Step A: Understanding the System and Step F: Monitoring, Evaluation, & Learning.

Assessing and Mapping Critical Ecosystem Services and NbS

The implementing team used extensive existing studies to understand the biodiversity and ecosystems of the GAM. They developed a map delineating public, municipal, or private ownership of green areas in the city and conducted numerous biodiversity and ecosystem assessments for the two interurban biological corridors and for the GAM as a whole. The ecosystem services were mapped out in detail and included regulating services, such as moderating climate extremes, cultural ecosystem services (including aesthetic benefits), and supporting services, such as habitat for biodiversity. Completed assessments were made publicly available in the online Atlas Verde de la Gran Área Metropolitana, which maps out species at risk, important connectivity routes for various species, existing protected areas, and the overall area covered by the interurban biological corridor. As part of the atlas, citizen scientists can also record sightings of biodiversity in the iNaturalist mobile phone nature app (Figure 6).

Figure 6. Biodiversity records collected by citizen scientists in the iNaturalist mobile phone app as part of the Atlas Verde de la Gran Área Metropolitana



Source: Screenshot of https://www.inaturalist.org/projects/biogam.

A guide to NbS complements the Atlas Verde, with the objective of enhancing the implementation of NbS in the different municipalities in the GAM. The guide provides recommendations and guidance on how to include nature in restoration and urban planning strategies and can be used both by city residents in their homes and gardens and at the municipal level by local governments.

In addition to extensive ecosystem studies, the project team conducted stakeholder engagement activities, including mapping out key actors representing conservation, municipalities, land-use planning, and urban settlements. The implementing team has included local governments, the Ministry of Housing and Urban Human Settlements, the National Institute of Housing and Urbanism, and various civil society organizations as project partners, with overall joint implementation by MINAE and SINAC.

Developing a Wide Range of Indicators to Track Changes in Biodiversity, Connectivity, and Ecosystem Functioning

The project team has developed 15 groups of indicators to measure project success under the pillars of sustainability, resilience, health and well-being, and equality, inclusion, and participation. These indicators were adjusted and refined following a pilot phase. In terms of biodiversity, SINAC (the implementing agency) already had a robust monitoring program in place due to its legal mandate to monitor biodiversity within protected areas. Their program includes bird counts, monitoring of fish and benthic organisms, and camera traps to capture the movement of iconic species such as jaguars and tapirs.

Outside of the biological corridors, SINAC implemented participatory biodiversity monitoring using citizen science apps, with data uploaded to a general database, which helped set baseline conditions. Currently, the team is working on identifying indicator species as proxies for ecosystem health, defining connectivity routes for birds, and defining routes for tourism, such as for birdwatching. Work is also being done to understand the spatial and temporal distribution of species at risk. The team continues to work on the identification of platforms and partners to support participatory monitoring. As a start, detailed methodological guides and monitoring templates are available to the general public, allowing for the systematized collection of data (Proyecto Corredores Biologicos Interurbanos, 2023).

Within the 15 groups of indicators, there are specific indicators related to urban biodiversity and climate change adaptation (Table 1), demonstrating that the project is oriented toward adaptation with biodiversity co-benefits. The biodiversity indicators cover not only area restored or conserved, but also changes in biodiversity, connectivity, and ecosystem functioning, given that a holistic consideration of these indicators is necessary to fully and effectively generate biodiversity co-benefits from NbS projects (Lo & Rawluk, 2023).

Table 1. Biodiver_City: Examples of urban biodiversity and resilience targets and indicators

Targets	Indicators	
Urban biodiversity: The city increases and strengthens urban biodiversity	1.1	Percentage protected natural areas
	1.2	Change in biodiversity of native or naturalized flora and fauna
	1.3	Index of biological connectivity
	1.4	Percentage of green areas
	1.5	Percentage cover of riparian vegetation
	1.6	Change in tree density
	1.7	Percentage city surface area in the process of recovery, ecological restoration, and natural rehabilitation
Resilience: The city is adapted to climate change impacts and strengthens its resilience	10.1	Annual economic losses in the city due to natural disasters
	10.2	Percentage of residents living in high-risk zones
	10.3	Percentage of businesses located in high-risk zones
	10.4	Percentage of the city covered in areas under threat
	10.5	Percentage of low-threat areas that have implemented NbS to reduce risks and vulnerability
	10.6	Local emergency care committees are active and trained in risk management through NbS
	10.7	Percentage of formal and informal settlements located in protected areas

Source: MINAE, 2022.

SINAC has also developed a management-effectiveness monitoring tool for the corridors, which consists of environmental, social, and economic indicators to determine the impact of the interurban biological corridors and a self-assessment tool that allows each local committee to analyze and evaluate its progress. The indicators consider landscape composition, biodiversity, management, water resources, waste management, the occurrence of mammals, avian routes, and the presence of endemic flora and fauna, among others.

The results of the project in terms of biodiversity and adaptation are currently being evaluated using these indicators (see Table 1). For example, annual bird counts had been carried out for each biological corridor but had not yet been systematically conducted for the seven interurban corridors. In 2023, a project grant enabled the first annual bird count in the interurban corridors

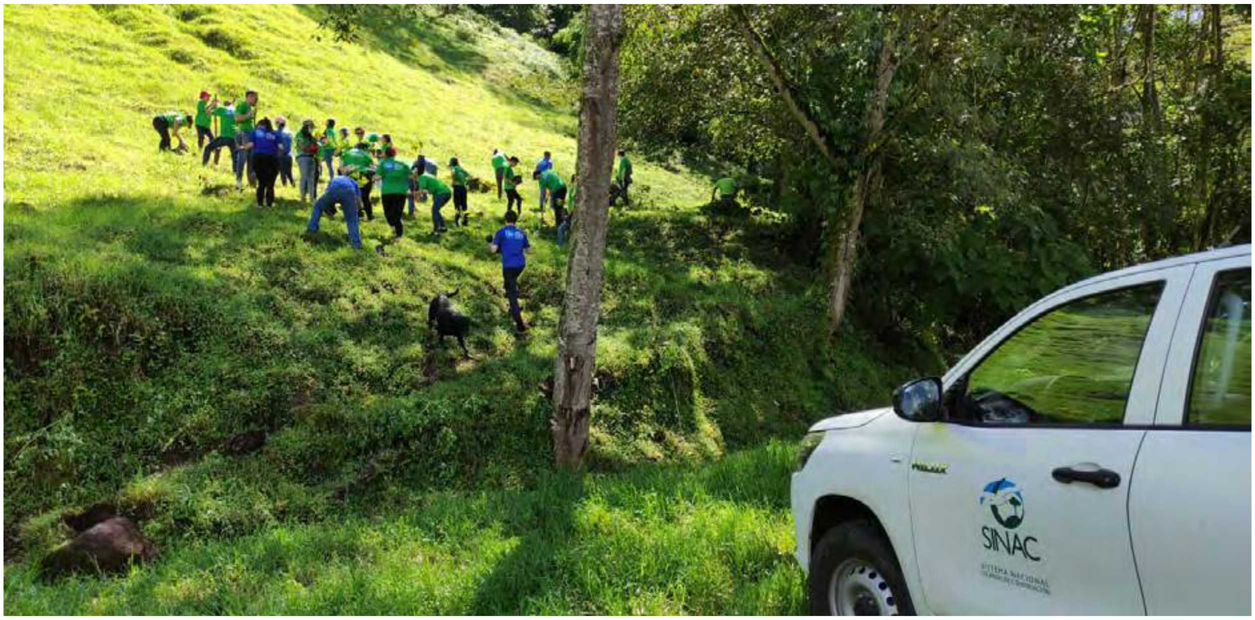


Photo: Jairo Sancho Rodríguez

for both the dry and rainy seasons, which will serve as a baseline for the assessment of bird biodiversity in the future.[1]

Other significant project achievements include the following:

- The limits and zonation of interurban biological corridors were established in the GAM and integrated into municipal planning.
- A "green city" concept was defined and agreed between the Ministry of Environment and Energy; other government agencies in charge of land management, urban settlements, and housing; and at least 15 municipalities within the GAM.
- The Atlas Verde, a Guide to Ecosystem Services, a catalogue of NbS, and other tools were made available to municipal decision-makers to integrate ecosystem services into urban planning.
- Two local committees for planning and management of the two interurban biodiversity corridors were established, along with participatory management plans.
- Awareness-raising campaigns on the value of biodiversity and ecosystem services were carried out on television, radio, media, and social media.

[1] This was a grant from the Global Environment Facility-funded project titled "Transitioning to an Urban Green Economy and Delivering Global Environmental Benefits," led by MINAE and implemented by the United Nations Development Programme in partnership with the Organization for Tropical Studies.

Lessons Learned

Several lessons from the Biodiver_City project can be applied to other urban greening and adaptation initiatives, particularly with regard to the design of biological corridors and coordination among different levels of government and project partners.

Overlapping Responsibilities and Jurisdictions Among Project Partners

One particular challenge was overall coordination among implementing and partner organizations, understanding who would "run the show" and when. For example, while SINAC has overall responsibility for the management of protected areas, urban settlements have now encroached onto protected areas, resulting in ambiguity between what the Ministry of Housing and SINAC were each responsible for. Coordination between municipalities and cantons was also difficult, given that biodiversity and ecosystem services flow across political boundaries. Thus, clearly defining roles and the scope of participation within the project is essential.

Mainstreaming Adaptation and Ecosystems Into Land Management and Urban Planning

Environmental considerations are not always reflected or mainstreamed in the work of partner organizations; for example, the relationship between urban settlements and the environment was not clearly understood. As such, these linkages should be clearly communicated and integrated into land management and city planning.

Overall Coordination of Green Initiatives in the GAM Is Needed

There are many initiatives related to green cities, sustainable cities, social welfare, clean rivers, and urban trees in Costa Rica; however, these are not well coordinated, given the lack of clarity regarding who is responsible for working on environmental issues in cities. As a result, the initiatives are operating in isolation and independent of one another. More strategic coordination of these initiatives is needed.

Need for Clearly Defined Priorities

There is a need for the government to define priorities for the GAM, whether it be job opportunities or green cities, and then delineate clear roles and guidance on projects and link it to national planning. The urbanization problems seen today in San José will be experienced in other cities that are beginning to expand, so a unified country vision for urbanization is needed.

Habitat Connectivity Considerations

There has been a lack of research and management attention to the ecological functioning of the biological corridors. For example, an evaluation of Costa Rica's biological corridors found that, as presently designed, they are able to maintain populations of iconic species such as the panther and certain pecari species (Beita et al., 2021). The habitat requirements for different species should be integrated into the design of more effective corridors that consider food and water

Photo: Jairo Sancho

sources for species, habitat types, optimal size to accommodate movement, and behaviour. In addition, biological corridors can benefit from a variety of elevation ranges, and they can be made more effective at fostering connectivity by complementing the corridors with activities such as restoration and management of remnant forests (Beita et al., 2021).

Biodiversity as a Driver of Development

The integration of biodiversity and ecosystem services into urban planning enabled the identification and development of new green ventures and businesses for local organizations and communities. These opportunities included urban ecotourism, commerce, circular economy, and recreation and leisure opportunities. The “green city” model contributes to a higher quality of life in cities that provides livelihoods, health, and well-being benefits, alongside adaptation and biodiversity co-benefits.

Conclusion

The two case studies demonstrate the practical aspects of understanding the system targeted for adaptation, from conducting biodiversity and ecosystem service assessments to mapping climate risks for urban populations. The case studies also demonstrate different considerations for monitoring, evaluation, and learning, including ways of integrating citizen science to boost monitoring efforts.

To ensure that NbS for adaptation interventions deliver biodiversity co-benefits (and thereby support resilient ecosystems), projects must be designed from the outset to provide measurable benefits for ecosystem health. Based on the local ecosystem context, these two case studies demonstrate how to combine different tools and methods to improve ecosystem health and capture a holistic picture of the biodiversity co-benefits gained from NbS for adaptation projects.

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