Chapter 3

Strengthening Systemic Resilience: Mainstreaming Nature-based Infrastructure Solutions

3.

Strengthening Systemic Resilience: Mainstreaming Nature-based Infrastructure Solutions

3.1. Introduction

The application of nature-based solutions has far-reaching potential to support the transition to low-carbon-resilient infrastructure

Owing to the long lifecycles of most infrastructure assets, choices made today on the types, features, and locations of infrastructure will heavily influence the world's ability to shift to lower carbon trajectories and strengthen systemic resilience.

Efforts to limit global warming to 1.5°C above pre-industrial levels[17] now require rapid and far-reaching transitions in energy, land, urban and industrial systems, and infrastructure. Ninety percent of today's infrastructure has been built over the last 50 years (IPCC, 2018). Meanwhile, 60 percent of the infrastructure needed by 2050 is yet to be built. This increases the need to immediately transition from a 'business-as-usual' to a low-carbon-resilient infrastructure.

The application of nature-based infrastructure solutions (NbIS) in sectors such as water and hazard mitigation has a far-reaching potential to support this transition (Box 3.1). NbIS not only have a low carbon footprint and address climate mitigation objectives but also offer a wide range of other co-benefits. For example, the use of deep-root systems for slope stabilization has been estimated to produce 85–90 percent savings compared to traditional engineered solutions (Truong, n.d.) Likewise, mangrove conservation and restoration not only protect coastal areas against storm surges but also improve water quality, replenish fish stocks, safeguard ocean health, and reduce coastal erosion (INFC, 2022).[18] In urban areas, green roofs, permeable surfaces, and vertical gardens address urban flooding and heat islands while at the same time reducing energy consumption.

Infrastructure design and use affect both climate change mitigation and adaptation (Rydge et al., 2015). As a result of the long lifecycles of most infrastructure assets, choices made today will heavily influence the ability

[17] Included as an aim, but not a binding commitment, under the Paris Agreement

[18] For example: https://www.iucn.org/regions/asia/our-work/regional-projects/mangroves-future-mff and https://cicloud.s3.amazonaws.com/docs/default-source/s3-library/publication-pdfs/guyana-green-gray-infrastructure-engineering-guidelines-inclexecsumm-final-updatedfront.pdf?sfvrsn=fa704d98_2

↓ BOX 3.1

Nature-based Infrastructure Solutions

Nature-based infrastructure solutions (NbIS) refer to practices that concurrently protect and provide infrastructure, adapt to climate change, promote environmental integrity and biodiversity, and provide social well-being. If widely adopted, they can play a crucial role in strengthening resilience.

The concept of ecosystem services (what nature provides for people) has evolved into the broader concept of nature-based solutions, based on the insight that while nature provides services for people, people also need to protect nature and safeguard environmental integrity and biodiversity to continue to receive societal benefits (Cohen-Shacham et al., 2016; WB, 2006). Nature-based solutions encompass the idea that humans should work with nature, not against it (Sowińska-Świerkosz and García, 2022).

Nature-based solutions are defined as '*...actions to protect, conserve, restore, sustainably use, and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic, and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, and resilience and biodiversity benefits*' (UNEA-5, 2022).

Nature-based solutions can be considered an umbrella concept encompassing practices such as ecosystem-based management, forest landscape restoration, ecological restoration, bioengineering, protected area management, watershed health, and ecosystem-based adaptation (Wadhawan and Bajpai, 2023). The term 'NbIS' is used in this report to refer to the application of nature-based solutions to address infrastructure requirements. In other words, it means directly connecting the natural environment with the built environment (FEMA, 2021).

IUCN (International Union for Conservation of Nature) offers the following eight criteria to assess what NbS is, to avoid misuse of the term "nature-based" for green-washing traditional grey projects (IUCN, 2020):

1. Nature-based solutions effectively address the societal challenges of climate change mitigation and adaptation, disaster risk reduction, economic and social development, human health, food and water security, and environmental degradation and biodiversity loss.
2. The design of nature-based solutions is informed by scale.
3. Nature-based solutions result in a net gain in biodiversity and ecosystem integrity.
4. Nature-based solutions are economically viable.
5. Nature-based solutions are based on inclusive, transparent, and empowering governance processes.
6. Nature-based solutions equitably balance trade-offs between achieving their primary goal(s) and providing multiple benefits.
7. Nature-based solutions are managed adaptively, based on evidence.
8. Nature-based solutions are sustainable and mainstreamed with an appropriate jurisdictional context.

Different terms are used for nature-based solutions in different geographical contexts. For example, *Green Infrastructure* (European Union), *Green Growth* (Vietnam), *Low-impact development* (USA), *Water-sensitive urban design* (Australia), *Natural Infrastructure* (Peru), *Ecosystem-based Adaptation* (India), and so on (Millennium Ecosystem Assessment, 2005). Ultimately, the terminology itself is less important than the concept behind the term.

of countries to shift to lower carbon trajectories (OECD et al., 2018) and strengthen systemic resilience, in LMICs where most infrastructure investment will occur in the coming decades.

If investments in fossil fuel-based infrastructure continue, countries will be locked into higher emissions, making it impossible to limit warming to 1.5°C or 2°C. It will also lead to leaving behind stranded assets in the energy, building, and transportation sectors and increasing fiscal constraints, thus reducing options for future responses (IPCC, 2018). Avoiding this lock-in requires a radical change in infrastructure governance and how infrastructure is designed and used (Seto et al., 2016).

Countries will have to transition towards low-carbon infrastructure systems to establish low-carbon and climate-resilient pathways that align with the Paris Agreement and meet their commitments under their Nationally Determined Contributions (NDCs). This is critical for limiting climate change and potentially catastrophic increase in disaster risks (Saha, 2018). Given the magnitude of already accumulated risk in LMICs, not taking aggressive action now means reducing future options for strengthening systemic resilience, as increasing loss and damage will further widen an already massive infrastructure deficit (Denton et al., 2014).

Chapter 1 discussed how the contemporary urban process, underpinned by investment in high-carbon infrastructure, *systemically* generates risk, which then feeds back into increasing infrastructure loss and damage. *Systemic* resilience, therefore, is contingent on designing infrastructure investments in a way that does not generate new systemic risk. Climate change mitigation and adaptation are the principal paradigms through which systemic risk is currently being addressed. However, progress in climate change adaptation is still 'unevenly distributed, fragmented, small in scale [and] incremental'. As a result, 'gaps exist between current levels of adaptation and levels needed to respond to impacts and reduce climate risks'. These gaps are 'partially driven by widening disparities between the estimated costs of adaptation and documented finance allocated to adaptation', meaning that the 'overwhelming majority' of global climate finance has so far been targeted at climate change mitigation (IPCC, 2023).

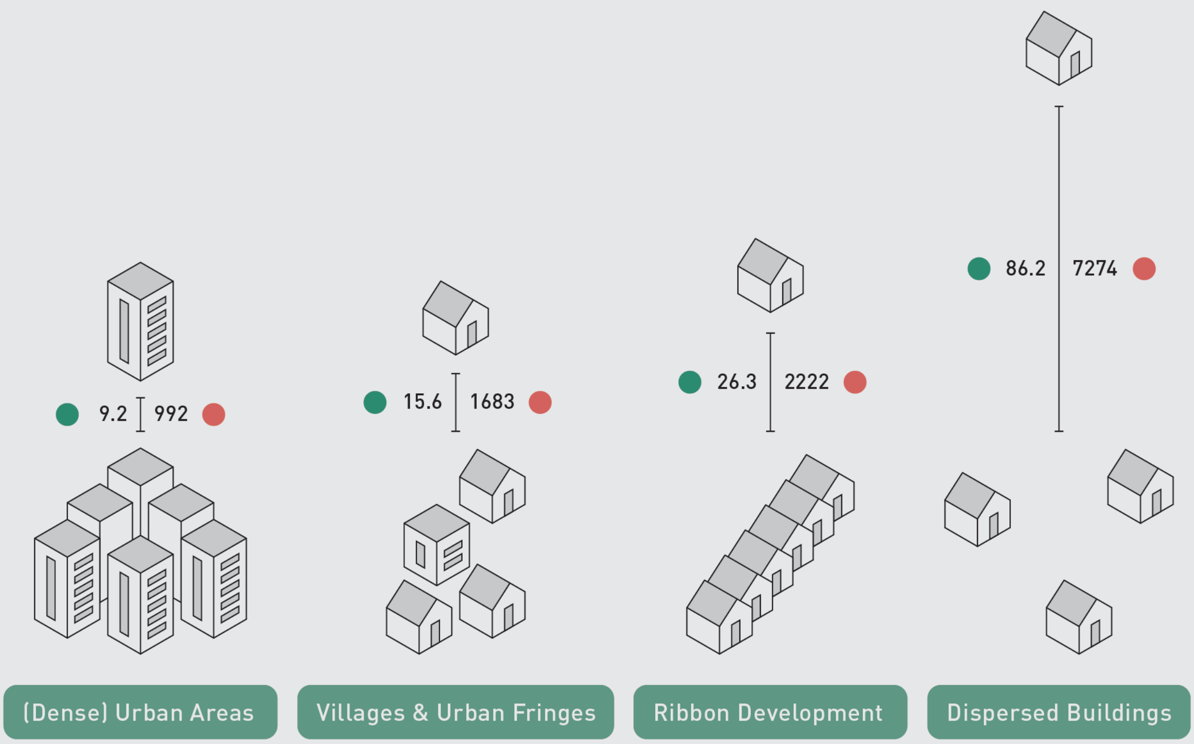
Systemic risk is associated not only with climate change but also with a range of concatenated drivers, including loss of biodiversity, poorly managed and planned urban development, growing social inequality, and weak governance. Strengthening systemic resilience, therefore, is not limited to climate change mitigation and adaptation but addresses a broader agenda. As Chapter 2 highlights, while climate change will increase the risk to infrastructure assets, particularly in LMICs, most of the infrastructure risk is already locked in or associated with geological hazards, such as earthquakes, tsunamis, and earthquake-induced landslides.

Fortunately, how infrastructure is developed and used is undergoing a rapid transformation. **Disruptive technologies in the energy, transportation, and construction sectors are now achieving the economies of scale necessary to be economically competitive. Fossil fuel-generated electricity costs 5–17 cents per kilowatt-hour, while solar energy-generated electricity costs only 3–6 cents per kilowatt hour and is trending down** (IRENA, 2021). In high-income countries, new building technologies, electric vehicles, and more efficient appliances are enabling a reduction in energy consumption.

↓ FIGURE 3.1

Comparing Costs of Infrastructure and Utilization across Different Urban Configurations

Source: Adapted from Vermeiren et al. (2022)



	(Dense) Urban Areas	Villages & Urban Fringes	Ribbon Development	Dispersed Buildings
Car	21	27.8	32.6	34.1
Bus	2	1.7	1.4	2
Train	3.7	2.6	2.8	2.2
Bike	1.2	1.7	1.9	1.9
Walking	0.8	0.5	0.5	0.3
Motorcycle	0.2	0.3	0.4	0.5
Other	0.9	0.9	2	2.6
Total	29.8	35.5	41.6	43.7

4.6 6.8 8 8.6

- Average running meter of infrastructure network per building
- Average annual infrastructure cost per building (€)
- Average passenger-km per day per transport mode
- Average daily transportation cost per person per urban sprawl type (€)

Moreover, smart energy systems, such as microgrids, are enabling renewable energy to feed more efficiently into national grids.

These technological changes are already reconfiguring investment flows. As highlighted in Chapter 1, about three-quarters of private infrastructure investment is concentrated in high-income countries, half of which has flowed into renewable energy generation, storage, and transmission. Unfortunately, LMICs have attracted only a quarter of this investment which is still flowing into sectors such as non-renewable energy and transport, which will further lock in systemic risk.

Other required transformations, for example, in urban layout and design, are lacking. Figure 3.1 highlights how more efficient urban layouts and design can dramatically reduce infrastructure costs, make more efficient use of land, reduce transportation costs and associated carbon emissions, and mitigate urban flood hazards.

In the case of NbIS, the potential benefits have been demonstrated in different country contexts through a wide range of applications. However, formidable obstacles to their widespread adoption remain. Many of the ecosystems that were the foundation for NbIS are in decline. Furthermore, the knowledge and capacities necessary for designing and implementing NbIS are insufficiently developed. Methods for identifying, estimating, and realizing the benefits and co-benefits of NbIS can provide are yet to become mainstream. Therefore, the absence of standards and documented best practices hinders the adoption and financing of NbIS. This chapter examines how these challenges can be addressed and how the broad potential of NbIS to strengthen systemic resilience can be fully leveraged.

3.2. Ecosystems are Declining

Ecosystem degradation, compounded by anthropic climate change, is limiting the earth's ability to provide the ecosystem services people value and depend on. It is also increasing the risk to infrastructure. Ecosystem degradation is a major risk driver; therefore, protecting and restoring ecosystems is critical to risk reduction and resilience building.

Healthy ecosystems sustain life on the planet and provide ecological integrity, biodiversity, economic systems, and human well-being through four categories of ecosystem services: *Supporting services*, such as nutrient cycling, soil formation, and primary production; *Provisioning services*, such as food, water, wood, fibre, and fuel; *Regulating services*, such as flood control, climate regulation, disease control, and water purification; and *Cultural services*, such as education, recreation, aesthetics, and spiritual values (Millennium Ecosystem Assessment, 2005).

The degradation of ecosystems means these services cannot be provided. As of 2021, over a million species are under threat of extinction. Since the 1870s, over half of the world's corals have disappeared, and 75 percent of the land surface has been significantly altered. In the last 50 years alone, 85 percent of wetlands have been lost (Díaz et al., 2019). Ecosystem degradation, compounded by anthropic climate change, is a core risk driver. Thus, protecting ecosystems from degradation is critical to strengthening systemic resilience. Protection has greater potential to supply ecosystem services than trying to restore ecosystem functions on degraded landscapes. Therefore, without protecting the ecosystems on which living beings depend, NbIS cannot prosper (Box 3.2).

↓ **BOX 3.2**

The Feedback Relationships between Ecosystem Decline and Infrastructure Risk

Building sea walls has become an increasingly common climate adaptation strategy to address sea-level rise and storm surge. However, sea walls can negatively affect the self-regulating functions of coastal ecosystems, such as mangroves (Gilman et al., 2008). Mangrove loss, in turn, can increase the risk to sea walls during tidal changes and storm surges, reducing their protective capacity over time. Thus, NbIS in the form of replanting or protecting mangroves not only provides coastal protection *per se* but also may reduce the risk for other *hard* coastal infrastructure, such as sea walls.

↓ **BOX 3.3**

Five Functional Categories of NbIS
Source: UNEP (2022)

Deliver infrastructure services directly

NbIS can directly deliver infrastructure services like flood protection, water filtration, and temperature regulation. These services can reduce or avoid the need for engineered infrastructure assets. NbIS, such as wetlands, constructed wetlands, reeds, and ponds, can filter pollutants and assimilate wastes, providing water treatment services and reducing requirements for built wastewater treatment facilities.

Enhance engineered infrastructure function

NbIS can enhance the functioning of engineered infrastructure assets and systems. In addition to increasing the efficiency of service provision, NbIS also reduces the need for operation and maintenance. Riparian vegetation can stabilize soils and reduce sedimentation and turbidity of reservoirs, thus reducing the need for flocculants and mechanized maintenance such as dredging that can require service downtime.

Protect engineered assets

Some NbIS can protect engineered infrastructure assets from climate impacts such as flooding, high winds, and coastal inundation. Agroforestry, especially deep-rooted trees on slopes, can help in stabilizing soils and reducing the occurrence of shallow, rapidly moving landslides onto road networks (Forbes et al., 2012).

Benefit the workforce

Implementation of NbIS can boost the health of infrastructure sector workers, create employment and decent work, and improve the productivity and sustainability of existing employment in various sectors (ILO et al., 2022).

Deliver multiple additional social, environmental, and economic benefits

NbIS can deliver societal benefits that advance progress towards global targets, such as SDGs and the Paris Agreement (Cohen-Shacham et al., 2016). For example, NbIS promotes opportunities for women's involvement in decision-making and governance, particularly in rural areas (IISD, 2021). This can benefit labour force participation and lead to better social outcomes.

As Box 3.3 highlights, NbIS can be used to *complement, substitute for, or safeguard* traditional 'grey' infrastructure, particularly in the water and hazard mitigation sectors, thus representing a paradigm shift towards designing and building with nature (McHarg, 1969). NbIS also increases opportunities for women's involvement in decision-making and governance, particularly in rural areas (IISD, 2021), offering a win-win for both the environment and the society (Bassi et al., 2021).

Figure 3.2 illustrates potential applications of NbIS to address riverine flooding, urban heat islands, water scarcity, and coastal erosion and flooding.[19]

It is estimated that NbIS cost, on average, only 51 percent of grey infrastructure projects and that 11 percent of all grey infrastructure could be replaced by NbIS (Bassi et al., 2021). The greatest potential for NbIS is in the water sector due to the importance of functional ecosystems for water capture, storage, filtration, and transmission and in protecting grey infrastructure (UNEP, 2023). Over time, the effectiveness of grey infrastructure degrades while that of NbIS increases. For example, as sea walls depreciate in quality, well-protected mangroves become stronger and more widespread as they grow older, thus strengthening resilience.

[19] Additional hazards and potential solutions can be found in position paper 3.1 (USFS, 2023).

As NbIS provide social, environmental, and economic co-benefits, their widespread adoption would influence the achievement of 115 of the 169 targets across all 17 SDGs. In specific infrastructure sectors, adopting NbIS would influence up to 25 to 44 percent more SDG targets compared to using *grey* infrastructure alone (UNEP, 2023). NbIS also reduce carbon emissions across infrastructure lifecycles, which will enable avoiding land use change and extending infrastructure lifespans. Transitioning to NbIS has the potential to create an estimated 59 million jobs by 2030, including livelihood-enhancing jobs that are directly related to ecosystem protection and restoration (WEF, 2022). By providing essential services and strengthening assets, service, and systemic resilience, NbIS thus positively contribute to restoring environmental integrity, biodiversity, and societal well-being.

Unfortunately, despite this potential, the current investment in NbIS represents only 0.3 percent of overall infrastructure investment (WEF, 2022). In LMICs, substantial barriers exist to the widespread acceptance and implementation of NbIS, including those related to education, policy, governance, and finance (Ghosh & Soundarajan, 2023; Håkanson, 2021; S. Sarabi et al., 2020; S. E. Sarabi et al., 2019). To address each of these barriers and realize the potential of NbIS, innovative solutions need to be adopted.

→ **FIGURE 3.2**

Potential Applications of NbIS
Source: USFS (2023)

Coastal Erosion and Flooding

Driven by: • Sea level rise • Storm surge, high tides, high surf, freshwater flooding • Loss of mangroves, coral reefs, sea grass, dunes, deltas, and beach vegetation • Alteration of coastal sediment regimes • Infrastructure close to shoreline • Higher global average temperatures • Continental ice sheet melting and collapse • Glacial melting • Warmer oceans, thermal expansion • Coastal land subsidence: due to seismic, changes, sediment starvation, groundwater extraction, weight of infrastructure

Nature-based Infrastructure Solutions

- Move infrastructure out of sea level rise and tsunami zone and prevent future development
- Restrict development close to coast and on barrier islands
- Maintain or restore coastal wetlands in estuaries, mud flats, salt marshes
- Develop integrated management plans for: water resources; coastal zone management; coastal zone adaptation

- Maintain or restore mangroves, coral reefs, sea grass, dunes, and beach vegetation
- Maintain or restore natural sediment fluxes along shorelines
- Use forestry best practices
- Combine green and gray solutions
- Allow saltwater inundation where possible and beneficial

Outcomes: • Social • Enhanced liveability, coastal protection • Potential to increase food security • Reduced mortality • Reduced number of disaster refugees • Economic • Reduced damage costs associated with storms and flooding • Environmental • Increased carbon storage • Decreased storm damage to ecosystems • Protected critical coastal aquatic species habitat • Enhanced biodiversity • Captured sediments may keep pace with sea level rise • Maintained natural sediment fluxes • Reduced pollution

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Extreme Heat & Urban Heat Islands

Driven by: • Climate warming • Asphalt and concrete • Dark surfaces • Lack of tree cover • Lack of vegetation • Tall buildings, narrow streets, limited airflow • Fuel combustion • Heating, ventilation, and air conditioning exhaust

Nature-based Infrastructure Solutions

- Establish and maintain urban forests on streets and in parks
- Maintain and restore shade trees in riparian areas
- Establish vertical forests on buildings, green roofs, grassed sidewalks
- Maintain or restore bodies of water and aquatic ecosystems

- Use topographic shading and building orientation to reduce solar radiation
- Create community gardens and other green spaces
- Implement agro-forestry to increase tree cover and shading on farms and homes

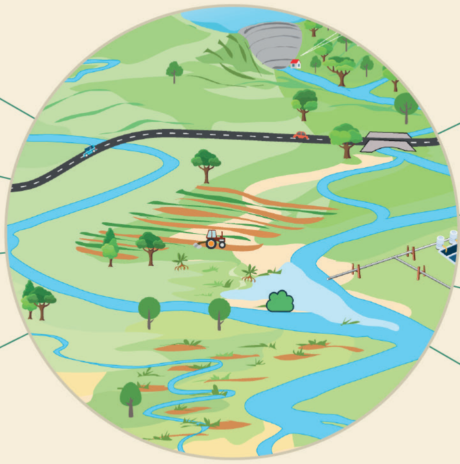
Outcomes: • Social • Reduced mortality • Decreased temperatures inside and out • Enhanced liveability • Potential to increase food security • Improved mental and physical health • Economic • Lowered utility bills • Reduced energy needs • Environmental • Increased carbon storage • Enhanced wildlife and pollinator populations • Improved air and water quality

Riverine Flooding

Driven by: • Extreme precipitation • Hardened surfaces, compacted soils • Increased runoff • Rapid snowmelt, glacial retreat • Water-repellent soils from fires • Encroachment of infrastructure into floodplains • Loss of wetlands and open water • Constricted floodplains and river channels • Channelization of deltaic rivers

Nature-based Infrastructure Solutions

- Use natural topography to capture, store, and slowly release water
- Minimize impervious surfaces and disconnect from waterways
- Evaluate watershed conditions and function
- Practice sustainable forest management and implement restoration and resilience treatments



- Maintain or restore wetlands, riparian buffer zones, retention ponds, streams, open water, forests, grasslands, and parks
- Allow stream channels to interact with floodplains
- Use regenerative agriculture techniques
- Establish integrated water resource plans

Outcomes: • Social • Reduced mortality • Protected vulnerable populations • Enhanced liveability • Economic • Reduced flood damage to infrastructure • Decreased damage costs • Environmental • Increased infiltration throughout watershed • Increased interaction of streams with floodplains • Reduced flood flows • Increased carbon storage • Enhanced wildlife and pollinator populations • Decreased water pollution • Enhanced spring system flows

Water Scarcity

Driven by: • Climate disruption • Increased evapotranspiration • Low rainfall, prolonged drought • Cross-basin water transfer • Water pollution • Overuse of water, groundwater depletion • Water-intensive crops • Inefficient or excessive irrigation practices • Accelerated runoff

Nature-based Infrastructure Solutions

- Maintain or restore stream systems, riparian buffers, wetlands, forests, with native vegetation species
- Maintain depth, infiltration capacity, permeability and cover of watershed soils
- Minimize impervious surfaces
- Regulate groundwater withdrawal

- Convert irrigation systems for water-use efficiency
- Grow drought-resistant crops in drought-prone areas
- Regulate and limit irrigation on highly porous soils
- Install permeable pavements, green roofs, and rainwater collection systems that can store runoff for reuse

Outcomes: • Social • Efficient use of water leads to increased availability • Reduced need for irrigation • Improved livelihoods • Improved health • Increased food security • Economic • Jobs are created • Reduced need for large-scale irrigation • Environmental • Increased organic matter and water content of soil • Increased carbon storage • Reduced runoff • Increased infiltration stores water on landscape for slow release during droughts and aquifer recharge • Increased water levels in springs, creeks, rivers • Reduced pollution • Increased biodiversity

3.3. Challenges and Opportunities for Integrating NbIS into Infrastructure Delivery

3.3.1. Knowledge and Capacity

Improved access to knowledge increases awareness and understanding of the capacity of NbIS to complement, substitute, or safeguard historically grey infrastructure.

Many LMICs also lack core knowledge of ways to introduce NbIS. Few professionals have experience in the planning, designing, implementing, maintaining, and monitoring of NbIS. Local government officials, civil engineers, households, investors, insurers, and MDBs, among others, may not have managed or previously imagined how NbIS can strengthen infrastructure resilience.

While grey infrastructure projects are generally planned and designed solely by engineers, NbIS require new interdisciplinary knowledge and skill sets that engineers and architects do not necessarily possess. For example, incorporating rain gardens or wetland features into urban infrastructure requires a holistic analysis rather than a linear calculation of surface runoff in a storm drainage system. Knowledge about the sustainability of ecosystems is required to avoid further degradation that would undermine the potential for NbIS.

University curricula are often outdated, slow to change, professionally siloed, and unfit to address interdisciplinary challenges such as NbIS. Rarely can one find research that quantifies ecosystem services, integrates nature-based values into modelling and cost-benefit accounting, and facilitates the design of NbIS. Even if such research exists, it is often not translated into practice. Moreover, it is difficult to access literature on NbIS which has been peer-reviewed for veracity, relevance, or trustworthiness. Finding literature on NbIS in languages other than English is rarer still.

As a result, a new approach is required to build capacities and share knowledge. Integrating NbIS concepts in engineering, urban planning, and architecture curricula is critical, as is introducing capacity-building programmes for infrastructure planners and managers in national and local governments, regulators, and utilities. Carefully reviewed, curated, up-to-date, and publicly available research, libraries, guides, design standards, and case studies, tagged by topic, are essential, including in different languages and multimedia formats such as mobile apps, webinars, and podcasts. All countries, particularly LMICs, will need national centres of excellence in NbIS, with the capacity to document and research good practices, disseminate knowledge, provide outreach to practitioners, and network information with other countries. Box 3.4 illustrates UNDP's efforts to integrate NbIS to strengthen storm and flood protection along the 3260-km coastline in Vietnam.

Curating literature on NbIS will encourage the emergence of *Communities of Practice* (CoPs). Bringing together land use planners, civil engineers, coastal specialists, foresters, infrastructure policymakers, hazard and risk modellers, financing experts, and others[20] in CoPs will be critical to moving NbIS into the mainstream. CoPs can help bind together and provide mutual support between local initiatives, increasing the confidence of households, communities, businesses, and local governments and sharing good practices to assist other communities facing similar issues.

Mature CoPs will also stimulate the national markets for professional services and technology necessary to implement NbIS projects through the creation and spin-off of small- and medium-sized NbIS businesses. *Exotic* locally championed and isolated projects may become *quotidian* normative practices, supported by mature markets for technology and professional services and readily available finance.

Box 3.5 illustrates how a not-for-profit organization can adopt an innovative initiative, utilize diverse funding sources, and support the contextual application of NbS through training and education for local government staff, developers, community members, and other relevant stakeholders (INFC, 2022). Monitoring project performance is critical to providing evidence-based proof of concept; it supports the adaptation of designs and adoption of additional and more expansive projects and helps to prioritize and focus on NbIS to enhance beneficial outcomes. Standardized quantitative metrics on data types, costs, benefits, and performance over the long term are required to develop benchmarks for success and effectiveness that can be compared across different interventions, sectors, contexts, NbIS, and engineered solutions (UNEP, 2022).

↓ BOX 3.4

Vietnam Coastal Communities Adapt to Climate Change

Source: USFS (2023)

In collaboration with the Vietnamese government and the Green Climate Fund, UNDP is strengthening storm and flood protection for coastal communities along the 3260-km coastline in Vietnam. The project is based on nationwide climate risk assessments, innovative architectural solutions, and NbIS. By planting and rehabilitating mangrove and nipa palm forests, the project is enhancing biodiversity and restoring coastal ecosystems and, in turn, benefiting the livelihoods of coastal communities.

To create storm surge buffers, 4000 hectares of mangroves will be planted, creating local jobs, and enhancing fisheries that support coastal livelihoods and ecotourism opportunities. Local community members are engaged in the design, implementation, and maintenance of storm- and flood-resilient housing benefiting up to 20,000 people and in the project's decision-making processes. By enhancing their understanding of the importance of sustainably managing mangroves and nipa palm forests, the project has helped coastal residents to strengthen their livelihoods through involvement in ecological and environmental protection.

[20] As an example, the Global Green-Grey Infrastructure Community of Practice is a forum for collaboration across the conservation, engineering, finance, and construction sectors to generate and scale-up green–grey climate adaptation solutions. The multidisciplinary CoP has grown to a global membership exceeding 140 organizations in the NGO, academic, government, and private sectors working to share ideas and facilitate collaboration; innovate and pilot new approaches; expand science, engineering, and policy activities; and implement and learn from projects in varied geographies and settings.

Linking NbIS monitoring to the achievement of the SDG and the goals of the Paris Agreement, the Bonn Challenge, the New York Declaration on Forests, the UN Decade on Ecosystem Restoration, and regional commitments, such as the 20x20 Initiative in Latin America, may also facilitate greater uptake of NbIS (Buckingham et al., 2019).

↓ BOX 3.5

Integrating Local and Indigenous Knowledge into Planning and Design: Stewardship Centre for British Columbia, Green Shores Program

Source: INFC (2022)

In 2005, the Stewardship Centre for British Columbia (SCBC) adopted the Green Shores Program and mobilized and refined it to accelerate ecological restoration approaches. The program provides technical NbIS guidance at three scales: local government, shoreline development, and homes. The programme builds awareness and capacity for local governments through workshops, one-on-one coaching, and milestone-based certification. The Green Shores Credits and Rating Guide helps homeowners, builders, and developers identify the benefits of NbIS through a rating system that rewards participants.

It is an inclusive process that brings developers, community members, local governments, and First Nations together in planning and design. One of the RC4S project sites, on K'omoks First Nation territory, facilitates collaborative NbIS design activities and the sharing of local and traditional knowledge, involving stakeholders from K'ómoks First Nation, Project Watershed, Northwest Hydraulic Consultants, Hapa Collaborative, Paul de Greef Landscape Architect, Pacific Salmon Foundation, and SCBC.

The programme provides technical support to assess the trade-offs between options and realize the social, economic, and environmental benefits. The report, *Green Shores 2020: Impact, Value and Lessons Learned*, shows the social impacts and extended cost-benefits of the projects in British Columbia (Eyzaguirre et al., 2020).

3.3.2. Identifying, Mapping, and Estimating Risk and Resilience

Without a credible and robust risk identification and estimation process at an appropriate scale, it is impossible to identify the resilience dividends that can accrue through adopting NbIS, compared with conventional grey infrastructure, thus blocking potential opportunities.

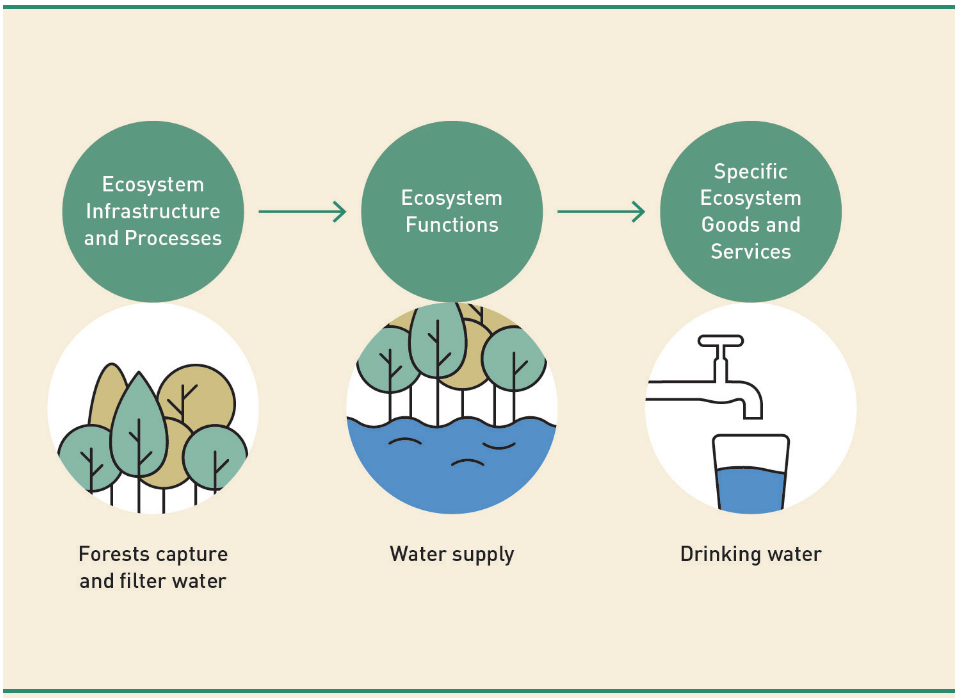
Ecosystems must be fully integrated into infrastructure planning and development at multiple scales to strengthen resilience. This requires recognition that resilience is contingent on healthy ecosystem function and an understanding of the impact environmental hazards has on infrastructure assets and of the way infrastructure can be a driver of increased systemic risk. For different scales of assessments, mapping and updating key elements at regular frequency is critical. For instance, at the national level, mapping and tracking river systems or the coastline alongside developmental changes can help build an understanding of their causal relationships with risk. At the project level, refinement of this mapping with community input can enable ecosystem fragility to be considered in project design to avoid damage or access to sensitive ecosystems that contribute to systemic resilience.

Figure 3.3 illustrates the connection between a healthy ecosystem, its functions, and its services. NbIS often harness the protective functions of ecosystems such as stormwater retention, wildfire resilience, slope stabilization, and infiltration.

The GIRI does not currently estimate the risk to ecosystems, though it should in the future. However, the necessary information on global biodiversity

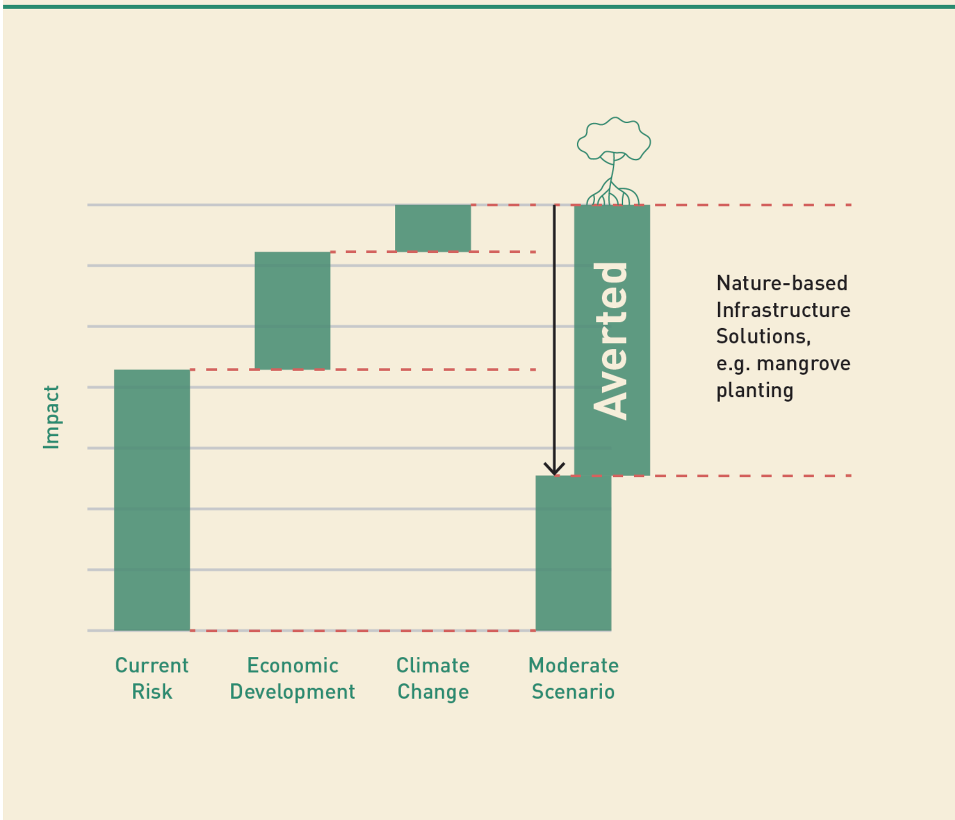
→ **FIGURE 3.3**

Mapping and Understanding Ecosystems
Source: USFS (2023)



hotspots and vulnerable ecosystems is already available (Chaplin-Kramer et al., 2022). As highlighted in Chapter 2, probabilistic risk identification and estimation, including modelling the underlying climate-related and geological hazards, the existing or potential future infrastructure assets exposed to those hazards and their vulnerability, and the modification of all the above through climate change and other risk drivers are the factors that need to be considered when estimating the contingent liability in infrastructure. A credible and robust risk identification and estimation process, at an appropriate scale, can help clearly identify the resilience dividends that can accrue through adopting NbIS.

This kind of analysis is critical to strengthening the case for NbIS but is rarely included in project design. Financial risk metrics, such as AAL, when integrated into the budgets and feasibility studies developed to finance infrastructure projects, enable the assessment of the benefits and costs of alternative strategies to strengthen resilience, including NbIS. For example, in assessing different climate adaptation options in Vietnam, a combination of mangrove planting and conservation, in combination with dykes and seawall construction and insurance, generated a net value, thus reducing the expected damages more than the cost under different climate scenarios (Figure 3.4).



↑ **FIGURE 3.4**

Assessing the Net Value of NbIS
Source: Bresch and Aznar-Siguan (2021)

3.3.3. Policy and Regulations

Effective legislation to protect and enhance ecosystems and their services is necessary to affirm a longer-term commitment, providing investors with greater confidence and reduced risks and encouraging greater investment in NbIS.

As NbIS are rolled out to strengthen infrastructure resilience, ongoing ecosystem degradation needs to be stopped. When environmental policy and regulations are weak and poorly enforced, it will lead to the degradation of the very ecosystem services on which NbIS are based. Economic drivers in many countries encourage moral hazard that leads to degradation and depletion of natural resources at a rate far faster than their regeneration.

Effective legislation to protect and enhance ecosystems and their services is necessary to affirm a longer-term commitment. It will provide investors with greater confidence and reduced risks, thus encouraging greater investment in NbIS. For example, in June 2022, the EU Commission proposed the EU Nature Restoration Law that, if enacted, will establish legally binding targets to protect and restore rivers, wetlands, forests, peatlands, marine, and urban areas to benefit biodiversity, climate, and people (European Commission, 2019). The Paris Agreement provides a framework to initiate similar actions across the globe. Similarly, the UN System of Environmental and Economic Accounting promotes a broader framework that includes social capital and environmental-economic accounting measures (UN System of Environmental and Economic Accounting, 2021), which, if adopted, could create a positive enabling environment for NbIS. Such legislation should integrate with existing environmental policies that protect air, soil, water, floral, and faunal resources. Working within an established environmental policy can help government sectors achieve resilience targets set by legislation (TARU Leading Edge, 2022). As all infrastructure development projects and operations should comply with national environmental policies, the use of environmental impact assessments can also become a vehicle for mainstreaming NbIS.

By 2020, the submitted NDCs under the Paris Agreement were found to be insufficient to keep the global temperature rise below 2ºC (Seddon et al., 2019). However, NDCs do provide a policy umbrella for the adoption of NbIS. In comparison to high-income countries, LMICs NDCs often give greater emphasis to NbIS with a particular focus on forest protection and restoration. As NDCs expand to include other NbIS, such as protecting and restoring rivers, wetlands, coastal and marine ecosystems, and improving soil and forest health in wildlands, agriculture, and urban areas, this can create further momentum (UNDP, 2019).

Some countries are considering the transition to net zero in the energy, transportation, and other sectors to be a critical issue of national security. For example, a massive reallocation of public and private capital in the USA is already occurring to catalyze the transition (Box 3.6).

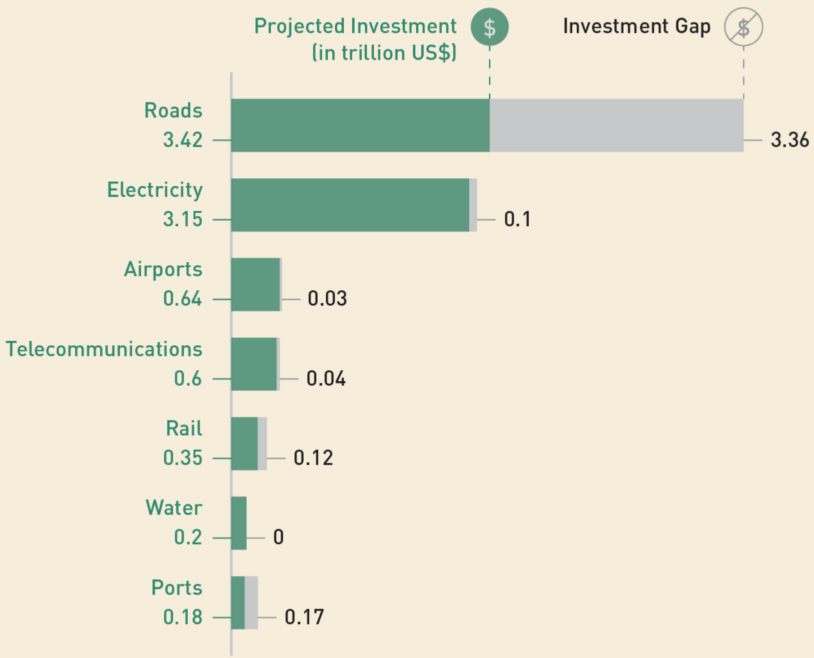
↓ **BOX 3.6**

US Federal Infrastructure Investment of
$1 Trillion for Growth and Resilience

Most infrastructure in the USA was built decades ago. Rising maintenance costs and unreliable services have eroded economic performance (Petroski, 2016). During the COVID-19 pandemic, poor infrastructure was recognized as a threat to human safety and a source of lost economic productivity.

Recognizing that the country was lagging behind other high-income countries, in November 2021, the US Congress approved a $1 trillion plan to upgrade roads, bridges, and water systems, modernize the electrical grid, and expand the adoption of electric vehicles and broadband internet access (Figure 3.5). It is also proposed to include social infrastructure for child and elder-care programmes.

On Earth Day 2022, President Biden announced protecting and restoring nature and using NbS as a core tenet of national policy. Executive Order 14072, Strengthening the Nation's Forests, Communities, and Local Economies, called for the accelerated deployment of NbS to tackle climate change and adapt (White House Council on Environmental Quality et al., 2022). Apart from existing modalities, such as municipal bonds, Public-Private Partnerships (PPPs), and increased corporate taxes, there is an increasing bipartisan support for a national infrastructure bank (Mallett, 2016), with an initial appropriation of $25–$50 billion that could help finance these investments.



↑ **FIGURE 3.5**

Projected US Infrastructure Investment Gaps by 2040
Source: McBride & and Siripurapu (2021)

↓ **BOX 3.7**

Incentive Design and the Impact of Rating Systems: Lessons from the Domain of Green Buildings in India

The stated benefits of NbIS for infrastructure resilience and sustainability will gain credibility when a third party audits a project using rating systems. Rating tools can serve as a market signal for resilience or sustainability and provide verified examples of good practice. Governments can guide markets by endorsing well-proven systems and incentivizing positively rated developments (Berrang-Ford et al., 2021).

The role of green building rating systems in promoting innovation in the construction sector and the design of incentives around it hold potential lessons for turbocharging the adoption of NbIS.

Rating systems need to be adapted to the local context. In India, GRIHA (Green Rating for Integrated Habitat Assessment) was developed by The Energy and Resources Institute (TERI) as a building rating system to address and assess non-air-conditioned and partially air-conditioned buildings at a time when international systems focused solely on rating air-conditioned buildings. GRIHA was adapted to each climatic zone in India and awarded points for unique vernacular building practices, such as rat-trap bonds and filler slabs, that reduce stored energy in a building. GRIHA was adopted nationally by the Ministry of New and Renewable Energy in November 2007 (Ministry of New and Renewable Energy & and TERI, 2010, p 18).

Incentives at the national, regional, and urban levels have now translated into high adoption rates of green building rating systems in India's private and public sectors. For example, the Ministry of Environment, Forest, and Climate Change provides fast-track environmental clearance for buildings certified by GRIHA, IGBC (Indian Green Building Council), LEED (Leadership in Energy and Environmental Design), EDGE (Excellence in Design for Greater Efficiencies), and IMF (International Monetary Fund). The Ministry of Housing and Urban Affairs approves an increased Floor Area Ratio (FAR) of 1 – 5 percent on plots of more than 3000 square metres in size on buildings certified by GRIHA.

GRIHA-certified 4- and 5-star projects are also eligible for financial incentives under SUNREF (Sustainable Use of Natural Resources and Energy Finance) India, an initiative of the French Development Agency (AFD) that supports green investments through environmental credit lines extended to local financial institutions. Many states in India have also adopted policies and incentives [for example, the Karnataka Green Building Incentive Policy, in draft version since 2018; Punjab Municipal Green Building Incentive Policy, 2016; Kerala State Housing Policy, 2011; Odisha Development Authorities (Planning and Building Standards) Rules, 2020; Haryana Building Code, 2017; Tamil Nadu Industrial Policy, 2021].

3.3.4. Good Practices and Performance Standards

Based on best practice, nationally developed and adopted performance-based standards for NbIS may provide a more flexible route that allows engineers and others to approve project designs without facing potential professional liability issues.

Design and performance standards that include and codify NbIS are uncommon. NbIS good practices are rarely systematically codified. This hinders the development of clear policies, regulations, codes, and standards. The lack of appropriate norms and standards for NbIS may slow down or complicate the approval process for new projects. It can also make it difficult or impossible for engineers or other professionals to sign off on NbIS projects, as it may invalidate their professional liability insurance.

Resilience standards are often scattered across different laws, regulations, guidelines, decrees, environmental assessments, and manuals, and are dispersed in multiple locations and formats. In many contexts, it is difficult, if not impossible, to identify what is appropriate for NbIS.

Prescriptive global standards for NbIS could provide a pathway for greater project financing. However, their application can be counterproductive unless standards are nationally and context-appropriate (TARU Leading Edge, 2022). Nationally developed and adopted performance-based standards for NbIS, based on good practices, may provide a more flexible route.

'Best or Good Practice' is a professional procedure that is accepted or prescribed as being correct or most effective in particular contexts. The term conveys a sense of acceptability, respect, and professional endorsement. Developing a framework of 'good practices' within a body of curated literature would encourage convergence around what could be the most appropriate performance-based standards in each context.

Developing and refining good practices may be a 'bottom-up' process to arrive at nationally or context-appropriate performance standards. For example, a 'Nature-based Infrastructure Design Hub' could leverage modern computing and information collection technology using an online, open-source structure, thus allowing users to input knowledge and data to crowdsource information about NbIS technology, performance, and cost to inform performance standards (Conservation International, 2022). Such a voluntary, collaborative effort would contribute to improving NbIS design, selection, implementation, cost-effectiveness, and performance.

It is particularly important to monitor if NbIS are constructed as planned, and maintained and enhanced over time (Furniss, 2014). Third-party certification may be needed to ensure that NbIS are based on standards when they exist and professionally sanctioned good practices when they do not. In other sectors, such as in building, third-party certification has played an important role in enabling change, as Box 3.7 shows. However, until a significant hazard event tests the functionality of an NbIS, it may not be practical to certify that it delivers as expected. The concept of 'Pay for Performance', which is often a requirement in investments, may not be appropriate for NbIS until performance monitoring improves and is fully codified (Blue Forest Conservation, n.d.).

Ultimately, if *exotic* isolated projects are to mature into *quotidian* normative actions, the implicit knowledge existing throughout societies and across professional disciplines needs to be unveiled. As such, building local and user involvement and co-ownership of NbIS projects is fundamental to social acceptance, economic success, and sustainability (Centola, 2021).

3.3.5. Integrating NbIS into National and Local Planning

National infrastructure development policies, strategies, and plans can provide a supportive environment to introduce NbIS at the national level and safeguard biodiversity and vulnerable ecosystems at the local level.

National-level plans may provide a planning scale larger than the site itself and consider the conditions of the surrounding landscapes at the regional or even national scale.This higher-level analysis can highlight both the potential risks to the planned infrastructure and the potential of the infrastructure to strengthen systemic resilience. Transboundary partnerships at sub-regional, regional, and national levels are often needed. For example, transboundary cooperation in the Himalaya and Terai regions of Nepal and northern India is required to address community resilience and flooding impacts on infrastructure.

Locally, planning can recognize the capacity of providing goods and services needed for infrastructure supply and protection, of regional or national ecosystems such as rivers, lakes, wetlands, forests, grasslands, savannahs, agricultural lands, and coastal zones.

Assessing ecosystems and the services they provide and of the risks, costs, and benefits of different alternatives for providing resilience can provide a sound basis for the development of such policies, strategies, and plans, both at the national and at the local levels and include sector-based planning by integrating territorial plans at the local level.

However, a profusion of complementary but often overlapping planning processes, including development plans, land use plans, environment plans, adaptation plans, and disaster risk management plans (Berke et al., 2015), does not necessarily make for good planning. Strong national normative capacities may be undermined by weak capacities for formulating and implementing plans at the local level. Land use planning is often not integrated with sector-based planning and evaluation of public investment, meaning that the resources needed to implement local plans may not be available. In LMICs, much development is unregulated and informal, invalidating the benefits of planning.

In LMICs, instruments such as National Adaptation Plans (NAPs) can be used to integrate NbIS into the planning process with sectors such as urban and infrastructure (Box 3.8). For local planning, in countries such as India, integration of NbIS can be targeted through the State Action Plan for Climate Change (SAPCC).

↓ BOX 3.8

Gender-inclusive NbIS and Ecosystem-based Adaptation: Lessons from Fiji and Dominica

Source: Bechauf (2021)

Fiji and Dominica, both highly vulnerable to climate change owing to their geographical contexts, depend on nature for their economic development.

Fiji adopted a national action plan (NAP) to scale up ecosystem-based adaptations by promoting gender and human rights approaches. This has generated social and economic returns and provided multiple benefits, including improved health, food security, and alternative livelihood opportunities, all aimed at building ground-up resilience to climate change. With one of the NAP's guiding principles *'the role of ecosystems in vulnerability reduction for people, their livelihoods, and socioeconomic development'* (Government of Fiji, 2018), Fiji aims to fulfil the bill of rights framed within its constitution. The NAP also embraces participatory and inclusive processes by engaging sub-national and local governments in the design and implementation of NbIS.

Meanwhile, Dominica created the Climate Change Trust Fund's legal establishment to support vulnerable segments of society. This was in pursuit of the national climate resilience building priority: *'Create the supportive enabling framework whereby communities and vulnerable segments of society (women, youth, elderly, people with disabilities) can manage their climate change risks, thereby addressing climate change impacts on vulnerable sectors... and threats to food security, human health, poverty alleviation, sustainable livelihoods and economic growth.'* Dominica pursues the Gender Equality and Social Inclusion (GESI) approach throughout the development process.

3.3.6. Reconstruction Following a Disaster

Unless NbIS is already mainstream in the country, the necessary support for well-established good practices, standards, trained professionals, and technology will likely not exist in post-disaster contexts.

Introducing new ways of implementing infrastructure resilience in post-disaster contexts remains challenging. In theory, post-disaster reconstruction could be an excellent opportunity to introduce NbIS. However, the urgency of restoring essential services often leads to replacing like with like and reconstructing pre-existing risk, precluding the possibility of introducing innovations such as NbIS that could strengthen resilience. Repairs usually occur as rapidly as possible, often replacing damaged assets in the same location without analyzing the causes of failure and considering other more effective alternatives.

For example, upper watershed degradation, inappropriate land use, loss of wetlands, and poor or inappropriate levee construction may have been the cause of flood damage to infrastructure in the lower watershed. A rapid bridge repair provides a provisional patch, responding to immediate social demand. At the same time, a NbIS project that could address the risk drivers may take years to design, approve, and finance (Box 3.9).

The application of methods such as FORIN (Alcántara-Ayala et al., 2016), through detailed analysis, can identify the cause of infrastructure failure in disasters and lay the ground for changes in policy and practice in favour of NbIS (Bella, 1997). As effective progress is not possible without robust failure detection, analysis, and adaptation, the knowledge gained from methods such as FORIN could help NbIS practitioners implement solutions that offer better outcomes.

3.3.7. Governance for NbIS

The engagement in and co-ownership of NbIS projects by the households and communities that provide or benefit from the ecosystem services generated is fundamental to their success and, above all, their sustainability.

Weak infrastructure governance is a major obstacle to the adoption of NbIS. Infrastructure projects' planning, designing, and implementation are often fragmented and siloed across different ministries and departments, discouraging a holistic approach to complex problems, such as urban heat islands. As Box 3.10 highlights, NbIS normally require interdisciplinary and cross-departmental coordination, with the extensive engagement of and ownership by communities and other stakeholders (Green et al., 2016), and processes that challenge entrenched bureaucratic structures and procedures. For example, implementing a successful stormwater upgrade with NbIS would require civil engineers, community organizations, government regulators, landscape architects, natural resource professionals, horticulturalists,

↓ **BOX 3.9**

Strategically Returning the Land to Nature:
The Town of High River, Alberta
Source: INFC (2022)

The managed retreat strategy in High River, Alberta, is a good example of the opportunities and challenges that post-disaster recovery offers when NbIS are introduced. After a devastating flood, the High River Council initiated a managed retreat strategy for the neighbourhood of Wallaceville and asked the province to initiate a Floodway Relocation Program (FRP). With the high risk of recurring floods, residents living in the floodplain were provided with a buyout option for their properties. The town's council initiated the floodplain buyout programme with provincial funding, providing incentives to remove exposed assets and people from high-risk areas to transit towards a naturalized floodplain.

The demolition of human-made structures provides space for nature to thrive again, yet restoration can expedite improvements in biodiversity. However, unlike other floodplain buyout programmes, the FRP did not include ecological restoration projects. It was voluntary and the limited one-way communication did not create shared responsibility for collective action.

The province owns the reclaimed land, and the town recommended transforming the area into an ecological park. However, some homeowners chose to rebuild despite being disqualified for disaster relief assistance in the event of another flood. Poorly executed knowledge sharing and communication about the risks and consequences were considered reasons for some people choosing to stay. As of 2015, the Wallaceville neighbourhood returned to an 'undeveloped' state. The town of High River integrated the buyout area into a park's master plan.

Global experiences, especially from LMICs, have also shown that resettlement in the context of risk reduction is complex, given that socio-economic and hazard risks compete for attention from communities and risk professionals and are rarely addressed holistically (Johnson et al., 2021). In these processes, often new environmental risks may emerge (Jain, Singh, et al., 2017). The overall relocation costs are significant and must be avoided, and other alternatives must be assessed in close partnership with affected communities (Jain, Johnson, et al., 2017).

financiers, and others to build a common vision and reach a consensus. Centralized and short-term budget cycles further hinder the adoption of NbIS.

Participatory planning and co-ownership of NbIS projects by the households and communities that provide or benefit from the ecosystem services generated are fundamental to their success and sustainability. Participatory engagement increases accountability and creates greater public visibility and resources to address public needs (Carothers & and Brechenmacher, 2014).

↓ **BOX 3.10**

Green Infrastructure for Stormwater Management

Source: USFS (2023)

The city of Portland, Oregon, used innovative green infrastructure design to address challenges such as urban flooding, water quality, biodiversity, heat islands, liveability, and climate change. The design addressed the risks posed by runoff in the existing combined sewer and stormwater systems across the city. It included both green and grey infrastructure, such as underground piping, eco-roofs, green streets, bioswales, rain gardens, sumps, and disconnected downspouts.

In addition, the city planted 59,000 trees, increasing the tree canopy by 9.3 percent in industrial, commercial, and residential areas, and installed over 550 eco-roofs covering more than 38 acres. Detailed modelling of the combined sewer system showed that green technology is more cost-effective than upsizing existing pipes in some city areas. The city's regulations, including a Stormwater Management Manual, require green roofs in some parts of the city and have a 'Green Street Stewards Programme' that partners with community members.

Portland funds construction projects through borrowed revenue bonds that are paid off with revenues from the city's sewer and stormwater rates. It has a strong commitment to inclusive governance, using outreach and communication, public/private partnerships, grant funding programmes, and collaborative planning and implementation with communities. It continues to adapt and modify its programmes based on feedback and monitoring and evaluation reports to ensure effective implementation.

3.3.8. In Search of a Political and Economic Imperative for NbIS

NbIS is often a slow solution in a context where many infrastructure requirements require quick action.

The prioritization of short-term economic gains over environmental integrity is an example of a moral hazard (Maskrey et al., 2023). Economic gains are *privatized*, while any resulting systemic risks are *shared* and *transferred* to other social groups or territories. NbIS may sometimes be unattractive politically precisely because it shares social and environmental gains and reduces opportunities for *privatized* profits.

NbIS is often a *slow* solution in a context where many infrastructure requirements need quick action. For example, grey infrastructure, such as a seawall, can be constructed in a relatively short time frame to deflect storm surges. At the same time, mangrove establishment or restoration is a longer-term venture. Even though effective, NbIS are often slower to mature and provide tangible benefits than grey infrastructure. The lengthy time frames required for planning and achieving measurable results may not mesh well with electoral cycles, thus undermining the political imperative for their adoption. Politicians normally favour highly visible projects with immediate results.

Similarly, investors prefer infrastructure projects that provide clear, tangible, and immediate benefits. The resilience dividends from NbIS may be slow to develop and require additional costs, while the social and environmental benefits do not accrue to the investor. At the same time, in many LMICs, powerful economic interests advocating grey infrastructure undermine the case for NbIS. Economic imperatives, such as the need to attract foreign direct investment, may override proposals to introduce NbIS if these are seen to hinder investment.

Additionally, NbIS often require more land than traditional infrastructure. High-priority areas for protecting or restoring ecosystems may not be publicly owned or may require negotiations with landowners to proceed, particularly in cities with limited green space, creating increased resistance.

Box 3.11 highlights how extractive activities, such as mining or timber, often fail to value the benefits provided by ecosystem services (such as wetland flood attenuation) to enhance infrastructure function (such as sediment and erosion control), and protect engineered assets (for example, mangroves protecting coast telecommunication networks) and co-benefits, including potential for increased ecotourism, food security, and employment opportunities.

There is no single recipe for improving political will in a way that would facilitate the uptake of NbIS. In many countries, adopting a national resilience strategy, policy, and plan following a catastrophic event that galvanizes political will may provide a vehicle for adopting NbIS. To be effective, a national resilience strategy would require political support at the highest level of government and developed with a long term vision. It would need to provide a framework for infrastructure planning across different sectors and at the territorial level. This would also require an interdisciplinary approach bringing together the skill sets currently siloed in different sectors, such as environment and public works, with the technical capacity to value the ecosystem services provided. Ultimately, and as discussed in Chapter 4, adopting a strong resilience policy and strategy may positively change the risk perception of the country in question, increasing investor confidence and analyst ratings and reducing the cost of capital. If a strong economic, financial, and social imperative emerges for nature-based infrastructure, it may generate a stronger political imperative.

↓ BOX 3.11

In Defence of Biodiversity in Intag, Ecuador
Source: USFS (2023)

The Intag community in Ecuador faces the dilemma of extracting significant copper reserves or valuing the ecosystem services of the area for their future growth. The cloud forest area measures 150,000 hectares and includes two globally significant biodiversity hot spots. The Ecosystem Service Valuation (ESV) found that 17 out of 23 ecosystem services across the landcover types in Intag provide regional and national communities with an average of $447 million in yearly benefits and ecosystem services, including carbon storage, water provision, erosion control, and pollination. On the other hand, economic feasibility studies estimated the areas had 318 million tonne of copper ore in the ground valued at $85 billion in 2011.

Ecuador's innovative constitution gives rights to nature, stating that 'nature has the right to exist, persist, maintain, and regenerate its vital cycles, structure, functions, and processes in evolution'. Ecuador's mining law also states that 'all mining investors must respect the right to the communities' information, participation, and consultation regarding environmental management of all mining activities.

For over two decades, the Intag community has worked to develop and implement an alternative and prosperous vision of the region's economy, which does not include mining. In 2022, Intag community leaders used the 2011 ESV report to support a lawsuit against the Ecuadorian government over mining concessions. This case is headed to Ecuador's Supreme Court, where it is likely to establish a key precedent for the fate of other cloud forests in the country.

A key recommendation of the report is that economic development within the Intag region is best achieved by tapping the vast value that ecosystem goods and services provide. This study allows decision-makers to develop a sustainable economy in which natural capital is an integral part of investments that maintain or rise in value over time. It is a first step towards understanding the significant economic and social risks of mining operations in Intag while accounting for the significant economic contributions that ecosystems make to the regional and national economies.

3.3.9. Building the Business Case for NbIS

Conventional methods for accounting costs and benefits and rates of return used in infrastructure financing often fail to include the systemic risks posed by infrastructure investments on the environment.

Many businesses and public services have good reasons for investing in NbIS. To stay viable, they depend on ecosystem services, including clean and abundant water, fertile soils, healthy forests, and biodiversity. Business leaders often state that investing in nature helps to achieve sustainability goals, strengthen their market brand, manage regulatory requirements, promote employee well-being, and reduce disaster risks (The Nature Conservancy, n.d.). Highlighting the positive social, economic, and environmental benefits that can accrue from NbIS is critical to its political attractiveness and viability. While reduced loss and damage should be accounted for in calculating the costs and benefits and rates of return on investment of NbIS projects, it should be noted that local politicians rarely win elections on promises of avoided future losses but rather on tangible present benefits (Lavell & Maskrey, 2014).

However, providing 'proof of concept' that NbIS can provide these benefits, by itself or in concert with grey infrastructure, continues to be a challenge. Much of the existing evidence is not widely available nor easily accessible. Rather than generating *more* proof, the challenge is to disseminate and market existing proof.

The conventional methods used in infrastructure financing to account costs and benefits and rates of return often fail to include the systemic risks posed by infrastructure investments on the environment. The net present value calculations do not account for the potential appreciation of the performance of NbIS over time, compared with the depreciation of traditional infrastructure, thus largely undervaluing NbIS. Notably, the long term benefits of protecting, supporting, or supplementing infrastructure with NbIS are not accounted for or monetized in a way that encourages investment.

In contrast, environmental cost-benefit (OECD, UN Environment, et al., 2018) may show how including NbIS in a project would have a greater cost-benefit ratio than grey infrastructure alone. **In the USA, it was found that for every 10 percent increase in forest cover above a water source, there was a 20 percent decrease in water treatment costs. Costs were 211 percent higher for a watershed with 10 percent forest cover than one with more than 60 percent** (Ernst et al., 2004). The USA has now begun to protect watersheds by limiting human intervention above municipal water supply points.

Unfortunately, environmental accounting methodologies and their use in cost-benefit analyses are still not standardized. At the same time, they require interdisciplinary input from natural scientists, engineers, and economists to minimize uncertainty and accurately account for all costs and benefits to societies and the environment (Center for Neighborhood Technology, 2011; The Water Research Foundation, 2021).

The 'valuation of ecosystem services is often confused with commodifying or privatizing nature' (Costanza et al., 2014). However, calculating and monetizing the environmental, social, health, and economic benefits of applying NbIS is fundamental. Valuation builds a more comprehensive, balanced picture of the resilience dividend accrued using land and ecosystems to support social and environmental well-being. Its importance, therefore, cannot be underestimated (Costanza et al., 2014).

Several methods (e.g., replacement costs, market pricing, hedonic pricing, avoided costs) exist that can monetize the economic value of ecosystem services. Due to the time required to gather the raw data for most of these valuation methods, the simpler benefit transfer method is often used. This method accumulates information from studies done in similar ecosystems to provide a low- and high-value range of ecosystem types and service values (Plummer, 2009). Improvement in the confidence of the benefit transfer methodology can be accomplished through in-depth studies shared by NbIS practitioners.

For the valuation of ecosystem services to become common practice in environmental policy and infrastructure investment decisions, three shifts need to happen: the realization that ecosystem services have a value, understanding and knowledge of how to monetize ecosystem service value, and a requirement to undertake valuation exercises to decide future land use.

3.3.10. Developing Markets for NbIS

When developing programmes that pay for ecosystem services, it is important that payments prioritize the land that offers the most significant level of ecosystem services or risk reduction.

Various conservation finance instruments have been used to protect and enhance the ecosystem services provided by given areas of land (Box 3.12). Conservation finance programmes require underpinning by strong community-based, local institutions. The engagement of local institutions plays an important role in the viability and sustainability of any conservation finance programme (Thuy et al., 2013). Therefore, it is critical that communities be engaged upfront in project design and CoPs be established to accompany them in the future.

When developing programmes that pay for ecosystem services, it is important that payments prioritize the land that offers the most significant level of ecosystem services or risk reduction. For example, a water company may fund landowners whose property drains directly into a water supply reservoir or stream system above its water intake system. The landowners would be funded based on the capacity of their land to reduce erosion and increase water infiltration to replenish groundwater. Similarly, cities or downstream communities could make payments to landowners to maintain or restore wetland and riparian areas to increase stormwater storage and attenuate peak flows to minimize flooding and improve the water quality downstream.

Potential threats, such as deforestation, mining, rainforest conversion for palm oil, soy, cattle grazing, and so on, to these ecosystem services should be identified and payment rates and schedules established to compensate landowners for not pursuing these other, often lucrative, land uses.

A known user base is also required to identify ecosystem service buyers (Box 3.12). For example, users of electricity from a hydropower plant, building owners or renters who benefit from reduced energy costs from green roofs, transport users benefiting from resilient roads, communities or powerline companies protected from wildfire, and so on. Ecosystem service providers can also be identified by identifying, estimating, and geolocating risks. For example, owners of land that affects adjacent and downstream infrastructure resilience. Infrastructure developers can then pay for the management of that land so that it provides the required ecosystem services. Payment rates could vary based on the ecosystem condition.

↓ BOX 3.12

Valuation of Ecosystems
Source: Eugene Water and Electric Board (2017)

Valuations of ecosystems vary by locality and ecosystem types. Figure 3.6 shows the values of ecosystem services obtained from the protection of riparian forests for developing a water quality protection programme by the Eugene Water and Electric Board (EWEB), USA. Other ecosystem services, such as habitat values, disaster risk reduction, recreation and tourism values, water temperature benefits, and cultural values, should have been added to the total ecosystem value but were not assessed in this study.

Even without considering the full range of benefits, EWEB's future costs for protecting riparian forests under the watershed protection programme were estimated at $1980 per acre, while the net present value of the benefits was $7131 per acre. This represents a return of approximately $2.60 for every $1 invested, over a 20-year period, due to reduced water quality treatment operation costs from implementing NbIS to protect the environment above the water treatment plant. When adequately valued, the ecosystem services can often justify the implementation of NbIS (Figure 3.6).

→ FIGURE 3.6

Examples of benefits and values of ecosystem services

3.3.11. Achieving Scale

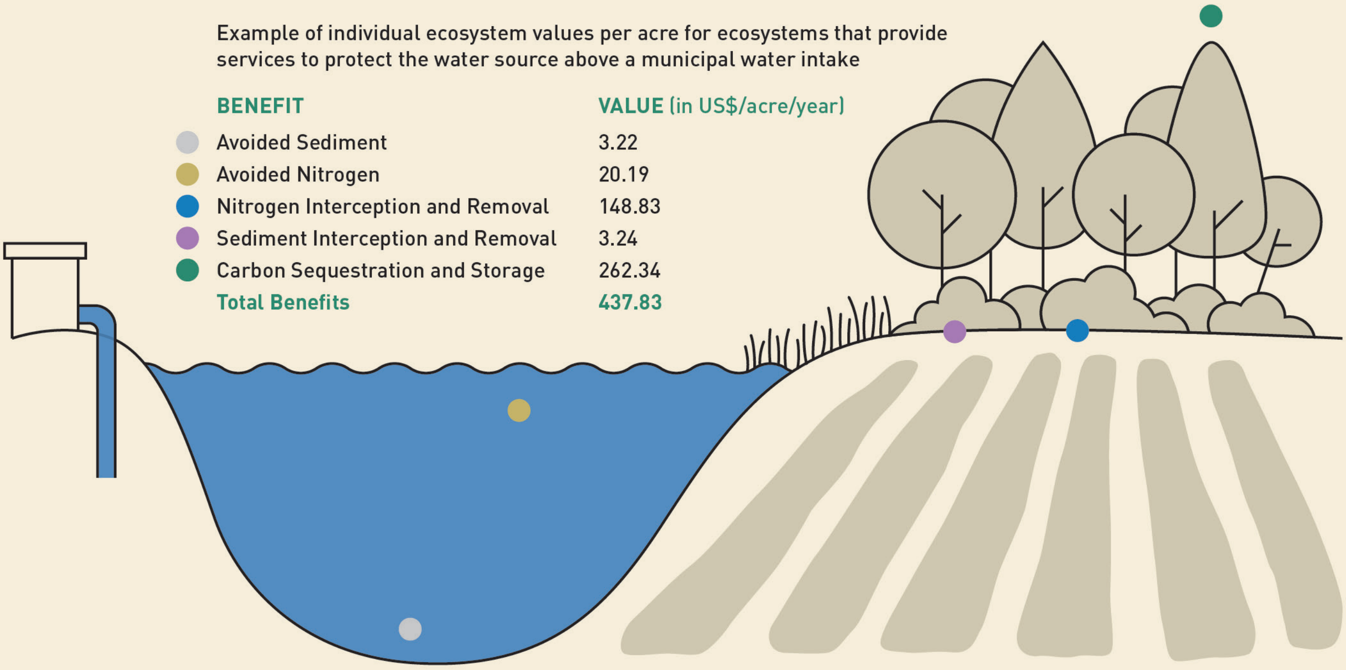
While pilot projects are often initially expensive, costs can be reduced as good practices are curated, norms and standards codified, and investors and project designers gain confidence.

According to a 2016 Forest Trends and JP Morgan report, over $3.1 billion in sustainable investment capital remained idle due to a lack of investment opportunities in conservation finance, and only 51 percent of government climate funds had been deployed due to a lack of projects in the pipeline or projects that were too small for private finance (Buchner et al., 2021). As a result, conservation-focused investors have not had sufficient opportunities to support NbIS projects (Hamrick, 2016).

Many NbIS projects are too small scale, and the expected returns on investment are too far into the future to be attractive to private investors. The challenges described above conspire to limit the development of self-sustaining national markets for NbIS. These markets remain small and undeveloped. Even when an investor wishes to include NbIS in a project, it may be difficult to access the necessary technology and expertise.

Example of individual ecosystem values per acre for ecosystems that provide services to protect the water source above a municipal water intake

BENEFIT	VALUE (in US$/acre/year)
Avoided Sediment	3.22
Avoided Nitrogen	20.19
Nitrogen Interception and Removal	148.83
Sediment Interception and Removal	3.24
Carbon Sequestration and Storage	262.34
Total Benefits	**437.83**



Example of the types of ecosystem services and their values per acre based on avoided costs at the water treatment plant resulting from the protection of riparian forests

NATURAL ASSET	VALUE (in US$/acre/year)
Wetlands	34,888
Lakes and Rivers	3,041
Riparian Forests	6,717
Forests	3,677
Shrub and Scrub	2,710
Grassland	695
Agriculture	644

However, while pilot projects are often initially expensive, costs can be reduced as good practices are curated, norms and standards codified (Blue Forest Conservation, n.d.), and investors and project designers gain confidence. In particular, the identification of financial incentives and innovations unlocks solutions to some of the systemic challenges. Bundling NbIS projects into investment pipelines that mutualize risk across sectors may draw private investors' interest and enable a centralized funding source for local NbIS practitioners to access. This structure combines bottom-up locally anchored knowledge and processes in project design and implementation with top-down investment opportunities and is further discussed in Chapter 4. Integrating NbIS into existing pipelines of grey infrastructure delivery systems can be a way to achieve scale, reduce loss and damage to infrastructure assets, and prevent loss of biodiversity. For instance, Jamaica Systemic Resilience Assessment Tool (J-SRAT) was developed to identify the co-benefits derived from NbIS (Box 3.13).

→ BOX 3.13

Jamaica Systemic Resilience Assessment Tool (J-SRAT) and Hybrid Projects Pipeline Structuring Methodology with the Deployment of Nature-based Solution (NBS)

Source: GCF (2023)

Societal Challenge Addressed: Water, energy, and transport infrastructure are resilience priorities for Jamaica. The J-SRAT integrates climate risk analytics into decision-making and planning for these critical infrastructure sectors (Figure 3.7). It shows how integrating NbIS can reduce loss and damage to infrastructure assets and loss of life and biodiversity from development pressures and extreme weather events. It also provides mitigation co-benefits when carbon-intensive hard infrastructure is replaced by NbIS, and existing carbon sinks are protected.

Scale of Design: A nationwide assessment was done of existing terrestrial and marine ecosystems and relevant existing and potential ecosystem services to reduce flooding, increase water quality, reduce droughts, and protect infrastructure from extreme wind events. Development and climate threats were identified and mapped, as well as potential NbIS to address those threats. A cost-benefit analysis of implementation and maintenance costs and factoring of the time required for NbIS to become effective was used to prioritize projects across the country.

Economic Feasibility: A comparison of high-level estimated capital expense (CAPEX) and operational expense (OPEX) was conducted for high-priority projects, as well as a broader analysis of the feasibility of mobilizing climate finance.

Inclusive Governance: Led by the Jamaican Government, the design included an inclusive multi-stakeholder structure involving financing, development, and project implementers.

Adaptive Management: The inclusive governance set-up was based on consultations allowing refinement of the approach-based ground truthing.

Mainstreaming and Stability: This step-by-step methodology facilitated upscaling in Jamaica or replication in other contexts.

↓ FIGURE 3.7

J-SRAT Tool Showing Sub-national Hazard Hotspots

Source: Oxford University