BRIEFING
3
NOTE

EbA in different ecosystems: placing measures in context

The climate change adaptation challenge varies geographically and with local circumstance. The pressures on, and condition of local ecosystems affect their capacity to deliver ecosystem services, and consequently people's vulnerability. Ecosystem-based adaptation (EbA) measures can help to secure ecosystem services and reduce people's vulnerability in ecosystem contexts ranging from largely natural to heavily modified landscapes, such as cities or agricultural lands.

This briefing note provides an overview of EbA measures commonly implemented in particular ecosystems (mountains, drylands, wetlands, coasts, and urban systems), reflecting interventions supported by the United Nations Environment Programme's (UNEP) EbA projects, and highlights through example outcome indicators how their contribution towards achieving identified adaptation goals can be monitored. To set the scene, it describes typical degradation cycles for terrestrial and coastal ecosystems and explores the environmental, climatic and socio-economic dynamics particular to selected ecosystems.

EbA measures in context: understanding degradation dynamics

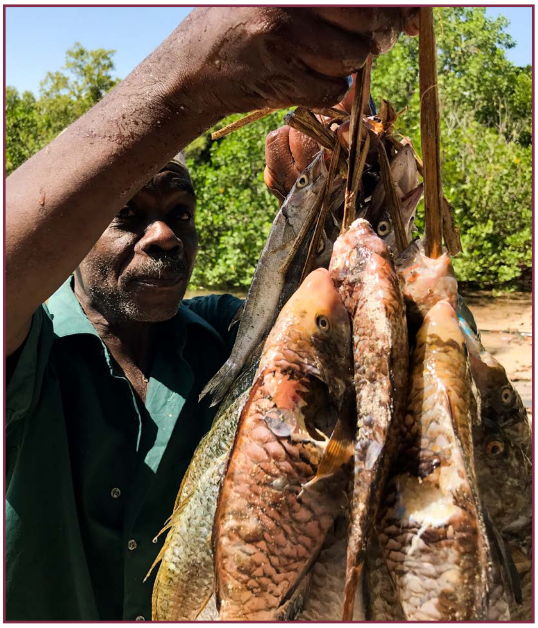
Effective EbA measures need to take into account the complex interactions amongst multiple ecosystem degradation processes that affect people's vulnerabilities to climatic and other factors.

Terrestrial ecosystems are under increasing pressure from changes in the use of land and natural resources, ultimately driven by population growth and lifestyle changes (Figure 1a). At the same time, climate change impacts, including increased risk of floods, droughts, landslides and soil erosion, are degrading ecosystems and their ability to provide services important to people, as well as directly causing harm to people, their property and production. This, in turn, puts people under increased pressure to resort to unsustainable ecosystem use and management, further degrading ecosystems and their capacity to deliver services. While climate change affects the various terrestrial ecosystems in different ways, and each ecosystem is accompanied by its unique set of socio-economic and political issues, this vicious cycle of degradation is common to most.

UN environment programme

Coastal ecosystems are impacted by many of the same degradation processes affecting terrestrial systems (Figure 1b). Distinct climatic pressures (from rising sea levels, increasing ocean temperatures, storm surges and associated impacts) and non-climatic degradation pressures occur in the sea and on coastal lands. For example, fish stocks are declining largely due to overharvesting, but rising sea temperatures and ocean acidification also affect species composition, biomass, range and abundance, thereby contributing to the degradation cycle.[1] Simultaneously occurring land- and sea-specific degradation processes can make coastal zones particularly vulnerable; for instance, small islands with steep topographic gradients are affected both by landslides and coastal erosion.

Such dynamics should inform the design of EbA measures. Although the measures themselves will primarily address climatic drivers of change, their effectiveness will ultimately be impacted by other pressures on land- and sea-scapes.



Hannah McNeish/UNEP

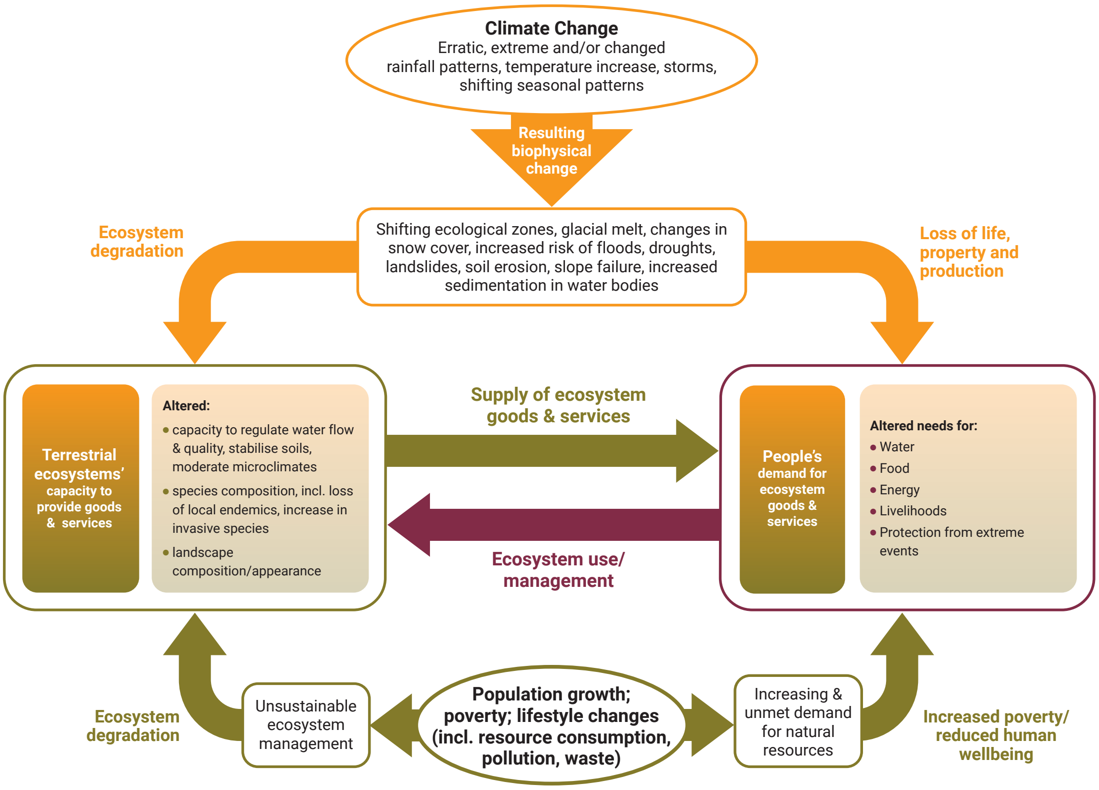


***Figure 1a.** Interactions of climatic and non-climatic degradation processes in terrestrial ecosystems.* *Aspects of climate change, as shown in the top oval, have numerous biophysical impacts, which can directly affect ecosystems (leading to ecosystem degradation) and people (causing loss of life, property and production). They can also trigger indirect impacts. Climate-induced ecosystem degradation affects the ecosystem's capacity to provide goods and services, reducing their supply available to people. As a result, on top of experiencing direct harm from climate change impacts, people can also suffer from shortages of vital ecosystem goods and services. The shortages can mean that ongoing use and management of these goods and services may further reduce the capacity of the ecosystems to provide them, increasing people's vulnerability to climate change.*

Simultaneously, non-climatic degradation processes, ultimately driven by population growth and lifestyle changes, as well as other political economy and governance factors, interact with the ones that are climate induced. On the one hand, increasing demand for land and other natural resources leads to unsustainable ecosystem management and use of goods and services, causing further ecosystem degradation. On the other hand, population growth and lifestyle changes lead to increasing and unmet demand for natural resources, which can increase poverty and reduce human wellbeing. 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.

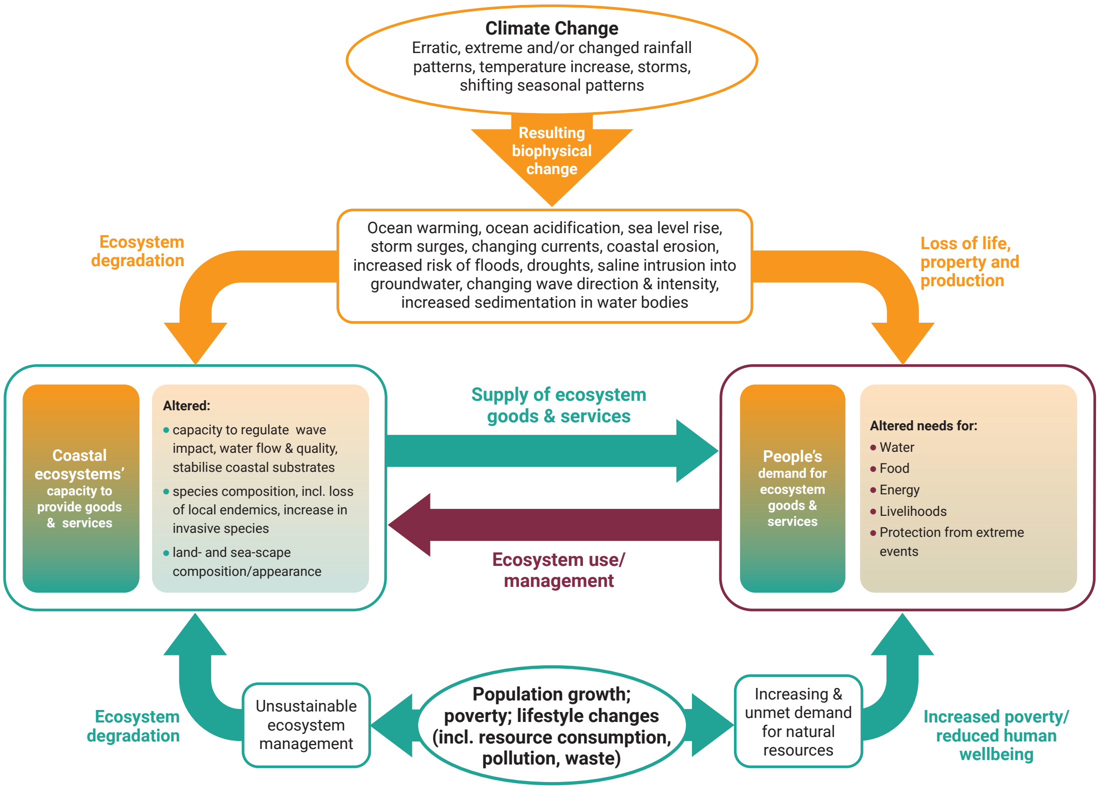


Figure 1b. *Interactions of climatic and non-climatic degradation processes in coastal ecosystems. In coastal ecosystems, climatic and non-climatic drivers of degradation act through similar processes to terrestrial systems (see Figure 1a). These ecosystems are subject to additional climatic drivers related to sea level rise, rising ocean temperatures and storm surges, and the impacts span terrestrial and marine environments.*

Implementing common EbA measures

While EbA can play a key role in addressing multiple processes within the degradation cycle, EbA measures need to target negative impacts arising from climate change as their primary goal, and this needs to be the basis for their selection and design.

To understand whether implementing the selected EbA measures is achieving these adaptation goals, monitoring and evaluation (M&E) are critical. Effective M&E requires indicators that are well matched to the objective of the EbA measure and provide appropriate information to track its immediate and intermediate outcomes and, eventually, its impacts. In addition to measuring change in biophysical processes, for example, EbA indicators need to track whether the impact of such processes on people is changing in the desired direction. In order to make data gathering and analysis realistic and achievable, indicator selection should also take into account the project's level of financial resources and available skills.

A well-designed M&E process should be established from the beginning of any implementation process, when baseline data should be gathered if they do not already exist. Subsequently, data should be collected at regular intervals, or following extreme events, and assessed against the baseline to understand how well an EbA measure is performing. In particular, given that EbA measures are expected to be effective under current and future climate change, M&E needs to be implemented over the long term. This means that an appropriate level of both financial and human resources need to be secured in order to support M&E beyond the duration of a project.

To provide insights into options for EbA implementation and how to track their effectiveness, the remainder of this section introduces EbA measures commonly used in five distinct ecosystems – mountains, drylands, wetlands, coasts and urban areas – along with associated outcome indicators. In each case, it introduces ecosystem characteristics, including typical degradation dynamics that contribute to social-ecological vulnerability.

Hannah McNeish/UNEP

Mountains

Mountain areas are characterised by a complex topography, with strong gradients of temperature and microclimates across small distances.[2] Mountain ecosystems, which vary globally and regionally depending on latitude and topography, tend to be significant for forestry and agriculture,[3] and play a vital role in hydrological cycles.[4] Being the 'water towers of the world', they regulate water supplies for rural and urban communities downstream and for hydroelectric power generation.


Adobe Stock

Box 1. The 'whole slope' approach to restoration

To address climate-related risks like flooding and erosion, ecosystems can be restored using a 'whole-slope' approach, which holistically addresses the diverse challenges and needs along a single slope. Restoring steep upper slopes with climate-resilient and multi-use ecosystems is combined with preparing lower slopes for agriculture and agroforestry, and restoring and protecting lowland wetlands. Implementing such measures side-by-side maximises adaptation benefits of restoration, including buffering against extreme events (e.g. droughts, floods, landslides). Additional benefits include improved water quality and supply, reduced soil erosion, improved crop production, increased supply of goods (e.g. fruit, fibre, timber), and alternative livelihoods.

Mountains are culturally and recreationally important, with high levels of biodiversity including crop genetic diversity and medicinal plants.

Populations living in mountains tend to be poorer than those in lowlands due to their remoteness and poor accessibility.[5] They are increasingly driven to unsustainable natural resource use and land use practices, which are making mountain regions increasingly vulnerable. For example, destabilised slopes resulting from land degradation are vulnerable to loss of fertile topsoil and landslides, resulting in sedimentation of downstream water bodies and impacts on infrastructure.

Mountain regions are also among the most vulnerable to climate change impacts. Water provision, for example, can be affected by changes in rainfall and glacial melt due to climate change. Increasing rainfall can also further destabilise slopes, causing erosion and landslides. EbA measures in mountains (Table 1) typically aim to address these by reducing the effects on local people of climate impacts related to slopes (Box 1) and hydrological regimes.

Table 1. Typical EbA solutions in mountain ecosystems, along with example outcome indicators that directly reflect the primary adaptation goal of each measure.

Climate change impact targeted	*EbA measure*	*Elements of outcome indicators*
Flooding and sediment deposition resulting from extreme rainfall, rainfall variability and increasingly frequent and severe storms	**Riparian reforestation/rehabilitation along riverbanks** to slow run-off and capture sediment before it reaches the water course, thus limiting down-stream flood damage to property and livelihoods *e.g. planting indigenous and climate-resilient species, revegetating micro-catchments, and demarcating riparian buffer zones*	• Frequency and severity of floods • Sediment load • Measures of flood damage (infrastructure, households, crops)
Landslides and slope failure resulting from increasingly frequent and extreme rainfall	**Reforestation/forest restoration** to stabilise slopes and prevent landslides, mud flows and debris flows, thus limiting risks to life, property and livelihoods *e.g. planting indigenous, climate-resilient and multi-use species that benefit local communities (e.g. by providing NTFPs, shade and wind breaks)*	• Frequency and severity of landslides • Measures of damage from slope failure (loss of life, damage to property, impact on livelihoods)
Altered hydrology, river flow and water availability resulting from rising temperatures and associated glacial melt, and changing amount, seasonality and variability of rainfall	**Watershed restoration** to increase water storage capacity and reduce surface run-off, thus improving water availability and quality, and reducing flood risk *e.g. community-based watershed restoration, including the development of watershed management plans*	• Variation in river flow • Per capita dry season water availability • Measures of water quality • Measures of flood damage (infrastructure, households, crops)

Drylands

Covering around 40% of the global land surface, drylands support around two billion people worldwide, 90% of whom live in developing countries.[6] Dryland ecosystems include deserts, grasslands, scrublands and woodlands, which provide important ecosystem services including water regulation, carbon storage and provision of fibre, timber, bioenergy and food, including globally important staple crop production.[7] While high in cultural and ecological diversity, drylands are characterised by low productivity and low soil moisture content. For this reason, they are prone to land degradation and desertification, and have a high incidence of poverty due to limited access to services.[8]

Due to these characteristics, drylands are extremely vulnerable both to human driven disturbance and to climate change. Population growth and unregulated expansion of human activities, such as agriculture, are increasingly degrading drylands, leading to soil erosion, nutrient depletion, salinization and water shortages.[6]

Climate change impacts, including rising temperatures and reduced rainfall, interact with these human drivers, exacerbating water shortages, soil erosion and desertification. As a result, dryland populations are extremely vulnerable, as they depend on rain-fed agriculture and cattle grazing for their livelihoods. Furthermore, the relatively low productivity of drylands provides few livelihood alternatives. Drylands EbA measures (Table 2) typically address the impacts on ecosystem services of reduced and/or increasingly variable rainfall to secure livelihoods (Box 2).

Table 2. *Typical EbA solutions in dryland ecosystems, along with example outcome indicators that directly reflect the primary adaptation goal of each measure.*

Climate change impact targeted	*EbA measure*	*Elements of outcome indicators*
Drought, desertification and soil erosion resulting from increasing temperatures, reduced and more variable rainfall, and increasingly frequent and severe wind/sand storms	**Establishment of a multi-use desert ‘Green Belt’** to increase water availability, improve soil quality, provide shade and wind breaks, thus improving food and income security *e.g. planting drought-tolerant species of trees, shrubs and crops whose roots can hold water in the soil*	● Extent of protective vegetation cover ● Measures of wind/sand storm impact ● Measures of soil quality ● Water availability (irrigation and household use) ● Agricultural yields and income (home consumption and market)
	Climate-resilient grazing and livestock management to regenerate vegetation, increase forage quality and quantity, increase water availability, improve soil quality, and safeguard livestock, thus improving food and income security *e.g. increasing perennial species cover to enhance forage production, shifting livestock breeds or species, adjusting flock management and/or developing drought contingency plans*	● Quantity of forage for livestock ● Water availability (irrigation, livestock and household use) ● Measures of soil quality ● Livestock survival rates ● Measures of food and income generated from livestock
Increasingly frequent and severe wildfires resulting from increasing temperatures, reduced rainfall and seasonality	**Rehabilitation and restoration of rangelands** to repair ecological processes and enhance fire resistance, thus reducing damage, loss of life and livelihoods from wildfires *e.g. using indigenous drought-tolerant and/or fire resistant grass, shrub and plant species, including species with multiple uses for local populations*	● Frequency and severity of wildfires ● Extent of loss and damage caused by wildfires (life, infrastructure, livelihoods)

Box 2. The ‘Green Belt’ approach

In the Northern Pistachio Belt and Eastern Forest Complex of Afghanistan, plans are underway to create a ‘Green Belt’ to improve watershed functioning and increase the resilience of rural communities. This involves restoring 1,400 ha of degraded forests using climate-resilient plant species that can also generate other ecosystem goods and services of value to local communities. It is expected that restoring forest ecosystems will minimise soil erosion; improve water quality and supply in watersheds; and reduce frequency and severity of floods, landslides and drought. Expected co-benefits include generating marketable ecosystem-based products (e.g. fruit, wood, honey, medicinal herbs) and enhancing agricultural productivity.

Wetlands

Wetlands combine characteristics of aquatic and terrestrial ecosystems. They include peatlands, estuaries, lakes and ponds, floodplains, mangroves and other coastal wetlands. Wetlands provide such ecosystem services as flood and coastal protection, water purification and supply, climate regulation (carbon sequestration and storage), provision of food and raw materials, and cultural services.[9] Communities living near wetland ecosystems are often highly dependent on the subsistence products and cash income they provide.

Increasing land use change has led to wetland degradation and loss of productivity, leaving local communities increasingly vulnerable. For example, removal of vegetation and its buffering capacity through agricultural expansion can exacerbate the impacts of pollutants and sedimentation, which cascade throughout the food chain, ultimately reaching human consumption.

People who depend on wetlands are also vulnerable to the increased incidence of climate hazards. Rainfall variability, rising temperatures and more frequent extreme events cause significant changes to wetland hydrological cycles, impact local wildlife, and reduce provisioning and regulating services to local communities. Wetlands EbA measures (Table 3) include maintaining and restoring ecosystems to address hydrological impacts of changing rainfall regimes, and ensure continued supply of ecosystem services to local communities.

Hannah McNeish/UNEP

Table 3. Typical EbA solutions in wetland ecosystems, along with example outcome indicators that directly reflect the primary adaptation goal of each measure.

Climate change impact targeted	*EbA measure*	*Elements of outcome indicators*
Flooding and increased invasive species resulting from extreme rainfall, rising temperatures and increasingly frequent and severe storms	**Wetland rehabilitation** to reduce flood damage, enable groundwater recharge and improve water quality, and reduce pests affecting agriculture, thus improving food and income security *e.g. planting species that are climate-resilient, promote growth of other species (e.g. through nitrogen fixation), have deep roots that bind soil, and meet multiple local needs (e.g. NTFP, fodder)*	• Frequency and severity of floods • Measures of flood damage (infrastructure, households, crops) • Agricultural yields and income (home consumption and market)
	Wetland protection to encourage growth of spawning/nursery grounds and areas of high species diversity, and to allow vegetation regeneration for flood protection, thus improving water quality, reducing pests and improving food and income security *e.g. designating multiple-use zones and strict protection zones in areas of ecological significance*	• Measures of species abundance and diversity • Measures of water quality • Frequency and severity of floods • Measures of flood damage (infrastructure, households, crops) • Agricultural yields and income (home consumption and market)
Flooding, salt intrusion, and drought resulting from extreme and variable rainfall, rising temperatures, and increasingly frequent and severe storms	**Climate-resilient agriculture** to reduce impacts of floods, droughts and saline intrusion into groundwater and farmlands, thus improving food and income security *e.g. agroforestry and conservation agriculture near floodplains, using species that are salt tolerant and/or flood resilient and have high nutritional value; using composting and natural methods of pest control*	• Frequency and severity of floods • Measures of flood damage (infrastructure, households, crops) • Salinity levels in groundwater and farmlands • Agricultural yields and income (home consumption and market)

Urban areas

Urban ecosystems include green infrastructure in cities, such as parks or gardens, as well as natural areas immediately surrounding urban centres, such as wetlands or forests. They help to regulate run-off and water flows, and provide services important to human health, such as air purification, noise reduction, urban cooling, and mental health benefits.[10]

Rapid or unplanned urban development and expansion can degrade the integrity of urban green spaces and surrounding ecosystems, with infrastructure, housing or croplands replacing wetlands and forests. This reduces ecosystem service flow and provision to urban areas, and increases the vulnerability of local communities. For example, unplanned urban expansion can lead to reduced water infiltration, more flooding, soil erosion, and water pollution in rivers and other open waters.

Climate change impacts on cities can include reduced water availability for household use, food insecurity and health risks relating to the prevalence of vector and water-borne diseases,[11] and 'heat island effects' created by cities themselves (Box 3). They especially affect those urban communities suffering the poverty and social marginalisation associated with informal settlements.

Urban EbA measures, such as integrating ecosystem service assessments into urban planning and management, can help cities maintain provisioning and regulating services, thus improving health and quality of life for local communities. They can also help increase adaptive capacity of local communities by enhancing the availability of natural resources (Table 4).

Table 4. Typical EbA solutions in urban ecosystems, along with example outcome indicators that directly reflect the primary adaptation goal of each measure.

Climate change impact targeted	*EbA measure*	*Elements of outcome indicators*
Flooding and soil erosion resulting from extreme rainfall and increasingly frequent and severe storms	**Urban reforestation** to slow run-off and stabilise soil, thus protecting infrastructure and buildings from flooding, undermining and siltation *e.g. planting climate-resilient and soil stabilising tree species and multi-use plants along roads*	● Frequency and severity of floods ● Measures of soil erosion ● Measures of flood damage (infrastructure, buildings)
Heat stress and droughts resulting from reduced and variable rainfall, and rising temperatures	**Creation of urban green spaces** to increase urban canopy layer and plant coverage, thus reducing 'urban heat island effect' and increasing water availability *e.g. including tree planting, parks and gardens*	● Extent of protective vegetation cover ● Measures of local microclimate (temperature and humidity)
Flooding resulting from extreme rainfall and increasingly frequent and severe storms	**Designation of flood risk management zones** to create vegetated buffers between high risk areas and infrastructure, thus reducing flood damage *e.g. establishing and manging buffer zone vegetation around waterways to buildings in flood risk zones*	● Frequency and severity of floods ● Measures of flood damage (infrastructure, buildings)

Box 3. Mitigating the urban 'heat island effect'

The urban 'heat island effect' is a phenomenon where the observed temperature in cities is higher than in surrounding areas. It is caused by the absorption and re-radiation of solar heat by buildings and asphalt, and other sources of anthropogenic heat (e.g. vehicles, air conditioning, power plants). With increasing frequency of extreme weather events due to climate change, the urban 'heat island effect' is likely to intensify.[12] Increasing green spaces in cities can help mitigate this phenomenon: urban parks and forests, street trees, ground vegetation, green roofs and facades all contribute to reducing air temperature through evapotranspiration and increased shade.[13] Green spaces also have additional benefits, including reducing surface water run-off, sequestering carbon, improving air quality, and providing aesthetic value and cultural services.

Coasts

Coastal ecosystems include sand dunes, seagrass beds, coral reefs and mangroves.[14] As about one third of the global population lives in coastal areas,[15] the goods and services these ecosystems provide are vitally important. Mangrove and reef-based fisheries, for example, provide food and livelihoods on which many coastal communities rely. Mangroves also provide wood, fodder and medicine, and act as carbon sinks. Coral reefs, among other things, generate income from tourism. Coastal ecosystems also help reduce flooding, erosion and damage caused by storm surges.

Coastal ecosystems are subject to impacts from high density human populations and associated development activities. Unsustainable fisheries, removal of vegetation, expansion of tourism, and pollution are some of the drivers degrading coastal ecosystems.

Climate change also has significant impacts on coastal systems. Increasing ocean temperatures can lead to coral bleaching and reef degradation, and sea-level rise increases the incidence of coastal erosion and flooding, as do increasingly frequent and severe storm surges. Many coastal EbA measures therefore address the flooding and erosion impacts of climate change (Table 5) by restoring or enhancing ecosystem services that also support livelihoods.

Table 5. Typical EbA solutions in coastal ecosystems, along with example outcome indicators that directly reflect the primary adaptation goal of each measure.

Climate change impact targeted	*EbA measure*	*Elements of outcome indicators*
Sea level rise, flooding, coastal erosion and saline intrusion resulting from rising temperatures and increasingly frequent and severe storm surges	**Mangrove restoration/rehabilitation** to reduce wave energy, erosion and storm surge water levels, thus limiting coastal flooding, saline intrusion into groundwater and farmlands, and damage to property and livelihoods *e.g. establishing climate-resilient and pest-resistant nurseries and replanting*	• Extent of coastal erosion • Frequency and severity of floods • Salinity levels in groundwater and farmlands • Agricultural yields and income (home consumption and market) • Measures of flood/storm damage (infrastructure, households, crops)
	Dune and beach stabilisation to reduce coastal erosion and flooding, thus limiting damage to property and livelihoods *e.g. planting indigenous climate-resilient pioneer dune plants that biologically fix or reforest the dune ridge*	
Increasing intensity of wave action, sea level rise, coastal erosion, disruption to spawning migration, changes in coastal fish abundance and diversity, resulting from rising temperatures, increasingly frequent and severe storm surges, ocean warming and acidification	**Coral reef rehabilitation** to attenuate wave intensity, and to increase habitat and nursery grounds for fish, thus reducing flooding, erosion and damage to property, and supporting fisheries and livelihoods *e.g. through restoring, rearing and transplanting coral reef fragments*	• Frequency and severity of floods • Extent of coastal erosion • Measures of fishing effort • Fish catch and income (home consumption and market) • Income from diving/snorkelling tourism

Key action points

- Understand the system dynamics, climatic and non-climatic drivers for the specific social-ecological context.
- Involve all relevant stakeholders in setting the adaptation objective and choosing context-appropriate EbA measures (see Briefing Notes 2 and 5), and complementary approaches (Briefing Note 4).
- Take advantage of existing tools and methods[16] to assess EbA options.
- Identify temporal and geographic trade-offs and limitations, 'winners' and 'losers' to help ensure costs and benefits are as equitably distributed as possible, and to avoid maladaptation.
- Establish effective monitoring and evaluation from the outset: select indicators matched to objectives and tailored to the measures implemented.
- Monitor progress towards intermediate outcomes, as well as eventual impact.

References

[1] Sumaila, U.R., Cheung, W.W.L., Lam, V.W.Y., Pauly, D. and Herrick, S. (2011) 'Climate change impacts on the biophysics and economics of world fisheries'. *Nature Climate Change* 1: 449-456.

[2] United Nations Development Programme (2015) *Making the case for ecosystem-based adaptation: the global mountain EbA programme in Nepal, Peru and Uganda*. New York: UNDP.

[3] Egan, P.A. and Price, M.F. (2017) *Mountain ecosystem services and climate change: a global overview of potential threats and strategies for adaptation*. Paris: UNESCO.

[4] Kohler, T., Wehrli, A. and Jurek, M. (2014) *Mountains and climate change: a global concern*. Sustainable Mountain Development Series. Bern: Centre for Development and Environment (CDE), Swiss Agency for Development and Cooperation (SDC) and Geographica Bernensia.

[5] Ibid.

[6] United Nations Environment Management Group (2011) *Global drylands: a UN system-wide response*. New York: United Nations.

[7] Thomas, R., Stewart, N. and Schaaf, T. (2014) *Drylands: sustaining livelihoods and conserving ecosystem services*. Hamilton: UNU-INWEH.

[8] Spear, D., Baudoin, M-A., Hegga, S., Zaroug, M. Okeyo, A. and Haimbili, E. (2015) *Vulnerability and adaptation to climate change in the semi-arid regions of southern Africa*. Ottowa: CARIAA.

[9] Russi, D., ten Brink, P., Farmer, A., Badura, T., Coates, D., Förster, J., Kumar, R. and Davidson, N. (2013) *The economics of ecosystems and biodiversity for water and wetlands*. London and Brussels: IEEP; Gland: Ramsar Secretariat.

[10] Gómez-Baggethun E. et al. (2013) 'Urban ecosystem services' in: Elmqvist T. et al. (eds) *Urbanization, biodiversity and ecosystem services: challenges and opportunities*. Dordrecht: Springer.

[11] Ibid.

[12] McCarthy, M.P., Best, M.J. and Betts, R.A. (2010) 'Climate change in cities due to global warming and urban effects'. *Geophysical Research Letters* 37, L09705, doi: 10.1029/2010GL042845.

[13] Shishegar, N. (2014) 'The impacts of green areas on mitigating urban heat island effect: a review'. *The International Journal of Environmental Sustainability* 9: 119-130.

[14] UN Environment (2016) *Options for ecosystem-based adaptation (EbA) in coastal environments: a guide for environmental managers and planners*. Nairobi: UN Environment.

[15] UN Environment (2006) *Marine and coastal ecosystems and human wellbeing: a synthesis report based on the findings of the Millennium Ecosystem Assessment*. Nairobi: UN Environment.

[16] UNEP-WCMC (2018) EbA Tool Navigator. Cambridge: UNEP-WCMC.

Prepared by UNEP-WCMC and UNEP, 2019