

Nature-based Solutions for Climate Resilience: Policy, Practice, and Evidence from Global Case Studies

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ABSTRACT

Nature-based Solutions (NbS) are increasingly recognized as effective, multifunctional approaches to addressing climate change and environmental degradation while promoting sustainable development. This paper critically examines the role of NbS in strengthening climate resilience in the Middle East and North Africa (MENA) region, one of the world's most climate-vulnerable areas. Using a qualitative analytical framework, the study combines policy review, comparative evaluation, and global case analysis to assess the integration of NbS into national adaptation and development strategies. Findings reveal that NbS—such as wetland restoration, agroforestry, green infrastructure, and coastal ecosystem rehabilitation—can deliver long-term mitigation and adaptation benefits at lower economic and ecological costs compared to conventional grey infrastructure. NbS projects also generate co-benefits including biodiversity protection, food and water security, and social inclusion.

However, implementation in the MENA region remains constrained by fragmented governance, limited financing, insufficient monitoring systems, and weak community engagement. The study highlights risks such as “greenwashing,” land tenure disputes, and overreliance on NbS without broader emissions reductions. Drawing on examples from Morocco, Egypt, the Netherlands, and Singapore, the paper identifies enabling factors for successful NbS: inclusive governance, cross-sectoral coordination, adaptive design, innovative financing, and robust evaluation frameworks. It concludes with recommendations for scaling NbS through policy integration, capacity building, blended finance mechanisms, and standardized metrics. The paper argues that NbS, when grounded in equity and ecological integrity, can serve as a cornerstone for climate-resilient development in MENA and beyond.

Keywords: Climate Change, Natural Solutions, Ecosystem Restoration, Sustainable Development Goals (SDGs), Environmental Governance and Policy.

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Introduction and Regional Climate Context

Introduction

Since the early years of the twenty-first century, climate change has become increasingly visible through a steady rise in global temperatures and the growing intensity of extreme weather events. Heatwaves, droughts, floods, and coastal hazards are now occurring with greater frequency and severity, creating new pressures on

ecosystems, economies, and public health. The Intergovernmental Panel on Climate Change affirms that human activities—particularly the combustion of fossil fuels and land-use change—are the primary drivers of the warming observed since the mid-twentieth century [1]. Global monitoring records further indicate that climate signals have accelerated since 2000, including ocean warming, melting ice masses, and ongoing sea-level.

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These trends are especially pronounced in the Middle East and North Africa (MENA) region, which is widely recognized as one of the most climate-vulnerable areas in the world. The region is already experiencing higher average temperatures, prolonged drought periods, and increasing irregularity in rainfall. Climate projection datasets, including the World Bank Climate Change Knowledge Portal and the IPCC Sixth Assessment Report (AR6), indicate that warming will continue across MENA throughout the coming decades. The magnitude of this warming varies depending on emission pathways such as SSP2-4.5 and SSP5-8.5, but the overall direction is consistent: higher temperatures, intensified heat stress, and greater variability in precipitation [1–4].

The impacts of these changes are not distributed equally. Vulnerable groups face disproportionate risks, including children exposed to heightened health threats from heat and pollution, rural communities affected by declining agricultural productivity, and coastal populations facing saltwater intrusion and land loss due to sea-level rise. These stressors contribute to growing food insecurity, reduced water availability, and an increased likelihood of internal migration, all of which complicate long-term development planning and climate adaptation efforts [2-5].

Within this context, governments and development institutions are increasingly searching for adaptation strategies that are effective, affordable, and capable of generating broader social and ecological benefits. Nature-based Solutions (NbS) have emerged as a promising approach, particularly for regions such as MENA where climate vulnerability intersects with biodiversity decline, water scarcity, and socio-economic pressures.

Study Objectives

This study examines the role of Nature-based Solutions (NbS) in strengthening climate resilience, with a particular focus on the MENA region. The research is guided by the following objectives:

- 1. To examine the conceptual foundations and practical applications of Nature-based Solutions** in relation to climate change mitigation and adaptation.
- 2. To compare the long-term effectiveness of NbS and conventional grey infrastructure**, including their ecological performance, cost efficiency, and social resilience outcomes.
- 3. To assess how NbS are reflected in national climate strategies and development frameworks** across the MENA region, including the extent of policy integration and institutional coordination.
- 4. To identify institutional, financial, and governance barriers** that constrain NbS implementation, coordination, and scaling.
- 5. To propose evidence-based recommendations** on policy reform, financing mechanisms, and research priorities that can support climate-resilient and inclusive development through NbS.

Study Methodology

This study applies a mixed qualitative and analytical research design that integrates document review, comparative evaluation,

and case study analysis. The methodology is designed to provide both a broad understanding of NbS frameworks and an applied assessment of implementation conditions and outcomes.

Document and Policy Review

The research includes a systematic review of institutional and policy documents published between 2020 and 2025. Key sources include reports and frameworks produced by the IPCC, World Bank, UNEP, FAO, and IUCN. These documents are examined to identify global and regional NbS standards, implementation priorities, and evidence on outcomes related to resilience and sustainable development.

Comparative Evaluation

A comparative assessment is conducted to examine the relative strengths and limitations of NbS, conventional grey infrastructure, and hybrid approaches. The comparison uses evaluation criteria related to ecological performance, cost-effectiveness, risk reduction, and social inclusivity. Assessment matrices adapted from IPCC and World Bank methodologies are used to ensure consistency and analytical rigor.

Case Study Analysis

To strengthen the applied dimension of the research, selected case studies from Morocco, Egypt, the Netherlands, and Singapore are examined. These cases represent diverse governance systems, environmental conditions, and development contexts. The analysis focuses on identifying success factors, institutional enablers, and transferable lessons relevant to NbS implementation in MENA.

Qualitative Content Analysis

A thematic content analysis is applied to academic literature and institutional publications from 2020 to 2025. The reviewed materials are coded to identify recurring themes related to NbS design principles, governance models, performance indicators, community engagement, and financing.

Analytical Framework

The study is guided by two internationally recognized frameworks: the IUCN Global Standard for Nature-based Solutions and the principles of the UN Decade on Ecosystem Restoration [6,7]. These frameworks provide a structured basis for evaluating whether NbS interventions align with ecological integrity, social inclusion, and long-term sustainability.

This combined methodology enables the study to link global evidence with regional realities, ensuring that conclusions are grounded in both policy analysis and practical implementation insights.

Literature Review

This section reviews major academic and institutional contributions to the Nature-based Solutions (NbS) literature between 2015 and 2025. It traces how NbS evolved from a broad ecological concept into a more structured policy and implementation framework, and it evaluates the evidence base on mitigation, adaptation, governance, financing, and equity. The review also highlights emerging research directions related to monitoring systems, metrics, and policy integration.

Conceptual Evolution and Standardization

Over the past decade, Nature-based Solutions have moved from a general ecological concept into an increasingly formalized approach used across climate, biodiversity, and development agendas. Early scholarship framed NbS as interventions capable of responding to societal challenges while conserving ecosystems. Cohen-Shacham et al. provided one of the most widely cited definitions, emphasizing biodiversity protection and human well-being as joint outcomes [8]. Reinforced this framing by linking NbS directly to sustainable development pathways.

As NbS gained institutional legitimacy, the need for clearer standards became increasingly important. Maes and Jacobs argued that NbS should be treated as part of sustainable infrastructure planning rather than as isolated conservation actions [9]. The publication of the IUCN Global Standard for NbS represented a significant milestone by establishing measurable criteria for design, implementation, and evaluation [6]. This shift toward standardization has shaped subsequent research, particularly in relation to monitoring, credibility, and accountability.

Evidence on Mitigation and Adaptation Potential

A large proportion of NbS research has focused on their capacity to support both climate mitigation and adaptation. Griscom et al. produced influential quantitative evidence showing that land-based interventions—such as reforestation, soil carbon improvement, and wetland protection—could contribute significantly to cost-effective carbon sequestration by 2030 [10]. This work helped position NbS as a climate strategy with measurable mitigation value.

Adaptation research has expanded the evidence base by demonstrating how ecosystems reduce vulnerability and buffer climate hazards. Chausson et al. emphasized that healthy ecosystems can protect communities from climate extremes while sustaining critical ecological functions [11]. The IPCC further recognized NbS as particularly relevant in urban and coastal settings, where climate risks are intensifying rapidly [12,13]. At the same time, Seddon et al. cautioned that NbS should not be presented as an alternative to emissions reductions, arguing that they must be implemented as complementary measures within broader mitigation strategies [11].

From Principles to Measurable Practice

As NbS became increasingly incorporated into climate planning and investment portfolios, research attention shifted toward measurement, performance indicators, and evaluation frameworks. Raymond et al. advanced assessment models for urban NbS that include indicators for climate regulation, stormwater management, ecosystem service delivery, and social outcomes [14].

More recent contributions have aimed to integrate ecological, economic, and governance factors into unified evaluation tools. Cohen-Shacham et al. expanded assessment approaches by combining biodiversity outcomes, climate resilience indicators, and governance quality metrics [15,16]. Despite these advances, Dunlop et al. observed that monitoring remains inconsistent

across projects and regions, and that short evaluation periods continue to limit robust conclusions about long-term effectiveness and trade-offs [17].

Finance, Governance, and Implementation Barriers

While NbS are widely promoted, the literature consistently shows that implementation is often constrained by institutional and financial barriers. Kabisch et al. highlighted that urban NbS projects frequently rely on local financing structures, which can be unstable or politically restricted [18]. Nesshöver et al. emphasized that NbS require coordination across sectors and agencies that are often fragmented in practice [19].

Recent studies have further emphasized persistent financing gaps and limited private sector engagement. Biasin et al. argued that fragmented funding and weak investment pipelines reduce the scalability of NbS initiatives [20,21]. Governance limitations—particularly unclear land tenure, weak accountability, and insufficient community engagement—have also been linked to project failure and social conflict [22]. To address these constraints, Atteridge et al. proposed blended finance mechanisms, including green bonds, public-private partnerships, and climate finance tools designed to reduce investment risk while maintaining environmental integrity [23,24].

Empirical Evidence on Co-benefits and Food Security

Beyond climate outcomes, empirical studies increasingly document the co-benefits of NbS for livelihoods, food systems, and water security. Locatelli et al. showed that forest-based approaches can enhance agricultural resilience through improved soil quality, reduced erosion, and microclimate regulation [25]. Paavola and Pringle similarly demonstrated that community-led NbS often strengthen food and water security by restoring ecosystem functions and diversifying livelihood strategies [26].

Recent evidence reinforces these findings under climate stress conditions. Nguyen et al. concluded that agroforestry systems and wetland restoration can improve drought resilience and stabilize food production [27,28]. Further showed that mangrove restoration provides both coastal protection and livelihood support, especially for communities dependent on fisheries and coastal resources.

Critical and Equity-Oriented Perspectives

As NbS gained prominence, scholars increasingly examined the ethical and political risks associated with their rapid mainstreaming. Görg et al. and Melanidis and Fisher cautioned that NbS can be used for “greenwashing,” particularly when projects are framed as climate solutions without addressing structural emissions sources or ensuring social safeguards [29,30].

Equity concerns have also become central to recent research. Seddon et al. emphasized that inclusive governance and meaningful participation are essential to avoid exclusion, displacement, and unequal benefit distribution [22]. Nelson et al. highlighted the importance of Indigenous and local knowledge systems, arguing that culturally grounded approaches strengthen legitimacy and long-term sustainability [31]. These perspectives

reinforce the view that NbS credibility depends not only on ecological performance but also on social justice and rights-based governance.

Recent Syntheses and Emerging Research Frontiers

Recent literature increasingly focuses on monitoring systems, data integration, and policy alignment. Dunlop et al. highlighted the expanding role of digital tools such as Earth observation, spatial analytics, and participatory monitoring in improving evaluation quality [17]. Nguyen et al. similarly stressed the importance of long-term monitoring for understanding whether NbS outcomes persist under future climate conditions [27,28].

At the policy level, Martin (2025) identified persistent challenges related to institutional coordination and financing, emphasizing that scaling NbS requires structural reforms rather than isolated projects. UNEP and the World Bank called for embedding NbS within national climate and development strategies, including Nationally Determined Contributions (NDCs), National Adaptation Plans (NAPs), and SDG frameworks [32-34]. Despite growing recognition, the literature suggests that NbS implementation remains constrained by governance fragmentation, limited financing, and uneven monitoring capacity.

Discussion of the Literature Review

The literature on Nature-based Solutions has expanded significantly over the past decade, evolving from conceptual framing into a more structured and applied field supported by global standards and growing empirical evidence. Foundational work such as Cohen-Shacham et al. established NbS as an approach that integrates biodiversity protection with societal benefits, while the IUCN Global Standard strengthened credibility by providing clearer principles and implementation criteria [6,8].

A consistent finding across the literature is that NbS can contribute meaningfully to both mitigation and adaptation. Griscom et al. demonstrated strong mitigation potential through land-based carbon sequestration, while Chausson et al. and the IPCC highlighted NbS effectiveness in buffering climate hazards, particularly in urban and coastal contexts [10-13]. However, the literature also strongly emphasizes that NbS must not be framed as a substitute for emissions reductions. The caution raised by Seddon et al. remains central: NbS can enhance resilience and store carbon, but they cannot compensate for continued high-emission development [11].

Methodological advances are also clear. Frameworks proposed by Raymond et al., Frantzeskaki et al., and Cohen-Shacham et al. reflect a shift toward measurable outcomes and integrated indicators [14-16]. Nevertheless, limitations persist. One of the most significant weaknesses in the evidence base is the lack of standardized metrics that can be applied consistently across regions and project types. Many studies remain constrained by short monitoring periods, which limits the ability to evaluate long-term durability, climate robustness, and unintended trade-offs. As noted by Dunlop et al. without consistent monitoring and shared evaluation protocols, NbS performance remains difficult to compare and generalize [17].

The literature further indicates that barriers to NbS implementation are frequently institutional rather than ecological. Governance fragmentation, weak cross-sector coordination, unclear land tenure, and limited community participation repeatedly emerge as drivers of failure or underperformance [14,22]. Financing constraints also remain persistent. Although innovative mechanisms such as green bonds and blended finance are increasingly proposed many countries still lack the institutional capacity to develop bankable NbS pipelines or attract sustained private investment [20,21,23,24]. This challenge is especially relevant in developing and climate-vulnerable contexts, including much of the MENA region.

Equity and legitimacy have become defining themes in recent NbS scholarship. Critiques of greenwashing show that NbS can be misused when projects prioritize branding or carbon accounting while neglecting rights, safeguards, and local participation [29,30]. In response, contemporary research increasingly emphasizes rights-based governance, social inclusion, and the integration of Indigenous and local knowledge as necessary conditions for sustainable NbS outcomes [22,31].

Overall, the reviewed literature confirms that NbS have matured into a credible climate resilience and sustainable development instrument, supported by stronger standards and a growing evidence base. However, critical gaps remain in long-term monitoring, standardized evaluation frameworks, and enabling governance and finance systems. Future research and policy should prioritize consistent metrics, stronger institutional coordination, long-term funding strategies, and socially inclusive implementation processes to ensure that NbS deliver durable, equitable, and climate-resilient outcomes—particularly in vulnerable regions such as MENA.

Climate Change and the Role of Nature-based Solutions in the MENA Region

The Middle East and North Africa (MENA) region faces escalating environmental and socio-economic challenges as global warming accelerates. Rising temperatures, water scarcity, and land degradation are placing mounting pressure on fragile ecosystems and human livelihoods. In this context, Nature-based Solutions (NbS) have emerged as a vital strategy for climate resilience, linking ecosystem restoration and sustainable management to human well-being. This chapter examines the concept of NbS, outlines regional climate trends, and highlights the comparative advantages of NbS over conventional infrastructure approaches, while establishing the conceptual framework for this study.

Nature-based Solutions and Climate Change Adaptation

Nature-based Solutions (NbS) offer practical approaches to both mitigating and adapting to climate change. Defined as actions that protect, manage, and restore natural or modified ecosystems to address societal challenges, NbS contribute to resilience building, disaster risk reduction, and sustainable livelihoods while delivering co-benefits for biodiversity and communities [6,35,36]. Common examples include mangrove and wetland restoration to mitigate coastal flooding, sustainable land

management to combat desertification, and the creation of urban green spaces to alleviate heat stress.

In the MENA region, where aridity, land degradation, and water scarcity are intensifying, NbS provide cost-effective, long-term adaptation strategies. By enhancing ecosystem services, strengthening local resilience, and complementing policy-driven and technological measures, NbS play a critical role in regional climate stability. Their inclusion in national adaptation plans, development frameworks, and urban planning is therefore essential for achieving sustainable climate resilience [2-4,37-39].

Projected Climate Trends and Warming in the MENA Region

Climate projections consistently indicate substantial warming across the MENA region throughout the twenty-first century. Under both moderate (SSP2-4.5) and high (SSP5-8.5) emission scenarios, mean surface temperatures are expected to rise significantly above historical baselines [1-4,37,38]. These increases will exacerbate existing pressures such as drought frequency, water scarcity, and soil degradation, further diminishing the adaptive capacity of both natural and human systems.

Table 1 summarizes temperature projections for selected MENA countries based on Coupled Model Intercomparison Project Phase 6 (CMIP6) simulations. Across these nations, mid-century (2041–2060) temperature increases are expected to range from roughly 1 °C to 4 °C, depending on the scenario and location [40].

Table 1: Temperature Change Projections for Selected Countries in the MENA Region (Representative Ranges)

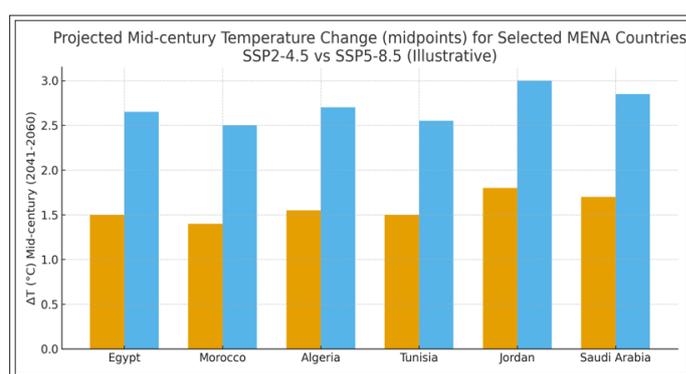
| Country | Near-term (2021–2040) ΔT (°C) [SSP2–4.5] | Mid-century (2041–2060) ΔT (°C) [SSP2–4.5] | Mid-century (2041–2060) ΔT (°C) [SSP5–8.5] | Main Data Source |
|--------------|--|--|--|---|
| Egypt | 0.7–1.4 | 1.0–2.0 | 1.8–3.5 | World Bank CCKP (2023); IPCC (2021) |
| Morocco | 0.6–1.3 | 0.9–1.9 | 1.7–3.3 | |
| Jordan | 0.8–1.6 | 1.2–2.4 | 2.0–4.0 | |
| Saudi Arabia | 0.7–1.5 | 1.1–2.3 | 1.9–3.8 | World Bank CCKP (2023); World Bank (2022) |
| Algeria | 0.6–1.4 | 1.0–2.1 | 1.8–3.6 | World Bank CCKP (2023); Zittis & Lelieveld (2021) |
| Tunisia | 0.6–1.4 | 1.0–2.0 | 1.7–3.4 | World Bank CCKP (2023); Lelieveld et al. (2020) |

Sources: (World Bank CCKP, 2023; World Bank, 2022; Zittis & Lelieveld, 2021; and Lelieveld et al., 2020) [35,36,40,41].

Notes:

- Ensemble mean ranges derived from Coupled Model Intercomparison Project Phase 6 (CMIP6) model outputs, as summarized in the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6, 2021) and the World Bank Climate Change Knowledge Portal (CCKP, 2023).
- For detailed model results and scenario-based values, refer to the World Bank Climate Change Knowledge Portal country datasets and regional analyses [35,36,40,41].
- Near-term (2021–2040) and Mid-century (2041–2060) values are projections from global climate models (CMIP6) under two Shared Socioeconomic Pathways (SSPs).
- SSP2-4.5 represents moderate warming outcomes, while SSP5-8.5 represents intense warming if emissions remain unchecked.

Figure 1 illustrates the median projected temperature change by mid-century under both scenarios, highlighting a clear warming gradient across MENA countries [40].



Sources: (World Bank CCKP, 2023; World Bank, 2022; Zittis & Lelieveld, 2021; and Lelieveld et al., 2020).

Figure 1: Projected Mid-century Temperature Change for Selected MENA Countries under SSP 2-4.5 and SSP 5-8.5 Scenarios

Current Climate Conditions in the MENA Region

Recent CMIP6 modeling and IPCC assessments identify the MENA region as among the most climate-vulnerable globally

[1]. Projections indicate that by the end of the century, major cities such as Cairo, Riyadh, Casablanca, and Tunis could experience temperature increases of +4 °C to +7 °C under the high-emission scenario SSP5-8.5 [1,41].

Case studies further illustrate the regional implications. In Upper Egypt, irrigation water demand is expected to rise under both RCP4.5 and RCP8.5 scenarios, increasing pressures on food and water security [42]. Similarly, the International Energy Agency (IEA, 2022) reported more frequent extreme heat days, higher cooling demands, and declining energy system performance. Collectively, these analyses underscore that without immediate adaptation measures, climate-related risks to energy, water, and agriculture will intensify [2-4,37,38].

Comparative Assessment of Nature-based and Conventional Approaches

Conventional grey infrastructure—engineered solutions such

as dams, seawalls, and drainage systems—has historically dominated climate adaptation strategies. While effective in providing immediate protection, these systems are often costly, inflexible, and ecologically disruptive [12,13]. The 2021 floods in Western Europe, which revealed limitations in existing drainage networks, and the 2023 Derna dam failures in Libya, which caused major losses, highlight the vulnerability of grey infrastructure to extreme events [43-47].

Nature-based Solutions, alongside hybrid approaches that integrate ecological and engineered measures, offer greater long-term resilience, adaptive capacity, and co-benefits, including biodiversity conservation and community engagement [2-4,37,38,48].

Table 2 compares the strengths, limitations, and complementarities of grey, green, and hybrid approaches.

Table 2: Comparison between Grey Solutions, Nature-based Solutions (NbS), and Hybrid Approaches.

| Criterion / Type | Grey Solutions (Engineering-based) | Nature-based Solutions (NbS) | Hybrid Solutions |
|---------------------------------------|---|--|--|
| Short-term effectiveness (Pro) | Provides immediate and direct protection through hard engineering (e.g., dams, seawalls). | Reduces risks by restoring and enhancing natural ecosystem functions. | Offers dual-layer protection combining engineered and natural systems. |
| Long-term resilience (Pro) | Limited; structures may degrade or lose effectiveness over time. | High resilience; adaptive and self-sustaining ecosystems. | Highest resilience through complementary mechanisms. |
| Co-benefits (Pro) | Single-purpose protection with limited added benefits. | Multiple benefits: hazard reduction, biodiversity, carbon storage, recreation. | Provides both physical protection and partial ecological benefits. |
| Economic cost (Con) | Very high construction and maintenance costs. | Lower cost and greater long-term economic efficiency. | Moderate; depends on balance of grey and green components. |
| Environmental impact (Con) | Can cause habitat degradation and biodiversity loss. | Supports ecosystem services and biodiversity conservation. | Minimizes negative impacts compared with grey-only approaches. |
| Failure risk (Con) | High vulnerability to extreme or unprecedented events. | Moderate; systems can recover or regenerate naturally. | Lower risk due to functional redundancy. |
| Social acceptance | May lead to displacement or reduced community support. | Generally, well accepted; often enhances community participation. | Widely accepted if co-designed with local stakeholders. |

Source: (IPCC, 2022; World Bank, 2023; UNDRR, 2021; Koks et al., 2021; Reuters, 2023; and Al Jazeera, 2023).

By combining ecological restoration with engineered infrastructure, hybrid approaches can maximize resilience while delivering multiple societal and environmental benefits, making them particularly well-suited for the climate challenges facing the MENA region [2-4,12,13,37,38,48].

Conceptual Framework of Nature-based Solutions (NbS)

Nature-based Solutions (NbS) represent practical, political, and procedural approaches aimed at protecting, managing, and restoring natural or modified ecosystems to address social, economic, and environmental challenges. These include climate change, disaster risk management, water and food security, and public health, while simultaneously generating co-benefits for biodiversity and human

well-being [49-51]. Over the past decade, NbS have gained recognition as a vital component of sustainable development strategies and global ecosystem restoration initiatives, including the UN Decade on Ecosystem Restoration [7].

Definition and Scope of Nature-based Solutions (NbS)

Nature-based Solutions are a relatively recent concept that has quickly gained global prominence. The International Union for Conservation of Nature (IUCN) defines NbS as “actions that aim to protect natural or modified ecosystems, manage them sustainably, restore them, effectively address societal challenges, and provide benefits for human well-being and biodiversity” [37]. This definition highlights the dual focus of NbS on human and environmental outcomes.

In practical terms, NbS are designed to address specific climate-related challenges, including flooding, drought, desertification, and extreme heat, while enhancing ecosystem services such as clean air, water regulation, food security, and opportunities for green employment. A broader operational definition emphasizes adaptive management, describing NbS as interventions that protect, sustainably manage, and restore ecosystems while simultaneously delivering measurable social and ecological benefits [17,49].

The literature stresses that NbS extend beyond isolated environmental activities, such as tree planting. Effective NbS require interventions that:

1. Address clearly identified societal problems.
2. Generate multiple co-benefits for biodiversity and community well-being.
3. Adhere to principles of sustainability, equity, and long-term effectiveness [22,49].

Global Standard Criteria and Principles for Nature-based Solutions (NbS)

To ensure consistent application and assessment of NbS, the IUCN established the Global Standard for Nature-based Solutions in 2020. This framework includes eight criteria and twenty-eight indicators that serve as benchmarks for authentic NbS projects. According to the standard, successful NbS initiatives should:

1. Directly address well-defined societal challenges, such as climate change, water scarcity, or food insecurity.
2. Integrate scientific evidence and local knowledge in their design.
3. Deliver measurable net benefits for ecosystems and biodiversity.
4. Demonstrate economic efficiency and long-term financial viability.
5. Ensure inclusive participation of stakeholders throughout planning and implementation.
6. Maintain transparency and accountability through measurable performance indicators.
7. Be integrated across sectors and aligned with policy and planning frameworks.
8. Manage risks and maintain flexibility to adapt to future environmental and social changes [6,15,16].

These criteria prevent superficial application of the NbS concept, ensuring that projects produce tangible benefits for both people and ecosystems.

Distinguishing Nature-based Solutions from Related Concepts

Although NbS shares similarities with other environmental and climate-related approaches, important distinctions exist [15,16,22].

- Climate-Smart Agriculture (CSA) focuses on improving agricultural productivity and resilience in response to climate change. While CSA primarily addresses the agricultural sector, NbS encompass a broader range of terrestrial, freshwater, and marine ecosystems.
- Ecosystem-based Adaptation (EbA) is closely related to NbS and often considered a subset, primarily targeting adaptation to climate impacts. NbS extend beyond adaptation to include mitigation and broader social, economic, and developmental objectives.
- Green Infrastructure is typically urban-focused, including measures such as green roofs, rain gardens, and urban parks to reduce flood risk and heat stress. NbS incorporate both urban systems and natural ecosystems, such as forests, wetlands, and coasts.
- Hybrid Solutions combine engineered (grey) infrastructure with natural systems to provide immediate physical protection while maintaining ecosystem functions. Examples include seawalls reinforced by coral reefs or mangroves enhancing coastal defense.

Overall, NbS provide an integrated framework linking environmental protection with sustainable human development, supported by global standards that ensure effective, scalable, and measurable outcomes.

Nature-based Solutions and Conventional Climate Strategies

NbS and Mitigation

Mitigation refers to reducing greenhouse gas emissions or enhancing carbon sinks. NbS contribute to mitigation by storing carbon through reforestation, wetland restoration, and grassland rehabilitation. However, the literature cautions against overreliance on NbS alone, emphasizing the need for complementary systemic actions in energy and industry transitions [12,13,22].

NbS and Adaptation

Adaptation involves adjusting human and natural systems to minimize adverse climate impacts. NbS serve as direct adaptation strategies, such as wetland restoration to reduce flooding, coastal tree lines to buffer storm surges, and drought-resilient agroecosystems. Their effectiveness is enhanced when interventions are locally designed and involve active community participation [12,13,52].

NbS and Resilience-Building

Resilience-building strengthens the capacity of ecosystems and communities to withstand and recover from shocks. NbS contribute by diversifying income sources, restoring biodiversity,

and improving ecosystem functions. While they enhance resilience to recurring stresses, NbS must be complemented by broader climate policies and systemic emissions reductions [17,22].

Core Principles of Nature-based Solutions (NbS)

NbS are guided by principles that ensure long-term sustainability, equity, and scientific rigor:

- **Working with nature:** Interventions harness natural processes, such as carbon storage, water regulation, and soil regeneration, rather than replacing ecosystems. Examples include wetland restoration for flood control, which offers sustainable, cost-effective alternatives to hard infrastructure.
- **Multiple goals and co-benefits:** NbS simultaneously address environmental, social, and economic objectives. Projects like mangrove restoration mitigate climate impacts, protect coastlines, and enhance local livelihoods.
- **Evidence-based effectiveness:** Successful NbS rely on scientific data, measurable indicators, and adaptive management to monitor ecological and social outcomes. Remote sensing, field data, and community feedback are key to balancing conservation and livelihood needs [49].
- **Equity and inclusivity:** Effective NbS engage local communities, integrate traditional knowledge, and ensure fair benefit-sharing. Inclusive approaches foster ownership and long-term sustainability [17,22].
- **Sustainability and adaptability:** NbS must remain viable over time and adapt to environmental and social changes. Given that ecosystem recovery can span decades, continuous adaptive management ensures ongoing relevance and resilience.

Nature-based Solutions (NbS) and Sustainable Development

Nature-based Solutions (NbS) provide an integrated framework linking environmental protection with social and economic development. By leveraging the functions of natural and managed ecosystems, NbS enhance climate resilience, strengthen livelihoods, and maintain ecological stability. They align closely with the 2030 Agenda for Sustainable Development, which emphasizes the interdependence of environmental health, social equity, and economic progress [6,12,13,50,51].

Nature-based Solutions and the Sustainable Development Goals (SDGs)

Alignment with the 2030 Agenda: NbS contribute directly to multiple Sustainable Development Goals (SDGs). For example, Goal 2 (Zero Hunger) benefits from sustainable agriculture practices, Goal 6 (Clean Water and Sanitation) is supported through watershed protection, and Goal 13 (Climate Action) is advanced via ecosystem-based adaptation and carbon sequestration. NbS also contribute to Goal 14 (Life Below Water) and Goal 15 (Life on Land) through the restoration of marine and terrestrial ecosystems, while indirectly supporting Goals 1 (No Poverty), 3 (Good Health and Well-being), and 11 (Sustainable Cities and Communities) by enhancing livelihoods, public health, and urban resilience [12,13,39,50,51]. FAO and UNEP analyses indicate that effective NbS implementation strengthens ecosystem services—including water regulation, soil

fertility, and biodiversity—which integrate climate adaptation and sustainable development into national policy frameworks [39,50,51].

Cross-sectoral integration: NbS foster collaboration across sectors, linking agriculture, water management, urban planning, and coastal protection. Examples include mangrove restoration, which enhances coastal resilience and supports fisheries, and urban greening projects, which reduce urban heat and improve air quality [7,39]. By facilitating such integration, NbS enable policies that combine environmental, social, and economic objectives, contributing to inclusive, low-carbon, and climate-resilient development in alignment with the 2030 Agenda.

Synergistic Co-benefits between NbS and Ecosystem Integrity

Ecosystem integrity, which encompasses biodiversity, food security, and ecosystem services, both supports and benefits from NbS. By restoring and protecting natural systems, NbS increase species and habitat diversity, maintain productive and resilient landscapes, and enhance the ecological functions that underpin human well-being. Healthy ecosystems, in turn, improve the effectiveness of NbS by increasing ecological stability, productivity, and adaptive capacity to climate change. This mutual reinforcement demonstrates that ecosystem integrity is both a foundation and an outcome of successful NbS interventions.

NbS and Biodiversity

NbS and biodiversity are mutually reinforcing. Actions such as habitat restoration, landscape connectivity, and sustainable land management conserve species, maintain genetic diversity, and strengthen ecosystem integrity. Biodiverse ecosystems enhance NbS effectiveness by providing essential ecological functions, including pollination, nutrient cycling, and natural pest regulation [17,49]. For instance, restoring mangroves or wetlands not only protects habitats but also improves carbon sequestration and resilience to extreme weather. Conversely, poorly designed interventions, such as monoculture plantations with non-native species, can undermine biodiversity and weaken ecosystem services [22]. Prioritizing native species, ecological compatibility, and adaptive management is therefore essential for achieving positive feedback between NbS and biodiversity outcomes.

NbS and Food Security

NbS and food security are deeply interlinked. Practices such as agroforestry, mixed cropping, soil and water conservation, and wetland rehabilitation enhance soil fertility, improve water retention, and stabilize microclimates, thereby increasing agricultural productivity and reducing vulnerability to climate extremes. Secure and sustainable food systems further reinforce local stewardship of NbS by aligning conservation goals with livelihood incentives [27,28,39]. Meta-analyses indicate that well-designed NbS can strengthen all four pillars of food security—availability, access, utilization, and stability—particularly when interventions are context-specific and participatory [43,44]. Integrating agricultural NbS into rural development enables communities to achieve both ecosystem

restoration and food system resilience, positioning NbS as a cornerstone of climate-smart agriculture.

NbS and Ecosystem Services

NbS enhance and rely upon ecosystem services in a reinforcing cycle. By restoring natural processes such as flood regulation, water purification, air filtration, and carbon storage, NbS deliver tangible social and economic benefits while sustaining ecological foundations [17,39]. These services, in turn, increase the performance and durability of NbS interventions. For example, reforestation that improves watershed regulation also protects downstream agricultural systems from floods and erosion, increasing the return on investment. Likewise, improved pollination and soil health enhance both agricultural yields and ecosystem resilience. Assessing these interactions through ecosystem service valuation highlights the interdependence of ecological health and human prosperity as outcomes of well-designed NbS.

Standards and Safeguards for Successful NbS Implementation

The successful application of NbS requires safeguards and adherence to standards to ensure interventions:

1. Achieve intended ecological and social objectives.
2. Avoid harm to ecosystems and local communities.
3. Include measurable indicators and monitoring frameworks.
4. Promote local participation and equity [12,13,22,49].

IUCN Global Standard: The International Union for Conservation of Nature (IUCN) developed the Global Standard for NbS, which provides eight criteria guiding design, implementation, and evaluation [6]. These criteria address clearly defined societal challenges, ensure biodiversity benefits, foster inclusive governance, balance trade-offs, and require adaptive management and monitoring. The standard serves as a global benchmark for credible, measurable, and socially equitable NbS projects.

UN Decade on Ecosystem Restoration (2021–2030) Design Principles: Led by UNEP and FAO, the UN Decade provides a framework for restoring degraded ecosystems. Its ten principles emphasize ecological integrity, inclusiveness, long-term sustainability, local ownership, and cross-sectoral integration. By promoting participatory, science-based restoration, the framework supports climate resilience, biodiversity recovery, and sustainable development.

Practical Challenges and Implementation Risks of Nature-based Solutions (NbS)

Despite growing recognition of Nature-based Solutions (NbS) as essential tools for climate adaptation and mitigation, their long-term success is not guaranteed. Several practical challenges can hinder effectiveness, including weak institutional capacity, short-term project design, insufficient community involvement, and the misconception that NbS alone can solve complex climate problems. Addressing these challenges through evidence-based planning, inclusive governance, and robust monitoring is critical for ensuring that NbS deliver meaningful, sustainable outcomes.

Temporal and Performance Challenges

The benefits of NbS manifest over varying timescales depending on the ecosystem type and intervention objectives. Urban greening projects may deliver cooling effects within a few years, whereas forest restoration, carbon sequestration, or soil fertility recovery may take decades. Short-term funding cycles and political priorities often do not align with these ecological timescales, leading to premature evaluation or abandonment of projects before their full benefits are realized [17].

Environmental variability—such as droughts, floods, or extreme temperature events—can further delay expected outcomes, creating perceptions of unreliability compared to engineered infrastructure. Establishing long-term monitoring systems, aligning funding and policy frameworks with ecological recovery periods, and implementing adaptive management strategies are essential to sustaining performance and demonstrating the effectiveness of NbS over time [12,13].

Justice and Ownership Risks

Failing to incorporate local governance structures or community participation can exacerbate social inequalities and reduce project legitimacy. NbS initiatives that disregard customary land rights or fail to ensure equitable benefit-sharing may lead to community resistance, displacement, or restricted access to essential resources [22].

Inclusive governance is therefore fundamental to the success of NbS. Engaging local stakeholders from the design stage ensures interventions are culturally appropriate, socially just, and environmentally sustainable. Recognizing traditional knowledge, respecting land tenure, and promoting shared ownership strengthens stewardship, fosters local adoption, and increases the likelihood of long-term maintenance and resilience of NbS projects [2-4].

Overreliance on NbS (“Solutionism”)

The Intergovernmental Panel on Climate Change cautions against overemphasizing NbS as a standalone solution for climate change [12,13]. While NbS contribute to adaptation and mitigation, they cannot replace the systemic transformations required in energy, industry, and transportation sectors. Treating NbS as a silver bullet—a tendency referred to as “solutionism”—can create an illusion of progress while diverting attention from structural reforms needed to address the root causes of climate change [22].

Overreliance on NbS may also distort policy and investment priorities. For example, large-scale afforestation or carbon offsetting initiatives are sometimes deployed as compensation for continued emissions rather than as part of a comprehensive mitigation strategy. Poorly designed projects risk negative ecological and social consequences, including reduced biodiversity, altered water cycles, and marginalization of local communities. Monoculture plantations, while temporarily sequestering carbon, can degrade soil quality and habitat diversity over time [15,16].

To mitigate these risks, NbS should be positioned as complementary measures within integrated climate frameworks. Combining NbS with emissions reduction strategies, renewable energy deployment, and sustainable land management policies ensures they enhance resilience and deliver co-benefits. Transparent monitoring, equity safeguards, and accountability mechanisms are essential to maintain scientific integrity and social legitimacy, reinforcing NbS as a robust, socially responsible, and evidence-based approach to sustainable development [2-4,12,13].

Evidence-based Design and Integration of Nature-based Solutions (NbS)

For Nature-based Solutions (NbS) to deliver sustainable and measurable outcomes, their design and implementation must be grounded in scientific evidence, social inclusion, and coordinated policy frameworks. Effective NbS address environmental, social, and economic dimensions simultaneously, ensuring interventions tackle multiple challenges while maintaining ecosystem integrity. The following principles outline key elements for achieving effective, equitable, and scalable NbS.

Multi-purpose and Adaptive Design

NbS should be conceived as multifunctional systems that provide co-benefits for both people and nature. Well-designed interventions can simultaneously support climate adaptation, biodiversity conservation, and livelihood improvement within a holistic planning framework [22]. Integrating ecological and social objectives from the outset allows projects to respond adaptively to changing climatic and socioeconomic conditions. Adaptive management—based on continuous monitoring and feedback from local communities—ensures interventions remain effective over time. It also allows for adjustments in response to environmental shifts or evolving community needs, enhancing long-term resilience and sustainability [12,13].

Monitoring, Metrics, and Evaluation

The success of NbS depends on robust, transparent, and measurable indicators capturing both ecological and social outcomes. Key metrics include biodiversity conservation, carbon sequestration, water regulation, food security, and equitable distribution of benefits. Combining scientific methods such as field surveys, remote sensing, and modelling with participatory evaluation processes improves both accuracy and accountability [49].

Regular monitoring not only supports adaptive management but also informs policy-making and investment decisions, demonstrating cost-effectiveness and long-term sustainability of interventions. By providing evidence of outcomes, evaluation frameworks strengthen the credibility and scalability of NbS initiatives.

Local Participation and Equity

Inclusive governance is fundamental to the legitimacy and sustainability of NbS projects. Interventions that respect local rights, knowledge systems, and customary practices are more likely to achieve sustained community engagement and ownership. Participatory frameworks should formalize co-

design processes, equitable benefit-sharing, and compensation mechanisms where livelihoods are affected.

Engaging local institutions and community organizations strengthens project continuity beyond initial funding periods and promotes social justice. Inclusive approaches foster trust, enhance community stewardship, and ensure NbS deliver both environmental and social benefits [17].

Cross-sectoral Integration

To maximize impact, NbS must be embedded within broader development and climate strategies. Coordination across agriculture, water management, energy, and urban planning sectors ensures policy coherence, prevents duplication of efforts, and enables efficient use of resources. Cross-sectoral integration also strengthens resilience by linking local ecosystem management with national adaptation and mitigation goals [12,13,50,51].

Institutional collaboration among government agencies, research organizations, and civil society is critical for scaling successful NbS practices. This coordination ensures that interventions contribute to systemic climate resilience while delivering multiple co-benefits for ecosystems and communities.

When designed based on evidence, implemented inclusively, and guided by clear performance standards, NbS can produce resilient, equitable, and sustainable outcomes. Achieving these results requires long-term monitoring, adaptive management, and continuous learning to avoid the pitfalls of poorly designed or short-term interventions [2-4,12,13].

Theoretical and Practical Opportunities of Nature-based Solutions (NbS)

This chapter examines the potential opportunities that Nature-based Solutions (NbS) can unlock across environmental, economic, social, and financial dimensions. If carefully designed and implemented, NbS can generate positive outcomes for ecosystems, communities, and economies, bridging climate adaptation, sustainable development, and resilience-building.

Environmental Opportunities

NbS provide significant environmental benefits by enhancing ecosystem functions and services. Urban vegetation—such as forests, green corridors, and parklands—acts as a natural air filter, capturing pollutants including fine particulate matter (PM_{2.5}) and nitrogen oxides. Integrating afforestation with smart urban planning can reduce heat islands, lower energy demand for cooling, and indirectly decrease secondary pollutant emissions [17].

Water quality and flood management are further areas of environmental opportunity. Wetlands, marshes, and restored coastal zones function as natural buffers, filtering pollutants such as excess nutrients and organic matter while storing water during heavy rainfall, thus mitigating flood risks [33,34]. In urban contexts, NbS interventions such as green roofs, permeable pavements, and bioswales slow runoff, reducing strain on engineered drainage networks. Municipal investment

planning can incorporate these interventions to enhance both environmental and infrastructure resilience [20,21].

Coastal protection is another critical benefit. Mangroves, seagrasses, and living shorelines absorb wave energy and reduce storm impacts, minimizing coastal erosion. Coral reef and reef barrier restoration further dissipate wave energy, protecting coastal communities and infrastructure. In several World Bank-supported projects, mangrove restoration has successfully combined environmental protection with livelihood improvement, illustrating how NbS can produce multiple co-benefits simultaneously [33,34].

Economic Opportunities

NbS create diverse economic opportunities by strengthening productive capacities and generating sustainable employment. Activities such as afforestation, habitat restoration, and ecosystem maintenance provide labor-intensive jobs, particularly in rural or marginalized areas. The report by CEBDS highlights that a nature-based economy could generate hundreds of millions of additional jobs by 2030 [53]. In practice, World Bank projects have demonstrated the potential for NbS to provide temporary employment to large numbers of households engaged in ecosystem restoration [33,34].

Beyond direct employment, NbS can enhance local economies through sustainable agriculture, agroforestry, aquaculture, and ecotourism. Diversified income streams reduce climate-related risks for farmers, increase resilience, and encourage local stewardship. Revenue from ecosystem services—including resource-use rights or carbon credits—can further strengthen community-based financing and reinforce local economic resilience.

Social Opportunities

NbS offer substantial social benefits, including community empowerment, social justice, and improved quality of life. Equitably designed interventions can prioritize populations most affected by climate change, such as rural or coastal communities, thereby reducing vulnerabilities and strengthening adaptive capacity. However, projects implemented without community involvement may produce “inverted justice” outcomes or land conflicts, highlighting the importance of inclusive governance [54].

Engaging local populations in design, implementation, and maintenance enhances acceptance, sustainability, and capacity-building. Incorporating traditional knowledge ensures alignment with local ecological, cultural, and social contexts. Additional social benefits include improved mental and physical health, access to green spaces, and opportunities for environmental education and awareness.

Financing Opportunities

Realizing theoretical opportunities requires innovative and sustainable financing mechanisms. Green Funds, both national and international, can provide seed funding for feasibility studies, infrastructure investment, or community grants. Carbon markets—both voluntary and regulated—offer financing by

monetizing credits generated through carbon sequestration in forests, wetlands, and other ecosystems [53]. Ensuring environmental integrity, permanence, and equity is critical for credible carbon financing.

Public–private partnerships (PPPs) represent another pathway, combining government support with private investment through risk-sharing instruments such as concessional loans, green bonds, and financial guarantees. Reports on NbS financing emphasize that investments remain fragmented, requiring coordination and clear frameworks to mobilize resources effectively (Climate and Sustainability Initiative).

Critical Reflections on Leveraging Theoretical Opportunities

Theoretical NbS benefits may fail to materialize without careful design, inclusive governance, and sustainable financing. Challenges include demonstrating additionality, maintaining long-term sustainability, and securing stable revenue or funding streams beyond initial project implementation.

Despite these challenges, NbS hold considerable potential for promoting environmental health, economic resilience, social equity, and innovative financing. Bridging the gap between theoretical opportunities and practical outcomes requires rigorous planning, community engagement, and evidence-based evaluation. Case studies—both global and local—are essential to illustrate best practices, highlight lessons learned, and inform scalable implementation strategies.

Applications, Challenges, and Recommendations of Nature-based Solutions (NbS)

This chapter examines practical applications of Nature-based Solutions (NbS) around the world, identifies key challenges to scaling them, and provides evidence-based recommendations for policymakers, researchers, and civil society. Lessons from successful projects demonstrate the potential for environmental, social, and economic benefits, while challenges highlight the need for integrated governance, sustainable financing, and inclusive participation.

Global and Regional Success Stories of Nature-based Solutions

Reforestation and Combating Desertification

Morocco: The Moroccan government, with support from the French Development Agency (AFD), launched the “Ghabati, Hayati” (My Forest, My Life) program in 2022, as part of the broader Forests of Morocco 2020–2030 strategy. With an annual budget of approximately €103 million, the initiative aims to reforest 50,000 hectares per year, enhance biodiversity, and strengthen local participation in forest management. Special focus is placed on empowering rural women and improving institutional capacity within the National Agency for Water and Forests (ANEF) through participatory governance and modern monitoring technologies [55–57].

Algeria: The Green Dam Project (Barrage Vert), initiated in the 1970s, has been modernized since 2020. Recent updates

include remote sensing and community-based management approaches to combat desertification and restore vegetation cover, emphasizing the importance of institutional sustainability in large-scale arid-zone projects [58].

Wetland and Coastal Restoration

The Netherlands: The country has been a global leader in flood management through NbS. The second phase of the Room for the River 2.0 program (since 2021) expands riverbeds and establishes green floodplains that combine ecological restoration with local agriculture and economic activities. The program addresses five key areas: water discharge, navigation, water quality, ecosystems, and spatial development, providing a replicable model for climate adaptation [59].

Egypt: Since 2023, initiatives in the Nile Delta governorates of Kafr El-Sheikh and Beheira focus on restoring agro-ecosystems, promoting climate-smart agriculture, and mitigating salinization risks. These projects, implemented jointly by FAO and IFAD, also enhance irrigation efficiency and promote biodiversity-friendly farming practices [50,51,60].

Urban Green Infrastructure

Singapore: The Active, Beautiful, Clean Waters (ABC Waters) program integrates rain gardens, green corridors, and stormwater management to reduce urban runoff and improve water quality. Monitoring has shown substantial reductions in peak stormwater flows, making it a global reference for sustainable urban planning [40].

Egypt: Pilot projects in New Cairo, launched in 2022, implement rain gardens and permeable pavements. Early studies indicate improved local temperature regulation, stormwater management, and air quality [61,62].

Climate-Smart Agriculture in the MENA Region

Egypt: FAO's Decent Life (Hayah Karima) initiative targets 36 villages, promoting climate-smart agriculture, drought- and salinity-tolerant crops, and inclusive participation of women and vulnerable groups. The EgCITE Program for Agricultural Innovation, funded by the Korea Green Growth Trust Fund and the World Bank, supports agri-tech solutions, early warning systems, and climate information applications [38,50,51].

These global examples illustrate that NbS succeed when locally tailored, financially sustainable, and community-inclusive, emphasizing integrated governance and continuous monitoring of environmental and social outcomes [55,60].

Key Challenges to Scaling up Nature-based Solutions

Despite their promise, NbS face several challenges that impede large-scale implementation.

Policy Gaps and Limited Integration

Many Nationally Determined Contributions (NDCs) and sectoral climate strategies lack systematic inclusion of NbS. Operational standards, institutional coordination across sectors, and performance metrics aligned with climate and biodiversity objectives are often missing, leading to discontinuity and limited policy impact [23,24,32,63,64].

Financing Gaps

Current funding for NbS is insufficient to meet targets under the Rio Conventions. Much of the funding relies on public or international grants, which can be volatile. Private investment is limited due to long payback periods, uncertain revenue models, and difficulties in valuing social and environmental benefits. Innovative financing solutions—such as green national funds, nature-focused green bonds, concessional loans, and payments for ecosystem services—are needed to bridge the gap [23,24,32,63,64].

Measurement and Evaluation Challenges

Evaluating NbS requires demonstrating additionality, permanence, and avoiding leakage, yet conventional monitoring methods often provide only short-term or partial assessments. Integrated frameworks combining remote sensing, field indicators, social surveys, and economic models are needed to capture long-term, multi-dimensional outcomes. Lack of standardized metrics also limits comparability across projects and investor confidence.

Governance and Institutional Coordination

Fragmented administration across sectors—environment, agriculture, water—leads to duplicated efforts, land-use conflicts, and poor maintenance. Multi-stakeholder governance, joint financing, and strong leadership frameworks are crucial for effective scaling [32-34,64]. Involvement of civil society and private actors enhances transparency and equitable benefit sharing.

Low Awareness and Community Participation

Local acceptance is critical. Communities often lack awareness of NbS benefits or fear loss of land rights. Co-design, incorporation of local knowledge, and tangible economic incentives increase acceptance and sustainability [32,37,64]. Community-level governance and transparent benefit distribution further strengthen project outcomes.

Recommendations

Policymakers and Decision-Makers

- **Integrate NbS into national frameworks and budgets:** Include clear objectives, dedicated financing, and indicators [32,64].
- **Adopt multi-sectoral legislative frameworks:** Harmonize environmental, agricultural, and urban planning policies [37].
- **Provide financial and policy incentives:** Tax benefits, risk guarantees, and green bonds can mobilize private capital [23,24,65].
- **Ensure social and rights compliance:** Protect land tenure, mandate community participation, and ensure transparency [6,32,64].
- **Invest in institutional capacity building:** Train professionals on NbS assessment, design, and management [22].

Researchers and Academic Institutions

- **Develop integrated measurement frameworks:** Combine ecological, economic, and social indicators [17,23,24].
- **Assess effectiveness:** Conduct cost-benefit and comparative studies to quantify NbS value [65].

- **Contextualize applied research:** Tailor studies to local socio-ecological contexts [6,32,64].
- **Strengthen science-policy interfaces:** Foster collaboration between researchers, practitioners, and policymakers [66].

Civil Society and the Private Sector

- **Engage in co-design:** Ensure gender and youth inclusion, train communities, and monitor benefits [32,37,64].
- **Private sector involvement:** Develop nature-positive business models using ecosystem services and carbon credits [64,65].
- **Promote innovative partnerships:** Combine government, private, and community funding via blended finance mechanisms [23,24,68].
- **Ensure accountability and transparency:** Use standardized environmental and social indicators to track performance [22,32,64].

Concluding Remarks

For NbS to progress from conceptual promise to operational success, implementation must be supported by coherent policies, sustainable financing, rigorous monitoring, and active community participation. When political will, scientific research, and community action converge—underpinned by innovative finance and institutional coordination—NbS can become a central pillar of climate-resilient and sustainable development [32,54,63,65,69-76].

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