

Review

Nature-Based Solutions for Enhancing Ecosystem Services: Mechanisms, Benefits, and Challenges

Jinyu Gong, Linxuan He , Luyao Cui, Shan Zhou, Xuemei Wang and Jingpin Lei *

Key Laboratory of Forest Silviculture of the State Forestry and Grassland Administration, Research Institute of Forestry, Chinese Academy of Forestry, Beijing 100091, China

* Correspondence: lei.jp@caf.ac.cn

Abstract

As a key pathway to address climate change and biodiversity loss, and to promote sustainable development, Nature-based Solutions (NbS) have increasingly emerged as a vital theoretical framework and practical tool in global environmental governance. This study provides a comprehensive overview of the primary categories of NbS, including ecological restoration approaches, issue-specific ecosystem-related approaches, infrastructure-related approaches, ecosystem protection approaches, and ecosystem-based management approaches. It also reviews the many ecological, social, and economic benefits generated by NbS practices globally and in China, such as enhanced carbon sequestration, disaster risk reduction, water purification, livelihood improvement, and increased tourism revenue. The findings highlight that the effectiveness of NbS is influenced by a variety of factors, including climatic conditions, spatial patterns, socio-economic contexts, and governance capacity. In addition, the delayed ecological responses and potential trade-offs among ecosystem services present challenges for the long-term implementation and upscaling of NbS. To improve the scientific rigor and applicability of NbS, future efforts should focus on long-term ecological monitoring and dynamic evaluation, developing integrated performance assessment frameworks, and strengthening the integration of local knowledge with supportive policy mechanisms. This review offers theoretical insights and practical guidance for enhancing the implementation of NbS in ecosystem management and policy-making.

Keywords: nature-based solutions; ecosystem services; climate change; benefit assessment; promotion potential



Academic Editor: Luis Diaz-Balteiro

Received: 24 May 2026

Revised: 3 July 2026

Accepted: 7 July 2026

Published: 9 July 2026

Copyright: © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

1. Introduction

Currently, global ecosystems are confronted with multiple severe challenges, including climate change, biodiversity loss, land degradation, food security crises, and ecosystem decline [1,2]. These challenges significantly undermine the structural integrity and functional stability of ecosystems, posing persistent threats to biodiversity and human well-being [3]. With the growing prominence of climate and environmental issues, societies have increasingly recognized the crucial role of natural ecosystems in maintaining Earth system stability and supporting socio-economic development. This awareness has further promoted the implementation of various ecological restoration measures [4–6].

To address these global challenges, early restoration efforts primarily relied on traditional gray infrastructure—such as levee construction and hard engineering—to restore or maintain certain ecosystem functions [7]. Although such engineering approaches can

effectively achieve short-term objectives like flood control and water storage, they tend to overlook the complexity, dynamism, and long-term sustainability of ecosystems. Studies have shown that these structures may disrupt hydrological processes, weaken habitat connectivity, and even pollute soil and water resources, thereby exacerbating ecological degradation and environmental risks over longer timescales [8,9]. Consequently, the international community has increasingly sought more integrated, coordinated, and ecologically friendly solutions that balance safety, cost-effectiveness, and long-term performance. In this context, Nature-based Solutions (NbS) have emerged as an innovative and holistic framework designed to complement the limitations of traditional engineering measures by harnessing natural processes to address climate, ecological, and socio-economic challenges simultaneously [10,11].

Since its introduction, NbS has been widely implemented across diverse ecosystem types worldwide, demonstrating substantial ecological, economic, and social benefits [10–12]. In recent years, the scope of NbS applications has expanded from habitat and wetland restoration to urban green infrastructure construction and agricultural landscape enhancement [10,13,14]. For example, the African Great Green Wall Program has enhanced vegetation cover in arid regions, improved ecological conditions, effectively curbed desertification, and yielded positive ecological and economic outcomes [15,16]. In Europe, the implementation of NbS in urban planning—such as expanding green spaces, optimizing landscape configuration, and increasing ecological connectivity—has significantly improved urban environmental quality and mitigated heat island effects [17]. In China, the restoration efforts in the Mu Us Desert, including shelterbelt construction, sand stabilization, and improved grassland management, have markedly reduced the frequency of sandstorms and contributed to better air quality and regional environmental conditions [18]. A substantial body of research further demonstrates that these nature-based conservation measures enhance the supply of ecosystem services, such as carbon sequestration, water regulation, and habitat quality, thereby strengthening ecosystem stability and adaptive capacity [19–21]. Moreover, the multiple co-benefits of NbS—improved ecological conditions, enhanced human health and well-being, increased climate resilience, and expanded green employment opportunities—have received growing attention [10,22].

In the context of global environmental change, NbS has increasingly become a key pathway for integrating ecosystem restoration with sustainable development. Exploring the potential of NbS to enhance ecosystem services holds significant ecological value [23] as well as substantial socio-economic relevance [21,24]. However, the performance of NbS is constrained by various factors, including climatic conditions, spatial configuration, and socio-cultural settings. Although global research on NbS continues to grow, uncertainties remain regarding its long-term effectiveness, potential trade-offs, and implementation limitations [25].

Although several recent reviews have summarized the development and applications of NbS in China, including Luo et al. [12], these studies mainly provide a general overview of NbS concepts, implementation pathways, and policy development. In contrast, this review discusses the ecological, social, and economic benefits of different NbS strategies, with particular emphasis on the ecological benefits of forest-based NbS and future research priorities under climate change. This manuscript is a narrative review and synthesis. Representative studies were identified through literature searches using keywords including “Nature-based Solutions”, “Ecosystem services”, “Climate change” and “Forest-based Solutions”. Accordingly, this paper aims to provide a comprehensive review of the core concepts and major types of NbS, with particular attention to their multiple benefits. Specifically, we (1) summarize the development of NbS and highlight representative cases from China; (2) examine the mechanisms through which NbS enhance ecosystem

services; (3) compare the multiple benefits of NbS across ecological, social, and economic dimensions; and (4) identify implementation limitations and future development pathways of NbS in China, with the goal of offering theoretical references and practical guidance for ecological restoration, sustainable forest management, and green development.

2. Evolution of the NbS Concept and Its Typology Framework

2.1. Development of the NbS Concept

NbS refer to a suite of actions that protect, sustainably manage, and restore natural or modified ecosystems to effectively and adaptively address environmental and societal challenges while simultaneously providing benefits to human well-being and maintaining biodiversity [10]. NbS aim to restore ecosystem functioning and enhance the supply of multiple ecosystem services. At their core, NbS advocate the use of ecosystem-based management approaches to strengthen overall ecosystem functioning [26,27]. Compared with traditional engineering measures, NbS exhibit greater ecological adaptability, lower economic costs, and broader multifunctional co-benefits, making them a key direction for future green development and ecological restoration [10]. In essence, NbS can be viewed as an important pathway for optimizing ecosystem service provision, as they seek to improve ecosystem structure and functional processes to enhance resilience, stability, and climate mitigation. From a long-term perspective, their ultimate objective is to support sustainable development and promote harmony between humans and nature [10,13,14] (Figure 1).

The initial development of the NbS concept was intended to guide humans in learning from nature, during which numerous nature-inspired practices emerged [28]. Its theoretical roots can be traced back to ecological restoration and ecological engineering theories in the 1970s, and the concept was formally introduced by the World Bank in the early 2000s [29]. The formal articulation of NbS marked a deeper understanding of the human–nature relationship, emphasizing that humans are not only beneficiaries of nature but also stewards responsible for protecting natural ecosystems [10,30,31].

Early research on NbS primarily focused on conceptual clarification and theoretical framework development. As international organizations continuously refined the definition, research gradually shifted toward practical applications and methodological development—including policy frameworks, cost–benefit assessment, and risk management strategies [31,32]. With the intensification of climate change and biodiversity loss, scholars and global institutions increasingly emphasized the relationship between NbS and ecosystem services, particularly the optimization of multiple objectives and enhancement of synergistic benefits [33,34].

As the concept evolved, NbS practices expanded considerably and now include approximately 20 specific pathways—such as reforestation, natural forest management, improved plantations, and conservation agriculture. These pathways aim to enhance ecosystem resilience while achieving multiple co-benefits, including climate mitigation, disaster risk reduction, and human well-being enhancement [10,14,33]. Today, NbS are recognized not only as an effective tool for environmental governance but also as a critical strategy for achieving the Sustainable Development Goals (SDGs) and fostering harmonious coexistence between humans and nature.

2.2. Major Types of NbS and Representative Studies

At present, the boundaries between NbS and related concepts remain somewhat ambiguous, and these terms are often used interchangeably—for example, Natural Climate Solutions (NCS) and Green Infrastructure (GI) [30]. As a key pathway for climate mitigation and adaptation, NbS encompasses a wide range of intervention types [30]: (1) Minimal or no human intervention in existing ecosystems, allowing natural processes to function largely

undisturbed (ecosystem conservation approach); (2) integrated management practices aimed at enhancing ecosystem service provision while maintaining long-term ecosystem sustainability (integrated ecosystem management approach); and (3) intensive human intervention or complete ecosystem transformation, potentially resulting in the creation of novel ecosystem types (ecosystem restoration or construction approach).

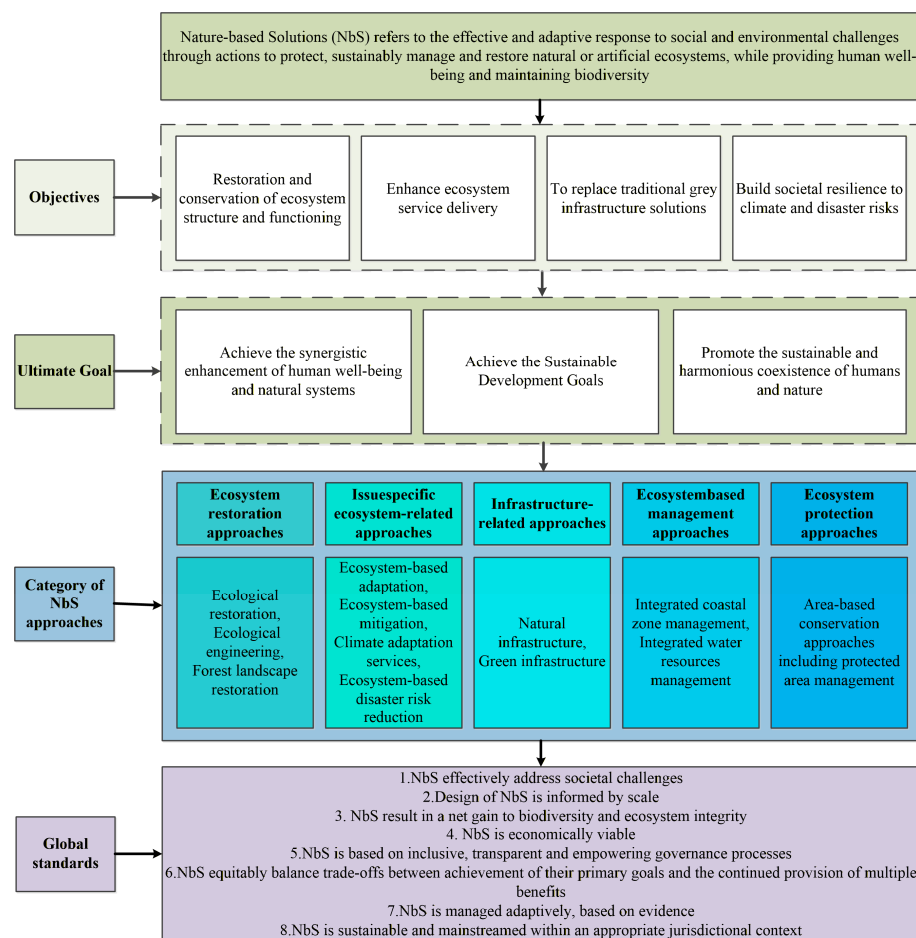


Figure 1. Objectives and global standards for the implementation of NbS. Note: Ultimate goals are based on [10,13,14], the category of NbS approaches is based on [10], and global standards are based on [35].

Building on these foundations, Cohen-Shacham et al. [10] proposed a more systematic and operational classification system comprising five major categories: ecological restoration approaches, issue-specific ecosystem-related approaches, infrastructure-related approaches, ecosystem protection approaches, and ecosystem-based management approaches (Table 1). This classification is based primarily on the mode and degree of human intervention, while also incorporating urban strategies and GI-related practices [36]. Compared with earlier frameworks, the Cohen-Shacham et al. [10] typology provides a more comprehensive and policy-relevant operational basis for NbS implementation.

In practice, NbS has been widely applied across diverse ecological management contexts worldwide [37]. The Nature Conservancy (TNC) has identified 20 NbS pathways at the global scale, including typical measures such as reforestation, avoided deforestation, and wetland restoration [38]. Although NbS offers multiple implementation options, the design of specific interventions must fully consider regional climate conditions, environmental characteristics, and landscape configurations to maximize primary benefits while balancing potential co-benefits [39,40].

Table 1. Common classifications of NbS and relevant case studies.

NbS Types	Examples	Main Features	Application Example	Ecosystem Pathways	Reference
Ecological restoration approaches.	Ecological restoration, ecological engineering, forest landscape restoration.	By restoring the structure, functions, and ecological processes of degraded or damaged ecosystems, the capacity for ecosystem service provision is enhanced.	The Three-North Shelterbelt Program, the Natural Forest Protection Program, and the Yangtze River Basin Wetland Restoration Project.	Afforestation, returning cropland to forest or grassland, preventing wetland degradation, and preventing vegetation degradation.	[10,41]
Issue-specific ecosystem-related approaches.	Ecosystem-based adaptation, ecosystem-based mitigation, ecosystem-based disaster risk reduction.	Strategies aimed at addressing specific social or environmental issues by utilizing ecosystem functions or services to provide solutions. These strategies typically focus on a particular issue, such as climate change or disaster risk.	The Sanjiangyuan Ecological Protection Project.	Grazing exclusion, artificial grass planting, and fencing for the restoration of degraded alpine grasslands.	[42]
Infrastructure-related approaches.	Natural infrastructure, green infrastructure.	Protecting, enhancing, or mimicking ecosystems or natural processes as forms of ‘infrastructure’ to deliver functions comparable to those of traditional ‘gray’ infrastructure.	Infrastructure such as green roofs, vertical greening, sponge cities, reservoirs, and canals.	Implementing vertical greening, tree planting, and grass cultivation.	[43,44]
Ecosystem protection approaches.	Area-based conservation approaches including protected area management.	Maintaining the integrity of native ecosystem structures and ecological processes through the establishment of protected areas or the implementation of regional conservation strategies.	Conservation of the Amazon Tropical Rainforest.	Establishing protected areas, preventing forest degradation, and managing natural forests.	[45]
Ecosystem-based management approaches.	Integrated coastal zone management, integrated water resources management.	Taking a holistic ecosystem-based approach by integrating multiple sectors and stakeholders to achieve coordinated resource management and sustainable development.	Ecological restoration and management of the Wuliangsuhai Basin in Inner Mongolia.	Afforestation, preventing wetland degradation, and promoting sustainable agriculture.	[46]

3. Mechanisms Through Which NbS Enhance Ecosystem Services

NbS emphasize not only the reduction in ecological risks but also the enhancement of ecosystem resistance and resilience [47]. By restoring ecosystem structure, strengthening key ecological functions, and mitigating climate-related risks, NbS comprehensively improve the supply capacity of ecosystem services and enhance overall ecosystem stability [10]. Specifically, NbS achieve their objectives through two complementary mechanisms: mitigation and adaptation. Mitigation refers to enhancing carbon sequestration and avoiding carbon emissions from ecosystems through NbS interventions, thereby lowering climate-related risks; adaptation involves improving ecosystem structure and enhancing ecological functions to increase ecosystem stability and resistance to external disturbances (Figure 2) [10,38,48]. First, the implementation of NbS measures—such as afforestation, wetland restoration, and natural forest management—helps restore spatial structure, strengthen resistance and resilience, and provide a foundation for the stable supply of ecosystem processes and services [27,49]. These measures increase vegetation cover, improve canopy complexity, and promote the development of belowground root systems, thereby restoring ecosystem structure and enhancing habitat heterogeneity. Increased vegetation cover also improves microclimatic conditions and strengthens ecological resilience by buffering ecosystems against environmental disturbances. Second, NbS enhance provisioning and regulating services by improving key ecological functions, including hydrological regu-

lation, nutrient cycling, and carbon cycling [33]. For example, forest canopies intercept precipitation and litter layers enhance surface water storage. Meanwhile, extensive root systems improve soil porosity and infiltration capacity, thereby reducing surface runoff and soil erosion while increasing groundwater recharge and water regulation. NbS further enhance carbon sequestration by increasing aboveground biomass, promoting belowground carbon storage through root development, and improving soil organic carbon accumulation. At the same time, forest conservation and peatland protection avoid greenhouse gas emissions associated with vegetation degradation and land-use change [38]. These processes collectively strengthen ecosystem functioning and enhance the long-term provision of services.

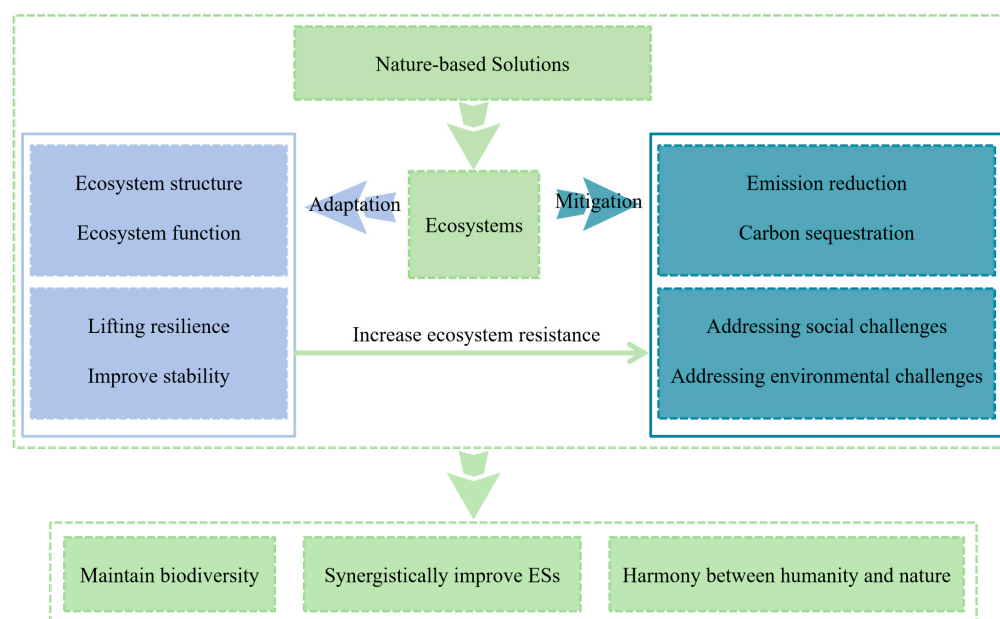


Figure 2. Mechanisms by which NbS enhance ecosystem services.

For example, the ecological restoration project in the upper Minjiang River in Sichuan, China, implemented a series of NbS measures, including the management of degraded alpine grasslands, natural forest conservation, and afforestation. As the restoration project progressed, the region's forest cover significantly increased, and regulating functions such as water conservation and soil retention were notably enhanced. The integrity of ecosystem structure and its regulatory capacity were significantly improved, yielding substantial ecological benefits. However, the total carbon storage in the river basin has decreased by 5.563×10^6 tons. The reason for this phenomenon is that this area is located in a topographic transition zone and is extremely sensitive to climate change [50–52].

Meanwhile, this project has contributed to local climate regulation and biodiversity recovery, providing essential ecological security support for the downstream Chengdu Plain and promoting regional sustainable development. This case clearly demonstrates the significant potential of NbS to enhance multiple ecosystem services, strengthen ecological resilience, and improve human well-being. Similarly, China's Natural Forest Protection Program represents another major NbS practice. The program has substantially increased forest carbon stocks, reduced carbon emissions from forest ecosystems, mitigated regional climate change, and significantly improved ecological quality within project areas [53,54]. However, the implementation of NbS also faces challenges in funding and management; ecological outcomes of NbS are not universally positive and largely depend on regional environmental conditions. For example, in arid and semi-arid regions, large-scale afforestation can increase evapotranspiration and soil water consumption, resulting in soil moisture

deficits and potential trade-offs between carbon sequestration and water regulation [55]. Therefore, the design and implementation of NbS should consider local climatic conditions, species selection, and water resource availability to maximize ecological benefits while minimizing unintended consequences.

4. Multiple Benefits of NbS

4.1. Classification of the Multiple Benefits of NbS

NbS not only play a critical role in ecosystem restoration and conservation but also generate significant co-benefits across social and economic dimensions (Table 2) [11,56]. Ecologically, NbS enhance ecosystem stability and resilience by strengthening carbon sequestration, improving hydrological processes, and restoring biodiversity [33]. Socially, NbS improve living environments, enhance public health and well-being, increase community resilience to extreme climate events, create green job opportunities, and help reduce social inequities [14]. Economically, NbS are often cost-effective, easy to maintain, and capable of generating long-term returns, such as promoting ecotourism, stimulating regional development, and increasing the value of agricultural and sideline products [7,24].

Overall, NbS commonly lead to synergistic improvements in ecological, social, and economic benefits during implementation. However, due to managerial trade-offs and regional constraints, the magnitude of these benefits may vary, often maximizing certain targeted outcomes while weakening others. For example, in China’s Kubuqi Desert restoration project, the initial goal was to curb desertification, control sandstorms, and safeguard local infrastructure and residents’ daily lives. Following implementation, the areas of forests, grasslands, and shrublands increased by 100.65%, 6.05%, and 2.24%, respectively, while the area of deserts decreased by 10.62%. Meanwhile, the GEP of Kubuqi was 55.48 billion yuan, among which the value of sandstorm prevention accounted for 39.39% [57].

Table 2. Social, economic, and ecological benefits of NbS.

Benefit Type	Category	Cases-Benefit	Reference
Social benefit	Promoting social cohesion, improving physical and mental health, enhancing well-being, and providing green jobs.	Kubuqi Desert Management—Improving the local ecological environment, reducing the occurrence of sandstorms, promoting ecotourism, creating employment opportunities, utilizing solar power generation, and advancing the development of green renewable energy.	[57–59]
		Loess Plateau Grain-to-Green Project—Improving habitat quality, increasing agricultural productivity, and enhancing the living conditions of farmers.	
Economic benefit	Providing cost-effectiveness, increasing the yield of agricultural by-products, and enhancing the economic value of ecosystems.	Loess Plateau Grain-to-Green Project—Increasing income from forest-based economies and enhancing ecological compensation for farmers. Xixi National Wetland Park Conservation Project in Hangzhou—Promoting ecotourism, driving local GDP growth, expanding sales channels for agricultural by-products in surrounding cities, and contributing to real estate value appreciation.	[60–62]

Table 2. Cont.

Benefit Type	Category	Cases-Benefit	Reference
Ecological benefits	Protecting and restoring ecosystem functions, enhancing the connectivity of natural areas, increasing biodiversity, and reducing pollution.	Dianchi Lake Ecosystem Restoration—Enhancing biodiversity, improving water quality, and restoring aquatic vegetation.	[63–65]
		Three-North Shelter Forest Program—Expanding vegetation cover, preventing wind erosion and sandstorm formation, and maintaining biodiversity. Sanjiangyuan National Park—Enhancing water conservation functions, restoring degraded grasslands, and increasing species diversity.	

4.2. Benefits of Forest-Based NbS

Forests constitute one of the largest terrestrial carbon reservoirs and provide a wide range of ecosystem services, including biodiversity conservation, water regulation, and soil retention [66]. Owing to their high biomass accumulation and complex canopy structures, forest ecosystems play a pivotal role in maintaining ecological functions and enhancing ecosystem resilience. Consequently, forest-based NbS are widely recognized as among the most promising approaches for addressing climate change and promoting sustainable ecosystem management [38]. Major forest-related NbS strategies include reforestation, natural forest management, avoided forest conversion, and improved plantation management. These interventions not only contribute to carbon sequestration but also support the simultaneous enhancement of multiple ecosystem services, generating ecological, social, and economic co-benefits.

One of the most important ecological benefits of forest-based NbS is their contribution to biodiversity conservation. Forest ecosystems provide critical habitats for a vast proportion of terrestrial species, and their vertically stratified vegetation structure creates diverse ecological niches that support species survival, reproduction, and community development [67]. Measures such as reforestation and natural forest conservation can improve habitat quality, enhance landscape connectivity, and alleviate habitat fragmentation, thereby facilitating biodiversity recovery and strengthening ecosystem functioning. Compared with monoculture plantations, natural forests and mixed-species forests generally support higher levels of biodiversity and exhibit greater ecological stability. As a result, forest restoration and conservation initiatives have received increasing attention within NbS research and practice [68].

Forest-based NbS also play a vital role in regulating hydrological processes and mitigating soil erosion. Forest vegetation can intercept precipitation, promote infiltration, and improve watershed hydrological conditions, thereby enhancing water conservation capacity and contributing to regional water security [69]. In addition, extensive root systems help stabilize soils, reduce surface runoff, and minimize soil loss. These functions are particularly important in mountainous and sloping landscapes, where soil erosion and land degradation are often severe. For example, the implementation of China’s Natural Forest Protection Program and the Three-North Shelterbelt Program has significantly reduced soil erosion and improved regional ecological conditions [64,70].

A notable characteristic of forest-based NbS is their ability to enhance multiple ecosystem services simultaneously, resulting in strong synergistic effects. Compared with some NbS strategies that primarily target specific objectives, forest restoration and conservation measures can concurrently increase carbon storage, improve biodiversity, strengthen water regulation, and enhance soil retention. Therefore, forest-based NbS are increasingly

regarded as an effective pathway for simultaneously advancing climate change mitigation, biodiversity conservation, and sustainable development goals [38].

Nevertheless, the effectiveness of forest-based NbS is influenced by climatic conditions, species composition, and management practices. For instance, large-scale afforestation in arid and semi-arid regions may increase ecosystem water consumption and potentially reduce water availability [55]. Similarly, although monoculture plantations can contribute substantially to carbon accumulation, they often provide fewer biodiversity benefits than natural forests and mixed-species stands [71].

4.3. Comparison of the Multiple Benefits of NbS

NbS demonstrate broad applicability and significant multiple benefits in enhancing ecosystem services, encompassing climate regulation, water resource management, biodiversity conservation, soil retention, and improvements in human well-being. Compared with traditional engineering measures or single-objective management approaches, NbS enhance ecosystem structure and function, enabling self-repair and sustained ecological succession, thereby creating synergistic effects among various ecosystem services [10].

However, different NbS implementation strategies exhibit certain heterogeneity in their effectiveness across ecosystem service types. First, ecosystem restoration and conservation projects—such as afforestation, forest protection, and wetland conservation—increase vegetation cover and thereby enhance carbon storage in terrestrial ecosystems, reduce atmospheric CO₂ concentrations, and mitigate global warming, resulting in substantial ecological value [38,72]. Second, issue-specific ecosystem-related approaches (e.g., sustainable agriculture, conservation tillage) effectively reduce soil carbon emissions, improve soil structure and organic matter content, and decrease topsoil erosion [73–77]. Third, infrastructure-related approaches (e.g., sponge cities, hydraulic engineering, and flood control) enhance hydrological regulation and water-cycle functionality in urban or regional contexts, thereby strengthening the capacity of urban ecosystems to withstand water-related hazards [78]. Furthermore, as climate change accelerates biodiversity loss, NbS can help slow species decline by expanding habitat areas, improving habitat quality, and increasing connectivity between habitat patches.

Overall, NbS implementation can enhance multiple ecosystem services, though the degree of improvement varies across service types [38,75,79,80]. Following Griscom's comparative framework for evaluating NbS benefits, we compared the enhancement effects of various NbS strategies (Figure 3). Many NbS strategies exhibit strong potential to improve ecosystem services, yet some strategies demonstrate particularly high effectiveness for specific services. For example, reforestation, avoided forest conversion, natural forest management, peatland restoration, and avoided peatland impacts are widely recognized as NbS pathways with substantial climate change mitigation potential [38]. Meanwhile, the “Avoided forest conversion” strategy provides substantial ecological benefits in terms of biodiversity conservation, climate stability, soil health, water quality, reduced risks of extreme events, food provision, cultural services, and health security, while offering comparatively lower social and economic benefits. In contrast, the “Improved plantations” strategy shows relatively limited potential for enhancing all three categories of benefits. This may be attributed to the relatively simple structure and species composition of plantations, their low biodiversity, and their weaker ecosystem functions. Compared with natural forests, wetland ecosystems, or mixed-species forests, plantations typically exhibit lower resistance and resilience, which leads to reduced overall benefits (Figure 3).

Peatland Restoration	+++	+	++	+++	+	++	++	++	++	++	+++	++	++	++	+++	++	+
Coastal Wetland Restoration	+	+++	+	+	+++	+++	+++	–	+++	++	+++	++	+++	++	+++	++	+
Avoided Peatland Impacts	+++	+++	+++	+++	+++	+++	+++	++	++	++	+++	++	++	++	++	+++	++
Avoided Coastal Wetland Impacts	+++	+++	+++	+++	+++	+++	+++	–	++	++	+++	++	++	++	+++	+++	++
Improved Rice Cultivation	++	++	++	++	++	+++	+	+	++	++	++	++	++	++	++	++	+
Grazing Animal Management	++	++	++	++	++	++	+	++	++	++	++	++	++	++	++	++	+
Grazing Improved Feed	+	++	++	++	++	++	–	+	++	++	++	++	++	++	++	++	+
Grazing Legumes in Pastures	++	++	++	++	++	+	–	+	++	++	++	++	++	++	++	++	++
Grazing Optimal Intensity	++	++	++	++	++	++	–	+	++	++	++	++	++	++	++	++	++
Trees in Croplands	++	++	++	+	+++	–	–	–	+++	++	++	+++	++	+++	++	+++	+++
Conservation Agriculture	+	++	++	++	+++	–	–	++	+++	++	++	+++	++	+++	++	+++	+++
Cropland Nutrient Management	++	++	++	+++	++	++	–	++	++	++	++	++	+++	++	++	+++	++
Biochar	++	++	+++	++	++	+	–	+	+	+	+	+	+	++	++	++	++
Avoided Grassland Conversion	+++	+++	++	++	+++	++	+	++	++	++	++	++	++	++	++	+++	++
Avoided Woodfuel Harvest	++	++	++	++	++	+	+	++	++	++	++	++	++	+	+	++	++
Fire Management	++	++	++	++	+++	–	–	+	++	++	+++	++	++	+	+	+++	++
Improved Plantations	+	+++	+	+	+++	+	+	–	++	++	++	++	++	++	++	++	++
Natural Forest Management	+	++	+	+	++	–	–	+++	++	++	+++	++	++	++	++	+++	++
Reforestation	++	+++	++	++	++	+++	+++	+++	++	++	++	+++	++	++	+++	++	+++
Avoided Forest Conversion	+++	+++	+++	+++	+++	+++	+++	+++	++	++	+++	++	++	++	++	+++	+++
	Biodiversity conservation	Climate stability	Soil health	Water quality	Reduced of extreme events	Food provision	Cultural services	Health security	Social cohesion	Public health	Disaster risk reduction	Jobs opportunities	Quality of life	Agricultural revenue	Ecotourism	Cost-benefit ratio	Long-term return on investment

Figure 3. Comparison of the ecological, social, and economic benefits of NbS. Note: This Figure was adapted and modified from [10], and the qualitative scores (+++, ++, +, and –) were adapted from Griscom’s standards [10]. The original assessment was based on expert synthesis of published evidence regarding the relative potential of each NCS pathway to provide ecological, social, and economic co-benefits. In the present review, these scores were retained and reorganized to facilitate comparison among different NbS strategies. “+” represents low benefit, “++” represents moderate benefit, and “+++” represents high benefit, with “–” indicating no data available. The ecological benefits include biodiversity conservation, climate stability, soil health, water quality, reduced risks of extreme events, food provision, cultural services, and health security. The social benefits include social cohesion, public health, disaster risk reduction, job opportunities, and quality of life. The economic benefits include agricultural revenue, ecotourism, cost–benefit ratio, and long-term return on investment.

5. Challenges and Limitations in the Implementation of NbS

Despite the advantages of NbS, such as cost-effectiveness and high ecological value relative to conventional industrial approaches, its role has been insufficiently emphasized in historical climate policies and governance frameworks. Moreover, the practical implementation of NbS still faces numerous challenges and limitations that may hinder their effectiveness and scalability [33,81].

5.1. Implementation Challenges

The effective implementation of NbS requires substantial financial investment, technical expertise, and robust policy support. However, these foundational prerequisites are often difficult to meet in practice. Large-scale ecological restoration projects (such as afforestation, wetland rehabilitation, and watershed management) typically require long-term national-level planning and coordination, demanding considerable human, financial, and material resources [82,83]. Furthermore, NbS often exhibits delayed ecological effects; while their long-term benefits may be substantial, their short-term economic and social returns are limited, which can dampen public interest and policy-maker commitment [25,33]. In addition, the lack of interdisciplinary technical expertise poses a significant barrier. The design and implementation of NbS rely on integrated knowledge across ecology, environ-

mental science, hydrology, and engineering. In under-resourced or developing regions, insufficient technical capacity can result in poorly executed interventions, potentially leading to suboptimal restoration outcomes or even secondary ecological damage [33]. Policy and institutional supports are also critical to the long-term success of NbS, especially in areas such as land-use planning, funding allocation, and environmental regulation. Nevertheless, in many regions, relevant policies and institutional mechanisms are either lacking or inadequately enforced, making it difficult to ensure the continuity and effectiveness of NbS initiatives [84]. Collectively, these constraints limit the widespread adoption and integration of NbS into mainstream climate governance frameworks.

5.2. The Response of Ecosystems Exhibits Uncertainty

NbS relies on natural ecological processes, which are inherently variable and sensitive to environmental drivers, resulting in significant uncertainty in ecosystem responses. Natural ecosystems exhibit divergent reactions to climate change and anthropogenic disturbances, depending on regional conditions and species composition [85]. The capacity for ecological recovery and service provision can vary substantially across geographic locations and habitat types, leading to heterogeneous outcomes when implementing identical NbS strategies in different contexts [86]. Moreover, ecological processes often exhibit time lags. Some NbS measures may produce minimal or even adverse ecological outcomes in the short term, with their full benefits only becoming evident after several years or decades [83,87]. For example, during the early phases of forest restoration, young trees have limited carbon sequestration capacity, and forest stands may initially act as net carbon sources. Only over the medium-to-long term do these forests transition into net carbon sinks, as biomass accumulates and ecosystem processes stabilize [88].

5.3. The Trade-Offs Between Ecosystem Services

A fundamental challenge in implementing NbS lies in managing the trade-offs between multiple ecosystem services. Although natural ecosystems are inherently multifunctional, NbS interventions often enhance one service at the expense of others [89,90]. For instance, vegetation restoration can significantly improve carbon sequestration, but increased plant transpiration may lead to elevated water consumption [91]. In arid and semi-arid regions, this can deplete groundwater resources, adversely affecting agricultural irrigation and drinking water availability [55,92]. Similarly, efforts to restore biodiversity through forest expansion can reduce land available for agriculture, potentially compromising food production and food security [93,94]. These examples underscore the importance of adopting a systems-thinking approach in NbS planning, one that carefully evaluates potential trade-offs and strives to balance competing ecosystem service objectives through adaptive management and participatory governance.

6. Future Research Directions and Recommendations

With the intensification of climate change and increasing anthropogenic pressures, effectively mitigating global warming and curbing ecosystem degradation have become urgent international priorities [95]. As a promising approach for both climate mitigation and adaptation, NbS has already demonstrated considerable potential through a growing body of research and practical case studies, particularly those involving forest-based strategies such as reforestation, natural forest management, and forest landscape restoration. However, in light of the dynamic and uncertain nature of future climate scenarios, further investigation is needed to clarify the mechanisms underlying ecosystem responses to NbS. Equally important is the establishment of a robust monitoring and assessment framework to support the scientific advancement and systematic implementation of NbS.

6.1. Establishing a Monitoring and Evaluation System for NbS Benefits

Given the complexity of ecosystem service trade-offs, the uncertainty of ecological responses, the time-lag in benefit realization, and the variability of outcomes across regions, long-term monitoring and quantitative evaluation of NbS is essential [96]. Particular attention should be paid to the long-term monitoring of forest-based NbS, including natural forest protection and forest restoration, to better understand their impacts on carbon sequestration, biodiversity conservation, water regulation, and other ecosystem services. Continuous, dynamic assessment enables early identification of implementation challenges, helps avoid negative trade-offs, and supports the timely optimization of management strategies to promote synergistic ecological gains. To this end, three key actions are required. First, a comprehensive monitoring indicator system should be established to represent various ecosystem service functions, along with standardized protocols for data collection and monitoring techniques. Second, long-term tracking mechanisms must be developed to assess temporal trends and spatial variability in ecosystem service outcomes, thereby facilitating more precise evaluations of ecological benefits. Third, based on accumulated monitoring data, evaluation methodologies should be continuously refined to improve the accuracy and reliability of NbS performance assessments.

6.2. Conducting Interdisciplinary Collaborative Research

Climate change is a multifaceted environmental and social issue, and the effective research and deployment of NbS demands interdisciplinary collaboration across fields such as ecology, geography, environmental engineering, and socio-economics [14,21]. Future efforts should aim to deepen such collaboration from several perspectives. First, to maximize the potential of NbS, it is essential to strengthen cost–benefit analyses and identify priority areas, thereby clarifying context-specific pathways for implementation under varying climate and socio-economic conditions [97]. Second, interdisciplinary teams should be formed to develop integrated models and decision-support tools that combine climate forecasting, ecosystem service modeling, and socio-economic assessments. These tools can provide multidimensional data and evidence for policy formulation and NbS implementation. Third, greater efforts are needed to conduct cross-regional and cross-scale comparisons of NbS outcomes, with particular emphasis on developing integrated assessment frameworks that link forest carbon sequestration, biodiversity conservation, and water regulation. Such studies would help identify both general patterns and context-specific responses of NbS to climate change across different regions and spatial scales, thereby providing a stronger scientific basis for ecological restoration planning and decision-making.

6.3. Strengthening Policy Support and Public Participation Mechanisms

The successful implementation of NbS as a climate and ecosystem strategy hinges on the presence of comprehensive policy frameworks and inclusive public participation mechanisms. Strong policy support not only ensures the provision of financial and technical resources but also promotes the scientific rigor and institutional standardization of NbS through legal and regulatory instruments. Simultaneously, governments and public institutions can play a central role in establishing social financing mechanisms for NbS, incentivizing private sector involvement in environmental governance. Such collaboration fosters synergistic interactions among natural capital, financial capital, and social capital. Moreover, widespread public participation enhances local relevance, improves environmental awareness, and fosters alignment between ecological conservation and community development. Therefore, future efforts should focus on improving incentive mechanisms, fostering participatory governance, and enhancing public environmental awareness to

establish long-term policy support mechanisms for the effective implementation and sustainability of forest-based NbS initiatives.

Author Contributions: Conceptualization, J.G., L.C., and L.H.; resources, S.Z.; writing—original draft preparation, J.G.; writing—review and editing, X.W.; supervision, J.L.; funding acquisition, J.L. All authors have read and agreed to the published version of the manuscript.

Funding: This study was supported by the National Key Research and Development Program of China (No. 2023YFE0112804).

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

- Shukla, P.R.; Skea, J.; Slade, R.; Al Khourdajie, A.; van Diemen, R.; McCollum, D.; Pathak, M.; Some, S.; Vyas, P.; Fradera, R.; et al. Climate Change 2022: Impacts, Adaptation and Vulnerability. In *Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; IPCC: Geneva, Switzerland, 2022.
- IPBES. *Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*; IPBES: Bonn, Germany, 2019.
- Millennium Ecosystem Assessment (Program). *Ecosystems and Human Well-Being: Synthesis*; Island Press: Washington, DC, USA, 2005.
- Costanza, R.; d'Arge, R.; de Groot, R.; Farber, S.; Grasso, M.; Hannon, B.; Limburg, K.; Naeem, S.; O'Neill, R.V.; Paruelo, J.; et al. The value of the world's ecosystem services and natural capital. *Nature* **1997**, *387*, 253–260. [[CrossRef](#)]
- Daily, G.C.; Söderqvist, T.; Aniyar, S.; Arrow, K.; Dasgupta, P.; Ehrlich, P.R.; Folke, C.; Jansson, A.; Jansson, B.-O.; Kautsky, N.; et al. The value of nature and the nature of value. *Science* **2000**, *289*, 395–396. [[CrossRef](#)] [[PubMed](#)]
- IPCC. *Climate Change Widespread, Rapid, and Intensifying*; IPCC: Geneva, Switzerland, 2021.
- Browder, G.; Ozment, S.; Rehberger Bescos, I.; Gartner, T.; Lange, G.-M. *Integrating Green and Gray: Creating Next Generation Infrastructure*; World Resources Institute: Washington, DC, USA, 2019.
- Palmer, M.A.; Liu, J.; Matthews, J.H.; Mumba, M.; D'Odorico, P. Water security: Gray or green? *Science* **2015**, *349*, 584–585. [[CrossRef](#)] [[PubMed](#)]
- Christopher, N.; Vachette, A.; Horne, A.; Kosovac, A. Enhancing river floodplain management with nature-based solutions: Overcoming barriers and harnessing enablers. *WIREs Water* **2024**, *11*, e1723. [[CrossRef](#)]
- Cohen-Shacham, E.; Walters, G.; Janzen, C.; Maginnis, S. *Nature-Based Solutions to Address Global Societal Challenges*; IUCN: Gland, Switzerland, 2016; xiii + 97pp.
- WEF. *Nature and Net Zero*; World Economic Forum: Geneva, Switzerland, 2021. Available online: <https://www.weforum.org/publications/nature-and-net-zero/> (accessed on 22 November 2024).
- Luo, M.; Cai, J.; Zeng, Z.; Zheng, Y.; Lin, T. Development and practices of nature-based solutions in China. *Nat.-Based Solut.* **2024**, *5*, 100109. [[CrossRef](#)]
- Seddon, N.; Smith, A.; Smith, P.; Key, I.; Chausson, A.; Girardin, C.; House, J.; Srivastava, S.; Turner, B. Getting the message right on nature-based solutions to climate change. *Glob. Change Biol.* **2021**, *27*, 1518–1546. [[CrossRef](#)]
- Raymond, C.M.; Frantzeskaki, N.; Kabisch, N.; Berry, P.; Breil, M.; Nita, M.R.; Geneletti, D.; Calfapietra, C. A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. *Environ. Sci. Policy* **2017**, *77*, 15–24. [[CrossRef](#)]
- Goffner, D.; Sinare, H.; Gordon, L.J. The Great Green Wall for the Sahara and the Sahel Initiative as an opportunity to enhance resilience in Sahelian landscapes and livelihoods. *Reg. Environ. Change* **2019**, *19*, 1417–1428. [[CrossRef](#)]
- Mirzabaev, A.; Sacande, M.; Motlagh, F.; Shyrokaya, A.; Martucci, A. Economic efficiency and targeting of the African Great Green Wall. *Nat. Sustain.* **2022**, *5*, 17–25.
- Cortinovis, C.; Olsson, P.; Boke-Olén, N.; Hedlund, K. Scaling up nature-based solutions for climate-change adaptation: Potential and benefits in three European cities. *Urban For. Urban Green.* **2022**, *67*, 127450. [[CrossRef](#)]
- Davies, C.; Wang, B.; Brack, D.; Qin, Q. Nature-Based Solutions: Lessons from European and Chinese Case Studies; EU–China Cooperation on Environment and Green Economy Project. 2024. Available online: <https://dml.or.id/nature-based-solutions-lessons-from-european-and-chinese-case-studies/> (accessed on 23 April 2025).
- Acreman, M.; Holden, J. How Wetlands Affect Floods. *Wetlands* **2013**, *33*, 773–786. [[CrossRef](#)]

20. Nesshöver, C.; Assmuth, T.; Irvine, K.N.; Rusch, G.M.; Waylen, K.A.; Delbaere, B.; Haase, D.; Jones-Walters, L.; Keune, H.; Kovacs, E.; et al. The science, policy and practice of nature-based solutions: An interdisciplinary perspective. *Sci. Total Environ.* **2017**, *579*, 1215–1227. [[CrossRef](#)] [[PubMed](#)]
21. Kabisch, N.; Korn, H.; Stadler, J.; Bonn, A. *Nature-Based Solutions to Climate Change Adaptation in Urban Areas: Linkages Between Science, Policy and Practice*; Springer International Publishing: Cham, Switzerland, 2017.
22. Chang, C.H.; Erbaugh, J.T.; Fajardo, P.; Lu, L.; Molnár, I.; Papp, D.; Robinson, B.E.; Austin, K.G.; Castro, M.; Cheng, S.H.; et al. Global evidence of human well-being and biodiversity impacts of natural climate solutions. *Nat. Sustain.* **2024**, *8*, 75–85. [[CrossRef](#)]
23. Keesstra, S.; Nunes, J.; Novara, A.; Finger, D.; Avelar, D.; Kalantari, Z.; Cerda, A. The superior effect of nature based solutions in land management for enhancing ecosystem services. *Sci. Total Environ.* **2018**, *610*, 997–1009. [[CrossRef](#)] [[PubMed](#)]
24. Chausson, A.; Smith, A.; Reger, R.Z.-Z.; O'Callaghan, B.; Clement, Y.M.; Zapata, F.; Seddon, N. Harnessing nature-based solutions for economic recovery: A systematic review. *PLoS Clim.* **2024**, *3*, e0000281. [[CrossRef](#)]
25. Wang, J.; Xu, J. Nature-based solutions for addressing biodiversity loss and climate change: Progress, challenges and suggestions. *Biodivers. Sci.* **2023**, *31*, 22496. [[CrossRef](#)]
26. Benayas, J.M.R.; Newton, A.C.; Diaz, A.; Bullock, J.M. Enhancement of Biodiversity and Ecosystem Services by Ecological Restoration: A Meta-Analysis. *Science* **2009**, *325*, 1121–1124. [[CrossRef](#)]
27. UNEP. *Background Paper Prepared by UNEP to Support the Intergovernmental Consultations on Nature-Based Solutions*; UNEP: Nairobi, Kenya, 2023.
28. Grant, G. *Ecosystem Services Come to Town: Greening Cities by Working with Nature*, 1st ed.; John Wiley & Sons, Incorporated: Chichester, UK, 2012.
29. Kathy, M.; Claudia, S.; Hickey, V. *Biodiversity, Climate Change, and Adaptation: Nature-Based Solutions from the World Bank Portfolio*; World Bank: Washington, DC, USA, 2008.
30. Eggermont, H.; Balian, E.; Azevedo, J.M.N.; Beumer, V.; Brodin, T.; Claudet, J.; Fady, B.; Grube, M.; Keune, H.; Lamarque, P.; et al. Nature-based Solutions: New Influence for Environmental Management and Research in Europe. *GAIA-Ecol. Perspect. Sci. Soc.* **2015**, *24*, 243–248. [[CrossRef](#)]
31. Raymond, C.M.; Berry, P.; Breil, M.; Nita, M.R.; Kabisch, N.; Bel, M.D.; Enzi, V.; Frantzeskaki, N.; Geneletti, D.; Cardinaletti, M.; et al. *An Impact Evaluation Framework to Support Planning and Evaluation of Nature-Based Solutions Projects Report Prepared by the EKLIPSE Expert Working Group on Nature-Based Solutions to Promote Climate Resilience in Urban Areas*; Centre for Ecology and Hydrology: Wallingford, UK, 2017.
32. Kabisch, N.; Frantzeskaki, N.; Pauleit, S.; Naumann, S.; Davis, M.; Artmann, M.; Haase, D.; Knapp, S.; Korn, H.; Stadler, J.; et al. Nature-based solutions to climate change mitigation and adaptation in urban areas: Perspectives on indicators, knowledge gaps, barriers, and opportunities for action. *Ecol. Soc.* **2016**, *21*, 2. [[CrossRef](#)]
33. Seddon, N.; Chausson, A.; Berry, P.; Girardin, C.A.J.; Smith, A.; Turner, B. Understanding the value and limits of nature-based solutions to climate change and other global challenges. *Philos. Trans. R. Soc. B* **2020**, *375*, 1794. [[CrossRef](#)]
34. Chausson, A.; Turner, B.; Seddon, D.; Chabaneix, N.; Girardin, C.A.J.; Kapos, V.; Key, I.; Roe, D.; Smith, A.; Woroniecki, S.; et al. Mapping the effectiveness of nature-based solutions for climate change adaptation. *Glob. Change Biol.* **2020**, *26*, 6134–6155. [[CrossRef](#)]
35. IUCN. *Guidance for Using the IUCN Global Standard for Nature-Based Solutions*, 1st ed.; IUCN: Gland, Switzerland, 2020.
36. Krull, W.; Berry, P.; Bauduceau, N.; Elmqvist, T.; Fernandez, M.; Hartig, T.; Mayerhofer, E.; Naumann, S.; Noring, L.; Raskin, K.; et al. Towards an EU research and innovation policy agenda for nature-based solutions & re-naturing cities. In *Final Report of the Horizon 2020 Expert Group on “Nature-Based Solutions and Re-Naturing Cities”*; European Commission: Brussels, Belgium, 2015.
37. Girardin, C.A.J.; Jenkins, S.; Seddon, N.; Allen, M.; Lewis, S.L.; Wheeler, C.E.; Griscom, B.W.; Malhi, Y. Nature-based solutions can help cool the planet—If we act now. *Nature* **2021**, *593*, 191–194. [[CrossRef](#)] [[PubMed](#)]
38. Griscom, B.W.; Adams, J.; Ellis, P.W.; Houghton, R.A.; Lomax, G.; Miteva, D.A.; Schlesinger, W.H.; Shoch, D.; Siikamäki, J.V.; Smith, P.; et al. Natural climate solutions. *Proc. Natl. Acad. Sci. USA* **2017**, *114*, 11645–11650. [[CrossRef](#)] [[PubMed](#)]
39. Li, Y.; Wang, G.; Chen, T.; Zhang, R.; Zhou, L.; Yan, L. Nature-Based Solutions in “Forest-Wetland” Spatial Planning Strategies to Promote Sustainable City Development in Tianjin, China. *Land* **2022**, *11*, 1227. [[CrossRef](#)]
40. Corgo, J.; Cruz, S.S.; Conceição, P. Nature-based solutions in spatial planning and policies for climate change adaptation: A literature review. *Ambio* **2024**, *53*, 1599–1617. [[CrossRef](#)] [[PubMed](#)]
41. Li, C.; Fu, B.; Wang, S.; Stringer, L.C.; Wang, Y.; Li, Z.; Liu, Y.; Zhou, W. Drivers and impacts of changes in China's drylands. *Nat. Rev. Earth Environ.* **2021**, *2*, 858–873. [[CrossRef](#)]
42. Shao, Q.; Fan, J.; Liu, J.; Lin, H.; Cao, W.; Xu, X.; Ge, J.; Wu, D.; Li, Z.; Gong, G.; et al. Assessment on the effects of the first-stage ecological conservation and restoration project in Sanjiangyuan region. *Acta Geogr. Sin.* **2016**, *71*, 3–20.
43. Chan, F.K.S.; Griffiths, J.; Higgitt, D.; Xu, S.; Zhu, F.; Tang, Y.T.; Xu, Y.; Thorne, C.R. “Sponge City” in China—A breakthrough of planning and flood risk management in the urban context. *Land Use Policy* **2018**, *76*, 772–778. [[CrossRef](#)]

44. Tan, P.Y.; Wang, J.; Sia, A. Perspectives on five decades of the urban greening of Singapore. *Cities* **2013**, *32*, 24–32. [[CrossRef](#)]
45. Nepstad, D.; Soares-Filho, B.S.; Merry, F.; Lima, A.; Moutinho, P.; Carter, J.; Bowman, M.; Cattaneo, A.; Rodrigues, H.; Schwartzman, S.; et al. The End of Deforestation in the Brazilian Amazon. *Science* **2009**, *326*, 1350–1351. [[CrossRef](#)] [[PubMed](#)]
46. Lü, C.-W.; He, J.; Liang, Y.; Mao, H.-F.; Liu, H.-L.; Wang, F.-J. Temporal and spatial distribution of biogenic silica and its significance in the Wuliangshuai Lake and Daihai Lake. *Acta Ecol. Sin.* **2010**, *30*, 100–105. [[CrossRef](#)]
47. Van Zanten, B.T.; Gutierrez Goizueta, G.; Brander, L.M.; Gonzalez Reguero, B.; Griffin, R.; Macleod, K.K.; Alves Beloqui, A.I.; Midgley, A.; Herrera Garcia, L.D.; Jongman, B. *Assessing the Benefits and Costs of Nature-Based Solutions for Climate Resilience: A Guideline for Project Developers*; World Bank: Washington, DC, USA, 2023.
48. Pörtner, H.-O.; Scholes, R.J.; Agard, J.; Archer, E.; Bai, X.; Barnes, D.; Burrows, M.; Chan, L.; Cheung, W.L.; Diamond, S.; et al. *Co-Sponsored Workshop Report on Biodiversity and Climate Change*; Zenodo: Geneva, Switzerland, 2021.
49. Turner, B.; Devisscher, T.; Chabaneix, N.; Woroniecki, S.; Messier, C.; Seddon, N. The Role of Nature-Based Solutions in Supporting Social-Ecological Resilience for Climate Change Adaptation. *Annu. Rev. Environ. Resour.* **2022**, *47*, 123–148. [[CrossRef](#)]
50. Gu, Z.; Chen, X.; Ruan, W.; Zheng, M.; Gen, K.; Li, X.; Deng, H.; Chen, Y.; Liu, M. Quantifying the direct and indirect effects of terrain, climate and human activity on the spatial pattern of kNDVI-based vegetation growth: A case study from the Minjiang River Basin, Southeast China. *Ecol. Inform.* **2024**, *80*, 102493. [[CrossRef](#)]
51. Qin, M.; Wu, X.; Zhou, Y.; Li, X.; Jiang, H.; Luo, D.; Liu, Y.; Ouyang, H. How is carbon storage in plateau-plain transition zone influenced? Evidence from Minjiang River Basin, China. *J. Clean. Prod.* **2025**, *491*, 144766. [[CrossRef](#)]
52. Sun, P.; Liu, S.; Jiang, H.; Lü, Y.; Liu, J.; Lin, Y.; Liu, X. Hydrologic Effects of NDVI Time Series in a Context of Climatic Variability in an Upstream Catchment of the Minjiang River. *JAWRA J. Am. Water Resour. Assoc.* **2008**, *44*, 1132–1143. [[CrossRef](#)]
53. Wu, S.; Li, J.; Zhou, W.; Lewis, B.J.; Yu, D.; Zhou, L.; Jiang, L.; Dai, L. A statistical analysis of spatiotemporal variations and determinant factors of forest carbon storage under China's Natural Forest Protection Program. *J. For. Res.* **2018**, *29*, 415–424.
54. Zhou, W.; Lewis, B.J.; Wu, S.; Yu, D.; Zhou, L.; Wei, Y.; Dai, L. Biomass carbon storage and its sequestration potential of afforestation under natural forest protection program in China. *Chin. Geogr. Sci.* **2014**, *24*, 406–413. [[CrossRef](#)]
55. Wang, Q.; Liu, H.; Liang, B.; Shi, L.; Wu, L.; Cao, J. Will large-scale forestation lead to a soil water deficit crisis in China's drylands? *Sci. Bull.* **2024**, *69*, 1506–1514. [[CrossRef](#)]
56. OenA, M. Nature-Based Solutions Are Gaining Momentum from International Initiatives Promoting Environmental, Social, and Economic Benefits. *Integr. Environ. Assess. Manag.* **2019**, *15*, 830–831. [[CrossRef](#)]
57. Liu, Y.; Kong, L.; Jiang, C.; Zhang, X.; Ouyang, Z. Accounting of value of ecosystem services in the desert: An example of the Kubuqi Desert ecosystem. *Front. Earth Sci.* **2024**, *11*, 1247367. [[CrossRef](#)]
58. UNEP. *Review of the Kubuqi Ecological Restoration Project: A Desert Green Economy Pilot Initiative*; United Nations Environment Programme (UNEP): Nairobi, Kenya, 2015.
59. Wu, X.; Wang, S.; Fu, B.; Feng, X.; Chen, Y. Socio-ecological changes on the Loess Plateau of China after Grain to Green Program. *Sci. Total Environ.* **2019**, *678*, 565–573. [[CrossRef](#)] [[PubMed](#)]
60. Ouyang, Z.; Zheng, H.; Xiao, Y.; Polasky, S.; Liu, J.; Xu, W.; Wang, Q.; Zhang, L.; Xiao, Y.; Rao, E.; et al. Improvements in ecosystem services from investments in natural capital. *Science* **2016**, *352*, 1455–1459. [[CrossRef](#)] [[PubMed](#)]
61. Wang, B.; Zheng, X.; Zhang, H.; Xiao, F.; Gu, H.; Zhang, K.; He, Z.; Liu, X.; Yan, Q. Bacterial community responses to tourism development in the Xixi National Wetland Park, China. *Sci. Total Environ.* **2020**, *720*, 137570. [[CrossRef](#)] [[PubMed](#)]
62. Guo, R.-Z.; Lin, L.; Xu, J.-F.; Dai, W.-H.; Song, Y.-B.; Dong, M. Spatio-temporal characteristics of cultural ecosystem services and their relations to landscape factors in Hangzhou Xixi National Wetland Park, China. *Ecol. Indic.* **2023**, *154*, 110910. [[CrossRef](#)]
63. Zhang, Z.; Li, J.; Lu, Y.; Yang, L.; Hu, Z.; Li, C.; Yang, X. Temporal and spatial changes in land use and ecosystem service value based on SDGs' reports: A case study of Dianchi Lake Basin, China. *Environ. Sci. Pollut. Res. Int.* **2023**, *30*, 31421–31435. [[PubMed](#)]
64. Quanqin, S.; Wei, C.A.O.; Jiangwen, F.A.N.; Huang, L.; Xinliang, X.U. Effects of an ecological conservation and restoration project in the Three-River Source Region, China. *J. Geogr. Sci.* **2017**, *27*, 183–204.
65. Zhai, J.; Wang, L.; Liu, Y.; Wang, C.; Mao, X. Assessing the effects of China's Three-North Shelter Forest Program over 40 years. *Sci. Total Environ.* **2023**, *857*, 159354. [[CrossRef](#)] [[PubMed](#)]
66. Tang, X.; Zhao, X.; Bai, Y.; Tang, Z.; Wang, W.; Zhao, Y.; Wan, H.; Xie, Z.; Shi, X.; Wu, B.; et al. Carbon pools in China's terrestrial ecosystems: New estimates based on an intensive field survey. *Proc. Natl. Acad. Sci. USA* **2018**, *115*, 4021–4026. [[CrossRef](#)] [[PubMed](#)]
67. Wiegand, T.; Wang, X.; Fischer, S.M.; Kraft, N.J.B.; Bourg, N.A.; Brockelman, W.Y.; Cao, G.; Cao, M.; Chanthorn, W.; Chu, C.; et al. Latitudinal scaling of aggregation with abundance and coexistence in forests. *Nature* **2025**, *640*, 967–973. [[CrossRef](#)] [[PubMed](#)]
68. Guo, Q.; Ren, H. Productivity as related to diversity and age in planted versus natural forests. *Glob. Ecol. Biogeogr.* **2014**, *23*, 1461–1471. [[CrossRef](#)]
69. Cui, J.; Lian, X.; Huntingford, C.; Gimeno, L.; Wang, T.; Ding, J.; He, M.; Xu, H.; Chen, A.; Gentile, P.; et al. Global water availability boosted by vegetation-driven changes in atmospheric moisture transport. *Nat. Geosci.* **2022**, *15*, 982–988. [[CrossRef](#)]

70. Huang, L.; Wang, B.; Niu, X.; Gao, P.; Song, Q. Changes in ecosystem services and an analysis of driving factors for China's Natural Forest Conservation Program. *Ecol. Evol.* **2019**, *9*, 3700–3716. [[CrossRef](#)] [[PubMed](#)]
71. Gurevitch, J. Managing forests for competing goals. *Science* **2022**, *376*, 792–793. [[CrossRef](#)] [[PubMed](#)]
72. Pan, Y.; Birdsey, R.A.; Fang, J.; Houghton, R.; Kauppi, P.E.; Kurz, W.A.; Phillips, O.L.; Shvidenko, A.; Lewis, S.L.; Canadell, J.G.; et al. A Large and Persistent Carbon Sink in the World's Forests. *Science* **2011**, *333*, 988–993. [[CrossRef](#)] [[PubMed](#)]
73. Lal, R. Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. *Science* **2004**, *304*, 1623–1627. [[CrossRef](#)] [[PubMed](#)]
74. Bossio, D.A.; Cook-Patton, S.C.; Ellis, P.W.; Fargione, J.; Sanderman, J.; Smith, P.; Wood, S.; Zomer, R.J.; von Unger, M.; Emmer, I.M.; et al. The role of soil carbon in natural climate solutions. *Nat. Sustain.* **2020**, *3*, 391–398. [[CrossRef](#)]
75. Miralles-Wilhelm, F. *Nature-Based Solutions in Agriculture: Sustainable Management and Conservation of Land, Water and Biodiversity*; FAO and TNC: Rome, Italy, 2021.
76. Demozzi, T.; Oberč, B.P.; Prieto López, A.; Larbodièrre, L.; Borges, M.A. *Sustainable Agriculture and Nature-Based Solutions*; IUCN, International Union for Conservation of Nature: Gland, Switzerland, 2024.
77. Teng, J.; Hou, R.; Dungait, J.A.J.; Zhou, G.; Kuzyakov, Y.; Zhang, J.; Tian, J.; Cui, Z.; Zhang, F.; Delgado-Baquerizo, M. Conservation agriculture improves soil health and sustains crop yields after long-term warming. *Nat. Commun.* **2024**, *15*, 8785. [[CrossRef](#)] [[PubMed](#)]
78. Temmerman, S.; Meire, P.; Bouma, T.J.; Herman, P.M.J.; Ysebaert, T.; De Vriend, H.J. Ecosystem-based coastal defence in the face of global change. *Nature* **2013**, *504*, 79–83. [[CrossRef](#)] [[PubMed](#)]
79. UNEP; IUCN. *Nature-Based Solutions for Climate Change Mitigation*; UNEP: Nairobi, Kenya; IUCN: Gland, Switzerland, 2021.
80. Seymour, F.; Langer, P. *Consideration of Nature-Based Solutions as Offsets in Corporate Climate Change Mitigation Strategies*; Working Paper; World Resources Institute: Washington, DC, USA, 2021.
81. Dunlop, T.; Khojasteh, D.; Cohen-Shacham, E.; Glamore, W.; Haghani, M.; van den Bosch, M.; Rizzi, D.; Greve, P.; Felder, S. The evolution and future of research on Nature-based Solutions to address societal challenges. *Commun. Earth Environ.* **2024**, *5*, 132. [[CrossRef](#)]
82. Sudmeier-Rieux, K.; Arce-Mojica, T.; Boehmer, H.J.; Doswald, N.; Emerton, L.; Friess, D.A.; Galvin, S.; Hagenlocher, M.; James, H.; Laban, P.; et al. Scientific evidence for ecosystem-based disaster risk reduction. *Nat. Sustain.* **2021**, *4*, 803–810. [[CrossRef](#)]
83. Wu, D.; Zhao, X.; Liang, S.; Zhou, T.; Huang, K.; Tang, B.; Zhao, W. Time-lag effects of global vegetation responses to climate change. *Glob. Change Biol.* **2015**, *21*, 3520–3531. [[CrossRef](#)]
84. Debele, S.E.; Leo, L.S.; Kumar, P.; Sahani, J.; Ommer, J.; Bucchignani, E.; Vranić, S.; Kalas, M.; Amirzada, Z.; Pavlova, I.; et al. Nature-based solutions can help reduce the impact of natural hazards: A global analysis of NBS case studies. *Sci. Total Environ.* **2023**, *902*, 165824. [[CrossRef](#)] [[PubMed](#)]
85. Chazdon, R.L. Beyond Deforestation: Restoring Forests and Ecosystem Services on Degraded Lands. *Science* **2008**, *320*, 1458–1460. [[CrossRef](#)] [[PubMed](#)]
86. Standish, R.J.; Parkhurst, T. Interventions for resilient nature-based solutions: An ecological perspective. *J. Ecol.* **2024**, *112*, 2502–2509. [[CrossRef](#)]
87. Gong, H.; Wang, G.; Fan, C.; Zhuo, X.; Sha, L.; Kuang, Z.; Bi, J.; Cheng, T. Temporal accumulation and lag effects of precipitation on carbon fluxes in terrestrial ecosystems across semi-arid regions in China. *Agric. For. Meteorol.* **2024**, *356*, 110189. [[CrossRef](#)]
88. Yao, L.; Liu, T.; Qin, J.; Jiang, H.; Yang, L.; Smith, P.; Chen, X.; Zhou, C.; Piao, S. Carbon sequestration potential of tree planting in China. *Nat. Commun.* **2024**, *15*, 8398. [[CrossRef](#)] [[PubMed](#)]
89. Wang, X.; Peng, J.; Luo, Y.; Qiu, S.; Dong, J.; Zhang, Z.; Vercruyse, K.; Grabowski, R.C.; Meersmans, J. Exploring social-ecological impacts on trade-offs and synergies among ecosystem services. *Ecol. Econ.* **2022**, *197*, 107438. [[CrossRef](#)]
90. Mazziotto, A.; Lundstrom, J.; Forsell, N.; Moor, H.; Eggers, J.; Subramanian, N.; Aquilue, N.; Moran-Ordóñez, A.; Brotons, L.; Snall, T. More future synergies and less trade-offs between forest ecosystem services with natural climate solutions instead of bioeconomy solutions. *Glob. Change Biol.* **2022**, *28*, 6333–6348. [[CrossRef](#)]
91. Peng, S.; Terrer, C.; Smith, B.; Ciais, P.; Han, Q.; Nan, J.; Fisher, J.B.; Chen, L.; Deng, L.; Yu, K. Carbon restoration potential on global land under water resource constraints. *Nat. Water* **2024**, *2*, 1071–1081. [[CrossRef](#)]
92. Jackson, R.B.; Jobbágy, E.G.; Avissar, R.; Roy, S.B.; Barrett, D.J.; Cook, C.W.; Farley, K.A.; le Maitre, D.C.; McCarl, B.A.; Murray, B.C. Trading water for carbon with biological carbon sequestration. *Science* **2005**, *310*, 1944–1947. [[CrossRef](#)] [[PubMed](#)]
93. Phalan, B.; Balmford, A.; Green, R.E.; Scharlemann, J.P.W. Minimising the harm to biodiversity of producing more food globally. *Food Policy* **2011**, *36*, S62–S71. [[CrossRef](#)]
94. Hua, F.; Wang, X.; Zheng, X.; Fisher, B.; Wang, L.; Zhu, J.; Tang, Y.; Yu, D.W.; Wilcove, D.S. Opportunities for biodiversity gains under the world's largest reforestation programme. *Nat. Commun.* **2016**, *7*, 12717. [[CrossRef](#)] [[PubMed](#)]
95. Ellis, P.W.; Page, A.M.; Wood, S.; Fargione, J.; Masuda, Y.J.; Carrasco Denney, V.; Moore, C.; Kroeger, T.; Griscom, B.; Sanderman, J.; et al. The principles of natural climate solutions. *Nat. Commun.* **2024**, *15*, 547. [[CrossRef](#)] [[PubMed](#)]

96. Epelde, L.; Mendizabal, M.; Gutiérrez, L.; Artetxe, A.; Garbisu, C.; Feliu, E. Quantification of the environmental effectiveness of nature-based solutions for increasing the resilience of cities under climate change. *Urban For. Urban Green.* **2022**, *67*, 127433. [[CrossRef](#)]
97. Petti, B.; Ottaviano, M. Identification of Agricultural Areas to Restore Through Nature-Based Solutions (NbS). *Land* **2024**, *13*, 1954. [[CrossRef](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.