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NATURE-BASED SOLUTIONS FOR ADAPTATION

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BEYOND CARBON: Valuing Biodiversity's Contribution to Climate Resilience through NbS for Adaptation

As climate change intensifies the frequency and severity of extreme weather events, societies face growing risks to ecosystems, infrastructure, and human well-being. In this context, biodiversity is increasingly recognized as critical to climate adaptation and resilience. Biodiversity enhances ecosystem stability, underpins natural capital and NbS, and generates a wide range of co-benefits that strengthen social and economic resilience. Understanding and valuing these contributions can help practitioners better assess the role of biodiversity in responding to climate impacts.

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BIODIVERSITY AS THE FOUNDATION OF ECOSYSTEM RESILIENCE

Biological diversity increases the resilience of ecosystems by reducing dependence on a narrow set of species to perform essential functions. In ecosystems with high species richness, key processes such as primary production, nutrient cycling, pollination, and water regulation are distributed across multiple species. As a result, if environmental conditions change or disturbances occur, the loss or decline of one species is less likely to cause system-wide collapse because other species can compensate.

From monoculture to agroforestry in Thailand

Natural disasters, crop failure, fires, and landslides are some of the climate impacts facing smallholder farmers and local communities in Nan province in northern **Thailand**. Historically, maize was the main cash crop in Nan and relied on heavy chemical inputs. This resulted in degraded land and soil quality, leading to erosion and flooding in downstream communities, particularly during the rainy season. The **Trees4All Initiative** uses financial incentives for smallholders to transition away from intensive monocropping while enhancing economic resilience through income diversification. The project provides farmers seedlings for tree planting and stingless bees and equipment to promote honey production. The bees provide key pollination services and serve as an ecosystem health indicator. Farmers are incentivized to care for the trees planted, as financial payments are contingent on monitoring tree growth. The farmers indicated that they have changed their behaviour and farming practices as a result of the project-induced benefits and moved away from monoculture. Together, the different project activities contribute to building a healthier ecosystem and enhance the farmers' resilience to climate change.

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Resilience is also enhanced by genetic diversity within species. Populations with higher genetic variation are more likely to contain traits that confer tolerance to heat, drought, salinity, or disease. This diversity facilitates adaptation over time, increasing the probability that at least some individuals will survive and reproduce under changing conditions. Genetic diversity therefore acts as a buffer against uncertainty, particularly in rapidly shifting climates.

In addition, biodiversity increases the number and complexity of species interactions, such as predator-prey relationships, mutualisms, and competition. These interactions can stabilize ecosystem dynamics by preventing any single species from dominating and by enabling compensatory responses to disturbance. Together, these mechanisms highlight how biodiversity enhances resilience by spreading ecological risk across many components rather than concentrating it in a few.

HARNESSING BIODIVERSITY THROUGH NBS FOR ADAPTATION

Nature-based Solutions (NbS) for climate adaptation explicitly leverage ecosystem processes and the services they provide to reduce climate risks while delivering benefits for biodiversity and people. By design, NbS take a whole-ecosystem approach to resilience, recognizing that healthy, diverse ecosystems are better able to sustain critical services, absorb shocks and recover from disturbances.

Examples include restoring mangroves to protect coastlines from storm surges, conserving wetlands to reduce flood risk, and expanding urban green spaces to mitigate heat stress. These interventions not only reduce exposure and vulnerability to climate hazards but also increase habitat quality, species richness, and ecological connectivity, all while addressing key societal challenges.

DIRECT VALUATION OF BIODIVERSITY AND LINKS TO FINANCE MECHANISMS

One form that biodiversity valuation can take is the value that a market assigns to a quantifiable unit, typically a geographic area, of restored or preserved biodiversity over a fixed period of time (WEF, 2023). In this sense, the value of biodiversity is determined by how much actors within a certain market are willing to pay for biodiversity's perceived benefits. This approach, evidenced by Nature-based climate adaptation in the Guinean forests of West Africa, focuses on measuring quantifiable changes over time in species, habitats, or ecosystem integrity. These valuation methods are specifically linked to financial instruments such as payment for ecosystem services (PES) and biodiversity credits, which incentivize and remunerate environmental conservation activities, particularly community-led interventions.

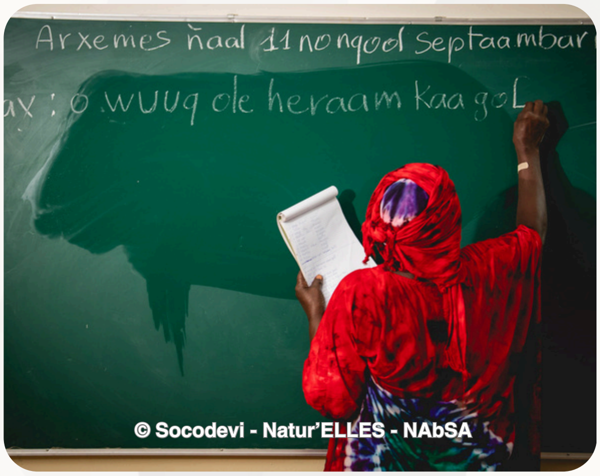
Frameworks such as the SD VISta Nature Framework and the Plan Vivo Biodiversity Framework establish robust methodologies to define baselines, monitor biodiversity outcomes, and issue verified units linked to conservation performance.

Similarly, the BioCarbon Biodiversity Standard integrates carbon and biodiversity metrics, while mechanisms like the Adaptation Benefits Mechanism and guidance from the International Finance Corporation Biodiversity Finance Reference Guide support alignment with private finance. Together, these market-based tools create price signals for the protection and strengthening of biodiversity and ecosystem services.

ASSESSING CO-BENEFITS TO UNDERSTAND THE FULL VALUE OF BIODIVERSITY FOR CLIMATE RESILIENCE

Market-based valuations of biodiversity, however, may not capture the true value of biodiversity's contributions to climate change adaptation. Fully understanding biodiversity's contribution requires accounting for co-benefits – additional social, environmental, and economic gains that arise alongside primary adaptation outcomes. Carbon sequestration is one of the most widely quantified co-benefits, often valued using the social cost of carbon, which estimates the economic damages avoided by reducing one additional ton of carbon dioxide emissions. In contrast, the financial value of carbon is calculated for use in carbon markets, which are pricing mechanisms that enable public and private actors to trade in greenhouse gas emission credits (UNEP, 2024).

However, NbS for adaptation generate many other co-benefits that are frequently overlooked or undervalued. These include improved air quality through pollution reduction, noise attenuation in urban environments, enhanced water quality through filtration and nutrient retention, improved soil health, local temperature regulation, and increased habitat quality. Social co-benefits such as recreation, education opportunities, job creation, higher property values, and energy savings can also be significant (Ommer et al., 2022).



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Ignoring these co-benefits can lead to systematic underinvestment in NbS, even though their total societal value may exceed that of grey infrastructure alternatives. Accounting for co-benefits therefore provides a more complete picture of biodiversity's role in climate adaptation and resilience.

THE ECONOMIC CASE FOR BIODIVERSITY IN CLIMATE ADAPTATION

Economic valuation methods help translate biodiversity's contributions into decision-relevant metrics, particularly in the context of climate change adaptation. Here, the focus is on valuing social benefits such as avoided climate damages, reduced healthcare costs, and increased long-term resilience.

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From an economic perspective, this insurance value lies in risk reduction – lower variance in outcomes and reduced likelihood of catastrophic losses. In the context of climate change, where uncertainty is high and extremes are becoming more common, this stabilizing function is particularly valuable.

APPROACHES AND TOOLS FOR VALUING BIODIVERSITY-RELATED CO-BENEFITS

There are multiple approaches to evaluating the value of biodiversity-related co-benefits, depending on the type of benefit and available data.

A common starting point is to define primary benefits, such as expected avoided annual damages from flooding or heatwaves. These benefits can often be estimated using climate risk models combined with damage functions.

Replacement cost methods are frequently used to value co-benefits such as habitat creation or water purification by estimating how much it would cost to provide equivalent services through artificial or engineered substitutes. For example, the value of inland wetland water quality regulation can be approximated by the cost of building and operating water treatment facilities that deliver similar outcomes (World Bank, 2023).

The avoided damage cost method is particularly relevant for co-benefits related to risk reduction, including air pollution mitigation and health outcomes (Ruangpan et al., 2024). By estimating reductions in healthcare costs, productivity losses, or mortality associated with improved environmental conditions, this method captures tangible economic gains from NbS.

Together, these approaches help quantify the often invisible but substantial contributions of biodiversity to climate resilience.

COST-BENEFIT ANALYSIS OF NATURE-BASED SOLUTIONS

Life-cycle cost-benefit analysis is especially useful for evaluating NbS because it captures costs and benefits over extended time horizons (Ruangpan et al., 2024). Unlike conventional infrastructure, biodiversity-based solutions, such as NbS for adaptation, often become more effective over time as ecosystems mature, meaning that their long-term benefits can substantially outweigh initial costs. This accruement of benefits can be captured by carrying out an analysis over longer periods of time and with the appropriate discount rate (lower discount rates give higher importance to what is happening in the future).

Example:
The example below is derived from a cost-benefit analysis[1] by the Natur'ELLES project of mangrove restoration in the Sine-Saloum Delta in **Senegal** in reducing damages due to flooding exacerbated by climate change over a nearly 30-year period. It illustrates the different types of co-benefits, in addition to carbon sequestration, that can be considered when assessing the value of an NbS that strengthens biodiversity.

[1] Based on a provisional report.

Costs	
Construction costs	The initial costs associated with carrying out the mangrove restoration.
Operational and maintenance costs	Ongoing costs required to conserve mangroves over time, such as community stewardship via patrols and sustainable harvest, bank-stabilization structures to control erosion, ongoing field records and annual technical reviews.
Total Costs	
Avoided costs	
Avoided damages to infrastructure	Savings resulting from reduced damages to residential buildings, public buildings and roads due to flood mitigation measures provided by the restoration
Avoided health-related costs	Reduction in healthcare expenditures from fewer respiratory illnesses attributable to mangrove restoration.
Benefits	
Fishery revenue	Benefits from preserving fish nurseries and biodiversity within the mangrove restoration, as healthy ecosystems contribute to the sustainability of fisheries.
Agricultural revenue	Benefit from enriching soil fertility through the buildup of organic material and improving water availability via enhanced groundwater recharge leading to more productive and resilient crop yields. Agricultural production includes rice, maize, millet, sorghum, and watermelon.
Seafood harvest returns	Enhanced seafood harvest through the restoration of mangrove nursery habitats that support fish, crustaceans, and mollusks; improved water quality from natural filtration of sediments and pollutants; and increased coastal ecosystem productivity leading to higher and more sustainable fishing yields
Drinking water supply	Improved drinking water supply by filtering sediments and contaminants, stabilizing coastal aquifers through enhanced groundwater recharge, and protecting watershed integrity, ensuring cleaner, more reliable freshwater sources.

[1] Based on a provisional report.

Food supply	Additional food produced by mangrove-supported systems that is retained for household consumption and community redistribution rather than sold in markets.
Wood supply	Increased wood supply by expanding forest area enabling sustainable harvesting of fuelwood and construction materials through managed regrowth cycles and community stewardship.
Job creation	New jobs generated through the implementation of the mangrove restoration project.
Carbon sequestration	The social cost value assigned to carbon dioxide captured and stored by restored ecosystems, contributing to climate change mitigation.
Total benefits and avoided costs	
Key Performance Indicators	
Net Present Value	The difference between the present value of the economic benefits (including co-benefits) and the present value of the economic costs associated with a project or initiative over its lifetime. It quantifies the net monetary impact of the economic aspects of the project, considering all relevant costs and benefits.
Benefit to Cost Ratio	A ratio that measures the efficiency of an investment by comparing the sum of economic benefits to the total economic costs associated with a project or initiative over a specified period. It provides a holistic view of the investment's economic viability, considering broader impacts beyond direct financial returns.
Internal rate of return	The discount rate that makes the net present value (NPV) of the economic benefits of a project or initiative equal to zero. It indicates the rate of return at which the project's economic benefits balance its costs, encompassing all economic impacts.

Example:

Cost-benefit analysis of large-scale restoration of rangeland in Jordan over a 25 year time horizon, using a discount rate of 5% (IUCN, 2015).

Benefits of large-scale restoration	Value (in million JOD)
Welfare economic value of natural forage	21.1
Avoided forage purchase	16.8
Additional groundwater infiltration	188.5
Avoided reservoir sedimentation	7.6
Benefits to the Jordanian society	**217.2**
Enhanced carbon sequestration	6.9
Benefits to the global society	**224.1**
Costs of large-scale restoration	
Implementation costs	0.8
Management costs	9.3
Total costs	10.1
Net present value of large-scale restoration	
To pastoral communities in the Zarqa River Basin if they bear the management costs	11.8
To the Jordanian society	207.1
To the global society	214

Benefit to cost ratio of large-scale restoration	
For pastoral communities in the Zarqa River Basin if they bear the management costs	2.1
For the Jordanian society	21.5
For the global society	22.2

The assessment showed that large-scale rangeland restoration, based on improved local level governance to enable pastures to be grazed and rested systematically within the Zarqa River Basin, could deliver 201 million JOD worth of net-benefits to Jordan. The rehabilitated rangelands offer carbon sequestration and other regulating services such as groundwater infiltration as well as important provisioning services such as livestock forage. With a benefit to cost ratio for Jordan of 21.5, indicating that each JOD invested in rangeland restoration returns more than twenty times its cost, the analysis demonstrates the long-term cost-effectiveness of NbS.

NBS AS A STRATEGIC INVESTMENT IN CLIMATE ADAPTATION

As climate change intensifies, adaptation strategies must prioritize long-term resilience rather than short-term risk reduction alone. Nature-based solutions (NbS) for climate adaptation play a critical role in this shift by addressing climate impacts while conserving and restoring biodiversity. By working with whole ecosystems, NbS enhance the capacity of natural systems to absorb disturbances, recover from shocks, and continue providing essential services under changing conditions.

Supporting biodiversity through NbS is particularly important because ecological diversity underpins the effectiveness and reliability of these solutions. Diverse ecosystems are more adaptable and less prone to failure than simplified or purely engineered alternatives, functioning as a form of natural insurance against climate uncertainty. In addition, NbS deliver multiple co-benefits, including carbon sequestration, improved air and water quality, and social and economic gains. Recognizing these benefits strengthens the case for integrating NbS into climate adaptation planning. Investing in NbS that protect biodiversity is therefore both a pragmatic and sustainable approach to climate resilience.

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