BACKGROUND PAPER

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THE ROLE OF THE NATURAL ENVIRONMENT IN ADAPTATION

BACKGROUND PAPER FOR THE GLOBAL COMMISSION ON ADAPTATION

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About this paper

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Executive Summary

Climate change impacts are already being widely felt and will increase in severity by the middle of this century, further changing rainfall regimes and increasing the frequency of high temperatures, storms, floods and other extreme events. These impacts are directly affecting people, economies and the natural world. Climate change alters the survival and distribution of species and contributes to ecosystem degradation, exacerbating the effects of unsustainable management. Climate change thus threatens the services that nature provides (ecosystem services), and their role in underpinning economies and societal well-being. These interactions can cause a downward spiral of resource depletion and increasing vulnerability, for example through reduced ecosystem productivity, increases in pests and diseases, reduced water quality and availability, increasing risks to lives, assets and infrastructure.

Adaptation action is crucial to minimize adverse outcomes from climate change for both ecosystems and society. The effectiveness of most adaptation action, whether using engineered measures or other approaches, depends fundamentally on continued or enhanced provision of ecosystem services. Additionally, and importantly, nature can be harnessed specifically to reduce climate hazards. As well as building people's resilience to climate change, such Nature-based Solutions (NbS) for adaptation can generate multiple additional benefits.

This paper provides an evidence-based overview of the role of the natural environment in adaptation to climate change to inform the flagship report and action tracks of the Global Commission on Adaptation (GCA). It explores how nature underpins economies and society, highlighting sectors of particular interest to the GCA (food security and rural livelihoods; cities; infrastructure; industry and supply chains) and the climate risks that affect them.

Identifying adaptation needs and appropriate actions to address them depends on understanding the interactions between climatic- and non-climatic drivers of change. Therefore, this paper draws attention to the role that environmental degradation plays in societal vulnerability to climate change. Feedbacks between this vulnerability and ecosystem condition mean that managing nature to maintain the integrity and function of ecosystems, and retain and enhance their services, is crucial to successful societal adaptation.

Essential approaches for maintaining and enhancing ecosystem resilience include conservation of large tracts of relatively intact ecosystems, restoration of degraded ecosystems, enhancement of ecosystem connectivity, and sustainable management of production landscapes and seascapes.

The paper also reviews experience of specific NbS for adaptation (and includes over 25 illustrative case examples), highlighting that they have both economic and practical advantages and can be used to address a wide range of climate hazards. NbS for adaptation can be low cost compared with hard infrastructure-based approaches for addressing climate hazards. They have potential to generate larger economic returns because of the co-benefits they deliver in addition to reducing climate risk. These include food, marketable products, jobs, carbon sequestration and storage, biodiversity conservation, improved health, and recreation opportunities. NbS for adaptation also offer flexibility, can complement engineered approaches, and can often be implemented with lower technical inputs.

Despite these advantages, some NbS for adaptation, especially those involving restoration of badly degraded ecosystems, can take time to deliver both their risk reduction benefits and their co-benefits in full. Their tendency to be highly context-specific can add to uncertainties about the effectiveness of individual NbS for adaptation in different locations and for addressing hazards of varying severity. NbS for adaptation may themselves be climate-sensitive, which is why understanding and managing for ecosystem resilience is critical.

There is a growing body of experience of using NbS for adaptation to a variety of climate hazards. NbS for adaptation in coastal zones, for example, include protection, management, or restoration of coastal marshes, mangroves, seagrass beds, and coral or oyster reefs, as well as stabilization or restoration of beach and dune systems. Annually, during the hurricane season, coastal wetlands in the USA provide an estimated US$23.2 billion in storm protection services. The world's mangroves are estimated to reduce the number of people affected by coastal flooding worldwide by some 39 percent, and the total value of flooding-related property damage by 16 percent. In addition to adaptation benefits, restoration and management of these ecosystems provide co-benefits ranging from biodiversity protection and carbon storage (mature mangroves can store nearly 1000t of carbon per hectare) to enhanced fish stocks and improved opportunities for tourism and recreation.

Risks from flooding, erosion and landslides that result from extreme precipitation can be reduced by restoration of upland forests and watersheds to reduce peak flows and stabilise soils; investing in watershed restoration and conservation activities could save water utilities across the world's largest cities an estimated US$890 million each year. Adoption of agroforestry approaches, and restoration and management of wetlands, floodplain vegetation and urban watercourses are also key NbS for adaptation to these hazards. Co-benefits from this range of NbS include enhanced supplies of wild-sourced food, increased carbon sequestration and storage, biodiversity conservation and improved water quality.

Management and restoration of watershed vegetation can also help reduce drought impacts by increasing infiltration and groundwater recharge. Agroforestry, rangeland rehabilitation, and urban green spaces can be used to reduce impacts from drought and heat, with co-benefits that include enhanced biodiversity, improved soil fertility and improvements to health and wellbeing.

The paper explores experience in the use of NbS for adaptation across four sectors. Most experience is evident in safeguarding food security and rural livelihoods in the face of hazards related to intense rainfall or drought, through protection and restoration of watersheds and wetlands, as well as changes to agricultural practices. Cities are increasingly using NbS for adaptation, especially to address flooding, drought, and heat island effects, through re-naturing water courses and creating urban green spaces. Awareness and application of NbS for adaptation to enhance the resilience of infrastructure are limited but growing. Coastal ecosystem restoration, often as a complement to traditional engineered approaches, has been an important strategy to protect investments from damage due to storm surges and flooding. There is also growing experience in watershed restoration to reduce the impacts of intense rainfall and sedimentation on hydroelectric facilities. Overall, there is less experience in using NbS for adaptation in industry and supply chains than in other sectors. However, large multinational companies with vulnerable supply chains and priorities related to their environmental and social performance have, for example, been active in promoting agroforestry and wider landscape-level planning and management to reduce risks from drought.

Despite the many advantages offered by NbS for adaptation, their use remains far short of their potential. Some common and interlinked barriers constrain both application of specific NbS for adaptation and protection and restoration of the natural environment to enhance underlying resilience. These are related to:

- Lack of awareness and/or understanding of these approaches, and associated entrenched attitudes and norms;
- Limited availability of knowledge and evidence to help make the case for working with nature;
- Policy and regulatory environments and governance challenges that influence the attractiveness and feasibility of using these approaches across temporal and spatial scales;
- Limited access to finance for applying and scaling up nature-based approaches; and
- Technical challenges and gaps in capacity that impede design and wider implementation

To help stimulate action at the scales needed to respond to these challenges and realize the benefits of NbS for adaptation, this paper presents a vision for the future use of nature in supporting societal adaptation. It also highlights opportunities and specific actions that will help key stakeholder groups to advance this vision.

Key recommendations include:

- Knowledge and awareness should be built through increased collaboration and exchange of experience across sectors, facilitated by governments, donors, civil society organisations and private sector actors.
- Climate impact and vulnerability assessments should as a matter of course include analysis of likely impacts on ecosystems and the implications for people's vulnerability.
- Planning, decision-making and action on adaptation should take a systems perspective. NbS for adaptation are best conceptualized and implemented at landscape or wider scales to take account of the interactions within and between ecosystems and the distribution of potential beneficiaries and impacts.
- Procurement, financing conditions, industry standards and other policies, should be improved to ensure that when a need for adaptation is identified, NbS are always included among the potential solutions evaluated and a consistent suite of benefits is assessed for all options under consideration.
- Financial institutions need to develop new funding streams and models (including de-risking strategies) that can support long-term investment in NbS for adaptation, including by private sector actors.
- Capacity should be developed by incorporating concepts of ecosystem dependency, climate risk, and NbS for adaptation into curricula and training programs for engineers, economists, environmental impact assessors, and development professionals.
- Governments, finance institutions, development and civil society organisations, corporate actors and research bodies need to promote wider implementation of NbS for adaptation, emphasising monitoring and evaluation, and disseminating and sharing experience across sectors.
- Public pressure can encourage necessary changes in policy and practice on the grounds that NbS for adaptation are critical to the public good.

1. Introduction

The global climate is changing, and the rate of change is increasing.[1,2] An increase in global mean temperature to 1.5ºC above pre-industrial levels is expected by the middle of this century, bringing further changes in precipitation regimes and increasing frequency of high temperatures and other extreme events, as well as rising sea levels.[2] Many regions are already experiencing extreme climate events, such as hurricanes and heatwaves, with increased risks of flooding and droughts. Projections show that drastic reductions in global greenhouse gas emissions are needed within the next decade to avoid even more severe impacts on natural and human systems.[2]

These changes affect the natural world and thus society and economies. Climate change impacts are already altering the survival and distribution of species, and affecting the function of ecosystems ranging from tundra to coral reefs; even under the most optimistic scenarios the severity of such effects will increase.[2,3] Ecosystems underpin economies and societal well-being through provision of ecosystem services[4] ranging from the provision of food, fiber, and medicines to the regulation of water flows, nutrient cycles, and global and local climates. The importance of nature's role is reflected in an increasing emphasis in both science and policy on Nature's Contributions to People[5] and the growing risks to them,[3] and a growing focus in policy, economics, finance and the private sector on the critical importance of natural capital.[6] Risks associated with climate change as well as biodiversity loss and ecosystem collapse are among the most critical global economic risks.[7] Poverty and disadvantage are expected to increase with global warming; women, underprivileged groups and communities dependent on agricultural or coastal livelihoods are particularly vulnerable in this respect due to their exposure to climate-related extreme events and limited capacity to adapt.[8]

Adaptation action is crucial to minimize adverse outcomes from climate change for both ecosystems and society. Effective adaptation action depends fundamentally on maintaining ecosystem integrity and securing ecosystem resilience,[i] and on harnessing nature and the goods and services it provides to reduce climate hazards. Applying such Nature-based Solutions (NbS) for adaptation can generate multiple additional benefits to society.

This paper aims to inform the development of the Global Commission on Adaptation's flagship report and action tracks by providing an evidence-based overview (drawn from peer-reviewed and gray literature and expert input) of the role of the natural environment in societal adaptation to climate change. It begins by exploring how nature underpins economies and society, highlighting sectors of interest to the Global Commission on Adaptation (GCA) (food security and rural livelihoods; cities; infrastructure; industry and supply chains) and the climate risks that affect them (Section 2). It then draws attention to the role environmental degradation plays in societal vulnerability to climate change (Section 3). In exploring solutions for these challenges, Section 4 focuses both on the importance of enhancing ecosystem resilience and on the potential of NbS for adaptation. It highlights concrete examples of applying NbS for adaptation to specific climate hazards relevant to GCA's major sectors or systems. The paper also identifies barriers and enablers for the use of NbS for adaptation (Section 5), and recommends key areas for action (Section 6). Case examples (Boxes A1-A25) are used across the text to illustrate the use of NbS by sectors and can be found in Annex A at the end of the document.

i. Resilience: The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation. Source: Mach, K., Planton, S., and von Stechow, C. eds. 2014. "Annex II: Glossary" In: *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* IPCC, Geneva, Switzerland, pp. 117-130.

2. The Natural Environment Underpins Resilient Economies

Many of the services that nature provides (ecosystem services) not only underpin current human well-being but are key to societal resilience to climate change. They support livelihoods and economies, help to moderate climate itself, and offer protection from climate-related impacts such as landslides and flooding. Understanding these dependencies is fundamental to identifying adaptation needs and appropriate actions to address them.

The role and importance of particular ecosystem services vary across contexts and scales. Provisioning services deliver resources (e.g. food, fiber, medicines) both for subsistence and for economic activities. These help diversify people's livelihoods and options for tolerating or managing climate impacts and support supply chains and markets. Regulating services that operate from local to global scales are also fundamental to economic well-being and resilience.[9] At local to watershed scales, ecosystems contribute to regulating water flow and flooding, water quality, soil quality and retention, and the spread of pests and diseases, stabilize slopes and shorelines, and help to moderate direct climate-related impacts.[10] At watershed to continental and global scales, ecosystems provide climate regulation through carbon sequestration, and by mediating distribution and dynamics of atmospheric water vapor and associated rainfall.[1,11] Supporting services, such as nutrient cycling, contribute to livelihoods, well-being and resilience by underpinning ecosystem function. Cultural services are central to physical, mental, and spiritual well-being in many contexts, and contribute to economic activities like tourism.

Climate change is already altering ecosystems and the services they provide.[1,2] Increasing incidence of floods, droughts, fires, landslides and soil erosion, and other climate impacts are directly contributing to ecosystem degradation and reduced provision of ecosystem services. For example, droughts and temperature increases adversely affect wetlands, including peatlands, and their important stocks of biodiversity and soil carbon, and reduce water quality. In marine systems, warming is contributing to increasing ocean acidity and decreased oxygen levels with adverse effects on many species and ecosystems.[2] Extreme climate events have already had significant and potentially irreversible adverse effects on habitat-forming species such as corals, seagrass, kelp and mangroves.[12] Climate change impacts are especially severe for coral reefs, which are projected to decline by 70-90% at global warming of 1.5ºC and to disappear almost entirely at 2ºC. Ongoing and future changes to terrestrial, aquatic, and marine systems have significant implications for the continued provision of goods and services that may be critical to societal resilience.[2,13]

How dependencies on ecosystems – and associated climate risks – vary among sectors is summarized in Table 1 and in the sector-specific accounts that follow.

TABLE 1 Ecosystem dependencies of economic sectors considered by the Global Commission on Adaptation. Stronger dependencies are indicated by darker blue colors.

		Food Security and Rural Livelihoods	Cities	Infrastructure	Industry and Supply Chains
Provisioning Services	Wild-sourced foods and fodder	• Key to food security for many rural populations	• Supplement urban diets	n/a	• Underpin some value chains, e.g. livestock
	Commercial and artisanal fisheries	• Key to food security for many rural populations	• Contribute to urban diets	n/a	• Underpin major value chains
	Fiber, medicines and other products (e.g. ornamental)	• Fundamental to many rural livelihoods • Supports health	• Supply urban populations	n/a	• Wild-sourced commodities, including: • Timber • Pharmaceuticals • Other non-timber products
	Genetic diversity	• Crop diversity, supporting food security	• Crop diversity, supporting food security	n/a	• Agricultural commodities • Pharmaceutical ingredients
	Water supply and quality	e.g. • Irrigation • Energy production • Domestic use • Resilience to drought	e.g. • Energy production • Domestic use • Commercial and industrial use	e.g. • Hydroelectric power generation • Navigation • Waste management	e.g. • Irrigation • Power supply • Industrial processing • Distribution networks • Waste management • Resilience to drought
	Timber and fuelwood	• Construction materials • Household energy • Supports forestry-based livelihoods	• Construction materials, including commercial/ industrial • Energy use by households and industries	• Construction materials	• Timber and associated industries
Regulating Services	Pollination	• Pollination of crops, with improved yields and reduced costs	• Pollination of urban crops, with improved yields and reduced costs	n/a	• Pollination of commodity crops, with improved yields and reduced costs
	Pest and disease control	• Natural pest control for crops, with improved yields/reduced losses • Mitigation of vector-borne diseases, improved health	• Natural pest control for crops, with improved yields/reduced losses • Mitigation of vector-borne diseases, with improved health	• Mitigation of vector-borne diseases, with improved workforce health	• Natural pest control for commodity crops, with improved yields/ reduced losses • Mitigation of vector-borne diseases, with improved workforce health
	Soil stabilization: erosion and landslide control	• Protection of lives and assets • Retained soil fertility • Reduced dust/air pollution • Maintenance of water quality	• Protection of lives, livelihoods, and assets (urban landslide reduction) • Maintenance of water quality • Reduced dust/air pollution	• Asset protection (from siltation/ landslides) • Reduced dust/air pollution	• Retained soil fertility • Asset protection (from siltation/ landslides) • Maintenance of water quality
	Flood regulation	• Protection of lives, livelihoods, and assets • Water quality, incl. control of water-borne diseases and flood-related chemical and other contamination • Provision of sediment in floodplains, supporting agriculture	• Protection of lives, livelihoods, and assets; reduced costs for flood protection • Water quality, incl. Control of water-borne diseases • Provision of sediment for delta building	• Asset protection; reduced costs for flood protection	• Asset protection; reduced costs for flood protection • Provision of sediment in floodplains, supporting agriculture • Water quality

		Food Security and Rural Livelihoods	Cities	Infrastructure	Industry and Supply Chains
Regulating Services	Coastal protection	• Protection of lives, livelihoods, and assets • Avoiding salinization of agricultural land and water supplies • Sediment retention and reduced coastal erosion	• Protection of lives, livelihoods, and assets • Avoiding salinization of water supplies • Sediment retention and reduced coastal erosion	• Asset protection • Reduced sediment retention and educed coastal erosion	• Reduced cost of coastal defense • Reduced sediment retention and reduced coastal erosion, including retaining the tourism value of beaches
	Local climate regulation	• Contributing to improved crop yields/ reduced losses • Improved nutritional content	• Improved health, e.g. Mitigation of urban heat island effects • Reduced energy consumption	• Asset protection • Reduced energy consumption	• Contributing to improved crop yields/ reduced losses • Asset protection • Reduced energy consumption • Improved health of workforce, e.g. mitigation of heat stress
	Inter-regional/global climate regulation	• Mitigation of global climate change impacts through carbon sequestration and storage	• Mitigation of global climate change impacts through carbon sequestration and storage	• Mitigation of global climate change impacts through carbon sequestration and storage	• Mitigation of global climate change impacts through carbon sequestration and storage
Supporting Services	Soil formation, primary production, nutrient cycling	• Improved productivity and crop yields • Reduced costs for fertilizers	• Improved productivity and yields from urban agriculture • Reduced costs for fertilizers	n/a	• Improved productivity and commodity yields • Reduced costs for fertilizers
Cultural Services	Nature-based tourism and recreation	• Contributing to local livelihoods • Recreation opportunities	• Recreation opportunities, green spaces • Wild animal and plant populations supporting urban livelihoods, e.g. traders, tourism	• Market/opportunities for infrastructure development to support tourism industry • New workforce opportunities	• Supporting tourism industry

2.1. Food Security and Rural Livelihoods

ECOSYSTEM DEPENDENCIES

Terrestrial and aquatic ecosystems underpin the world's food production and are of fundamental importance for sustaining food security and livelihoods, especially for the rural poor. Ecosystems also provide income opportunities and shelter and support health. Ecosystem goods can thus be directly linked to the basic requirements of a good quality of life for many communities.[14]

Nearly 70 percent of the estimated 1.1 billion people living in poverty in rural areas depend directly on the productivity of ecosystems for their livelihoods,[15] and agriculture is the direct livelihood of 2.5 billion smallholder farmers.[16] Aquatic ecosystems also make a major contribution to food security and livelihoods, supplying 17 percent of the global population's intake of animal protein in 2015.[17] Poor and undernourished populations are particularly reliant on inland fisheries for both nutrition and income.[18]

Ecosystems play a role in all four critical dimensions of food security: production, access, utilization, and stability.[19] Food production depends not only on the health and biodiversity of farm-level agro-ecosystems, but also on provisioning, regulating, and supporting ecosystem services at landscape-level. For example, wetlands provide vital freshwater sources to large populations.[20] Pollination is also critical, as it directly affects the yield and/or quality of 75 percent of globally important crops,[21] and contributes an estimated US$235 to $577 billion annually to the global economy.[22] Ecosystems also support food production by contributing to soil health, nutrient cycling, erosion control, and the regulation of crop and livestock pests and diseases.

Ecosystem-based livelihoods contribute to purchasing power that helps secure access to food for households or communities.[23] Recent work has established that rural populations in developing countries obtain about a quarter of their income from harvesting non-timber forest products (NTFPs) such as shoots, roots, mushrooms, and insects,[24] and in some cases far more.[25,26] Such harvesting is particularly important in women-led households in rural areas,[19] and is dependent on the health and productivity of the forests and other ecosystems.

Food utilization depends on adequate diet, clean water, sanitation, and healthcare enabling physiological needs to be met. It has clear ecosystem dependencies. For example, water from forested watersheds is less contaminated than that from non-forested watersheds.[27] A wide variety of wild foods rich in micronutrients contribute to the diets of large numbers of people, particularly in developing countries;[15] one study found that 77 percent of households in communities in or near tropical forests in 24 countries collected wild foods.[28]

Food stability is at risk under climate change.[29] When harvests fail, ecosystem goods can provide both nutrients and income to buy food.[8] For example, wild fruits and firewood have been estimated to provide 42 percent of total income during recent drought years in Tanzania.[30] Ecosystems can also mitigate the impact of extreme weather events in the first place.

CLIMATE RISKS

The impacts of climate change on ecosystems and their services present a major threat to food security and rural livelihoods.[31] Climatic variability and extremes are already key drivers behind the recent rise in global hunger and one of the leading causes of severe food crises, with drought causing more than 80 percent of the total damage and losses in agriculture.[32]

Crop, livestock, forest, and aquatic production are all projected to be affected by climate change. Key climate hazards are higher temperatures, altered rainfall, greater pressure from pests and diseases, increased occurrence of invasive alien species, more frequent extreme events, and in aquatic environments, lower oxygen levels, greater acidity, and higher levels of turbidity or siltation.[33] The impacts are already being felt; for example, 95 percent of 860 smallholder farmers in 6 landscapes across Central America are experiencing climate-related impacts.[34] Globally there has already been an overall 1 percent decline in calorie production from the top ten crops.[31] Recent projections suggest losses in marine fisheries production may be at least as severe.[12,35]

Climate change risks in this sector have been described as a cascade beginning with agro-ecosystems and agricultural production, to economic and social consequences, and finally to food security and nutrition.[36] At farm level, climate change can cause loss of capital and income, which, compounded by commodity price volatility, limits the capacity of households to make other necessary expenditures, including for health and education.[30] Beyond compromising food availability and access, climate change impacts on nutritional quality, food safety, sanitation, and drinking water quality can also reduce the health of populations as well as their food utilization.

Climate change can act as a threat multiplier on already degraded ecosystems, further reducing ecosystem services important for agriculture. Loss of diversity in agro-ecosystems and production systems leads to heightened vulnerability to climate variability, pests, and commodity price fluctuations. In the face of climate hazards, the adaptive capacity of communities with livelihoods dependent on direct use of natural resources is often constrained by the loss of ecological functioning in the landscapes they inhabit.

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2.2. Cities

ECOSYSTEM DEPENDENCIES

The well-being of urban populations also depends on ecosystems, both within and outside cities, and the services they provide. Urban ecosystems (green and blue spaces) found in cities or peri-urban areas contribute provisioning services such as food and fresh water for these populations.[37] It is estimated that, if well implemented in cities around the world, urban agriculture (e.g. in peri-urban farms or community gardens) could account for up to 10% of global production of vegetable crops, whilst producing additional benefits such as energy savings, nitrogen sequestration, pollination, climate regulation, soil formation, and pest control.[38] Urban agriculture may be particularly important for ensuring food security of poorer urban residents, particularly during economic or political crises.[32]

Urban ecosystems also provide regulating services that protect urban citizens, assets, and infrastructure from higher incidence of heat waves, drought, storms, flooding, and other impacts of climate change. Vegetation can intercept rainfall, help to stabilize soil (reducing landslide risk), enhance infiltration into the soil (reducing run-off), and moderate urban temperature (reducing heating and cooling costs).[32] Green spaces can bring the added benefits of air purification and noise reduction. In addition, urban ecosystems provide socially and economically important aesthetic, mental, and physical benefits that contribute to human health and well-being.[31] The presence of green spaces is associated with better mental health.[39] Green areas also encourage physical activity and recreation, improving urban citizens' health and reducing health-related costs.[40]

CLIMATE RISKS

Growing numbers of urban populations are increasingly vulnerable to multiple climate change hazards such as heat stress and heat island effects,[41] reduced water quality and availability,[42] flooding, heavy precipitation and storms, and food insecurity.[43] Degradation of ecosystem services in urban areas leads to a further reduction in ecosystem resilience to climate change, leaving cities even more vulnerable to its impacts.

By 2050, sea level rises of at least 0.5m compared to the 2000 to 2004 baseline period will affect nearly 600 low-lying coastal cities, with economic losses of up to US$1 trillion.[44] Many delta and coastal cities also suffer from aquifer depletion and soil subsidence due to groundwater extraction, increasing vulnerability to sea level rise.[45,46] Flooding and intense precipitation events related to climate change increase the risk of landslides and contamination of water, putting dense urban populations in danger.[47,48] Degradation of urban and peri-urban ecosystems increases these risks, which can be especially high for poor and marginalized groups and people living in informal settlements. An estimated 150 million people globally live in cities with constant water shortages;[49,50] this number is projected to increase to nearly 1 billion people by mid-century. Even normally, well-supplied cities are already experiencing shortages; during a drought in 2015, water in Sao Paulo's main reservoir dwindled to only 4% of its capacity, causing drinking water shortages and rationing that led to social unrest.[51] Climate-related threats to human health and well-being will become more frequent through illness, direct physical injuries, malnutrition, or impacts on mental health.[52,53] Climate change also poses risks to economic activity and jobs. Disruptions to infrastructure, energy supply, transport, and communications, as well as to the tourism and construction sectors put urban areas further at risk.[54] Cities in developing countries and poor urban populations are particularly vulnerable to such impacts due to existing poverty and environmental stresses.[55]

2.3. Infrastructure

ECOSYSTEM DEPENDENCIES

Infrastructure encompasses the structures, services, and amenities that support the functioning of economies and underpin our day-to-day lives.[56] It includes both natural or green infrastructure (e.g. watersheds, wetlands, river floodplains) and built or gray infrastructure (such as reservoirs, power plants, dams, or irrigation/drainage networks).[57] Key infrastructure sectors include those relating to energy, transport, telecommunications, water, and waste management.[58] Infrastructure such as transportation, energy transmission, water, telecommunication systems, and sea walls, provides services that are integral to societal wellbeing while supporting a range of social and economic activities.

Infrastructure depends on a number of ecosystem services to fulfill its functions.[51] A wide-ranging review for the ENCORE (Exploring Natural Capital Opportunities, Risks and Exposure) project found that the infrastructure sector depends on nature in many ways, including for the supply of water, protection against floods, and control of erosion and related sedimentation.[59]

Dependencies on provisioning services include the need for clean water to supply hydroelectric facilities as well as waste management and industrial installations. Regulating services are important for both asset protection and function for most forms of infrastructure. Roads, for example, may rely on ecosystems for flood regulation, coastal storm protection, erosion control, landslide prevention, water quality regulation, and air quality regulation.[51] Such dependencies, while important and very beneficial, are not always known or fully valued by businesses operating within the sector.[60]

CLIMATE RISKS

As recognized in some national climate change risk assessments,[61] climate change puts infrastructure sectors at risk. The vulnerability of infrastructure is due both to its dependencies on ecosystem services (e.g. water supply for hydroelectric power generation) and to the potential for asset damage or service disruption (e.g. damage to coastal pipelines due to storm surges). Actual risk will depend on various factors, including the type and location of the infrastructure[51] and the condition of surrounding ecosystems. In Haiti, for example, erosion in the deforested watershed of the Péligre Dam reduced its capacity by half, including its electricity generation capacity[62] along with its value for irrigation and flood control.[63]

Previous extreme events have illustrated the impacts that climate change is already having on infrastructure. For example, due to the 2009 heatwave, Melbourne's electricity supply suffered significant disruption, resulting in loss of power for over 500,000 residents.[64] Flooding in eastern China in 2011 caused major damage to over 20,000 roads and numerous rail links and airports, and cut power to millions of households.[65] Modelling potential impacts of flooding illustrates that not only is the direct impact of climate change on infrastructure of concern, but also the economic losses that service disruption may cause.[51] For example, in a study modelling flooding of the Seine in Paris, up to 30 to 55 percent of the modelled damages of US $3 to 30 billion affected the infrastructure sector, and 35 to 85 percent of the business losses were caused by disruption of energy supply and transport.[51] Moreover, many infrastructure assets are developed for long time horizons, increasing their vulnerability to incremental or gradual changes in climate,[66] which may be exacerbated by ecosystem degradation.

2.4. Industry and Supply Chains

ECOSYSTEM DEPENDENCIES

Terrestrial and aquatic ecosystems support production and profitability for key industries and supply chains around the world. Important provisioning services include those from forests, which provide wood for timber, paper, and non-timber forest products and from marine, coastal and other aquatic ecosystems, which provide fish, shrimp, and other products. For example, global production and trade in wood and paper products alone was US$247 billion in 2017;[67] in 2016, the fisheries and aquaculture industry produced a total first-sale value of US$362 billion.[29] Regulating and supporting services from ecosystems are also essential to sustaining industries and supply chains. The continued production of agricultural commodities requires pollination, secure water supplies, sufficient soil quality, and protection from erosion and natural disasters. Furthermore, wildlife-provided pest control services support higher yields of agricultural commodities such as cocoa.[68] Offshore fisheries areas with mangroves provided higher total catch (123 kg per fishing hour), income from fishing (US$44 per hour), and number of species caught (44) than areas without mangroves (18 kg per hour; US$2.62 per hour; and 24 species).[69]

Ecosystem status and services affect how goods are produced, shipped, and consumed through protection of key infrastructure. Mining and mineral processing facilities, for example, are large consumers of water (for ore processing, transport, dust control, and community supplies).[70,71] Ecosystems also provide natural assets vital to one of the world's fastest-growing economic sectors, tourism. In 2017, international tourism generated US$1.6 trillion in export earnings,[72] and numbers are increasing.[73] Protected areas and other natural attractions, as well as natural processes such as snowfall for ski resorts, are essential for the continued sustainability of numerous tourism businesses.

CLIMATE RISKS

Industries and the supply chains that underlie them can be vulnerable to climate change impacts at several key points along these chains. These include raw materials production, product processing, distribution and delivery, and markets.

The threats posed by climate change to food security, subsistence agriculture, tourism, and livelihoods (discussed above) apply to many important global supply chains, and disruption in one region may have global implications. For example, maximum catch potential in marine exclusive economic zones globally is projected to decrease by at least 2.8 to 5.3 percent by 2050.[29] Climate change will also affect other sections of these supply chains through changes in quality of raw materials, disruptions to key processing inputs, impacts on health and safety, and impacts on processing facilities and distribution networks from extreme events (e.g. severe flooding in Thailand in 2011 led to business disruption in more than 14,500 companies reliant on Thai suppliers with total insured losses of US$15-20 billion[74]). Climate change impacts on ecosystems can affect the costs of goods, infrastructure, and services needed for processing and distribution, and consequently markets and prices.[75]

Climate change will have negative impacts on the tourism industry, including leading to substantial geographic shifts in demand as the sector is susceptible to extreme weather.[76] Climate-induced changes in environmental assets, such as biodiversity, beaches, glaciers and other features, may be especially critical for tourism.[2,77] For example, it is estimated that between 49 and 60 percent of coastal resorts in the Caribbean would be at risk of erosion damage with 1 meter sea level rise.[78] In Australia, warming of ocean waters has caused coral bleaching and die-off, impacting an industry that contributes US$3.9 bilion to the country's economy each year (Box 1).[79] In the Swiss Alps, the depth of snow cover is expected to decrease between 30 and 70 percent by the end of the century, negatively impacting the ski industry and the livelihoods of alpine villages where tourism can sustain up to 90 percent of the local economy.[80]

BOX 1 Climate Change Impacts and Responses on the Great Barrier Reef

The Great Barrier Reef is the world's most extensive coral reef ecosystem. The Reef region contributes an estimated US$3.9 billion/year[ii] to the Australian economy. Climate change has been identified as the dominant factor affecting the future of the reef, along with declining water quality from runoff, loss of coastal habitats, and impacts from fishing, which also contribute to reducing the reef's resilience.[81]

Following a marine heat wave in 2016, accumulated heat exposure exceeded a critical threshold. A regional-scale shift in the composition of coral assemblages occurred, with some taxa suffering a catastrophic die-off. Integrity and function were affected in 29 percent of the 3,863 individual reefs making up the Great Barrier Reef.[82] Mass coral bleaching and a severe tropical cyclone negatively affected an estimated 80 percent of the reefs of the Marine Park over 2016-2018.[83]

The Reef 2050 Plan, developed in 2018, sets out long-term management actions, including a number of NbS-based actions to address climate change impacts, such as reducing land-based pollution and coral reef restoration to restore ecological functions and help foster community and industry resilience.[84]

Tourism industry actors are also responding to climate change through their own actions. The most common environmental actions being undertaken by tourism operators were recycling, risk management, responsible waste disposal, and reduced energy use.[85]

Johnwalker1_AdobeStock

ii. Reference for the year 2012.

3. Ecosystem Degradation Compounds Vulnerability

Ecosystem services (as described in Section 2) depend on the condition and functioning of the ecosystems themselves. Therefore, there is generally a link between ecosystem resilience, which is critically underpinned by biodiversity, and the resilience of societies, and between degradation[iii] of those ecosystems and heightened vulnerability of associated livelihood systems and peoples.[86] Consequently, sustainable ecosystem management and ecosystem restoration[iv] are vitally important for climate change adaptation (see Section 4).

Conversion and degradation of ecosystems result from their unsustainable use and management, including resource exploitation,[87] which may ultimately be driven by population growth and lifestyle changes (Figure 1). Climate change, as a so-called "threat multiplier", compounds these pressures, causing further degradation and loss of ecosystem services, including those offering protection to people, their property, and livelihoods. This often triggers further unsustainable ecosystem use and management. The result can be a downward spiral of fragility, resource depletion, and conflict.[88]

In the Sahel, for example, government-supported expansion of farming into rangelands has caused increased pressure on remaining grazing resources, resulting in rangeland degradation. This has been exacerbated by periods of drought, giving rise to conflicts between nomadic pastoralists and farmers, and further degradation of soils and rangeland vegetation.[89] In the marine environment, fish stocks are declining largely due to overharvesting, but rising sea temperatures and associated hypoxia and ocean acidification also affect species composition, biomass, ranges, and abundance, contributing to the degradation cycle.[90] In the southern Caribbean sea, warming temperatures have caused changes in wind and seawater circulation patterns, reducing ocean upwelling. This led to decreasing levels of plankton production which, coupled with overfishing, caused sardine fisheries in the region to collapse by up to 87 percent.[91] Such processes, whether in a terrestrial or aquatic environment, can push an ecosystem past a tipping point beyond which it experiences "regime shift": collapse into an undesirable state that can no longer sustain a particular livelihood system.[92] Examples include soil salinization, the transition from forests to savannas, and fisheries collapse. Reversing such impacts and restoring ecosystem health can be notoriously difficult.[93,94,95,96]

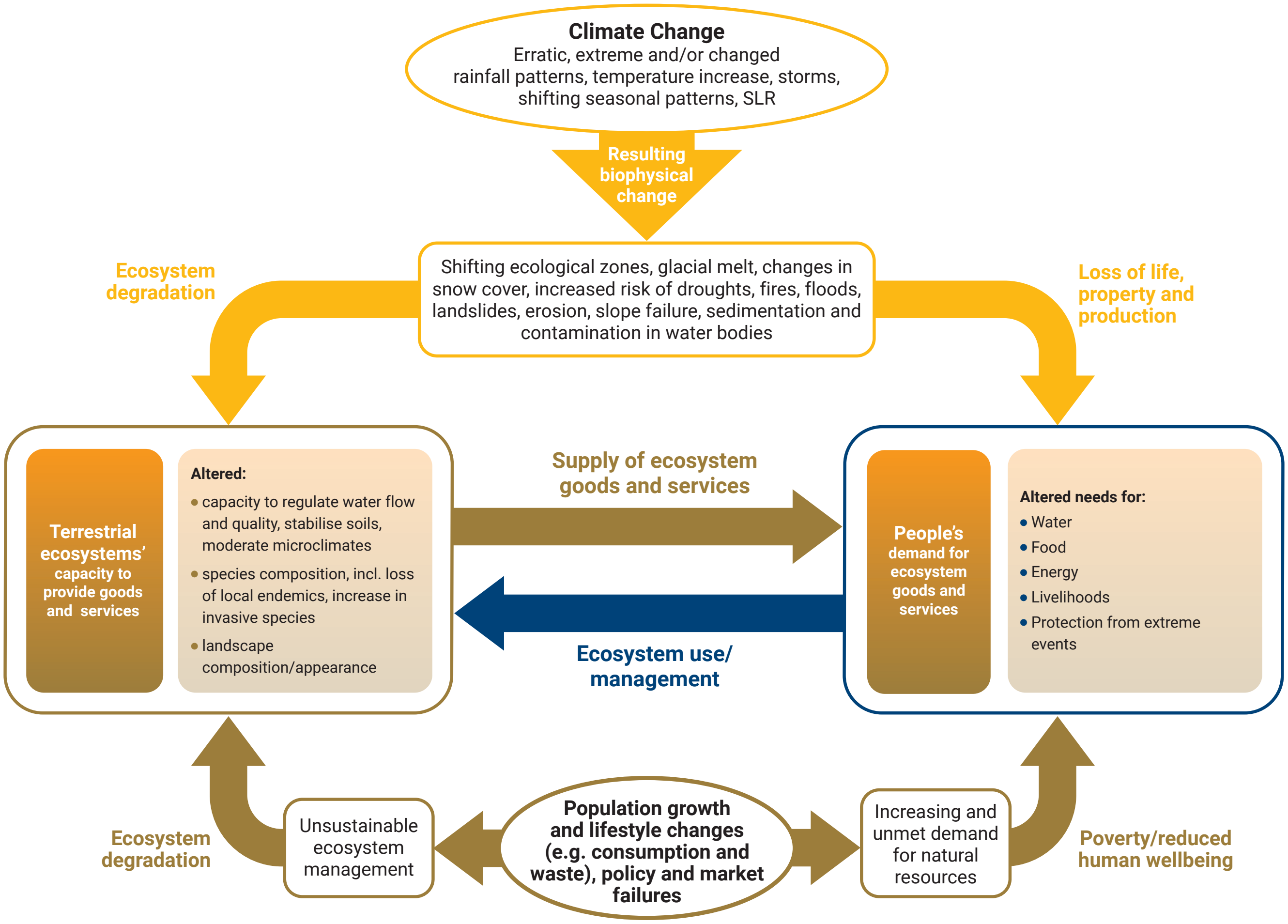
Beyond its local impacts, this cycle of degradation and climate impact is critical at broad geographical and even planetary scales.[97] For example, deforestation in the major tropical forest regions has potentially large impacts on the global climate system.[98] This in turn has important implications for agricultural yields, and therefore for food security and the climate vulnerability of global populations.

Thus, combatting degradation and supporting the resilience of ecosystems is crucial for supporting social and economic resilience and adaptation in the face of climate change at scales ranging from local to global. This can only be achieved by ensuring management and restoration approaches take into account anticipated climate impacts as well as the tolerance of ecosystems to these impacts.

iii. Degradation is disturbance or disruption of an ecosystem that causes a long term reduction in its capacity to provide goods and services. Changes in ecosystem structure, composition, and function, and loss of biodiversity are all associated with ecosystem degradation

iv. Including both biophysical reduction of degradation and reduction or elimination of its drivers

FIGURE 1 Interactions of climatic and non-climatic degradation processes in terrestrial ecosystems.



Aspects of climate change (top oval) have numerous biophysical impacts, which can directly affect ecosystems (leading to ecosystem degradation) and people (causing loss of life, property, and livelihoods). They can also trigger indirect impacts: climate-induced degradation reduces the ecosystem's capacity to provide goods and services to people. The resulting shortfalls in vital ecosystem goods and services can lead to unsustainable management that may further reduce the capacity of the ecosystems to provide them, increasing people's vulnerability to climate change.

Non-climatic degradation processes, driven by population growth and lifestyle changes, interact with climate-induced processes. Increasing demand for land and other natural resources (left) leads to unsustainable ecosystem management and use of goods and services, causing further ecosystem degradation. Population growth and lifestyle changes (right) lead to increasing and unmet demand for natural resources, which can increase poverty, reduce human wellbeing, and exacerbate inequality. This, in turn, affects people's demand for ecosystem goods and services, further driving unsustainable use and management of the ecosystem, thereby degrading it and reducing its capacity to supply necessary goods and services. These simultaneous negative feedback loops form a vicious cycle of degradation.

4. Nature-based Solutions for Adaptation

Given the dependencies described in the previous sections, reducing societal vulnerability to climate change both requires and can benefit from efforts to secure ecosystem services that support climate adaptation and resilience. Firstly, feedbacks between ecosystem condition and societal vulnerability to climate-related impacts mean that **managing nature to maintain the integrity and function of ecosystems, and retain and enhance their services, is crucial to successful societal adaptation**. Essential approaches for maintaining and enhancing ecosystem resilience include conservation of large tracts of relatively intact ecosystems, restoration of degraded ecosystems, and implementation of landscape management regimes that maintain or enhance connectivity, and limit adverse impacts on ecosystems and biodiversity. Such approaches should be informed by climate change projections and built on the best available information on ecosystem responses.

Secondly, nature and the services it provides can be harnessed specifically to address climate hazards in particular contexts. Such **Nature-based solutions (NbS) for adaptation (Box 2)** can deliver multiple additional benefits to society. NbS for adaptation have been used to address a wide range of climate-related hazards. These include: **coastal hazards** such as sea level rise, storm surge and associated flooding, and erosion (Box 3, Section 4.1a); **inland flooding, landslides** and **soil erosion** linked to intense precipitation events (Section 4.1b); **drought** (Section 4.1c); and heat effects, including forest fires and **heat** islands effects in urban environments (Section 4.1d). NbS for adaptation should form part of an overall adaptation strategy, which may well also include engineered solutions.

BOX 2 Nature-based Solutions for Adaptation

Nature-based solutions (NbS) are actions that work with and enhance nature to support biodiversity and help address societal challenges.[99,100,101]

In the context of adaptation, most NbS correspond to:
Ecosystem-based adaptation (EbA), "*the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change.*"[102]

and/or

Ecosystem-based disaster risk reduction (Eco-DRR), "*the sustainable management, conservation, and restoration of ecosystems to reduce disaster risk, with the aim of achieving sustainable and resilient development.*"[103]

BOX 3 Nature-based Solutions for Coastal Hazards[104,105]

Coastal wetlands, such as mangroves and salt marshes, stabilize coastlines by trapping sediment and by reducing wave height and velocity with their dense vegetation. Salt marshes can reduce non-storm wave heights by an average of 72 percent, and mangroves are estimated to reduce them by 31 percent.

Coral and oyster reef systems can control coastal erosion by reducing wave velocity; one estimate suggests that coral reefs reduce non-storm wave heights by as much as 70 percent.

Sandy beaches and dunes prevent coastal erosion caused by strong winds, waves, and tides. They can also stop waves and storm surge from reaching inland areas.

Seagrass helps stabilize sediment and regulates water currents that contribute to coastal erosion. Seagrass beds reduce non-storm wave height 36 percent on average.

There is a growing body of documented experience in the use of NbS for adaptation, especially in the context of disaster risk reduction (sometimes referred to as Eco-DRR).[106,107] The World Bank and the Global Facility for Disaster Reduction and Recovery (GFDRR) are stepping up their support for NbS for adaptation (EbA and Eco-DRR). Just over 1 in 10 of the Bank's disaster risk management (DRM) projects now contain some element of NbS.[108] Since 2009, when the Convention on Biological Diversity (CBD) defined the concept of ecosystem-based adaptation (EbA), UN Environment, UNDP, International Union for Conservation of Nature (IUCN) and The Nature Conservancy (TNC) have all made substantial investments in supporting EbA implementation in developing countries using Global Environment Facility (GEF), Green Climate Fund (GCF), and other funds. Among major bilateral donors, Germany has placed a very high emphasis on EbA, committing €172 million to date to this issue from its International Climate Initiative. The potential is great for scaling up the use of NbS still further through the efforts of a wide range of actors.

In many cases, there are **both economic and practical advantages** to using NbS for adaptation. A growing body of evidence suggests that many NbS for adaptation are **low cost**, especially compared with many hard infrastructure-based approaches for addressing climate hazards.[109] For example, it can be two to five times cheaper to restore coastal wetlands than to construct submerged breakwaters to deal with wave heights of up to half a meter; median restoration costs are US$1.11/ m^2 (ranging from US$0.01 to US$33.00) for salt marshes, and US$0.1/ m^2 for mangroves (ranging from US$0.05 to US$6.50).[99] Other forms of restoration are more costly (US$2-7,500/ m^2 for coral reefs and US$107-316/ m^2 for oyster reefs), but still far less than the cost of much hard infrastructure, which can be prohibitive, especially for some developing countries.[110] However, the protective value of hard infrastructure and the confidence with which it is viewed may be much higher, so careful cost-benefit analysis is needed in any given situation. NbS and built infrastructure may also be used in tandem to help buffer against unpredictable impacts of climate change which built infrastructure alone may not be able to withstand.

Further economic advantages to NbS for adaptation derive from their **potential for generating larger economic returns** because of the **co-benefits** (benefits in addition to their adaptation value) they generate. These include provisioning services that have financial values, such as wood fuel and NTFPs; job creation; biodiversity conservation; carbon sequestration and storage; and social co-benefits such as improved health and recreation opportunities. Full consideration of co-benefits, whether through monetary valuation of ecosystem services or other approaches, can shift the balance in cost-benefit analysis. This tends to highlight especially the advantages of hybrid or mixed approaches, in which NbS for adaptation are used to increase the effectiveness or reduce the cost of engineered approaches (as in the role of wetlands in reducing the costs of infrastructure-based protection for coastal cities)[111] and generate favorable benefit-to-cost ratios due to the value of the co-benefits (Boxes 4, A1), which may increase as the nature-based components mature.

BOX 4 Adaptation Cost-benefit Analysis in Lami Town, Fiji

Climate change is projected to increase flooding and erosion threats to the rapidly growing population and infrastructure of urban and peri-urban Lami Town. To help understand the full impact of different adaptation options, a cost-benefit analysis was carried out for four different adaptation interventions. The scenarios used had different levels of ambition with regard to use of EbA.

The analysis considered benefits over a 20-year time horizon, including reduced health costs, avoided damages to businesses and households, and wider ecosystem services being maintained or enhanced. Despite assumed lower impacts in terms of damage avoided, ecosystem-based options were identified as having the highest return per dollar of investment.

Source: Rao, N.S., Carruthers, T.J.B., Anderson, P., Sivo, L., Saxby, T., Durbin, T., et. al. 2012. A comparative analysis of ecosystem–based adaptation and engineering options for Lami Town, Fiji. A synthesis report by the Secretariat of the Pacific Regional Environment Programme.

Scenario	Benefit-to-cost ratio (FJD)	Assumed damage avoidance
Ecosystem-based options	$19.50	10–25%
Emphasis on ecosystem-based options	$15.00	25%
Emphasis on engineering options	$8.00	25%
Engineering options	$9.00	25–50%

Benefit-to-cost ratio for each scenario of adaptation options, and assumed damage avoidance.

Such co-benefits are among the reasons that **NbS for adaptation are gaining prominence in the policy arena**. International agreements and conventions both within and beyond the climate change arena are increasingly recognizing the potential of NbS for adaptation, and this is reflected in national commitments under these agreements.[112,113] For example, of 167 Nationally Determined Contributions (NDCs) submitted under the Paris Agreement, 70 include actions broadly aligned with EbA in the adaptation component, and a further 33 countries refer to conservation activities in this context.[114] These commitments are especially prevalent among developing countries (all low-income countries refer to NbS in the adaptation component of the NDCs), and much less so among high-income nations (27 percent include NbS for adaptation).

NbS for adaptation also offer **flexibility**. They have some ability to adjust in response to further environmental change (e.g. through the landward shift of mangroves), unlike built solutions, and they can **address multiple climate challenges**.[115] They can often be implemented with lower technical inputs, although they do depend on sufficient expertise to address questions of feasibility and effectiveness. This very flexibility and the vulnerability of different sectors to many of the same climate-related hazards means that NbS for specific hazards may be applicable in multiple sectors.

While NbS for adaptation offer considerable benefits and advantages, there are also limitations and constraints that need to be considered. Some NbS, especially those involving restoration of badly degraded ecosystems, can be slow to develop their adaptation benefits or deliver potential co-benefits in full. Depending on the immediacy of the risks involved it may be necessary to supplement such interventions with engineered approaches in the short term. Delays to accrual of benefits also mean that benefit-cost ratios are variable over time. The appropriateness, design, effectiveness and co-benefits of NbS for adaptation tend to be highly context-specific, as they depend on biophysical conditions and the status, details and needs of the social-ecological system, as well as on the hazards that need to be addressed. This context specificity adds to uncertainties about the effectiveness of individual NbS for adaptation in any given context and in relation to hazard severity, which compounds the inherent uncertainty in climate projections and hazard estimation (see also Box 10, Section 5). In some cases, NbS may be less effective for adaptation to high magnitude climate hazards. Finally, NbS for adaptation may themselves be climate-sensitive, which is why understanding and managing for ecosystem resilience is critical.

Despite these limitations, NbS have real potential to contribute to adaptation. The following sections first introduce NbS commonly used for adaptation in relation to specific climate hazards, followed by insights into current practice and experience in using NbS in particular sectors.

4.1. NbS for Specific Hazards

NbS for adaptation have been used to address a broad range of climate hazards in a variety of contexts. This section discusses NbS commonly used for adaptation to specific climate-related hazards in four groups: coastal hazards, and hazards linked to intense precipitation, drought, and heat. Each group includes hazards that both result from similar climate change variables (e.g. rising temperatures, changing rainfall patterns, increased frequency of extreme events) and share common solutions, which generate similar co-benefits in addition to adaptation (Table 2).

Decision-making and action on NbS for adaptation should take a **systems perspective**. NbS for adaptation are best conceptualized **at landscape and wider scales** to take account of the interactions within and between ecosystems and the distribution of potential beneficiaries and impacts.[116] Without this, actions taken to reduce vulnerability in some locations may exacerbate it elsewhere. For example, dams built to store irrigation water and/or generate hydropower on the Upper Senegal, Logone, Chari have degraded downstream wetlands critical to the livelihoods of farmers, herders, and fishers of the region, resulting in hardship, migration, and conflict.[117] Information and decisions at hydrological basin scale are equally important for the use of NbS in coastal zones because sediment loads have critical impacts on reefs and other systems. These connections are the basis for recommended 'ridge-to-reef' approaches to understanding and managing both social and ecological systems and their interactions.[118] These approaches are especially important for small island developing states[119] and efforts to enhance reef resilience.[120] In coastal zones, too, the scale of action and ecosystem continuity affect the degree to which NbS confer coastal protection and resilience.[121,122]

TABLE 2 Nature-based solutions that can reduce impacts related to major climate hazards, and their potential co-benefits.

More than one of the solutions may be appropriate for addressing a given impact depending on geographic, social-ecological and economic contexts. Different subsets of co-benefits will accrue depending on the option selected and the way it is implemented (i.e. there is not a one-to-one correspondence between the multiple entries across cells of a given row).

Hazard	Example impacts	Nature-based Solution(s) for adaptation	Potential co-benefits
Coastal • Sea level rise • Storm surge • Coastal erosion	• Loss or saline inundation of productive land • Inundation of coastal cities, roads, factories, refineries and other installations leading to loss of life and asset damage	• Mangrove protection and restoration to anchor sediments, and dissipate wave energy (e.g. Boxes A2, A3) • Coastal marsh and dune management and restoration to dissipate wave energy and/or complement engineered protection (e.g. Box A4) • Coral reef management and restoration to attenuate wave energy (Box A5)	• Improved fish stocks • Biodiversity conservation • Carbon sequestration and storage • Sediment accretion • Tourism and recreation
Intense precipitation • Flood • Soil erosion • Landslide	• Loss of crops, livelihoods, assets, and lives due to inundation in rural areas • Loss of soil and associated fertility leading to reduced harvests and supplies of agricultural commodities • Disruption to urban lives, economic activity, transport • Sedimentation that affects urban and other water supplies, navigation, and industrial and infrastructure function (e.g. hydropower) • Loss of life and physical damage to assets, leading to transport disruption and lost productivity	• Management and restoration of watershed vegetation to enhance infiltration, reduce run-off and peak flows, and stabilize soils and slopes (e.g. Boxes A6, A7, A8, A9, A10) • Agroforestry and/or "conservation agriculture" to enhance canopy interception of rainfall and rainwater infiltration and reduce soil exposure, reducing run-off and erosion (e.g. Box A10) • Riparian buffer and floodplain management and restoration to accommodate overspill and reduce assets at risk (e.g. Boxes A11, A12) • Urban watercourse restoration, and 're-naturing' to reduce assets at risk and secure river banks (e.g. Boxes A13, A14, A15) • Maintenance and restoration of urban greenspaces to improve rainwater infiltration and reduce run-off (e.g. Box A13) • Management and restoration of wetlands to store or slowly release floodwater and filter sediments (e.g. Box A7)	• Increased availability of wild-sourced food (including freshwater fish) and other products • Pollination services • Carbon sequestration and storage • Improved soil fertility • Biodiversity conservation • Improved water quality • Improved physical and mental health in urban populations

Hazard	Example impacts	Nature-based Solution(s) for adaptation	Potential Co-benefits
Drought	• Reduced harvests, livestock losses, damage to livelihoods and interrupted supplies of agricultural commodities • Water shortages affecting lives, sanitation, and economic activity • Disruption to transport and industrial processes (e.g. hydropower)	• Management and restoration of watershed vegetation to enhance infiltration, recharge groundwater stores and maintain surface water flows (e.g. Boxes A10) • Establishment of 'Green Belts' to increase water availability, improve soil quality, provide shade and windbreaks • Climate-resilient grazing and livestock management to regenerate vegetation, increasing forage quality and quantity, and water availability, improve soil quality (e.g. Box A7)	• Increased availability of wild-sourced food (including freshwater fish) and other products • Pollination services • Carbon sequestration and storage • Improved soil fertility • Biodiversity conservation
Heat • Urban heat island • Fire	• Reduced harvests, livestock losses, interrupted supplies of agricultural commodities • Damage to human health and well-being • Damage to infrastructure assets and function (e.g. power distribution) • Damage to lives, livelihoods, and assets	• Agroforestry to enhance canopy cover and provide shade • Rehabilitation and restoration of rangelands to repair ecological processes and enhance fire resistance • Improved forest management for fire risk reduction (including removal of invasive fire-prone plants) • Management and restoration of watersheds • Creation of urban green spaces to increase vegetative canopies, providing shade and evaporative cooling and provide shade layer and plant coverage (e.g. Box A13)	• Carbon sequestration and storage • Improved soil fertility • Biodiversity conservation • Improved physical and mental health in urban populations

4.1a. COASTAL HAZARDS

Climate change-related hazards in coastal zones include **flooding** and **erosion** due to **sea level rise**, **wave impacts**, and **storm surges**. These effects are exacerbated by land subsidence linked to freshwater extraction and compounded by saline intrusion.[123] NbS for adaptation options in coastal zones include protection, management, or restoration of coastal wetlands, mangroves, seagrass beds, and coral or oyster reefs, as well as stabilization or restoration of beach and dune systems (Box 3).

Coastal wetlands such as salt marshes and mangroves provide areas of extra water storage and increased friction that help to reduce the force and impacts of waves, storm surges, and flooding.[101,125,126] Annually, during the hurricane season, coastal wetlands in the USA provide an estimated US$23.2 billion in storm protection services.[127] During Hurricane Sandy in 2012 for example, coastal wetlands in the northeast USA prevented direct flood damage to property valued at US$625 million.[128] The world's existing mangroves are estimated to reduce the number of people affected by coastal flooding globally by some 39 percent, and the total value of flooding-related property damage by 16 percent.[129] Restoration of mangrove forests can help reduce wave energy, contribute to vertical soil build up,[130] and stabilize sediments, reducing coastal erosion and flooding, including during storm surges,[118,131] often far more cost effectively than engineered solutions.[95,132] One estimate valued the storm damage that could potentially be averted by coastal wetland restoration in high risk areas along the gulf coast of the United States through 2030 at US$18.2 billion.[133]

Wetland rehabilitation can help with restoring sediment balance, thereby reducing or redressing land subsidence that increases vulnerability, and can help to reduce saltwater intrusion (Box A3).[134] Coastal wetland or mangrove restoration also has the potential to increase the life and/or effectiveness of engineered approaches; Red Cross investments in mangrove restoration in Viet Nam were estimated to generate US$15 million in avoided damages, including estimated savings of up to US$295,000 in damages to dikes (Box A16).[135] When immediate protection is needed while nature-based ecosystem restoration solutions become established, engineered approaches can be designed to both facilitate restoration and add to its long-term effectiveness. Such combinations of engineered approaches with NbS for adaptation are referred to as hybrid or **'gray-green' approaches** for adaptation (Box 5).[59]

BOX 5 Hybrid or Gray-green Approaches to Coastal Protection.

Bechtel and Conservation International (CI) are combining gray (engineering) and green (mangroves) approaches to reduce the vulnerability of coastal communities in the Philippines to the impacts of typhoons.[124] A combination of mangrove restoration with breakwaters brings together the benefits of engineered structures with the added wave attenuation and flood control value of mangroves. This is expected to provide multiple benefits, including for livelihoods, and reduce maintenance costs.

Additional benefits from mangrove restoration include enhanced biodiversity and increased habitat for economically important species (Box A13), provision of forest products and support to livelihoods. Mangrove restoration also contributes to climate change mitigation; on average mangroves store nearly 1000 t of carbon per hectare.[136] The present value of minimum CO_2 emissions absorbed by planted mangroves has been estimated at US$218 million[137] (Box A2). Such approaches can also provide opportunities to engage with carbon markets and the tourism sector to leverage additional funds.

Protection and restoration of oyster reefs, coral reefs, and seagrass beds also provide coastal protection by attenuating wave force,[125] which both provides direct protection and enables regeneration of other ecosystems, and can provide multiple benefits such as improved fish habitats and abundance (Box A17).[138] Successful restoration of oyster reefs in Mobile Bay, Alabama, USA at a cost of US$3.5 million for 5.9 km of reef has reduced average wave heights and energy at the shoreline by 53 to 91 percent, while also enabling substantial seafood production, reducing nitrogen loads in the coastal waters, and increasing carbon sequestration and storage.[139]

On average, coral reefs reduce wave energy by 97 percent and wave height by 64 percent, protection levels in the upper range of those reported for artificial structures.[140] It has been estimated that in the absence of the world's coral reefs, global annual damages from coastal flooding would double, the costs from frequent storms would triple, and the costs of flood damage from severe storms (100-year events) would increase by over 90 percent to US$272 billion.[141] Between 100 and 200 million people benefit from coastal risk reduction provided by coral reefs; Indonesia, India and the Philippines have the greatest numbers of at-risk people benefitting from such protection.[142] Although coral reef restoration can be a costly process, the costs of reef restoration projects are reported to be on average significantly lower (median US$1,290/m) than the costs of building artificial tropical breakwaters (median US$19,791/m).[128] Degraded reefs can also be restored using submerged artificial reef structures that provide a substrate for coral colonization and reestablishment, while also providing a buffer against wave energy and protecting coastlines.[143] Additional benefits from the restoration of coral reefs include the provision of habitat and nursery grounds for species important for livelihoods, as well as economically beneficial recreation and tourism opportunities (Box A5). Other actions to secure the protection services of coral reefs include the establishment of protected areas or no-take zones in order to protect the reefs from human disturbances.

Restoration of sand dunes provides coastal stability by absorbing and dissipating wave energy and preventing stormwater from flooding inland areas.[144] Restoration measures may include protection to minimise disturbance, sand trapping, and beach nourishment, as well as the planting of indigenous climate-resilient pioneer dune plants that biologically fix or reforest the dune ridge. One cost estimate for creating vegetated dunes is US$0.3 thousand to US$5 thousand per linear foot.[95] Co-benefits of dune creation, protection, and management include protecting freshwater habitats, enhancing coastal/brackish habitats, contributing to water purification and regulation in coastal aquifers, and creating recreational opportunities (Box A4, Section 4.1.b).

4.1b. HAZARDS LINKED TO INTENSE PRECIPITATION

Hazards linked to intense precipitation include **flooding**, **landslides**, and **soil erosion**. Floods affected 2.3 billion people and accounted for 25 percent of all reported weather-related economic losses between 1995 and 2015.[119] The global risk from river flooding is projected to increase by as much as 187% by 2050, exposing 450 million flood-prone people to a doubling of flood frequency.[130] Extreme rainfall triggers landslides; from 2004 through 2016, nearly 56,000 people were killed by landslides globally.[145] Intense precipitation is also linked to soil erosion, with huge economic implications for the agriculture sector (global losses due to erosion from arable lands have been estimated at US$400 billion annually)[146] and major impacts on water quality and aquatic ecosystems. NbS for adaptation are commonly used to address each of these hazards.

NbS for adaptation can complement and enhance the effectiveness of flood risk management infrastructure such as dams, levees, floodwalls, and channel modifications,[59] or reduce the need for such measures.[147] NbS to reduce the risk of flooding include protection, management, and restoration of vegetation in stream and river catchments and along flood plains, as well as wetland restoration and management/restoration of river courses themselves.[111] Key ecosystems in which NbS for adaptation are often implemented to address precipitation and storm hazards include:

- **Upland forests and watersheds**. Conservation and restoration efforts in these areas help to increase water infiltration and soil water storage capacity, improve drainage, and promote soil stability.[148] These functions help to reduce peak flows, especially during short-duration events that can lead to flash-flooding,[98] and reduce impacts on downstream assets and populations.[51] Restoration of upland areas reduced peak flow in 82 percent of studies reviewed.[149] To be effective for flood regulation, restoration needs to be implemented at scales relevant to hydrological processes, landscape, or ideally basin scale. Costs for forest restoration are in the range of US$2000-3,500 per hectare (where land does not need to be acquired). Investing in watershed restoration and conservation activities could save water utilities across the world's largest cities an estimated US$890 million each year.[151]
- **Wetlands, lakes, and marshes**. These help to collect and slow or prevent the release of floodwater, storing as much as 9-14,000 m^3 of water per hectare;[137,152] wetland conservation, management, and restoration are therefore key NbS for reducing flood risks. Wetlands also filter out sediment, helping reduce the impacts of soil erosion on water quality and economic functions such as navigation and energy generation. Costs of wetland restoration vary geographically – estimates range from US$810 to US$36,400/ha for coastal wetland,[153] and a more general estimate suggests a figure of US$33,000/ha.[154]
- **Rivers and floodplains**. Conservation and restoration of rivers and their floodplains may include establishing backwaters and planting or restoring wetland or riverbank vegetation, allowing for the creation of more natural rivers and streams.[155] Restoring and renaturing areas surrounding rivers and watercourses in urban areas can increase flood storage capacity and reduce flooding.[156] Such measures have been shown to help reduce flood-prone areas in cities (Box A14) while stabilizing water supplies, increasing biodiversity, and providing opportunities for recreation.

Restoration and conservation management of these areas bring extensive co-benefits, including the provision of forest and aquatic products that contribute to livelihoods, slope stabilization, soil retention (Boxes A6, A9), water regulation, carbon sequestration, recreational opportunities, and biodiversity conservation benefits.

4.1c. DROUGHT

Drought has wide-reaching social, economic, and environmental impacts, ranging from famine and associated human mortality to agricultural losses, energy shortages, and deaths of livestock and wildlife. It is estimated that 4 billion people live in areas already prone to water scarcity.[157] According to estimates from the Food and Agriculture Organization of the United Nations (FAO), the agriculture sector suffered 83 percent of all economic losses due to drought from 2005 to 2015, some US$29 billion.[158] Increases in frequency and intensity of drought are expected in many regions of the world by 2050.[2] Water scarcity can lead to or exacerbate conflict, and increase migration from rural areas to cities. It can also contribute to deforestation[144] and other forms of environmental degradation that further reduce resilience.

NbS for adaptation to address water supply focus on improving hydrological function (quality, quantity, and flow) and soil properties (e.g. water retention ability, soil binding), and can enhance the effectiveness of, or reduce the need for, costly gray infrastructure.[50] They include the restoration of vegetation in catchment areas to increase infiltration and groundwater re-charge that permit continued water availability during periods of reduced rainfall. Forest restoration also helps improve the availability of higher quality drinking water (Box A18).

In drylands, the use of drought-tolerant species is particularly important. In some cases the inclusion of trees in farming systems, or agroforestry techniques,[159] can reduce the impacts of drought on crop production by reducing heat loads/providing shade; reducing evaporation, run-off, and erosion; and building alternative income streams. These systems can improve groundwater recharge, reduce soil surface evaporation, and maintain soil health by reducing erosion and adding nutrients through leaf litter and organic matter. [160] Co-benefits include additional livelihood options, enhanced carbon storage, and biodiversity benefits.

Other approaches to dryland restoration include the construction of earth bunds to retain moisture around planted trees (Box A19). Grassland and pastureland can also be managed to reduce the impacts of drought and extended dry periods. For example, in South Africa, the Meat Naturally Initiative aims to improve the quality and availability of fodder and enhance biodiversity in communal rangelands through clearing alien species that have reduced water flows and available grazing land. Transforming the grazing pattern from one of open access and annual burning to one of controlled seasonal rotation and reduced burning regime can also contribute to reducing vulnerability and can bring added benefits for local people such as access to formal markets.[161]

4.1d. HEAT, INCLUDING FOREST FIRES AND URBAN HEAT ISLAND EFFECTS

Global mean surface air temperatures have been rising over the past century, leading to longer, more intense, and more frequent periods of extreme heat. Exposure to heat waves leads to increased mortality and illness and has negative consequences for societies, economies, and the environment. Temperature extremes and heat waves are already impacting cities worldwide and are likely to increase in coming years. In Europe, over 70,000 people died during the heat wave of 2003.[162] It is estimated that by 2050, nearly 1000 cities in the world will experience summertime temperature highs of 35ºC, and that the urban population exposed to these temperatures will increase by 800 percent.[163] As these events become more frequent, adverse impacts on health, human life, and urban infrastructure and services will increase, particularly in the most vulnerable and disadvantaged areas. It is estimated that high temperatures could have an economic cost of US$2 trillion globally by 2030.[164] Heat waves are also associated with increased incidence of wildfires, exacerbated by drought.[165] Costs associated with wildfires in the 2003 heat wave in Europe were estimated at nearly US$14.5 billion.

NbS for adaptation measures used to influence local temperature include efforts to increase canopy cover, shading, and evaporative cooling. This may include forest and wetland restoration, as well as shifts to silvopastoral[166] or agroforestry systems that include trees in cultivated and settled areas.

Urban measures include green spaces and green infrastructure such as green roofs, which help cool surfaces and moderate temperature by increasing evapotranspiration, shading, and reduction of urban heat island effect (UHI).[167,168] The air temperature difference between green areas and areas of the city with less vegetation can be as much as 4ºC.[169] Trees in cities provide savings on the order of 10 percent on air conditioning.[170] Increasing the number of water bodies in cities can also contribute to the cooling effect, helping to reduce UHI by up to 0.9ºC.[171] These measures can be complemented with other approaches such as the use of high-albedo materials (e.g. light-colored roofs and walls or pavements), which decrease the amount of solar radiation absorbed by urban structures and reduce air temperature.[172] An annual investment of US$100 million in urban tree planting could provide an estimated 1ºC of temperature reduction to 77 million people, while having co-benefits such as pollution control, improved human health and well-being, and biodiversity benefits, and contributing to climate change mitigation through carbon sequestration and storage.[173] Green spaces can also help renew urban areas, boost economic activity, improve worker productivity and job satisfaction, and create opportunities for developing tourism.[174]

4.2. Sectoral Use of NbS for Adaptation

As summarized in Figure 2, NbS for adaptation have been used by all sectors to address a variety of climate hazards. The majority of experience lies in the food security and rural livelihoods sector, especially to address hazards associated with intense precipitation and drought. There is also a considerable body of experience in addressing coastal hazards, especially risks to infrastructure.

FIGURE 2 Level of experience in using NbS to address climate hazards per sector based on over 100 cases of NbS implementation, drawn from an ad-hoc review of experience, published case studies, and consultation.

4.2a. FOOD SECURITY AND RURAL LIVELIHOODS

Food production – as well as the availability of wild food – is highly dependent on healthy ecosystems. These provide a direct source of food as well as a host of regulating and supporting services such as pollination, irrigation water, and soil formation that underpin food security and rural livelihoods (see Section 2.1). Recognition of these interdependencies has led to widespread awareness of the utility of NbS for adaptation for safeguarding food security and rural livelihoods in the face of climate change. A substantial amount of experience in using NbS for adaptation comes from interventions for this purpose. An analysis of the intended outcomes of 58 NbS projects found that while 33 percent of projects aimed to protect assets, 29 percent addressed food security, and 14 percent worked to secure livelihoods.[175] Another review of 41 NbS projects revealed that over 50 percent included a livelihoods-diversification component in addition to other NbS measures.[176]

The focus of such interventions has been mainly on rural populations, largely in developing countries, as the food security and livelihoods of smallholder farmers, fishers and pastoralists are the most vulnerable to climate change impacts due to their high dependence on natural systems. The application of NbS for adaptation to improving food security and livelihoods in rural populations has largely been driven by public sector actors and civil society and implemented as separate local scale projects. UN institutions such as FAO, UNDP and UN Environment have emerged as strong supporters and key implementers of NbS for adaptation in this context, with NbS for adaptation featuring among organizational strategies,[177] signature programs,[158,178] and solutions.[179] The World Food Programme has begun integrating NbS for adaptation into its portfolio of work.[180] Using NbS for adaptation to address climate threats to rural livelihoods is also very common among conservation NGOs that work with local communities on climate change adaptation, such as IUCN, WWF, Wetlands International, CI, TNC, and Birdlife International. International development organizations, such as the German Society for International Cooperation (GIZ), have also adopted NbS for adaptation directed at food security and rural livelihoods. Much of the financial support for such work has come from donors such as the GEF, GCF, and Adaptation Fund, as well as government ministries/agencies, notably the German Government (BMZ, BMU,[181] GIZ, KfW) and USAID.

The cross-cutting nature of NbS for adaptation in the context of food security and livelihoods typically demands the involvement of multiple partners and ideally several government departments (e.g. agriculture, food and water, environment and forestry, climate change). The Ecosystem-based Adaptation for Food Security in Africa Assembly (EBAFOSA),[182] for example, was formed to bring together key stakeholders and actors along the entire NbS-driven agriculture value chain to combat food insecurity, climate change, ecosystem degradation, and poverty.

There is a substantial amount of experience in using NbS to address risks to food security and rural livelihoods from hazards related to intense precipitation. In this context, the use of NbS for adaptation often puts particular emphasis on maximizing co-benefits in addition to achieving the primary adaptation goal.[183] For example, when reforesting upland habitats to reduce downstream flooding (Box A10), interventions select plant species that have multiple uses, such as providing NTFPs to support livelihoods. Similarly, NbS interventions that protect wetlands in order to buffer flood impacts on rural communities emphasize maximizing the many co-benefits such as improving water quality, reducing pests and offering additional sources of food (Box A20). In coastal zones, mangrove restoration is used to limit coastal flooding and saline intrusion into groundwater and farmlands, but also to increase the abundance of fish species so support livelihoods (Boxes A16, A21).

The NbS approaches used to address drought most frequently have involved restoration activities across different ecosystem types to improve hydrological function (quality, quantity, and flow) and soil condition (e.g. water retention ability, soil stabilization) (Boxes A10, A19). Agro-ecological practices have also been used to reduce crop vulnerability to the impacts of drought: during the severe drought of 2008 to 2009 in Brazil, losses in maize production for farmers using these approaches were less than half of those using conventional cropping.[184] In Niger's Maradi and Zinder regions, landscapes have been transformed and the use of traditional practices to protect and manage vegetation have enhanced tree cover ten-fold. Soil fertility, crop yields and drought resilience have increased, resulting in a surplus of vegetables for export, and the daily forage for firewood - a task mainly falling to women - has been cut from 3 hours to 30 minutes.[185] Other examples of NbS for water management in the context of drought include the use of temporary stone and earth embankments to capture floodwater and run-off from ephemeral rivers, roadsides and hillsides (e.g. in Ethiopia[186]).

The potential of NbS for delivering both adaptation and co-benefits can be maximized by increasingly moving away from small-scale or pilot interventions to implementing NbS for adaptation at appropriate scales, both geographically (e.g. watershed, landscape) and in relation to the number of stakeholders and beneficiaries involved. However, this could also intensify the challenges of reconciling demands on land to meet the growing need for food production. Nonetheless, this broadening of scales is essential to achieve a paradigm shift to adaptation constituting a core component of agricultural development in the context of climate change.[187]

4.2b. CITIES

The world's cities are growing rapidly, are expected to house two-thirds of the global population by 2050, and are increasingly vulnerable to multiple climate change risks. These risks are especially critical for the urban poor and marginalized populations (Box 6). One of the barriers to the use of NbS for adaptation in cities has been the amount of land required. Urban areas represent prime property value; unless there is clear prioritization allocated towards green infrastructure, realizing NbS may be difficult. Despite this, the use of NbS for adaptation in cities is increasingly being promoted and incorporated into urban climate adaptation plans. Of 210 cities across the world disclosing their adaptation actions to the Carbon Disclosure Project (CDP) in 2016,[vi] 101 reported planting trees and creating green spaces as actions taken to adapt to climate change.[190]

Cities are complex environments where ecological and social systems interact. Achieving successful delivery of ecosystem services requires actors from different sectors and policy areas to come together to develop holistic strategies. The implementation of NbS in urban areas normally involves simultaneously a variety of actors from the private sector, conservation NGOs, civil society and community-led organizations to governmental actors across multiple levels. International organizations, such as GIZ, IUCN, and ICLEI - Local Governments for Sustainability, have also been active in promoting and implementing NbS for adaptation in urban environments.

BOX 6 Informal Settlements, Environmental Degradation, and Climate Risk

Roughly one billion people live in slums or informal settlements,[v] many of which are located in areas vulnerable to climate hazards. For these people, climate risks are intensified by lack of housing, services, and infrastructure; environmental degradation due to unsustainable urban development; and lack of integrated planning. The marginalized poor, lacking access to sustainable energy and other resources, have few options but to use the environment in unsustainable ways, potentially increasing their vulnerability.

In Africa, for example, many growing and economically important cities (e.g. Lagos, Accra, Dar-es-salaam) are located in low-elevation coastal zones. In many, such as Monrovia, the informal settlements are in areas extremely vulnerable to sea-level rise. Unless urban planning and land issues that exclude low-income households from formal housing are addressed, adaptation efforts in coastal cities will remain inequitable.[188]

The vulnerability of the urban poor is especially evident in the impacts of extreme events. Cyclone Nargis, which struck Myanmar's Irrawaddy region in 2008, is an example. The storm severely damaged the Labutta township area (home to some 315,000 people, with about 46,000 living in Labutta town itself) and resulted in 130,000 deaths. The township is still recovering from the cyclone and remains highly vulnerable to the impacts of climate change due to inter-linked socio-economic, ecological, and infrastructure conditions.[189] For example, the highly productive deltaic mangroves in Labutta are rapidly being degraded by land conversion, increasing the sensitivity of the township's population to climate change and associated extreme events.

To address such vulnerabilities, ecosystem rehabilitation and preservation are essential in urban areas. These need to involve local communities and relevant local authorities – including those involved in energy, transport, and housing – to ensure that interventions are sustainable and meet the needs of the population. Furthermore, upgrading of slum settlements that is undertaken in partnership with organized local communities has greater potential for reducing vulnerability.

v. Defined as a household where inhabitants lack one or more of the following: lack of access to improved water source, lack of access to improved sanitation facilities, lack of sufficient living area, lack of housing durability and lack of security of tenure. Source: UN-Habitat. 2016. *Slum Almanac* 2015/16. Nairobi: UNON, Publishing Services Section.

vi. CDP runs a global disclosure system for investors, companies, cities, states and regions to manage their environmental impacts. https://www.cdp.net/en.

Public bodies tend to be central to providing investments for the implementation of NbS in urban areas,[191] with instruments for financing NbS often including fees and revenue from national or municipal taxes. However, local governments often lack the autonomy to implement NbS, particularly when under financial pressure. Other sources of financing for urban NbS may include bilateral and multilateral donor funds, foundations, or private investment.[192] Major funding bodies for the implementation of NbS in urban areas have included GCF, GEF, the Least Developed Countries Fund, the World Bank, and bilateral cooperation, including the German government-funded International Climate Initiative (IKI) and the European Commission (EC).[193]

Cities are increasingly using NbS for adaptation to address coastal hazards, flooding, drought, and heat island effects. Protection and restoration of mangroves or coastal marshes (Section 4.1.a.) can be cost-effective ways to reduce the risk of flooding in urban areas located near coasts, estuaries, or river deltas (Boxes A1, A13). In the Belgian Scheldt estuary, for example, restoration of wetlands and tidal marshes will be completed in 2030 at a cost of US$669 million, which compares favorably with the yearly cost of flood risk estimated to reach over US$1.1 billion by 2100.[101]

Other NbS for adaptation suitable for urban areas include green spaces, bio-swales, green roofs, and water retention plantings in open spaces or urban parks[194] (Boxes A14, A15). Such 'bio-retention areas' reduce flood risk by increasing infiltration capacity and helping to control stormwater and flood runoff, and help improve water quality by filtering pollutants and removing heavy metals from water.[98] Management of the watercourse outside cities is also key to reducing flood risk (Boxes A11, A12). In addition to its adaptation benefits, the creation of urban green spaces to reduce flooding has also been shown to increase property values by 5 to 15 percent.[195]

An increased urban canopy layer and plant coverage can also reduce heat stress and the impacts of drought.[200] At a median cost of US$468 per ºC temperature reduction over a 100 square meter area, tree planting is a cost-effective solution and for some locations may be lower cost than any 'grey' strategy.[168] TNC estimates that an annual investment of US$100 million in tree planting could provide a 1ºC temperature reduction to 77 million people, while contributing to co-benefits for pollution control, human well-being, biodiversity, and climate change mitigation.[168]

Cities commonly address inadequate water supply by building infrastructure to obtain or store more water, or by improving water-use efficiency or water quality.[201] However, restoring or strengthening the role of natural ecosystems in the provision of water services can often be more cost-effective than, or a good complement to, conventional built infrastructure, ensuring urban water security (Boxes 7, A18, A22). For example, Water Funds have emerged as popular long-term mechanisms to support landscape restoration at the watershed level and to ensure water security, improved water quality and flood risk mitigation for urban and peri-urban populations.[202] A recent assessment of opportunities for natural infrastructure approaches in Latin American watersheds found that nearly 83 percent of inhabitants in Latin America's largest cities could benefit from such action.[203] Globally, water protection activities in urban source watersheds can potentially provide well-being benefits to some 4.4 billion inhabitants of those watersheds, including some of the world's poorest, who have the most to gain from improvements in water quality and quantity.[204]

There is growing evidence of the effectiveness of NbS for adaptation in contributing to increased climate resilience and delivering additional benefits for growing urban populations (e.g. goods and services with financial value,[205] health and well-being, cultural and recreation opportunities,[206] climate change mitigation [207]).As implementation requires engagement with a diversity of actors, the use of NbS for adaptation can also bring both social and economic benefits, including economic stimulation and job creation across multiple sectors.[208]

BOX 7 The Water & Cities Alliance

Recognizing the linkages between watershed ecosystems and water supplies, three major cities in Latin America formed the Water and Cities Alliance, which aims to secure water supplies by protecting and restoring nature in their peri-urban areas. Grasslands and forests in Mexico City's nearby watershed are restored and protected to provide 70 percent of the water to 23 million inhabitants. In Rio de Janeiro, local communities are supported to conserve lands in the Guandu watershed and the Mega Rio basin. In Colombia, sustainable and climate-smart land uses are being implemented in a conservation corridor outside Bogotá.[196,197,198, 199]

4.2c. INFRASTRUCTURE

Extreme events have highlighted the vulnerability of infrastructure to climate change,[209] leading the sector to seek ways to build more resilient infrastructure.[210] Traditionally, infrastructure resilience has been based on structural measures such as increasing the height or length of seawalls to withstand events like 1 in 100-year floods. However, this is not a reliable basis for predicting or prepare for future conditions in a changing climate. One response to this uncertainty is the exploration of the use of NbS for infrastructure adaptation, both to manage risk and deliver co-benefits.

Awareness and application of NbS for infrastructure adaptation are growing through international agreements,[190,211] regional or national policies,[212,213] the programs of conservation organizations,[214] and the work of professional bodies.[215] A number of countries and regions are developing policies to support sustainable and/or resilient infrastructure,[216,217] some of which include specific reference to NbS (see Boxes 8, 9 in Section 5). Several organizations also have programs to raise awareness of NbS and support its uptake.[218,219,220] For example, in 2018, the US Army Engineer Research and Development Centre released *Engineering with Nature: An Atlas*.[132] Ecoshape has developed the Building with Nature Innovation Platform,[221] and the World Association for Waterborne Transport Infrastructure (PIANC) has also published a guide for working with nature in navigation infrastructure.[222] TNC and the International Water Association (IWA) recently launched a joint research project to build capacity among water regulators to develop policies and regulations that are supportive of nature-based solutions in water management.[223] The use of NbS to manage coastal flood risk at the regional level has also been gaining traction in this sector.[101]

Despite this, the term 'nature-based solutions' is still not widely known or understood within the infrastructure sector,[224,225] and relevant approaches are not always recognized as a means for adapting to climate change. Furthermore, conventional infrastructure remains the default to build resilience, with many private sector stakeholders averse to other approaches.[226]

A wide range of stakeholders can be involved with infrastructure development, including civil society, research institutions, conservation actors and other NGOs, the private sector, funders, and governments. Given that infrastructure can operate across sub-national, national, and regional boundaries, many actors may need to be involved with the planning, approval, implementation, and maintenance of infrastructure. Implementing NbS for infrastructure resilience can equally require large areas of land and large-scale engagement with multiple actors (Box A6); however, even in the case of smaller or pilot-scale projects, partnerships are important (e.g. with technical experts or others with experience). As a relatively new approach (both technically and in terms of the policy environment), partnerships are often developed between organizations experienced in delivering NbS for adaptation and local communities, government, and/or private sector actors.[187,198] Water funds are a common example.[187] Public-private partnerships (PPP) can also provide a useful structure for the implementation of NbS for infrastructure adaptation.[227] A number of conservation actors also support the uptake and use of NbS in this sector. Examples include the IUCN's Ecosystems Protecting Infrastructure and Communities project[198] and TNC's work on water funds.[187]

A range of financing approaches exists for using NbS to build infrastructure resilience, including government funding, privately financed projects (often driven by a clear business case and/or sustainability or environmental initiatives), donor-funded schemes, and multiple source funding.[228] Multilateral Development Banks (MDB) are an important source of financing for infrastructure[229] and could become a new source of funding for NbS for adaptation. For example, the MDB Working Group on Sustainable Transport committed to providing more than US$175 billion of transport funding between 2012 and 2022, with a focus on more sustainable transport projects.[230]

Despite the potential of NbS for adaptation for the infrastructure sector, its use has been less common than for some other sectors (Figure 2). The hazards to infrastructure most commonly addressed are storm surges and flooding. As for cities, the infrastructure sector has frequently used coastal restoration (including mangroves, marshes and coral reefs) to protect investments from these hazards, often as a complement to traditional engineered approaches. For example, engineered breakwaters have been combined with mangrove protection[231] and management to reclaim as much as 180 m of lost coastal land, and reduce coastal erosion and damages to dikes in Viet Nam (Box A2). Similar efforts combining gray infrastructure with foreshore afforestation and mangrove protection are increasing within the sector (Boxes A2, A3, A4, A16). Other examples include use of constructed wetlands for wastewater treatment,[232,233] restoration of dunes or other habitats.[132] Stormwater management by restoring natural prairie pothole wetlands in Alberta will avert the need for investment of US$257 million for engineered stormwater ponds (Box A12), and natural flood management practices such as the use of woody debris dams have successfully averted flood losses in the UK (Box A11).[234]

Water shortages also challenge the infrastructure sector. Built infrastructure, which is typically fixed in terms of location and capacity, and can rely on transfers of water over long distances, can be particularly vulnerable to a decreased water supply. NbS for adaptation have been used to address such issues (Box A23), as well as to improve water quality and availability, secure water supply, and reduce pollution through the integration of natural elements into the design of Sustainable Urban Drainage Systems (SUDS).[235]

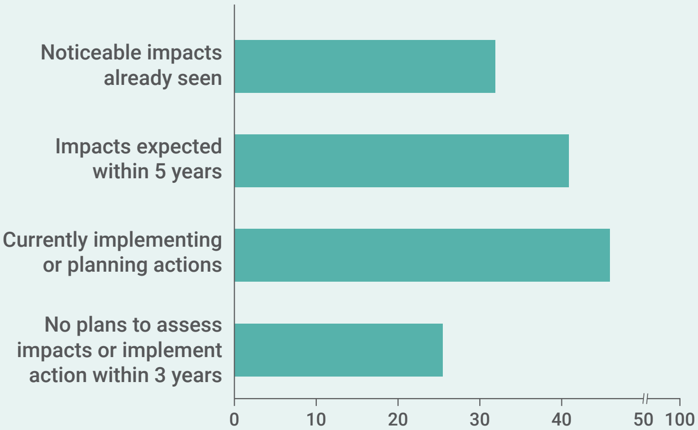
Landslides and soil erosion also pose major risks to infrastructure, including railways, roads, and power distribution networks. Examples of NbS for adaptation being used to reduce such risks include the management of adjacent vegetation (particularly upslope forests) and the use of bio-engineering techniques to stabilize soils, including in forest ecosystems and mountainous areas in Asia and South America (Box A6).

As extreme events become more frequent, they threaten assets and their function, and risk higher production costs due to a lack of important environmental services (such as water provision). NbS for adaptation may help to make infrastructure more resilient in a cost-effective way while providing additional benefits to a wide range of stakeholders.

4.2d. INDUSTRY AND SUPPLY CHAINS

Although exposure to climate change hazards differs substantially across industry sub-sectors and points in supply chains, there is a growing awareness of climate change risks to business. More than 1 in 4 companies surveyed across Europe, North America, Latin America, and Asia[236] indicate that at least one area of their value chain has already been impacted by climate change. While nearly half foresee at least one such impact within five years, only 40 percent of respondents report that they are currently implementing or planning actions to respond to climate change (Figure 3).

FIGURE 3



Results of a survey of 1241 companies on their perceptions, experience and plans for action on climate impacts affecting their value chains.[236]

Among those addressing climate risks to business and industry, only a relatively small set of private sector actors are currently investing in NbS for adaptation.[237,238] Use of NbS for adaptation appears to be more widespread in the agriculture sector than among processors and manufacturers. Major actors promoting and/or using NbS for adaptation to address climate change and/or improve long-term sustainability in the industry and supply chains sector can be broadly categorized as follows:

- Large, multi-national companies with vulnerable supply chains and priorities related to their environmental and social performance (such as Nestle, Olam, Coca Cola, Michelin)
- Business alliances, think-tanks and advisory services (including some NGOs) aimed at promoting sustainable practices among the private sector, such as the World Business Council on Sustainable Development (WBCSD), Business for Social Responsibility (BSR) and Rainforest Alliance
- Organizations and associations that support farmers and other small-scale producers/businesses (e.g. cooperatives, industry associations)
- Regulators, particularly local and national governments, who can set enabling policies and institutional frameworks (e.g. regulating payments for ecosystem services, setting standards)
- Finance facilities (e.g. Livelihoods 3F Funds, GCF Private Sector Facility, Tropical Landscapes Finance Facility)

Overall, there is less experience in the industry and supply chain sector in using NbS than in other sectors. To date, the climate hazards most frequently addressed by this sector have been drought, hazards linked to intense precipitation, and coastal hazards.

To address drought, water shortages, and increased temperatures affecting production, agroforestry is increasingly being used in conjunction with organic and/or sustainable agriculture techniques and certification[239] and wider landscape-level planning and management (Box A24). A growing number of national and international standards and certification programs for agricultural commodities[vii] potentially provide access to new markets and a basis for other resilience-building approaches. For example, the Nescafe Plan implemented in 14 countries includes training farmers in water efficiency and soil conservation along with promoting agroforestry and intercropping (Box A24). Costs of these approaches vary significantly across programs and regions. In Colombia, the Nescafe Plan has involved an investment of US$3.06 million, though overall returns are estimated at US$5 million, including increases of 35 percent in productivity and 41 percent in net farmer income, with only a 5 percent increase in production costs.[240]

vii. e.g. Rainforest Alliance's Sustainable Agriculture Standard, the Sustainable Rice Platform (SRP) Standard for Sustainable Rice Cultivation, Roundtable on Sustainable Palm Oil Supply Chain Certification Standard, and, though not a standard, the newly launched Global Platform for Sustainable Natural Rubber

Landscape or watershed management at wider scales can address changes in temperature, precipitation, and water availability affecting industries and supply chains. This approach may offer particular benefits where a supply chain relies on a large number of smallholder farmers or individual businesses spread across a landscape (Box A7), or where water-related services are crucial (Box A6). For example, Olam's climate-smart agriculture activities with cocoa farmers in Ghana include landscape-level planning and forest conservation and restoration.[241]

Coastal ecosystem conservation and restoration is a relatively widespread approach to tackling coastal hazards threatening industries and supply chains, including aquaculture, rice production, and tourism. Approaches used include conservation, restoration and afforestation of mangrove and other coastal forests; conservation and restoration of inland forests to reduce run-off and sediments; and conservation and restoration of damaged coral reefs. There has been particular emphasis on mangrove restoration in the Asia-Pacific region where there is a concentration of aquaculture and assets on the coast, and experience of severe impacts from natural disasters in recent years. For example, the IUCN Mangroves and Markets project in the Mekong Delta of Viet Nam (Box A25) has sought to improve coastal protection and the resilience of aquaculture by incentivizing local shrimp farmers to conserve and replant mangrove forests.

Although there has so far been less experience overall in using NbS for adaptation in industry and supply chains than in other sectors, industry and supply chain actors can use many of the same NbS for adaptation to address relevant climate hazards. Therefore, they can build directly on the experience of other sectors to integrate NbS into adaptation strategies and interventions, and uptake of NbS for adaptation is likely to increase in response to growing awareness of the need to address climate risks.

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5. Barriers and Enablers

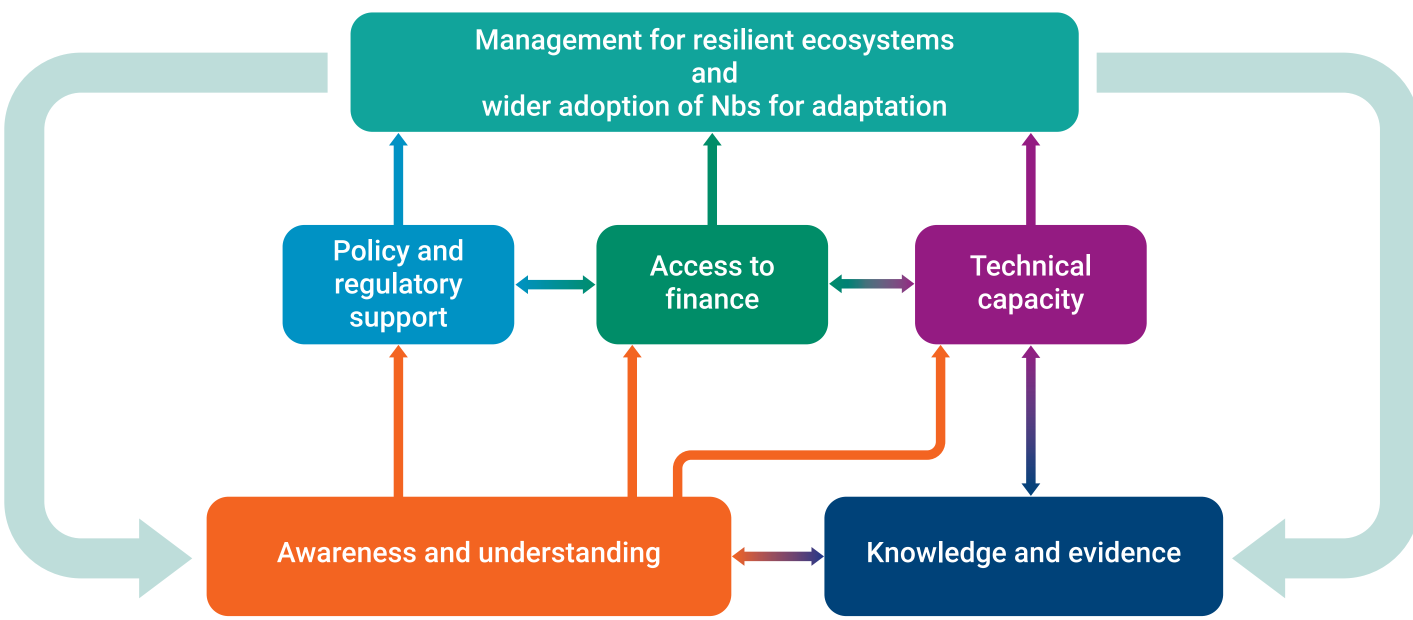
Despite the many advantages offered by NbS for adaptation, their use remains far short of their potential. This section presents a summary of the barriers and enablers for NbS use, based on an extensive review of existing experience and the perspectives contributed by experts and experienced practitioners who met during a 2019 workshop supported by GCA.

Across the sectors explored, improved ecosystem management and the wider adoption of NbS for adaptation are constrained by some common and interlinked barriers or challenges related to:

- Lack of awareness and/or understanding of these approaches, and associated entrenched attitudes and norms;
- Limited availability of knowledge and evidence to help make the case for their use;
- Policy and regulatory environments and governance challenges that influence the attractiveness and feasibility of using them across temporal and spatial scales;
- Access to finance for applying and scaling up these approaches;
- Technical challenges and gaps in capacity that impede design and wider implementation.

Each of these is discussed in more detail below along with some enablers that can support progress, which can be clustered into five sets of interlinked building blocks (Figure 4).

FIGURE 4 Building blocks to support improved management for ecosystem resilience and wider adoption of NbS for adaptation.



Barriers exist in all of these areas, but can be overcome. Increasing awareness, understanding, knowledge and evidence would underpin and motivate improvements to policy and regulatory environments and financing regimes to support wider adoption of good management and NbS for adaptation, leading to an enhanced knowledge base as well as improved capacity and awareness.

LACK OF AWARENESS AND UNDERSTANDING; AND ENTRENCHED ATTITUDES

Many of those confronting, or charged with reducing, climate-related risks have limited awareness of either the importance of ecosystems to societal resilience or the potential of NbS to help meet adaptation objectives. This gap in awareness is rooted in educational norms and reinforced by poor information flow and narrow institutional and discipline-specific 'cultures'. The awareness gap both contributes to and is compounded by entrenched attitudes and perceptions that built or technological solutions are the only suitable options. This can be linked to a lack of trust in what is perceived as a 'conservation agenda' of little practical value. Engineers and city planners tend to think of the environment in certain ways and focus on standard infrastructure and urban development paradigms. Politicians see the substantial spending associated with built solutions as critical to voter approval. Corporate actors tend to frame consideration of ecosystems in terms of carbon footprints and mitigation rather than meeting adaptation needs. Taking the longer-term evolution of benefits is challenging within systems that frequently emphasize immediate impact and short term gains.

In contrast, many civil society actors, and the following groups and processes represent avenues for fostering greater awareness and understanding of the benefits of NbS for adaptation.

- **Indigenous groups and local communities** may have a better understanding of their reliance on ecosystems, which can inform discussions about climate change and the search for adaptation solutions.
- **Extension services** are potential avenues for raising awareness of, and interest in, NbS for adaptation in agriculture and rural development, and for bolstering technical capacity for managing ecosystems and developing and applying NbS for adaptation.
- **Professional networks and peer-to-peer support organizations**, including trade and professional associations (e.g. the Institute of Civil Engineers in the United Kingdom) and industry clusters (e.g. coastal tourism) provide opportunities for raising awareness and sharing experiences of NbS for adaptation. They can also serve as sources of expertise to help fill capacity gaps.
- **Policy or issue-based networks** can fulfill a similar role. They can provide powerful avenues for mobilizing information on successful demonstrations of NbS for adaptation, and can support peer-to-peer learning. This is particularly true for cities, where a groundswell of municipal-led activism and drive for sustainability is evident through the activities of such networks as ICLEI - Local Governments for Sustainability, C40, Urban Alliance, UN Habitat, UNDP Cities, and the Asian Cities Climate Change Resilience Network. These networks have already made substantial progress on collectively defining and publicizing climate-related challenges, especially on mitigation issues.
- **International and national policy processes** also represent opportunities to advance awareness and use of NbS for adaptation. This includes the need for nations to revise their Nationally Determined Contributions under the Paris Agreement, National Adaptation Plans (NAPs), and the emerging post-2020 framework of the CBD. National commitments on Land Degradation Neutrality (LDN under UNCCD) can also encourage countries to prioritize the restoration of ecosystems that support adaptation. Growing efforts on highlighting and promoting synergies among these international agreements and processes provide an excellent opportunity for drawing attention to the role of ecosystems and NbS for adaptation to climate change.

LIMITED AVAILABILITY AND ACCESSIBILITY OF KNOWLEDGE AND EVIDENCE

As for other adaptation solutions, the adoption and implementation of NbS for adaptation rely on an understanding of the climate challenges, the processes and mechanisms by which a solution can be expected to work, the limitations to its effectiveness, and measures that can enhance that effectiveness and co-benefits.

Climate projection information may not be available or may be highly uncertain for the scales at which industries operate or infrastructure is developed, or at local scales needed for decisions about rural livelihoods. These and other uncertainties about the mechanisms and effectiveness of NbS for adaptation make it challenging for even relatively aware and receptive design teams, planners, and decision makers to incorporate NbS for adaptation into options for dealing with climate change. Further, several specific sources of uncertainty (Box 10) increase the difficulty in developing solid predictions about the likely value of working with ecosystems (and compare this with other options). These uncertainties make it particularly challenging for private sector actors and authorities to integrate NbS in their adaptation strategies.

BOX 10 Box 10. Sources of Uncertainty on NbS Effectiveness

- **Ecosystem responses** to climate change
- **Impacts of anthropogenic pressures** and drivers on those responses
- **Time frames** needed to realize NbS benefits in relation to rates of climate change
- **Spatial and temporal trade-offs** (e.g. upstream vs downstream impacts)
- **Scale of co-benefits** and processes generating them

Solutions to this barrier include:

- The development and implementation of carefully designed and monitored pilots
- Well-designed and widely disseminated research that adds to the evidence base and reduces uncertainties on the effectiveness of NbS for adaptation in particular contexts and at different scales, or identifies solutions for specific technical challenges
- Accessible platforms[viii] designed to enable wide and cross-disciplinary dissemination of pilot results
- Targeted outreach to professional bodies
- Ongoing efforts to develop and apply standards for NbS for adaptation design and implementation
- Cross-disciplinary partnerships to convey necessary knowledge and evidence between sectors and demystify the processes for acquiring it

Explicitly addressing the uncertainties will help to reduce the disincentives arising from knowledge and evidence gaps. In addition, the rise of natural capital approaches facilitates the assessment of a wide range of benefits from ecosystems and represents an additional opportunity to advance the evaluation of NbS for adaptation in relation to alternatives.

viii. e.g. Nature-Based Solutions Initiative (https://www.naturebasedsolutionsinitiative.org/); PANORAMA Solutions for a Healthy Planet (https://panorama.solutions/en).

TECHNICAL CHALLENGES AND CAPACITY GAPS

Lack of appropriate technical capacity is a commonly cited barrier to the adoption of NbS for adaptation across sectors. The skills needed to identify and implement NbS are not normally included in the training of the professionals often involved in designing and implementing adaptation solutions (e.g. engineers). Project teams, especially in non-environmental sectors, are rarely diverse enough to encompass skills and knowledge from relevant disciplines. These gaps in capacity can result in NbS being viewed as difficult or infeasible, or not being considered at all.

Enablers that help to overcome gaps in technical capacity include:

- Partnerships that provide access to expertise in academic, technical institutions; civil society organizations and professional bodies; or sharing such resources between implementers
- Publicizing successful implementation or pilots of NbS for adaptation
- Sharing examples of necessary inputs and documents for developing NbS, like terms of reference, feasibility studies, and monitoring protocols
- "Building back better" and "building back greener" initiatives following catastrophic failure (e.g. of infrastructure) or disaster, such as those endorsed by development banks and under the Sendai Framework for Disaster Risk Reduction
- Applying the "safe to fail" paradigm in engineering and infrastructure and in a broader application, especially in cities,[242] aiming to control or minimize the consequences of infrastructure failure

A wide range of existing tools and resources, ranging from hydrological and sedimentation models to participatory planning approaches, are easily available and suitable to support NbS design and implementation.

POLICY AND REGULATORY ENVIRONMENTS AND GOVERNANCE CHALLENGES

A wide range of sectoral policies and regulations at national and sub-national levels influence the implementation of climate action, as do corporate policies. The policy and regulatory environments have a powerful influence on the attractiveness and feasibility of conserving ecosystems and using NbS for adaptation to address climate risk (Boxes 8, 9). National climate change policies and commitments in principle provide overarching frameworks for adaptation including NbS, and the CBD mandates attention to ecosystem resilience. NAPs, in particular, can be important enablers for the implementation of NbS, as they are intended to harmonize and mainstream adaptation planning across all sectors in the medium and long-term. At the same time, it is challenging to address policy and regulatory barriers to wider adoption of NbS for adaptation. Such barriers include:

- A lack of harmonization and coordination among sectoral policies and their implementation, and in particular, failure to consider adequately the value of NbS and their co-benefits can reduce their inclusion in adaptation strategies.
- Specific sectoral policies, such as for transport, infrastructure, land use, and agriculture may have adverse impacts on ecosystem condition and create barriers to implementation of NbS for adaptation.
- Maintaining ecosystem resilience and implementing NbS for adaptation commonly require action at scales that transcend jurisdictional or even national boundaries, and necessitate coordination among diverse stakeholders as well as an understanding of relevant decision-making processes and laws (including on land ownership).
- Weak environmental regulations or ineffective application of such regulations hinder the wider inclusion of environmental management and NbS in adaptation programs. Requirements for Environmental Impact or Strategic Environmental Assessment (EIA/SEA), for example, are often weakly or inconsistently enforced and rarely include consideration of climate change impacts, especially at broader spatial scales. The environmental degradation resulting from poor EIA and environmental management plans may reduce the resilience of ecosystems and opportunities for using NbS for adaptation.

Enablers for enhancing ecosystem resilience and promotion of NbS for adaptation include:

- Linking policies to the co-benefits produced and the potential to deliver on multiple international commitments
- Fostering cross-sectoral dialogue on the needs and options for adaptation
- Mechanisms that incentivize or compensate land-owners and other influential actors for their efforts to support multiple objectives, such as tax breaks, extension services, and de-risking activities
- National budget cycles that provide suitable entry points for integrating NbS for adaptation across sectors and policy objectives
- Linking NbS for adaptation to policies and programs with longer time horizons
- Efforts to enhance the transparent disclosure of risks associated with environmental degradation and the role of intact ecosystems in resilience to climate change
- Involving authorities and other stakeholders in dialogues and scenario processes to visualize dependencies and courses of action that meet multiple objectives
- The formation of "special districts" and ordinances that transcend municipal or jurisdictional boundaries
- Working with stakeholder or community associations to reduce conflict and facilitate coordination among multiple stakeholders
- Natural resource management frameworks that take the ecosystem as the planning unit, such as integrated water resource management (IWRM) and integrated coastal zone management (ICZM), in order to facilitate transboundary and cross-jurisdictional management

Along with an increasing number of cities' commitments to resilience, the commitments by a number of large companies[ix] to climate-proofing on the one hand, and to 'greening' of supply chains (e.g. under the New York Declaration on Forests) on the other, offer an opportunity to bring the two together to support implementation of NbS for adaptation.

BOX 8 Canada's Climate Resilient Buildings and Core Public Infrastructure Project

The National Research Council of Canada is delivering the Climate Resilient Buildings and Core Public Infrastructure Project to integrate climate resilience into the design guidelines, standards, guides, codes and related materials for future infrastructure built assets and rehabilitation work in Canada. This work includes:

- Considerations of climate change incorporated into guidelines related to flooding, wildfires, buildings, bridges, water, wastewater, roads, and transit
- Proposed provisions for building codes to incorporate considerations of climate change and durability
- Projected climatic design data for a range of future Canadian climate parameters covering over 650 locations across Canada
- More research and resources for building and infrastructure professionals across Canada to adapt to a changing climate

ix. e.g. Nestle, Coca Cola, Shell.

BOX 9 National Approaches to Ecosystem-based Adaptation in South Africa

In support of its National Development Plan, and recognizing the role that biodiversity, ecosystem services and ecological infrastructure can play in support of South Africa's just transition to a low carbon economy and resilient society, South Africa has developed a national strategy for EbA. Known as South Africa's Strategic Framework and Overarching Implementation Plan for Ecosystem-based Adaptation, the strategy sets out a vision for EbA, and identifies four priorities or outcomes required to achieve that vision, including:

- Effective coordination, learning and communication to mobilize capacity and resources for EbA
- Research, monitoring and evaluation provide evidence for EbA's contribution to a climate resilient economy and society
- Integration of EbA into policies and plans supports an overall climate change adaptation strategy
- Implementation projects demonstrate the ability of EbA to deliver a wide range of co-benefits

The strategy was developed in partnership between the National Department of Environment Affairs (DEA, now known as the National Department of Forestry and Fisheries) and the South African National Biodiversity Institute (SANBI), which is an entity of the National Department and also a national accredited entity of the Adaptation Fund (AF) and Green Climate Fund (GCF). The strategy has catalyzed a national coordination mechanism for EbA, the development EbA guidelines for policy makers, practitioners and funders, and has further supported efforts to ensure that EbA is reflected in climate change and other relevant policies and plans.

SANBI is further advancing the objectives of the EbA strategy in its approach to AF and GCF project programming, including its GCF Funding Framework, through which it seeks to support projects that include nature-based solutions to climate change in their responses, including EbA and Ecosystem based Mitigation approaches.

Sources: National Planning Commission. 2011. "The National Development Plan – Vision 2030." The Presidency Republic of South Africa; DEA (Department of Environmental Affairs) and SANBI (South African National Biodiversity Institute). 2016. "Strategic Framework and Overarching Implementation Plan for Ecosystem-Based Adaptation in South Africa: 2016–2021." Pretoria: DEA; DEA (Department of Environmental Affairs) and SANBI (South African National Biodiversity Institute).2018. "Ecosystem-Based Adaptation Guidelines." Pretoria: DEA; SANBI (South African National Biodiversity Institute).2017. "GCF Funding Framework 2017-2022." SANBI.

ACCESS TO FINANCE

Challenges relating to finance apply across the whole spectrum of adaptation options, with global public finance for adaptation totaling US$23 billion in 2016 contrasting sharply with spending for mitigation of US$112 billion.[243] This challenge is still greater for the use of NbS for adaptation; planners and practitioners commonly cite limited access to appropriate finance as a major barrier. Indeed, most NbS for adaptation efforts have been funded by a relatively restricted set of national governments, multilateral donors, and international NGOs, often at local scales and as standalone projects. Private sector investment in NbS has been limited (one study estimated that just over 3 percent of corporate investment in adaptation targeted NbS),[244] but may be growing in some sectors.

Challenges in accessing finance for NbS for adaptation are exacerbated by a lack of understanding of the links between ecosystems and adaptation among the staff of financial institutions, and the lack of recognized performance metrics. Most existing funding models do not match well to the need for continuous low-level investment over long time frames that characterize NbS.

However, there are emerging funding models with the potential to increase access to finance for NbS for adaptation:

- Blended finance[x] approaches have helped to green some areas of investment but are not yet widely applied to support NbS for adaptation.
- Green bonds,[245] green credit lines[246] and payments for ecosystem services[247] offer ways to target finance for NbS for adaptation; Water Funds are a particularly promising mechanism.
- Some institutions, such as multilateral development banks, provide concessional lending or technical cooperation that helps to underwrite risks, enabling other institutions to develop financing instruments favorable to NbS for adaptation.
- Landscape finance schemes are emerging in the context of climate mitigation[xi] and can provide resources that enable improvements to ecosystem conditions in the context of other investments.
- The insurance industry has great potential to incentivize investment in NbS for adaptation to reduce risk, through reductions in premiums or through the economic pressure exerted by high premiums or refusal of insurance resulting in increased liability in high-risk areas (e.g. TNC's parametric insurance mechanism for reef insurance in the Yucatan Peninsula).[248]

Improvements to the evidence base on NbS for adaptation effectiveness and cost-effectiveness, along with emerging technical and professional standards, will help to increase the acceptability of these approaches within financial institutions. Natural capital approaches have helped to value the role of NbS for adaptation and could provide further arguments for increased finance, especially taking into account the value of co-benefits.

x. Blended finance: the strategic use of development finance for the mobilization of additional finance towards sustainable development in developing countries. Organisation for Economic Co-operation and Development (OECD), 2018.

xi. e.g. Tropical Landscapes Finance Facility.

6. The Way Forward and Recommendations for Action

Despite the potential that nature offers for overcoming many of the climate-change-related challenges facing people across the globe, current efforts to build on this potential are largely siloed within the environmental sector and limited in scale. To help stimulate action at the scales needed to realize the benefits of NbS for adaptation (overcoming barriers and building on the enablers highlighted in Section 5), this section presents a vision for the future use of nature in supporting societal adaptation.

Based on wide-ranging research and consultation, and input from contributors, this paper proposes the following vision to guide the use, integration, and upscaling of NbS for adaptation:

Societies are adapting more effectively to climate change impacts through **widely recognizing** the role of nature in underpinning societal resilience and **building on it at scale**, both through efforts **to maintain and restore ecosystem health and resilience in general** and through specifically applying **NbS for adaptation**.

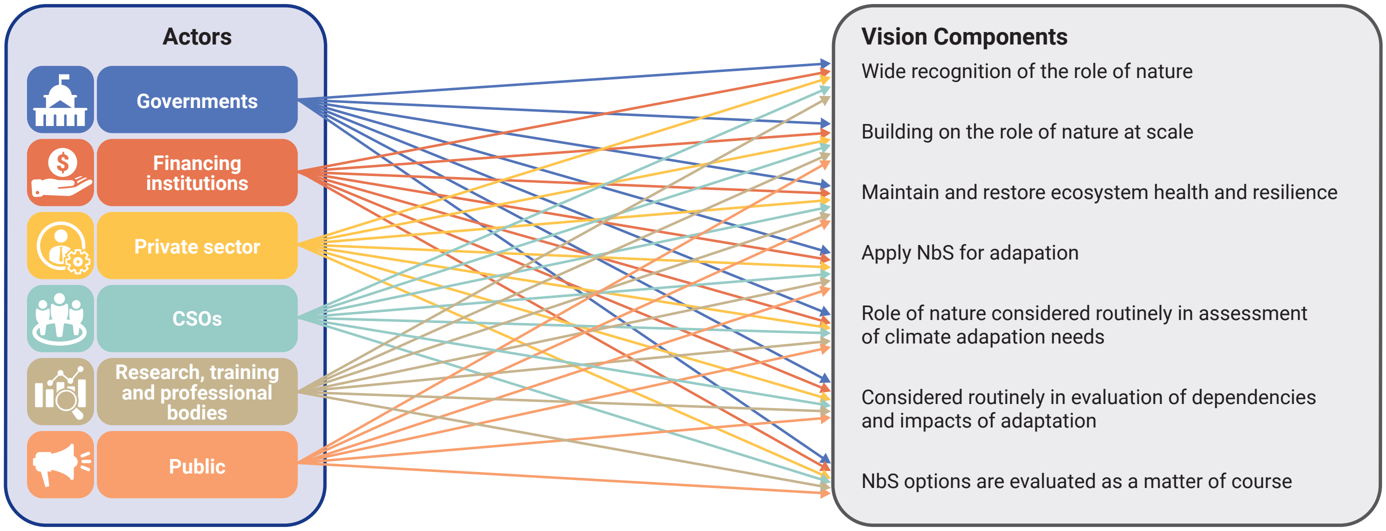
To help achieve this, the role of nature is considered routinely in the **assessment of climate adaptation needs**, and in the evaluation of the **environmental impacts and dependencies of adaptation and other interventions**. The potential of NbS for meeting societal adaptation needs is widely recognized, and **NbS options are evaluated as a matter of course** during processes for identifying and choosing adaptation solutions.

Achieving this vision will require action by many different groups of actors, each of which has different roles to play in influencing components of the vision (Figure 5).

Key Components of the Vision

- **Wide recognition**: governments at all scales, financing institutions, private sector, civil society organizations, and the general public are aware of and acknowledge the contributions nature can make to climate change adaptation.
- **Building on it at scale**: expanding beyond pilots to work with nature at geographical scales (e.g. watershed, landscape, coastline) and locations appropriate to meeting adaptation needs.
- **Maintain and restore ecosystem health and resilience in general**: conservation, management and restoration of ecosystems to enhance their resilience in the face of climate change and other pressures.
- **Apply NbS for adaptation**: using nature to help people adapt to specific climate hazards as part of an overall adaptation strategy.
- **Routine consideration in assessment of climate adaptation needs**: climate impact and vulnerability assessments [always] include analysis of likely impacts on ecosystems and their implications for people's vulnerability.
- **Considered routinely in evaluation of dependencies and impacts of adaptation and other interventions**: all feasibility assessments include analysis of how the intervention relies on ecosystems, their services and the resilience of these. Environmental impact evaluations include assessments of impacts on ecosystem resilience and implications for people's vulnerability to climate change.
- **NbS options are evaluated as a matter of course**: whenever a need for adaptation is identified, NbS are always included among the potential solutions evaluated.

FIGURE 5 The web of action needed to advance the vision of increasing effective efforts to maintain and enhance ecosystem health and resilience and apply NbS for adaptation.



The major groups of actors are: Governments at all levels (from local to national); Financing institutions, including public and private, commercial and philanthropic donors and development agencies; Private sector actors, ranging from small companies to multinational corporations; Civil society organizations (CSOs) (local, national and international); Research, technical, and training institutions and professional bodies; and the public (individuals and communities).

Some major changes are needed to advance improvements in ecosystem management and wider adoption of NbS for adaptation. Key recommendations for action include:

- Knowledge and awareness should be built through increased collaboration and exchange of experience across sectors, facilitated by governments, donors, civil society organisations and private sector actors.
- Climate impact and vulnerability assessments should as a matter of course include analysis of likely impacts on ecosystems and the implications for people's vulnerability.
- Planning, decision-making and action on adaptation should take a systems perspective. NbS for adaptation are best conceptualized and implemented at landscape or wider scales to take account of the interactions within and between ecosystems and the distribution of potential beneficiaries and impacts.
- Procurement, financing conditions, industry standards and other policies, should be improved to ensure that when a need for adaptation is identified, NbS are always included among the potential solutions evaluated and a consistent suite of benefits is assessed for all options under consideration.
- Financial institutions need to develop new funding streams and models (including de-risking strategies) that can support long-term investment in NbS for adaptation, including by private sector actors.
- Capacity should be developed by incorporating concepts of ecosystem dependency, climate risk, and NbS for adaptation into curricula and training programs for engineers, economists, environmental impact assessors, and development professionals.
- Governments, finance institutions, development and civil society organisations, corporate actors and research bodies need to promote wider implementation of NbS for adaptation, emphasizing monitoring and evaluation, and disseminating and sharing experience across sectors.
- Public pressure can encourage necessary changes in policy and practice on the grounds that NbS for adaptation are critical to the public good.

Different stakeholder groups have different contributions to make to implementing these broad recommendations and achieving the components of the vision. These are presented below.

Build wide recognition of the role of nature in underpinning societal resilience:

- Promote exchange of experience among ministries and jurisdictions, and at different levels of government, on:
  - Integration of ecosystem management into sectoral policies
  - Use of NbS for adaptation and links with other goals, e.g. mitigation
- Support long-term monitoring in areas where ecosystem management and/or NbS for adaptation are implemented

- Share experience of funding NbS for adaptation, including innovative models, successes and challenges
- Use portfolio experience as well as monitoring and evaluation to:
  - Build understanding of cost-effectiveness/ efficiency of NbS for adaptation measures
  - Identify examples where ecosystem management has supported other interventions

- Exchange experience (especially early adopters) within trade associations and sectoral collaboration partnerships (e.g. round tables) on integrating ecosystem management in operations and/or applying NbS for adaptation; draw on data and monitoring and evaluation results

- Awareness-raising activities targeting sector-specific audiences in government, finance, the private sector, and the public, covering: importance of ecosystems; experience and potential of NbS for adaptation
- Improve evaluation of effectiveness and cost-effectiveness to enhance evidence base and provide inputs to sector-specific business cases

- Develop definitive evidence for and demonstrations of importance of ecosystem management and potential of NbS for adaptation under different climate change scenarios
- Integrate concepts, evidence, and elements of best practice in all feasible curricula and training
- Improve evaluation of effectiveness and cost-effectiveness to enhance the evidence base and provide inputs to economic case assessments

Build on the role of nature at scale:

- Ensure revisions of NAPs, NDCs and other strategies recognize the role of nature in underpinning societal resilience; include ambition to use NbS for adaptation as part of the overall strategy
- Institute planning and budgeting horizons for ecosystem management and NbS for adaptation that last beyond political cycles to enable and guarantee sustained management and tracking of outcomes
- Include resilience considerations in strategic environmental assessment, integrated and cross-sectoral planning at multiple scales, and review of sectoral policies

- Support enhanced monitoring and evaluation to capture both adaptation outcomes and co-benefits, including long-term impact evaluation, across the full range of adaptation options supported
- Develop new funding streams and models (including de-risking strategies) suitable to support long-term investment in NbS for adaptation

- Act at scales wider than CSR activities to meet operational adaptation needs, using ecosystem management and NbS
- Build alliances with like-minded companies to build resilience in supply chains

- Mobilize successful demonstration and pilot experiences as models for broader scale action
- Form coalitions to address ecosystem management or NbS for adaptation goals (e.g. Global Mangrove Alliance)
- Provide input and support to policy revision processes, emphasizing implementation of ecosystem management and NbS for adaptation at scale and across sectors

- Develop research evidence and modeling approaches to identify most effective scales and options for intervention under different climate and development scenarios

- Increase consumer demand for climate-smart products
- Pressure governments to make and act on necessary policy revisions

Enable routine consideration of nature in assessment of climate adaptation needs:

- Investigate and adopt appropriate methods
- Incorporate methods and pointers to data into guidelines and procedures
- Require consideration of ecosystems in vulnerability and adaptation needs assessment for government use, e.g. in NAPs and other adaptation strategies

- Fund data and method development
- Fund assessments of ecosystem dependencies and associated climate risks for projects and populations, especially in developing countries
- Require consideration of ecosystems in vulnerability and adaptation needs assessments used to request financial resources

- Investigate and adopt appropriate methods, developing 'industry standards' as appropriate
- Use appropriate methods to assess and disclose operational climate risks linked to ecosystems, and identify options for addressing them

- Contribute to developing assessment methods; involve stakeholders in tailoring them to sectors and specific user groups
- "Socialize" and build capacity to use new methods
- Build on existing experience in environment sector to increase consideration of ecosystems in vulnerability assessments conducted in development and other sector CSOs

- Develop relevant data sets, frameworks and assessment methods for identifying ecosystem-mediated climate risks

- Exert consumer and voter pressure to incorporate ecosystem-mediated climate risks in assessment and disclosure of vulnerability, on the grounds that failure to do so affects the public good

Ensure the role of nature is considered routinely in evaluation of dependencies and impacts of adaptation and other interventions actors need to:

- Require feasibility studies for proposed government-supported work to include assessment of ecosystem dependencies and associated climate risks
- Require EIAs to assess how any identified impacts on ecosystems and their services may affect climate resilience; and proponents to employ good practice in avoiding and mitigating these impacts
- Enforce EIA regulations

- Require feasibility studies for proposed projects to include assessment of ecosystem dependencies and associated climate risks
- Incorporate into performance standards a requirement to explicitly assess how any identified impacts on ecosystems and their services are likely to affect people's climate resilience; and to employ good practice in avoiding or mitigating such impacts

- Include assessment of ecosystem dependencies and associated climate risks as standard practice in feasibility studies and ensure access to relevant capacity
- Routinely assess, and put measures in place to avoid or mitigate impacts on ecosystems and their services that are likely to affect people's climate resilience; and seek opportunities to enhance resilience, in compliance with legislation and/or good practice

- Mobilize available methods for identifying ecosystem dependencies from ecosystem assessment and other communities of practice, and tailor these to professionals involved in feasibility assessments
- Advocate for appropriate enforcement of EIA regulations that take impacts on resilience into account

- Incorporate concepts of ecosystem dependency and associated climate risk to curricula and training programs for development professionals, engineers, economists, environmental impact assessors etc.

- Exert consumer and voter pressure to motivate enforcement of EIA regulations that take impacts on resilience into account

Ensure NbS options are evaluated as a matter of course whenever a need for adaptation is identified:

- Adjust procurement policies to make sure they:
  - Require comparison among adaptation options to meet specific needs, explicitly including NbS as both stand-alone and complementary activities for engineered options
- – Consider the long-term effectiveness and resilience of different options under changing climatic conditions
- – Include full range of costs and benefits, for balanced comparison
- Reflect priorities identified in NAPs

- Encourage supported governments, institutions, and companies to include requirements for review of NbS options in project-related procurement policies that:
- – Compare among adaptation options to meet specific needs, including NbS activities as both stand-alone and complementary for engineered options
- – Consider the long-term effectiveness and resilience of different options under changing climatic conditions – Include full range of costs and benefits for balanced comparison

- In decision-making processes for addressing climate risk, adjust standard practice to include:
  - Compare among adaptation options to meet specific needs, including NbS as both stand-alone and complementary activities for engineered options
  - Consider long-term effectiveness and resilience of different options under changing climatic conditions
  - Include a full range of costs and benefits for comparison; evaluate these at appropriate temporal and spatial scales

- Mobilize successful experiences to inform identification and selection of adaptation options
- Promote and build capacity for inclusion of NbS (as stand-alone and complementary activities for engineered options) in processes for selecting adaptation options that evaluate a full range of costs and benefits for all options, and consider the long term effectiveness and resilience of the options under changing climatic conditions.

- Develop frameworks and methods for comparing adaptation options that evaluate a full range of costs and benefits for all options at appropriate temporal and spatial scales

SUMMARIZING THE WAY FORWARD

Recognition of nature's importance for climate resilience needs to extend beyond civil society, research organizations, and environment departments to a full range of sectors within government, financial institutions and private entities. Only with such recognition and understanding can the necessary action be prioritized and implemented. Along with other actors, the public has an important role to play in raising awareness and stimulating action.

Adaptation action at scale requires adequate resources. Innovative funding streams and models are needed to support sustained management of nature, to ensure its contribution to resilience, and to enable wider uptake of NbS for adaptation. Also essential is ensuring that adaptation actions themselves do not compromise the health and resilience of ecosystems or their role in supporting societal resilience. The regulatory environment and standards of good practice have roles to play in broadening uptake, enhancing effectiveness, and avoiding perverse outcomes and maladaptation.

Ongoing monitoring and research are needed to understand ecosystem responses to climate impacts and to support adaptive management. This will ensure the health and resilience of ecosystems and their adaptation benefits in the face of long term climate risks. Conservation action can help to reduce other impacts on ecosystems that otherwise add to their vulnerability.

Nature can play a powerful role in helping society cope with the impacts of climate change at all scales. Making the most of this potential requires efforts from actors across society. Such efforts will mainstream and scale up understanding and action that enhances the resilience of ecosystems to climate change and uses natural assets to reduce particular climate risks.

Annex A: Case Studies

BOX A1 Urban Coastal Resilience: Howard Beach, Queens, New York – Cost-Benefit Evaluation of Alternatives Involving Different Combinations of Hard Infrastructure and NbS

Hazard: Storm surge, flooding

Sector: Cities

Vulnerability: City residential areas affected by Hurricane Sandy and needing protection from future storm impacts. The City selected Howard Beach (a residential neighborhood) as the focus for the commissioned study due to the damage it suffered during Hurricane Sandy as well as its vulnerability to high-frequency, low-impact flooding from sea-level rise—risks that will increase over time.

Actions: Cost-benefit evaluation of five alternatives involving different combinations of hard infrastructure and NbS and taking account of co-benefits:

- All-green options: Nature and nature-based infrastructure (shoreline and wetlands) – wetland and marshland areas are restored or enlarged
- Hybrid options: wetland restoration and installation of movable flood walls/flood gates
- All-gray option: Flood wall and flood gates – no restoration or creation of wetlands, construction of a flood wall along vulnerable areas, installation of flood gates at the mouth of basins to be closed during high-water events

Policy Enablers/Context: In 2013 the New York City Special Initiative for Rebuilding and Resiliency (SIRR) asked TNC to evaluate the role of nature and natural infrastructure in protecting communities from sea-level rise, storm surges, and coastal flooding.

Implementation Costs: Costs for the preferred option (hybrid) include both construction and lifecycle costs: US$74.6 million in 2014 dollars at a three percent discount rate, for a 50-year project lifespan.

Impacts/Avoided Losses:

- The alternative that provides the most community protection while also maximizing environmental benefits at a reasonable cost is a hybrid option. It saves US$225 million in damages from a 1-in-100-year storm event while generating ecosystem services
- The all-gray alternative provides the highest level of flood protection and also avoids US$225 million in flood damages, but it has unintended consequences for the surrounding community, generates the least ecosystem services and ecological benefits, and it is costly
- The all-green options do not meet the flood mitigation objectives—they avoid less than US$1 million in flood damage losses

Co-Benefits: salt marsh habitat and bird watching/wildlife viewing values; improved water quality; carbon sequestration in restored wetlands; habitat for fish species.

Risks/Challenges: The analysis assumes a 100-year flood event, but does not include damages from less severe or more severe storm events. Thus, the expected value of flood damages avoided is underestimated; analysis does not include community preferences.

Source: TNC. 2015. Urban Coastal Resilience: Valuing Nature's Role. Case study: Howard beach, Queens, New York. TNC. https://www.nature.org/media/newyork/urban-coastal-resilience.pdf

BOX A2 Integrated Coastal Management Programme, Vietnam

Hazard: Sea level rise, flooding, storm surge, coastal erosion, saltwater intrusion, drought

Sector: Infrastructure

Vulnerability: Along the mangrove-mud coasts of the Mekong Delta, erosion, flooding, and storms are affecting the lives of thousands, often poor farmers and fishers. According to official studies, more than a third of the Delta area could be underwater by the year 2100. Some areas of the coast are already being eroded by 30 meters a year. The mangrove forests along the coast, which protect the hinterland from floods and storms, are in dramatic decline. In early 2016, the Mekong Delta suffered its most severe drought in 90 years. This, together with rising sea levels, resulted in a heavy intrusion of saltwater into rice-growing areas.

Actions:

- Numeric modeling of hydro- and sediment-dynamics to plan the optimal placement and design of breakwaters
- Planning and construction of breakwaters (T-shaped fences)
- Monitoring and maintaining the breakwaters
- Protecting and planting mangroves for an effective area coastal protection strategy

Implementers: Integrated Coastal Management Programme, GIZ, German Federal Ministry of Economic Cooperation and Development, German Federal Minister for the Environment, Nature Conservation, and Nuclear Safety, local authorities and local communities.

Policy Enablers/Context:

- Records of loss of floodplains through erosion reveal urgency for intervention
- Interest in collaboration on the side of the national government regarding policy development and implementation
- Availability of data and technology as well as expertise to collect data, build and monitor breakwaters
- Historical records of mangrove occurrence for the site to assess the feasibility of natural regeneration of mangroves or mangrove rehabilitation.

Impacts/Avoided Losses: Erosion has been halted in some sites. Up to 180 meters of land lost to the sea has been restored in other sites; new mud flats can now be grown with mangroves and other plants. Financially, direct costs for dike maintenance and repair were drastically reduced. Security for people living directly behind the dike has been improved.

Co-Benefits: Carbon sequestration; habitat for bird, fish and mammal species; new and secured livelihoods.

Risks/Challenges:

- Coastal engineering know-how as well as proper information is compulsory, which can be challenging to retrieve, depending on country context
- Construction of T-fences must follow quality standards and must be well supervised
- Long-term GPS-surveillance needed and requires monitoring of neighboring areas
- Establishment of mangrove forest can take several years

Source: Schmitt, K. 2015. "Ecosystem-based coastal protection through floodplain restoration, Vietnam." https://panorama.solutions/en/solution/ecosystem-based-coastal-protection-through-floodplain-restoration. Accessed March 25, 2019; (Richter, L. (GIZ), based on documents contributed by Klaus Schmitt); (Schmitt, K (GIZ), personal communication)

BOX A3 Building with Nature - Towards a Resilient and Prosperous Coastline in Northern Java

Hazard: Flooding, coastal erosion, sea level rise

Sector: Infrastructure (coastal defense)

Vulnerability: The Business as Usual scenario in 2030 shows a fully flooded area with evacuated villages and land loss due to mangrove loss, subsidence caused by unsustainable groundwater extraction, and sea level rise. Economic development is projected to be hampered due to blocked transportation routes, continuous repairs of public and private infrastructure, loss of land, and economic losses in the agriculture and aquaculture sectors.

Actions:

- Introduction of a Building with Nature approach (BwN), a design philosophy and process for hydraulic engineering that works with and alongside the dynamics of nature
- Enhancing coastal safety along a 20-km coastline by restoring mangroves
- Introduce a model for sustainable aquaculture that provides space for mangrove restoration, decreases use of chemicals, and enhances shrimp and fish production
- Financial incentive mechanism: in return for engagement in conservation and restoration measures, communities receive financial support to develop sustainable livelihoods
- Stimulate stakeholder dialogues and roadmap development to mitigate (addressing groundwater extraction) and adapt to (flood protection) subsidence in Semarang and Demak district
- Demark a protected mangrove zone in the Demak district
- Bring the BwN approach into mainstream coastal zone management through policy dialogue, training, and alignment with other adaptation and development initiatives

Implementers: EcoShape (BwN innovation platform), Wetlands International, Ministry of Marine Affairs and Fisheries, Ministry of Public Works and Housing, Witteveen+Bos, Deltares, Wageningen University & Research, UNESCO-IHE, TU Delft, Von Lieberman, Blue Forests, Kota Kita, Diponegoro University, and local communities.

Policy Enablers/Context: Hard infrastructures like dams and sea walls had proven to be ineffective along the rural mud-coast, as these exacerbated erosion, were unstable and expensive, and failed to deliver vital economic, environmental and social services that the mangrove belt provides.

Implementation Costs: The total current funding of the program amounts to US$11 million, including an investment of US$1.6 million in the replication of permeable structures by the Indonesian Ministry of Marine Affairs and Fisheries.

Impacts/Avoided Losses: Reduced poverty risk for vulnerable groups affected by coastal hazards; increased resilience of 70,000 people and 6000 ha of aquaculture ponds in the Flagship project area; reduced impact of sea level, which in Demak district (Central Java) is projected to cause flooding 6 km inland by 2100, inundating 14,700 ha and affecting 71,676 people.

Co-Benefits: Sustainable aquaculture practices are already leading to increased aquaculture productivity and tripled income, boosting farmers' support; mangrove restoration efforts have resulted in enhanced fisheries; biodiversity benefits, carbon sequestration, avoided greenhouse gas emissions from soils and enhanced water quality.

Risks/Challenges:

- Severe land subsidence, as a result of groundwater extraction in the South Western part of Demak, seemingly affects the entire 20 km coastal stretch of the project. BwN measures soften and delay the impact of hazards, helping communities to adapt or transform their livelihoods, but will reach a threshold if unsustainable groundwater extraction is not addressed.
- The government struggles to accommodate needs for short-term development and long-term sustainability. Lack of clarity in mandate between line ministries and agencies at different spatial scales, combined with the absence of governance frameworks for integrated coastal zone management, prevents translation of policies into practice.

Source: (Toll, S., personal communication, February 25, 2019)

BOX A4 North Norfolk Coastal Restoration (UK)

Hazard: Flooding, coastal erosion

Sector: Infrastructure; industry and supply chains

Vulnerability: Risk of saline flooding to farmland as well as to freshwater or wet grassland conservation sites, property, and infrastructure; structural damage to sea wall following storm surges.

Actions:

- Sand dune restoration
- Restoration of shingle beach
- Removal of gray infrastructure fronting sand dunes to allow the development of a more natural form
- Fencing used to aid sand trapping in front of an eroding dune ridge, which protects the freshwater area and property
- Restoration of the natural functioning shingle barrier beach to facilitate natural post-storm recovery and maintain flood protection while reducing or removing maintenance requirements

Implementers: Environment Agency of England; North Norfolk District Council

Policy Enablers/Context: Shoreline Management Plans are active along the Norfolk coast, and provide a strategic assessment of the risks associated with coastal erosion, taking into account the future implementation of coastal policies, geology, likely impacts of climate change, and the existing condition of the coast, including coastal defenses.

Impacts/Avoided Losses: Restoration of dune function; creation of 7.5 ha of intertidal habitat; protected and enhanced freshwater habitat; created habitats that are more resilient to the effects of climate change.

Co-Benefits: Improved the aesthetic value of the coastline.

Source: Bridges, T., Bourne, E., King, J., Kuzmitski, H, Moynihan, E., and Suedel, B. 2018. *Engineering with Nature*: an Atlas. Vicksburg, MS: U.S. Army Engineer Research and Development Center. http://dx.doi.org/10.21079/11681/27929.

BOX A5 Coral Gardening for Climate Change Adaptation in Vanuatu

Hazard: Ocean acidification, increasing temperatures, sea level rise, tropical cyclones

Sector: Food security and rural livelihoods; Industry and supply chains (tourism, fisheries)

Vulnerability: Coral reefs are currently under threat from climate change, invasive species and human activities, jeopardizing the livelihoods of people engaged in agriculture, forestry and fishing and dependent on natural resources. Extreme weather events also have a particularly detrimental impact on tourism.

Actions:

- Damaged coral reefs restored with over 3000 heat stress-tolerant coral fragments, contributing to climate change adaptation and eco-tourism revenue
- Partnerships established between local tour operators and bungalow owners allowing for upscaling and promoting the coral gardening activity; in exchange for financial sponsorship to the community, incoming international visitors have the opportunity to participate in restoration activities
- Women encouraged to take the role of resource champions in each of the committees, offering special gender-focused trainings and capacity development workshops

Implementers: Secretariat of the Pacific Community, Marine Protected Area Nguna Pele, Department of Tourism Vanuatu, GIZ.

Policy Enablers/Context: Implementation in the context of a marine local protected area with community stewardship and engagement; a strong partnership of protected area network with other stakeholders such as tour operators and the Department of Tourism.

Impacts/Avoided Losses: Eco-tourism partnerships between local communities and the tourism sector and the participation of women and girls contributed both to resilience building and higher revenues for 7 island villages. Sustainable income flows were re-invested in local adaptation and environmental management projects, climate change adaptation, and eco-tourism revenue.

Co-Benefits: Habitat for fish species

Risks/Challenges: Coral varieties that are particularly resilient to climate change impacts of bleaching and ocean acidification have been used, but coral stability and resilience under a >1.5° scenario is in jeopardy due to tipping points for coral ecosystems.

Source: Bartlett, C. and Whitely, T. 2018. "Coral Gardening for Climate Change Adaptation in Vanuatu." https://panorama.solutions/en/solution/coral-gardening-climate-change-adaptation-vanuatu. Accessed March 25, 2019.

BOX A6 Itaipu Dam, Paraguay/Brazil

Hazard: Soil erosion, drought

Sector: Infrastructure (energy)

Vulnerability: Hydroelectric plant vulnerable to loss of function/productivity due to reduced water supply and/or sedimentation.

Actions: To reduce variation in flows, maintain production, reduce sedimentation, and prolong the average lifetime of the hydropower plant:

- Watershed forest restoration and management totaling nearly 101,000 ha, planting over 26 million trees in 40 years
- Management of other land including altered agricultural practice

Implementers: Private company (Itaipu Binacional) and local communities

Policy Enablers/Context: Existing legal framework for protecting watershed forests and compensating land owners preserving forests important for water; company ownership of land involved in initial phases.

Impacts/Avoided Losses: Company ability to maintain production enhanced by more stable flows, damage to turbines reduced, lifespan of the reservoir extended; dam supplies 91 percent of electricity consumed in Paraguay and 15 percent of the electricity consumed in Brazil, electricity price rises during drought are the norm in Brazil; dredging costs also avoided.

Co-Benefits: Consolidation of the protected belt of the reservoir as a biological corridor; climate change mitigation through carbon sequestration and storage (estimated at over 5.9 million tonnes CO2e per year); introduction of native arboreal species of high economic, cultural and ecological value; scenic beauty; support for local livelihoods.

Risks/Challenges:

- Large area, limitations in relation to logistics and security
- Extractive activities such as hunting, fishing, and unsustainable forest uses; intentional forest fires; encroachment invasions; clandestine dumps
- Conservation activities can only be achieved successfully after the implementation of long-term awareness efforts designed to change previous attitudes
- Presence of invasive alien species, pest attacks, and extreme weather affect restoration activities and create negative impacts on the growth of trees and related ecosystem services
- ITAIPU's support of monitoring and surveillance has to be coordinated with public institutions according to government procedures

Source: Itaipu Binacional, personal communication, May 20, 2019)

BOX A7 Ecosystem-based Adaptation (EbA) in Mountain Ecosystems Program - Nor Yauyos Landscape – Livestock Production (Peru)

Hazard: Temperature extremes, drought

Sector: Industry and supply chains; food security and rural livelihoods (livestock production)

Vulnerability: Increased variability in seasonal patterns and reduction in surface water run-off, as well as frost and extreme events such as hailstorms, are affecting agricultural production and communities in one of the most vulnerable regions to climate change in Peru.

Actions: Restoring water channels and reservoirs to secure provision of water for the reserve communities and downstream users; grassland management to enhance pastoral livelihoods and increase resilience to drought and frost; vicuña* management to produce animal fiber and communal livestock management in natural grasslands, and to enhance tourism potential.

Implementers: Ministry of Environment and other government agencies, the Mountain Institute, IUCN, protected area management, and regional governments.

Policy Enablers/Context: Key national policies already integrate climate change adaptation and EbA in a comprehensive manner, and there is a willingness to work on new policy instruments. Collaboration with protected area service and management provides an entry point for planning and working at the community and landscape levels. Local/traditional knowledge and practices can be integrated as part of EbA. Building on existing structures and institutions supports implementation and strengthens the link between government and communities.

Implementation Costs: Cost-benefit analysis (including market and non-market benefits) was conducted for sustainable grassland management, Vicuña management, and animal husbandry in the Tanta site. Two different project areas are included: i) community farm, where domestic livestock are raised; and ii) vicuña project, where vicuñas are managed in the wild:

- Main costs of the community farm: equipment and inputs (e.g. fences, trucks, veterinary services), labor (e.g. maintenance; shepherding; training programs; and provision of technical assistance)
- Main costs of the vicuña project: inputs for the basic gathering of wild vicuña, shearing equipment, labor for herding and shearing, training, and internship program
- Eight ecosystem services were valued in terms of change in productivity: food for domestic cattle and vicuña, provision of alpaca fiber, provision of sheep wool, provision of alpaca meat, provision of sheep meat, provision of beef, provision of vicuña fiber, and provision of water for agriculture

Impacts/Avoided Losses: Cost-benefit analysis showed that that the EbA measures had high profitability compared to the BAU scenario (without the project) over 2014-2023. The Net Present Value with the project was US$841,902.95 compared to US$486,571.34 without.

Co-Benefits:

- Reduced pressure on natural pastures, wetlands, and alpine ecosystems, favoring their recuperation
- Under new native pastures, a hectare now provides for three sheep per hectare, a six-fold increase; new introduced species pasture can support up to 18 sheep per hectare
- Enhanced carbon storage in grasslands
- Enhanced provision of animal fiber from Vicuña
- Biodiversity conservation, e.g. diverse habitats for predator and prey animals
- Improvement in health among community members from consuming healthier livestock products
- Strengthening of local organizations and management of communal lands
- Capacity building and technical assistance in enhanced livestock and vicuña management
- Enhanced scenic beauty and boost in recreation and tourism activities

Risks/Challenges:

- Difficulty in assessing multiple benefits provided by EbA (e.g. some benefits are provided in the short-term and at a local scale, but many are long-term benefits at larger scales)
- Actors most interested in more tangible, immediate economic and social benefits
- Lack of labor force due to outmigration can impede implementation
- Attaining certain ecosystem benefits may require a larger scale of implementation
- The lack of such data can lead to undervaluing EbA benefits and can affect monitoring of EbA benefits

* Vicuña are a South American member of the camel family, closely related to the alpaca and llama

Source: United Nations Development Programme (UNDP). 2015. *Making the Case for Ecosystem-Based Adaptation: The Global Mountain EbA Programme in Nepal, Peru and Uganda*. New York: UNDP.

BOX A8 Resilient Landscapes in the Serrana Region of Rio de Janeiro, Brazil

Hazard: Landslides, flooding

Sector: Cities

Vulnerability: Region prone to landslides, mudslides, and flooding due to its steep topography and frequent heavy rainfall. Deforestation and forest degradation destabilizes the soil and increases the risk of landslides. Hillside terrains have been occupied by favelas and roads, which cut through the slopes and increase the risk of landslides, putting these populations at risk.

Actions:

- Construction of river parks and reforestation of riparian areas
- Construction of natural channels for water infiltration to help control flooding
- Reforestation and regeneration of riparian forests (Mutirão Reflorestamento Project)
- Establishment of Permanent Protection Areas
- Introduction of alternative land use systems (e.g. agroforestry)
- Implementation of engineered structures: dredging, dams, embankment restoration, construction of water reservoirs
- Introduction of early warning and risk mapping and monitoring systems

Implementers: Brazilian Ministry of Environment, Government of Rio de Janeiro, Rio de Janeiro municipalities and communities.

Policy Enablers/Context: Brazil Forest Code considers natural ecosystems located in hillside terrains as Permanent Protection Areas due to their environmental functions and bans the felling of forests in slopes between 25° and 45°.

Impacts/Avoided Losses: Reforestation of 600ha across Rio de Janeiro; Cachoeiras de Macau municipality: forest management-improved water quality in a watershed that supplies drinking water to 2.5 million people.

Co-Benefits: Carbon sequestration; habitat for biodiversity; watershed and soil protection.

Risks/Challenges: Better coordination needed among national and state governments, institutions, and communities, e.g. through the establishment of partnerships; barriers due to institutional coordination, bureaucracy, and corruption; environmental awareness and education is needed at the local level; greater focus on short-term reaction to landslides and flooding than long-term prevention strategies.

Source: Nehren, U., Sudmeier-Rieux, K., Sandholz, S., Estrella, M., Lomarda, M. and Guillén, T., eds. 2014. "Case Study 1." Chap. 1 in *The Ecosystem-Based Disaster Risk Reduction Case Study and Exercise Source Book*. PEDRR and CNRD.

BOX A9 Land Rehabilitation through Reforestation – the Power of Property Rights in the Green Wood Energy Value Chain, Diana Region, Madagascar

Hazard: Desertification, drought, wildfires

Sector: Industry and supply chains

Vulnerability: Deforestation and erosion have degraded many fertile soils; frequent floods destroy paddy fields affecting food security; farmers increasingly turn to charcoal production to make a living, resulting in deforestation and degradation that affects water resources and increases vulnerability to natural disasters and climate change.

Actions: Allocation of clear land tenure rights to communities as basis for village–based individual reforestation schemes and restoration of land; sustainable management of fuel wood plantations and introduction of optimized kiln technology; set up the marketing of green-labelled charcoal product and optimization of combustion technologies via improved cook stoves; creating conducive policies and laws to strengthen green charcoal value chain.

Implementers: Directorate of Rural Development of the Diana Region, Ministry of the Environment, Ecology and Forests, Ministry of Energy, GIZ, CIRAD, Organisation for Security and Co-operation in Europe, ASA Programme.

Policy Enablers/Context: Restoration key element of NDC and FLR strategies; land tenure security in pilot areas; multi-stakeholder coordination via regional biomass energy exchange platform; wood energy modernization strategy; existence of legal frameworks for reforestation and charcoal production from plantations (free permits granted by the forest department); tax reductions for sustainable charcoal; growing demand for efficient stoves and charcoal.

Impacts/Avoided Losses:

- 40,500 people have access to sustainable household energy and benefit from reliable supply as well as lower fire and health hazards (less indoor air pollution)
- 12,500 households (approximately 45,2000 people) use improved cook stoves; they save approximately 1,600 t of charcoal annually, worth a total of US$ 209,000 or US$17 per household (25 percent less expenditure)
- 4,200 households afforested 9,000 ha of wasteland around 68 villages; soil fertility and water retention has been improved
- Wood fuel production on 9,000 ha already offsets unregulated exploitation of more than 90,000 ha of natural forests
- approximately 1,000 ha of forest area are sustainably used per year with a yield of 4,700 t of green charcoal
- The approach is currently scaled up in other regions of Madagascar on 15,000 ha also as part of NDC implementation

Co-Benefits: Carbon sequestration, livelihood improvement, improved health, erosion prevention, microclimate generation.

Risks/Challenges: Choice of species for restoration was based on economic criteria (e.g. short rotation cycles, resistance against climatic fluctuation) rather than biodiversity criteria; the charcoal value chain is often dominated by tight networks of middlemen, able to control market prices; until use regulations and taxation take effect, sustainable charcoal suffers a competitive disadvantage compared to charcoal from non-regulated sources.

Sources: Knodt, R. 2018. "Land rehabilitation through reforestation – the power of property rights in the green wood energy value chain, Madagascar." https://panorama.solutions/en/solution/land-rehabilitation-through-reforestation-power-property-rights-green-wood-energy-value. Accessed on March 25, 2019; (Bertram, G. (GIZ), personal communication based on documents provided by Christian Burren and Richard Knodt); (Burren, C (GIZ), personal communication); Knodt, R. (ECO Consult), personal communication)

BOX A10 Ecosystem-based Adaptation (EbA) in Mountain Ecosystems Program – Mount Elgon, Uganda

Hazards: Soil erosion, flooding, landslides, drought

Sector: Food security and rural livelihoods

Vulnerability: Rural communities in the Mount Elgon catchment rely heavily on rain-fed subsistence agriculture for their food security and livelihoods. This makes them particularly vulnerable to changes in precipitation patterns and to exacerbating climate hazards such as drought, floods, soil erosion, and landslides.

Actions: Mount Elgon Protected Area catchment-scale management, including:

- **Ecosystem restoration** including gravity flow scheme, soil and water conservation, river bank management, and tree planting (using indigenous, drought-tolerant tree and grass species)
- **Conservation agriculture** including soil conservation (through agroforestry, mulching, grass banks, hedgerows, contours, and trenches) and use of drought-resistant seed varieties

Implementers: Ministry of Water and Environment and other government ministries and authorities, Makerere University Institute of Natural Resources, Mt. Elgon Conservation Forum, District Local Governments, UNDP, IUCN, UN Environment, community-based groups.

Policy Enablers/Context: Supportive national frameworks are in place that include EbA-relevant priorities or measures, including: national policy on adaptation priorities; The Second National Development Plan 2015-2020; formulations and/or revisions of national policies, plans and guidelines: National Environment Management Plan; NBSAP, NDC and NAP; and Ministry of Water and Environment guidelines on integrating EbA into district-level planning processes and development plans. Local policies and plans include a territorial plan for the management
of Mount Elgon, parish climate change adaptation plans and community environment action plans.

Implementation Costs: Cost-benefit analysis results show that:

- EbA practice viability can be sustained in the long run, even at the relatively high 12 percent discount rate
- Profitability of EbA practicing farmers across the landscape was significantly higher than that for non-EbA-practicing farmers
- EbA is expected to be more effective and the investment is expected to lead to a higher return compared to non-EbA investments; a 2 percecnt increase in soil productivity as a result of EbA investment is assumed above the status quo
- Practicing EbA with perennial crops significantly enhanced profitability

Impacts/Avoided Losses: minimized nitrogen, phosphorus, and potassium (NPK) soil nutrient loss from avoided soil erosion; less need to compensate by purchasing external inputs such as fertilizers.

Co-Benefits: Increased cohesion among parish actors from establishing water groups and jointly implementing activities; improved health from stable water supply, enough food and better nutrition; decrease in conflicts of water use and time spent in search for water; improved agricultural livelihoods and increased income from increased local commercial sale of more varied and healthier crops, enabled by the catchment-scale approach; increase in community cohesion and resilience as farmers help each other.

Risks/Challenges: Communities are most interested in more tangible, immediate economic and social benefits, and it is not always easy to demonstrate how these are based on ecosystem services; cost-benefit analysis can be challenging, as confidence in the values/methodology used may be low; implementing multi-sectoral policy, with several Ministries in charge of delivery; public financing for climate change remains limited due to lack of resources, weak regulatory instruments and institutional capacity to deliver.

Source: UNDP. 2015. *Making the Case for Ecosystem-Based Adaptation: The Global Mountain EbA Programme in Nepal, Peru and Uganda*. New York: UNDP.

BOX A11 Capturing the Multiple Benefits Associated with Nature-based Solutions: Lessons from a Natural Flood Management Project in the Cotswolds, UK

Hazard: Flooding

Sector: Infrastructure, Cities

Vulnerability: River catchment in the southern Cotswolds is prone to flooding, putting several towns and villages within the catchment at risk.

Actions: More than 400 natural flood management interventions (including the construction of 170 woody debris dams, one dry stone wall deflector, 15 earth bunds, six gully systems, 1.7km fencing, one dry pond); plantation of 400 trees.

Implementers: Regional Flood and Coastal Committee, local council, local community

Policy Enablers/Context: The catchment of the Stroud River Frome was designated as a Drinking Water Protection Zone in 2016 to ensure water quality. The area is also prone to flooding, and community consultations concluded that hard engineering protection against flooding was not a viable option and would impact the local environment and landscape. As a result, the use of NbS was proposed by the local community groups.

Implementation Costs: US$348,000 over 3 years; Cost of NBS interventions: US$50,000

Impacts/Avoided Losses:

- US$2.1 million avoided losses from flooding in businesses and domestic properties
- 20 percent of the catchments (corresponding to an area of 52.5km^2) flows through NbS interventions
- Measures implemented attenuated water during high flow events and promoted infiltration instead of surface runoff. Water peak level reduced by almost 1.4 meters
- Reduced river levels avoided flooding in 53 properties located along the catchment

Co-Benefits:

- Increased plant diversity in the woodland
- Change in flow and sediment transport around the woodland has created a more diverse range of river habitats
- Livestock is fenced out of watercourses, reducing erosion and the amount of silt that is entering the watercourses
- Engagement and involvement of the local community

Risks/Challenges:

- Limited monitoring points exist along the catchments to compare pre- and post-installation of NbS measures
- No baseline data was available on the effectiveness of local interventions on biodiversity, geomorphology, and hydrology
- Effectiveness of NbS measures in each particular location is dependent on many site-specific variables (e.g. geology, type of land management, ecology, timings). More research is needed to determine how transferable the benefits of different types of measures are

Source: Short, C., Clarke, L., Carnelli, F., Uttley, C., and Smith, B. 2019. "Capturing the multiple benefits associated with nature-based solutions: Lessons from a natural flood management project in the Cotswolds, UK." *Land Degradation & Development*, 30(3): 241-252.

BOX A12 Water Management Benefits of Prairie Potholes in the Shepard Slough Complex, Alberta

Hazard: Flooding

Sector: Cities, Infrastructure

Vulnerability: Province of Alberta is vulnerable to flooding events, exacerbated by wetland degradation. The "prairie pothole" wetlands are inland wetlands that do not typically form connections to streams and rivers when water volumes are at average levels, of special interest because they are scattered across an area where land use pressures have had a profound impact on the water storage capacity of wetlands.

Actions: Pilot project to assess the value of benefits from 'prairie pothole' wetlands in the 'White Zone', an expanse of land covering approximately the lower third of Alberta and containing both the Bow River and South Saskatchewan River Basins.

Implementers: Alberta Province

Policy enablers/context: As a result of the 2013 flooding in southern Alberta's Bow River and South Saskatchewan River basins, the province has sought to explore all options to reduce the risk of future flooding. Avoiding wetland loss or restoring natural wetlands can provide a wider range of benefits at a lower cost. Wetlands restoration, too, prove to be far less costly than constructing artificial wetlands of the same size. The value of the additional ecosystem benefits provided by the Shepard Slough wetlands was recognized by the Government of Alberta and Ducks Unlimited, making a persuasive case for stopping wetlands drainage and ending residential, industrial and agricultural encroachment on intact wetlands in the area.

Implementation Costs: Impacts/ Avoided losses:

- General estimates are that the full cost for restoration of natural wetlands in the White Zone is as low as US$10,000/ha, increasing to between US$19,000 and US$23,284/ha in areas closest to Calgary
- Flood or stormwater storage for 36.3 million m^3
- Avoided investment of US$257 million for engineered storm water ponds

Co-Benefits:

- Clean water provision and lower costs for water purification
- Carbon sinks (i.e., the White Zone's wetlands have captured over 160,000 T of CO2-equivalent since the 1960s)
- Wildlife habitat
- Settings for scientific research and education
- Recreation opportunities - tourism linked to the wetlands was found to generate US$3.4 million of revenue for the province at a low investment cost
- Access and proximity to wetlands in the area also positively impacts property value, increasing the average worth of a house by US$3,340 - $3,900

BOX A13 Restoration of Urban Mangrove Ecosystems in Ciénaga de la Virgen, Cartagena, Colombia

Hazard: Storm surge, flooding, sea level rise, drought

Sector: Cities

Vulnerability: Cartagena, as the financial and economic centre of Colombia, is heavily exposed to climate hazards. Inland wetlands, forests, and mangroves have been degraded due to unsustainable land use and land conversion. Coastal communities, urban and rural infrastructure, and private sector activities (especially tourism) are facing risks to their socio-economic wellbeing.

Actions:

- Pilot projects for the restoration of mangroves in vulnerable coastal areas
- Restoration and maintenance of forests close to natural streams and rivers in the urban area
- To fund these activities, a financing strategy was set up jointly with the private sector, national and regional actors, involving the implementation of a specific fee for conferences and events that take place in the city.
  Fee revenue compensates for the strain on natural resources and will be used to fund the planting of trees

Implementers: Ministry of Environment and Sustainable Development of Colombia, GIZ, Marine and Coastal Research Institute, Mayor of Cartagena de Indias, Environmental Public Establishment Cartagena, INVEST in Cartagena, Botanical Gardens of Cartagena, Cartagena Water Fund, Social Foundation, NGOs and local communities.

Policy Enablers/Context: The existence of a city climate change plan in Cartagena (Plan 4C) provided a policy context, assisted by private sector involvement and engagement during the development process. EbA measures were embedded in an overall adaptation strategy. A general willingness to cooperate beyond institutional boundaries for improving environmental factors and human wellbeing facilitated the project.

Implementation Costs: Event footprint compensation in 2017-2018 mobilized around US$33,500 of private funds, ensuring the planting and maintenance of 2,400 new trees for Cartagena over the following three years. GIZ supported local institutions in the development of the innovative financial instrument and invested around US$15,600 in the pilot compensations.

Impacts/Avoided Losses: 2,400 trees and mangroves planted; The Colombian Ministry of Environment and the National Planning Department have adopted and mainstreamed the EbA approach in their operations, habitat for bird, fish and mammal species.

Co-Benefits: Carbon sequestration; Habitat for bird, fish and mammal species.

Risks/Challenges:

- Lack of public and private financial instruments that can guarantee the economic sustainability of EbA measures in the long run
- Many of the restoration measures have only long-term effects. It is crucial to include measures with short-term benefits, to gain institutional, private and public support for EbA measures
- Scaling up actions will require the coordinated action of government institutions, local communities, and in particular the private sector; it is crucial to develop appropriate incentives for forming partnerships
- Monitoring and evaluating EbA measures is still difficult given the complexity of risk models and the lack of unified impact indicators at the global or national level

Sources: Gomez-Villota, F. 2016. "Pilots for the restoration of mangrove ecosystems in Ciénaga de la Virgen (Cartagena, Colombia)." https://panorama.solutions/en/solution/pilots-restoration-mangrove-ecosystems-cienaga-de-la-virgen-cartagena-colombia Accessed March 25, 2019; (Bertram, M (GIZ) personal communication, based on documents provided by Felipe Gomez Villota); (Villota, F. (GIZ), personal communication)

BOX A14 Singapore Active, Beautiful, Clean Waters (ABC Waters) Programme

Hazard: Flooding, drought

Sector: Cities (inland waters)

Vulnerability: Drainage capacity vulnerable due to a large urban population and increased stormwater runoff during rainfall events.

Actions: To transform utilitarian canals, drains, and reservoirs in Singapore into clean flowing rivers, streams, and lakes that blend naturally into the urban environment.

Implementers: Singapore National Water Agency, local communities.

Policy enablers/context: The Singapore 2016 Climate Action Plan identifies more frequent and severe droughts and higher risks of flooding as key water-related risks. The Urban Redevelopment Authority (URA) master plan zones land use in Singapore and allocates land to various agencies for development. Agencies would usually defend the land space allocated for their development purposes. The ABC Waters Programme provided an opportunity to break out of this silo thinking and develop a truly integrated landscape.

Implementation Costs: ABC Waters Programme was implemented in phases, starting with the first five-year plan (2007-2011) comprising twenty-eight projects at an estimated cost of US$300 million.

Impacts/Avoided Losses:

- The flood-prone area has been reduced from 3200 ha to 32 ha
- The incorporation of green infrastructure in urban areas adds monetary value as there is a willingness by the public to pay more for properties in precincts with green infrastructure
- Savings in water cost was US$390.68 million annually
- Skyrise green spaces avoid the costs of runoff treatment and save US$19,654 annually
- Total environmental benefits amount to US$2.4 million
- The program has been successful at encouraging communities to take ownership of Singapore's waterways and waterbodies with 321 active partners adopting ABC Waters sites

Co-Benefits:

- Enhancing livability in residential areas
- Improved air quality
- Improvement in water runoff quality
- Reduced energy use and CO2 emissions
- Biodiversity enhancement

Risks/Challenges: Densely populated area and increase in stormwater run-off due to increasing urbanization; Frequent storms and pockets of flooding in low-lying areas; drainage capacity must be enough to cater for high peak flows despite the city having limited space.

Sources: Padawangi, R., Buurman, J., and Lim, W. 2011. "Evaluation of Singapore's ABC Waters Programme." Conference Paper. Singapore: 4th International Perspective on Water Resources and the Environment; Lim, H., and Lu, X. 2016. "Sustainable urban storm water management in the tropics: An evaluation of Singapore's ABC Waters Program." *Journal of Hydrology*, 538: 842-862; Ministry of the Environment and Water Resources (MEWR) and Ministry of National Development. 2016. *Singapore's Climate Action Plan: A Climate-Resilient Singapore, For a Sustainable Future*. Singapore: MEWR; Yau, W., Radhakrishnan, M., Liong, S., Zevenbergen, C., and Pathirana, A. 2017. "Effectiveness of ABC Waters Design features for runoff quantity control in urban Singapore." *Water* 9(8): 577; Centre for Livable Cities (CLC). 2017. *Urban Systems Studies: The ABC Programme: water as an environmental asset*. Singapore: CLC Publishing; Wang, M., Zhang, D., Adhityan, A., Ng, W., Dong, J., and Tan, S. 2018. "Conventional and holistic urban storm water management in coastal cities: a case study of the practice in Hong Kong and Singapore." *International Journal of Water Resources Development*, 34(2): 192-212.

BOX A15 Sponge City Program in China

Hazard: Flooding, drought

Sector: Cities

Vulnerability: Rapid urbanization has led to flooding and water shortages. Urban sprawl has increased impervious areas and converted many forests, grasslands, and lakes, breaking the natural water cycle that allows stormwater to infiltrate and replenish the groundwater storage.

Actions: The Sponge City Program pilots in 16 cities; new investment and financial supporting mode based on Public-Private Partnership concept employed to handle the Sponge City (SPC) construction and operation cost.

Implementers: China Ministry of Finance, Ministry of Housing and Urban-Rural Development, and Ministry of Water Resource.

Policy Enablers/Context: Because of the challenges and severe problems of urban flooding, city managers, engineers, and scientists for water resource management started to invest money and time on urban stormwater management in the last several decades. The SPC concept became more popular after Chinese president Xi Jinping and the central government promoted it at the central urbanization conference in 2013. Although the SPC program was developed in a short time, the basic research and demonstration projects focusing on stormwater management concepts and practices such Sustainable Urban Design System (SUDS), Water Sensitive Urban Design (WSUD), Low Impact Urban Design and Development (LIUDD) have been carried on for more than ten years in China.

Impacts/Avoided Losses: Relieves cities' water shortage situation to avoid forest, lake, and wetland degradation and break the natural water cycle; stormwater could be reused through the construction of natural storage, natural infiltration, and natural depuration facilities during SPC construction.

Risks/Challenges: The geography and topography of Jinan pilot city promotes flash flooding, putting lives and property at risk; difficult to control water pollution load brought by stormwater runoff; in Baicheng pilot city, drainage facilities built in the 1970s and 1980s are too old to manage stormwater, and untreated wastewater discharged into the stormwater pipe illicitly.

Source: Li, X., Li, J., Fang, X., Gong, Y., and Wang, W. 2016. "Case Studies of the Sponge City Program in China. Program Brief. Minneapolis: World Environmental and Water Resources Congress.

BOX A16 Mangrove Plantation and Disaster Risk Reduction (MP/DRR) Project in the Disaster-prone Coastal Provinces of Northern Viet Nam

Hazard: Storm surge, flooding, sea level rise, drought

Sector: Infrastructure; Food security and rural livelihoods

Vulnerability: Rapid population growth, coastal modifications and land-use changes such as agricultural intensification and expansion, wetland conversion and urbanization.

Actions: Reforestation and afforestation in mangrove, casuarina, and bamboo forests on coastal and riverine areas.

Implementers: International Federation of Red Cross and Red Crescent Societies (IFRC), local communities.

Implementation Costs: Overall costs for the project spanning 17 years are US$8.88 million.

Impacts/ Avoided losses:

- Creation of 9,462ha of forest (8,961 of which were mangroves) in 166 communes
- Protection of approximately 100km of dike lines
- Damages to dikes have been reduced by US$80,000 to US$295,000
- Total savings due to avoided risks in the communities at large approximately US$15 million
- Number of direct beneficiaries of the project: 350,000
- Two million were indirectly protected through the afforestation efforts
- Provision of additional income for coastal communities through an increase in per hectare yield of aquaculture products such as shells and oyster by 209 to 789 percent. Direct economic benefits from aqua product collection, honeybee farming, etc., between US$344,000 and US$6.7 million in the selected communes
- Ecological benefits: the present value of estimated minimum CO2 emissions absorbed by the planted mangrove stands at US$218 million, assuming a price of US$20/t CO2e

Co-Benefits: Carbon sequestration; nutrient retention; sediment retention; biodiversity habitat; flood attenuation; wastewater treatment; water supply and recharge.

Risks/ challenges: Need for greater coordination for long-term planning between the VNRC, the Ministry of Agriculture and Rural Development, and the Ministry of National Resources and Environment; need for the VNRC to improve the capabilities of staff and volunteers.

Source: IFRC. 2018. *Mangrove plantation in VietNam: measuring impact and cost benefit.* Geneva: IFRC. https://www.ifrc.org/Global/Publications/disasters/reducing_risks/Case-study-Vietnam.pdf.

BOX A17 Incentive-based Hilsa Conservation Program, Bangladesh

Hazard: Changes in water availability, i.e. changes in water flow and river morphology

Sector: Industry and supply chains; Food security and rural livelihoods (capture fishery)

Vulnerability: overfishing and habitat degradation leading to a sharp decline in hilsa stocks. The hilsa fishery employs half a million professional fishers, and an additional 2.5 million people are engaged in part-time fishing activities or in the supply chain. It contributes 1 percent of the country's GDP and accounts for 11 percent of total national fish production. Around 250 million Bengali people depend on hilsa for nutrition.

Actions:

- Five sanctuary sites declared in important nursery areas to reduce pressure on hilsa juveniles
- Four nationally important spawning grounds established, covering 6,900km^2
- Fishing ban in four spawning grounds each October
- Enforcing the Protection and Conservation of Fish Act 1950
- Offering lost-earnings compensation to fishers affected by the ban: affected households (initially 186,000, increasing to 224,000 by 2016) received 30kg (later increased to 40kg) of rice each month through the government's Vulnerable Group Feeding Programme
- Awareness-raising for the bans

Implementers: Bangladesh Department of Fisheries

Policy Enablers/Context: Government prioritization of hilsa conservation; the presence of appropriate incentives; established local institutions and by-laws; and a number of national-level institutions, policies, and legislative instruments to support sustainable fisheries management. Hilsa protection measures are also already mainstreamed into existing government processes.

Implementation Costs: Overall expenses for the incentive scheme are more than offset by increased export tax revenue. It is unclear whether the program is of overall financial benefit to all fishers; compensation may not have covered losses from fishing restrictions, and there were some unintended negative economic impacts at the local level. Losses may have been partly offset by catch improvements, which created broad economic benefits felt throughout Bangladesh.

Co-Benefits: More diverse livelihoods and improvements in food security; improved incomes in the fishing industry; wider ecosystem benefits from the protection of hilsa habitats.

Risks/Challenges: Lack of capacity and cooperation between relevant institutions/agencies at local level; lack of support for community-based natural resource management; limited formal financial services available to help address high levels of fisher poverty; lack of supportive policy framework for addressing climate change in the fisheries sector; knowledge gaps on hilsa ecology and potential climate change impacts on the species; insufficient transboundary collaboration with Myanmar and India to manage hilsa across its entire habitat.

Source: Reid, H., Ali, L., Islam, M., and Hicks, C. 2018. Mainstreaming adaptation benefits for Bangladesh's freshwater ecosystems. London: International Institute for Environment and Development (IIED). https://www.alnap.org/system/files/content/resource/files/main/17476IIED.pdf.

BOX A18 Miyun, Jiaquan and Dongjiang Source Watershed Hebei/Guangdong/Jiangxi, China

Hazard: Drought, soil erosion

Sector: Cities (drinking water supply)

Vulnerability: Water pollution, soil erosion, and forest degradation due to agricultural chemicals, unsustainable land use, and unregulated urban developments.

Actions:

- Comprehensive environmental and ecological restoration using nature-based measures
- Drinking water source protection using nature-based measures
- Refinement and implementation of a Watershed Protection Roadmap (Jiaquan)
- Management of other land including altered agricultural practice
- Dongjiang Source area: implementing forest, wetland, and protected area management, alternative livelihoods (beekeeping), environmental improvement in the rural area, and the introduction of waste management system

Implementers: Government (National Forestry and Grassland Administration, Forest Department of Fengning County), academia (China Research Academy of Environmental Science, Research Centre for Eco-Environmental Sciences, China Academy of Science, Guangdong Academy of Forestry, Global Water Partnership China), social groups (Beijing Forestry Society, China Irrigation and Drainage Development Centre), and private sector (DANONE Waters China) in combination with local communities.

Policy Enablers/Context: The Action Plan for Water Pollution Prevention and Control aims to improve the country's water quality until 2020. In 2016, a compensation mechanism was established between two provinces of Jiangxi and Guangdong, which tries to ensure the water quality of Dongjiang River.

Implementation Costs: US$1 million (corresponding to 3 million Chinese yuan)

Impact/Avoided Losses:

- Miyun and Jiaquan Watersheds: improved water quality and watershed ecology
- Protection of 20 ha natural forests and restoration of 20 ha core areas around the spring from plantations to natural vegetation
- The direct impact of domestic waste into rivers has been minimized in three watersheds
- 30 percent increase in farmers' income due to alternative livelihoods

Co-Benefits: Biodiversity conservation, support for local livelihoods, environmental education opportunities.

Risks/Challenges: Community concerns/perceptions on potential economic losses; not-functioning and subsequent claims by communities for compensation; long-time scales needed to show effectiveness of natural-based solutions and to raise awareness and build capacity in the communities.

Sources: (Raza, A., personal communication, February 28, 2019)

BOX A19 Ecosystems Protecting Infrastructure and Communities Programme (EPIC) Coastal and Rural Areas of Senegal

Hazard: Drought, flooding, soil salinization

Sector: Food security and rural livelihoods

Vulnerability: Soils are vulnerable to degradation due to salinization of water and land, attributed to low freshwater inputs during periods of drought, deforestation, and inland fresh water extraction. Traditional poultry farming is also vulnerable to climate change as the high heat causes massive mortalities.

Actions:

- Baseline scientific studies: Mapping and assessment of climatic risk on agriculture and livestock sectors
- Capacity building and awareness-raising on Ecosystem-based disaster risk reduction
- Actions to reduce and prevent land salinization and erosion:
  - 76 anti-salt bunds were constructed
  - 1766 plants have been produced (2 nurseries) and planted in degraded lands
  - 104 ha sown to cereal crops produced 37,250 kg of cumulative production
  - Using assisted natural regeneration techniques, 7192 saplings are now growing in 232 ha of cultivated land
- Action to support the poultry farming sector: 120 roosters were introduced as an income-generating livelihood for women

Implementers: IUCN; local communities.

Policy Enablers/Context: Seven main policies related to climate change, disaster risk reduction, and mitigation of environmental destruction. This enabling environment includes a focus on disaster risk prevention, development of national and regional contingency plans, the organization of relief by mobilization of the civil society, and monitoring of Senegal's progress on climate change adaptation and mitigation.

Implementation Costs: Approximately US$440,000

Impacts/Avoided Losses: Avoided loss of agricultural yield due to soil degradation (salinization and erosion); avoided loss of incomes in poultry farming (introduction of a more resistant variety of rooster).

Co-Benefits: Biodiversity conservation; support for local livelihoods (income generation).

Risks/Challenges: Scaling-up of the proposed nature-based solutions to address national challenges; involvement of local stakeholders in maintaining the infrastructures and activities (reparation of fascines, assisted natural regeneration, etc.); long-term monitoring necessary to assess improvement of soil quality and crop yields.

Source: (Raza, A., personal communication, February 28, 2019)

BOX A20 Enhancing Capacity, Knowledge and Technology Support to Build Climate Resilience of Vulnerable Developing Countries (EbA through South-South Cooperation: EbA South)

Hazard: Storm surge, flooding, sea level rise, drought

Sector: Food security and rural livelihoods

Vulnerability: Poverty, dependence on rain-fed agriculture, limited capacity of regional and national institutions to plan and implement adequate adaptation technologies and practices.

Actions:

- On-the-ground EbA interventions in pilot countries: planting high-value tree species in fallow lands, converting marginal rice croplands to agroforestry, enrichment planting in forests and degraded shrublands, diversifying income earning potential
- Trainings, tools, and knowledge products developed to support effective planning and implementation of EbA technologies, including web platform; EbA planning tool, ALiVE: Adaptation, Livelihoods and Ecosystems; EbA handbook; guideline on EbA research; workshop with Asia Pacific Adaptation Network (APAN)
- Long term research programs for measuring the short- and long-term effects (ecological, hydrological and socio-economic) of EbA interventions being applied within the project

Implementers: UN Environment, National Development and Reform Commission of China (NDRC), Chinese Academy of Sciences (IGSNRR, CAS).

Implementation Costs: US$4.9 million from GEF SCCF; over US$7 million co-finance from China

Impacts/Avoided Losses:

Nepal:

- **2048 no-intervention scenario**: US$1 spent on growing agroforestry or loss incurred (the opportunity cost of lost wealth) results in US$6.93 of human benefit
- **2048 with expanded EbA south scenario**: US$1 buys $21.39 in human benefit. This implies US$1 buys 209 percent (or 3 times) more wellbeing than a no-intervention scenario
- **2048 expanded agroforestry scenario**: US$1 buys $15.41 in human benefit. This implies US$1 buys 122 percent (2.2 times) more wellbeing than a no-intervention scenario

Seychelles:

- **2028 with intervention scenario**: Reduced risk of rainwater flooding, enhanced property prices and transport access in the short term. However, the current interventions alone are unlikely to be adequate in 10 years' time. Changes to wetland functionality due to the establishment of drains has negative impacts on the receiving ocean habitats if they are not combined or offset with catchment management upstream of the flooding area. Human benefits are estimated to be 19 percent over a no-intervention scenario
- **2028 Catchment management and drains scenario**: Accommodates human pressure on the system in a changing climate and generates a net positive impact. Environment management and site-specific interventions are likely to promote a resilient Mahé society
- **2028 no-maintenance scenario**: maintenance of the existing interventions is required to ensure that the intervention does not generate net cost or loss to Mahé society

Risks/Challenges: If the project generates greater wellbeing, it could attract more people to the area and dilute intended benefits. Social interventions (e.g. promoting land rights, better management of common resources, or supporting better urban development and management), need to be combined with NBS measures to sustain intended benefits.

Sources: Mander, M. 2018. "Ecosystem Services Supply, Demand and Values at Petit Barbarons, Seychelles." *Ecosystem-based Adaptation through South-South Cooperation (EbA South) Final Report*. Nairobi: UNEP; Mander, M. 2018. "Ecosystem Services Supply, Demand and Values at Chiti, Nepal." *Ecosystem-based Adaptation through South-South Cooperation (EbA South) Final Report*. Nairobi: UNEP.

BOX A21 Best Management Practices for Silvo-Aquaculture in Bac Lieu, Mekong River Delta, Viet Nam

Hazard: Flooding, Storm surge, sea level rise, soil erosion

Sector: Food security and rural livelihoods

Vulnerability: Overutilization and degradation of natural resources; poor culturing techniques and water management; lack of capital; farms vulnerable due to monoculture and subsequent loss of profit. To supplement income, farmers often collect natural resources from adjacent mangroves, causing further degradation.

Actions: Promoting best management practices for silvo-aquaculture, including ecological farming techniques and the integration of mangroves in shrimp ponds; supporting Farmer Interest Groups along the Mekong Delta coast; raising awareness of mangrove ecosystem conservation benefits and diversifying farmers' incomes.

Implementers: Department of Agriculture and Rural Development, Bac Lieu Experimental Station for Aquaculture, GIZ, small-scale aquaculture farmers, silvo-aquaculture farmers, and coastal area residents.

Policy Enablers/Context: Shrimp cultivation is a key economic sector with a substantial share of GDP; farmers were willing to adapt farm management and contribute lessons learned; aquaculture research station with extensive technical and local knowledge; existing farmer interest groups to receive and disseminate the information.

Impacts/Avoided Losses: In 2013, the 200 farmers applying the method earned US$320 per year/ ha due to increased yield and reduced input cost. The survival rate of shrimp increased by 45 percent.

Co-Benefits: Micro-climate regulation; livelihood improvement; reduced environmental impacts such as erosion and contamination.

Risks/Challenges:

- Maintaining the interest of involved farmer groups will be crucial to the project's success. At least one year of trials is necessary to develop successful Best Management Practices
- 75percent of the shrimp production in the Mekong Delta is small-scale and occurs under the application of traditional farming practices that do not include existing mangrove forest and are often poorly managed, leading to low efficiency in the production and low profitability or even loss while negatively impacting the environment

Sources: Steurer, L. 2015. "Best Management Practices for Silvo-Aquaculture, Vietnam." https://panorama.solutions/en/solution/best-management-practices-silvo-aquaculture. Accessed March 25, 2019; (Bertram, M (GIZ), personal communication, based on unpublished information contributed by Lisa Steurer); (Steurer, L. (GIZ), unpublished information)

BOX A22 Nicaragua Climate Adaptation and Water

Hazard: Drought, extreme events

Sector: Cities

Vulnerability: Nicaragua is experiencing frequent water rationing, high system losses, lack of domestic metering, low water collection rates, and poor water quality, particularly in rural areas. The country also experienced disparity in terms of urban and rural access to water and sanitation.

Actions:

- Pilot adaptation initiatives to enhance climate resilience in selected municipalities
- Four municipal plans for the protection of families to cope with climate change of the selected municipalities (San Juan de Limay, Juigalpa, San Ramon, and Murra) were developed and a water resources policy, including a climate change adaptation dimension, was prepared by the National Water Authority (ANA)
- Implementation of the first economic compensation for ecosystem services program for the protection of critical water sources in climate-vulnerable rural communities
- Ten tools were used to incorporate climate change adaptation in water and sanitation investments
- Seven WASH systems were constructed in the selected communities
- Conservation and reforestation around water sources
- A Climate Information Module for water and climate change was integrated into the National Water Resources Information System (SiAGUA) and ANA
- Three weather and oceanographic monitoring stations were established and are functioning in Corn Island. Also, an index for wetland protection was developed to increase the protection of recharge areas of aquifers to support the adaptation capacity of water supply in Corn Island
- Policy and operational tools were developed to incorporate climate change adaptation
- Implementers: World Bank, Ministry of Environment and Natural Resources, Emergency Social Investment Fund (FISE), municipalities, community organizations

Policy enablers/context: Nicaragua's National Development Plan 2008-2012 aimed to address water supply and sanitation access.

Implementation Costs: US$5.97 million

Impacts/Avoided losses:

- 270 farmers received payments for participating in the program
- 700 technicians of key public institutions were trained in water resources and climate change
- 59 drinking water supply sources and recharge areas were protected
- 3,028 hectares of land were conserved, reforested, and restored to increase protection water sources
- Technical studies on hydrology and a risk assessment on climate change were carried out
- Access to improved water sources for 338 households were provided, reaching 1,786 people
- All vulnerable communities were able to manage and operate the delivered WASH systems and protect water resources, achieving the target of all vulnerable communities being able to do so
- 25,929 people benefited from the project (50 percent of whom were women)

Risks/Challenges:

- National budget does not provide funding for the continuity for the program; no long-term financing is ensured, even though the World Bank has been supporting the government in the development of a REDD+ strategy, which, once approved, will provide payments for emissions reduction from forest degradation and deforestation and also has been preparing a project which will include similar payments for ecosystem services program to protect first land in the Caribbean region
- Since March 2018 the country experienced political turmoil, impacting project implementation
- Despite FISE continuing to invest in water supply to poor communities, it has been hesitant to include climate change aspects in its project design

Source: Ferl, K. 2018. *NI Climate Adaptation and Water GEF - Implementation Completion Report (ICR) Review (Project ID: P127088).* Washington, D. C.: World Bank Group.

BOX A23 Mexico's Water Reserves as an Innovative, Cost-effective and Replicable Nature-based Solution

Hazard: Flooding, drought

Sector: Infrastructure (water management)

Vulnerability: Loss of the adaptive capacity of river basins as a result of disruptions in the hydrological cycle, the natural flow regime and the ecosystem functions that sustain water availability for people and nature.

Actions:

- Water reserves for people and nature adopted in 295 of Mexico´s 765 river basins, covering ca. 500,000 km^2
- Nearly 50 percent of current surface runoff protected to maintain hydrological conditions, based on environmental flow assessments and human needs projections to 2050
- 60 natural protected areas and 41 wetlands of international importance designated as Ramsar sites (ca. 110,000 km^2) strengthen their protection and capacity to adapt to changing conditions

Implementers: National Water Commission (CONAGUA); National Commission for Natural Protected Areas (CONANP); Alliance World Wildlife Fund - Gonzalo Rio Foundation; Inter-American Development Bank (IADB); Universities and river basin councils.

Policy Enablers/Context: Existing legal framework to adopt water reserves; Long-term collaboration between government and NGO to build a public policy based on field/local experiences, adopted in official national and sectoral development plans and technical instruments, such as the Mexican Norm for Environmental Flows.

Implementation Costs: US$3 million

Impacts/Avoided Losses:

- Natural buffer capacity for ecosystem-based adaptation
- Water availability for 45 million people, by reducing high-risk water scarcity scenarios
- Resilience of 101 natural protected areas (189 protected species) by reducing vulnerability and keeping healthy habitats
- High investments on infrastructure for water transfer and storage under climate change uncertainty

Co-Benefits:

- Climate change mitigation through riparian forest (ca. 25,000 km) and mangrove/coastal lagoons conservation (blue carbon) (ca. 1,500 km)
- Support of local livelihoods preserving flood plain agriculture, fishing, tourism, and indigenous sacred places
- Secure human rights for water and a healthy environment for present and future generations
- Strengthen water governance by sharing information and water management goals (transparency and accountability)

Risks/Challenges: Develop further engagement of local stakeholders on EbA understanding; further develop specific rules as needed for water use needs/projects and comply with water reserve goal; full integration of surface and groundwater management under risk management plans.

Source: Barrios-Ordoñez, E., Salinas-Rodríguez, S., Martínez, A., López, M., Villón, R., and Rosales, F. 2015. "National Water Reserves Program in Mexico. Experiences with Environmental Flows and the Allocation of Water for the Environment." Technical Note Nº BID-TN-864. Mexico City, Mexico: Interamerican Development Bank.

BOX A24 Sustainable Coffee Production in Colombia – Nestlé, Rainforest Alliance, FNC and Others

Hazard: Drought, pest outbreaks (e.g. leaf rust and coffee borer)

Sector: Industry and supply chains

Vulnerability: Lowered yield and quality due to increased temperatures and reduced water availability; the majority of coffee producers are smallholder farmers, and vulnerable to economic/market changes, natural disasters, and climate change; continuous decreases in national production levels in recent years.

Actions:

- Promotion, training, and application of coffee production standards/codes (e.g. the Common Code of the Coffee Community (4C); Rainforest Alliance certification/Sustainable Agriculture Network (SAN) standard; FNC "Cafés Especiales" strategy
- Soil analysis and soil conservation measures
- Improved inputs, such as higher quality seedlings and leaf rust tolerant varieties
- Traceability system

Implementers: Private company; farmers, industry associations, NGOs, local and national authorities.

Policy Enablers/Context: National "Cafés Especiales" strategy since 2002, as well as previous experience with FNC standards; existing technical support/extension services via FNC; shade-grown coffee and other practices already in line with standards (adoption of new practices minimised); group certification reduced auditing costs; high premium price for certified Colombian coffee in early years (though this decreased over time).

Implementation Costs: Investment of US$3.17 million during 2011-2015

Impacts/Avoided Losses:

- Nescafe Plan: 1.87 million kg additional 'green coffee' produced per year worth around US$5 million per year; 35 percent increase in productivity; 41 percent increase in net farmer income
- Rainforest Alliance certification in Santander: by 2010, more than 1000 farms were RFA certified; average premium received was about 2 percent above the price paid for standard, noncertified coffee; certified farmers more likely to sell to a cooperative, to have access to credit for rejuvenating coffee plantations, and to have off-farm income as well

Co-Benefits:

- Improved water source protection through fencing and reforestation, and use of water-saving technologies (Manos al Agua collaboration has seen water quality improve in 80 percent of catchments)
- Improved agro-biodiversity in certified farms
- Improved waste management, with certified farmers more often collecting trash and recycling, and less likely to throw wastewater into fields
- Improved farm management skills, such as record keeping and market knowledge
- Participating farmers more likely to stay in business
- Spill-over effects, with environmentally friendly practices reaching non-certified farmers
- Improved social conditions, such as occupational health and safety

Risks/Challenges:

- Water management knowledge/practices may have limited impact without wider action; technological improvements may be needed that require capital investment
- Market effects, e.g. supply vs. demand for certified product; as the supply of certified coffee increases, price premium has decreased
- Smallholder farmers may need additional capital, access to extension, and other forms of support if more significant changes to practices are required for certification

Sources: Rueda, X., and Lambin, E. 2013. "Responding to globalization: impacts of certification on Colombian small-scale coffee growers." *Ecology and Society* 18(3): 21; Johr, H. 2017. "Embeddedness in the context of corporate sustainability at Nestlé." Presentation at University of Zurich, January 19, 2017; Nestlé. 2017. "Nestlé in society: Creating Shared Value and meeting our commitments 2017."; Nestlé. 2013. "Nestlé in society: Creating Shared Value and meeting our commitments 2013."

BOX A25 Mangroves and Markets, Viet Nam

Hazard: Coastal flooding, sea level rise

Sector: Industry and supply chains (aquaculture)

Vulnerability: Negative effects of flooding and sea level rise (e.g. saline intrusion) on low-lying communities and shrimp farming in the Mekong Delta.

Actions:

- Promotion of and training in organic certification among shrimp farmers
- Use of payment for ecosystem services (PES) to incentivize farmers to conserve/restore mangroves
- Mangrove polyculture/integrated mangrove shrimp farming; standards and related government decisions require the rehabilitation and/or maintenance of a certain proportion of mangrove cover (e.g. under Naturland standard, rehabilitation to at least 50 percent mangrove cover within 5 years)

Implementers: IUCN; provincial governments; private sector (shrimp companies)

Policy Enablers/Context: Viet Nam's Ministry of Agriculture and Rural Development has been preparing a national regulation on PES in aquaculture, and through the project Ca Mau Province piloted a PES scheme, requiring seafood companies to pay farmers an incentive of US$25 per hectare of mangrove conservation and restoration; consumer demand for certified/mangrove shrimp in some markets; strategic plan for agricultural development to 2020 may increase opportunities for farmers to access capital/credit.

Implementation Costs:

- On average, households spent around 4.3 person-days per hectare maintaining/rehabilitating mangrove forest on their land, worth a total of around US$43
- With an average of 5 hectares per household of shrimp pond and average forest cover of about 50 percent, households have 2.5 ha eligible for the payment rate of US$22 per hectare of forest. This amounts to approximately US$62.50 per household per year. If supporting 1000 farmers, the total would be around US$62,500 per year

Impacts/Avoided Losses: Lack of information on avoided losses, but information on avoided costs and profitability available:

- Certified mangrove-shrimp brings the highest profit of US$2,000/ ha, while conventional extensive shrimp farming brings the lowest profit of about US$1,000/ ha. The key factor is that mangrove-shrimp farming produces larger shrimp that can be sold at a higher price
- Total cost saved by mangrove services for shrimp farming is USD$1,375 to US$5,304 per year for intensive farming

Co-Benefits: Minh Phu, Viet Nam's largest shrimp exporter, has so far signed contracts with 1,150 farmers managing 6,972 hectares; extension services and training provided for 1,300 shrimp-farming households; annual income increasing from US$2,684 - $3,132 to US$6,711 - $8,948 after joining the program; reduced illegal logging of mangrove trees; improved provision of mangrove provisioning services.

Risks/Challenges: Delays in receiving premium payments, or payments not reaching farmers; restricted access to education in the Mekong Delta, leading to heavy investment in training; there is currently no organic hatchery in Mekong Delta; existing extension services cannot meet demand from farmers; demand for aquaculture products, including certified products, is growing, but consumers lack information on the status of these products (e.g. whether certified or not); shrimp diseases such as white spot syndrome.

Sources: IUCN. 2017. *Shrimping Horizons: How shrimp farmers are saving thousands of miles of mangrove in Vietnam*. IUCN; IUCN. 2016. *Mangroves & Markets final workshop: results and lessons learned*. IUCN; GIZ. 2013. *Status of small-scale environmentally friendly shrimp production in Ca Mau Province, Viet Nam. Integrated Coastal Management Programme (ICMP)*. Bonn: GIZ; Phan V. 2018. "Results from a study on the legal aspects in mangrove shrimp farming for international certification and payment for forest environment services in Ca Mau province." Draft Report. Scaling up Mangrove EbA in the Mekong Delta (MAM2). SNV; Nguyen, H. 2018. "Mangrove ecosystem services to shrimp farming in mangrove-forest system: State of the literature; and Outcomes of the pilot Payment for Forest Ecosystem Services (PFES) in Ca Mau" Draft Report. Scaling up Mangrove EbA in the Mekong Delta (MAM2). SNV.

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The Global Commission on Adaptation seeks to accelerate adaptation action and support by elevating the political visibility of adaptation and focusing on concrete solutions. It is convened by 20 countries and guided by more than 30 Commissioners, and co-managed by the Global Center on Adaptation and World Resources Institute.