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Editorial: Nature-based solutions for climate change adaptation

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Editorial on the Research Topic

Nature-based solutions for climate change adaptation

Nature-based Solutions (NbS) have emerged as a viable option to restore and maintain natural ecosystems while delivering important co-benefits such as mitigating extreme events and reducing vulnerability. Additionally, NbS provide a means to tackle societal, environmental, and economic challenges, and biodiversity decline, and present an alternative to traditional engineering solutions. In the [United Nations \(2022\)](#) definition, NbS are “actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human wellbeing, ecosystem services, resilience and biodiversity benefits.” Co-benefits may include, for instance, mitigation for extreme events, improved water quality and availability, carbon sequestration and storage, recreational and cultural values, and reduced vulnerability. As climate change impacts increase in severity, and climate change adaptation becomes crucial in adjusting to changing conditions, NbS have become a novel area of focus for adaptation both at the community, regional, and global scales.

It is our pleasure to present this Research Topic of Frontiers in Environmental Sciences, focused on [Nature-based Solutions and Climate Change Adaptation](#), which includes 12 articles, representing work by 126 authors from around the world. Together these contributions explore this rapidly evolving field through a range of perspectives, methodologies, and disciplinary approaches.

Several of the studies examine NbS through the lens of the provision of ecosystem services and biodiversity. Although the relationship between ecosystem services and NbS can be nuanced, and sometimes ambiguous ([Remme et al., 2024](#)), ecosystem services are generally understood to be one of the operational mechanisms through which NbS deliver benefits. Enhancing biodiversity and ecosystem functions further supports resilience by stabilizing ecological processes, buffering against disturbances, and providing adaptive capacity. For instance, mangrove restoration not only sequesters carbon but also protects coastlines from storm surges, illustrating the dual role of ecosystem services in mitigation and adaptation. The studies touching upon this theme encompass the valuation, enhancement, and trade-offs of ecosystem services such as carbon sequestration, water

regulation, pollination, and biodiversity conservation. They highlight the role of both restored and conserved ecosystems in delivering critical services that underpin human wellbeing and ecological stability. From a methodological perspective, studies implement techniques based on spatial modeling and ecosystem services assessment, including meta-analytic value transfer, that allow characterization of service flows under different land use and climate scenarios. From this Research Topic, McDonald et al. assess NbS by examining the linkage between global mitigation efforts and local ecosystem service outcomes.

Environmental economics and planning form another key theme. Economic justification is essential to scaling and mainstreaming NbS. By demonstrating positive benefit-cost ratios and long-term returns, economic analyses validate NbS as viable alternatives to grey infrastructure. Investment planning frameworks also help prioritize resilience-building interventions in regions with limited resources, ensuring efficient allocation of funds. By employing spatially explicit economic assessments, discounting methods, and scenario-based planning, the studies analyze the financial returns of restoration and conservation initiatives. These approaches inform policy development and support private sector investment by quantifying the economic viability of NbS. Studies in this field employ spatially explicit economic assessments, including discounting methods and scenario-based investment planning, to evaluate the returns on restoration and conservation projects. These analyses are crucial for informing policy and attracting private sector investment. In this Research Topic, van Zanten et al. examine developing a national policy for mangroves in Indonesia by explicitly using cost-benefit analysis.

While challenging to implement, effective governance, policy, and institutional frameworks are prerequisites for successful NbS deployment. Policies that integrate NbS into planning processes, provide technical guidance, and ensure cross-sectoral coordination enhance the scalability and sustainability of resilience strategies. Institutional support may ensure that NbS are maintained and monitored over time. Regulatory, institutional, and policy mechanisms may either enable or constrain NbS implementation. Several studies examine the enabling and constraining roles of policy and governance mechanisms. Research in this area examines the development of standards, stakeholder coordination, and the role of government support in facilitating NbS implementation. Methodologies include policy analysis, stakeholder mapping, and institutional diagnostics. Morris et al. use stakeholder engagement to identify challenges to NbS in the context of managing coastal hazards and protection.

Community involvement is equally critical for the uptake and effectiveness of NbS. Engaged communities are more likely to support and maintain interventions, enhancing their long-term climate resilience (Puskás et al., 2021). Moreover, equity considerations ensure that NbS reduce vulnerability for marginalized populations and promote inclusive adaptation. Studies presented here examine the social dimensions of environmental interventions, including public awareness, stakeholder participation, gender dynamics, and conflict resolution. Studies utilized surveys, participatory mapping, and qualitative interviews to assess community perceptions and engagement levels. In this Research Topic, planning approaches presented in Box et al. in Southeast Australia address natural

hazards by proposing a method to enabling councils to develop resilient investment cases, and Donatti et al. describe how grassland restoration practices can reduce human-wildlife and social conflicts in Kenya.

In both rural and urban contexts, strategic planning is crucial to ensure the feasibility and effectiveness of NbS. Urban areas face distinct challenges such as heat islands, stormwater management, and air pollution. Incorporating NbS into urban planning can significantly enhance resilience while improving environmental quality. Strategic planning also ensures that green spaces are equitably distributed and accessible (Benati et al., 2024). Studies in this Research Topic examine spatial planning, land consumption, and the integration of green infrastructure in urban and peri-urban areas. Methods and tools to analyze scenarios include GIS-based land use modeling, urban growth simulations, and green infrastructure standards. In this Research Topic, Teerlinck et al. examine small-scale NbS in urban settings, and their spatial and ecological importance, and Schaffert et al. focus on how visualization and spatial awareness can help communities manage land preservation.

Hydrological and coastal dynamics are central to many NbS, particularly in flood-prone and coastal regions, which are experiencing ever increasing impacts with climate change. Understanding these processes is essential for designing interventions that are both effective and resilient. For example, levee setbacks and marsh terraces must be engineered to optimize sediment retention and wave attenuation under varying flow conditions. Studies in this Research Topic examine water flow, sediment transport, flood risk, and coastal erosion in relation to ecological restoration. Studies employed hydrodynamic modeling, sediment analysis, and field experiments to understand the physical processes that influence NbS performance. To illustrate these in our Research Topic, Jung et al. test and evaluate marsh terrace design for resilience to storm conditions among other factors, and van den Berg et al. examine the stability of tidal marsh vegetation to high flow velocities as an alternative to dike development. Calderwood et al. identify the trade-offs in groundwater recharge and floodplain habitat in the context of levee setbacks.

Finally, the geographic scope of the studies in this Research Topic spans from local to global. Local contexts matter, and governance systems, ecological conditions, and cultural factors are often highly place-specific. Initiatives such as the UK's Natural England or Louisiana's Coastal Master Plan offer valuable lessons. In this Research Topic, Grace et al. describes the evolution of standards for green infrastructure in the UK, and Carruthers et al. identify critical gaps for the financial viability of blue carbon accreditation in Louisiana. However, direct transfer of such models is not always feasible. Ecological characteristics (e.g., species composition of mangroves or marshes) and social contexts require tailored solutions. Similarly, ecological characteristics (e.g., species composition of mangroves, grasslands, or marshes) require local adaptation. Cultural and social dynamics are deeply rooted in local contexts. Policy frameworks like green infrastructure standards and blue carbon accreditation provide opportunities for communities and regions for shared planning outcomes. In addition, ecosystem service valuation techniques can be adapted to different biophysical and socio-economic contexts.

Each of the studies in this Research Topic covers a specific topic with wider insights for designing, evaluating, analyzing, siting, and

managing NbS in the context of climate change adaptation. Across the world, NbS activities have been used to upgrade water systems, reduce heat island effects, improve stormwater management, green infrastructure building and upgrading efforts, and provide multifaceted benefits to both ecosystems and communities.

Despite the growing interest in NbS, further research is needed to build a stronger conceptual and technical foundation. Key areas include defining metrics for effectiveness, understanding ecological trade-offs, scaling successful models, and integrating NbS into multi-level governance frameworks. By synthesizing insights from ecology, economics, governance, and community engagement, this Research Topic demonstrates the rich interdisciplinary nature of NbS research. The articles featured here contribute to filling these gaps, offering evidence and tools to support more informed decision-making in both developed and developing contexts. The research presented could unveil key insights in applicability, measurement, effectiveness, and scalability. These findings can be used to improve research, design implementation, and decrease the negative impacts of climate change.

We thank all contributing authors for their dedication to advancing knowledge in this critical field. We are delighted to present this Research Topic as a resource for researchers, policymakers, and practitioners working to address the global climate challenge through nature-based innovation.

Author contributions

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