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Bridging Nature-Based Solutions, Governance and Landscape Architecture: Insights from the Global North and South

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Abstract

Nature-Based Solutions (NBS) have emerged as a prominent and rapidly expanding strategic approach for addressing climate change, biodiversity loss, and socio-ecological resilience in cities, especially within European sustainability agendas where NBS are embedded in EU policy frameworks. Nevertheless, their practical implementation remains uneven across the globe, with relatively strong mainstreaming in Europe but more fragmented uptake in other regions. These disparities stem from a gap between policy-oriented NBS discourse and its translation into design and spatial practice. This study investigates how governance-related NBS research can be more effectively translated into landscape architecture and design practice. It integrates insights from narrative literature reviews, project-based experiences, and international conference sessions. We argue that effective NBS implementation requires alignment with landscape architecture (systems-multi-scale planning, design, site-specific ecological materialization and aesthetic mediation) and governance integration. Through comparative analysis of Global North and South contexts, we identify differences in institutional capacity, socio-cultural perception of nature, and knowledge systems that shape NBS implementation. We propose a multi-scale, co-creative framework connecting environmental knowledge, governance interface, and design practice. The findings demonstrate that NBS cannot succeed solely as a science and policy approach; instead, they must be spatially translated through culturally responsive and ecologically informed landscape design processes and maintenance.

Keywords: nature-based solutions; landscape architecture; governance; socio-ecological systems; co-creation; Global North; Global South

Academic Editor: Corrado Zoppi

Received: 16 June 2026

Revised: 22 July 2026

Accepted: 23 July 2026

Published: 25 July 2026

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1. Introduction

Historically, landscape architecture has shaped human interaction with outdoor spaces, integrating aesthetics, functionality, and environmental stewardship [1]. Its roots trace back to ancient civilizations, where gardens served practical, ceremonial, and social purposes [2,3]. Over time, the discipline has evolved from ancient gardens through European traditions (e.g., Italian Renaissance, French formal, English landscape and Gardenesque style gardens) to contemporary public parks and other green infrastructure, responding to cultural and political shifts, technological innovations, and societal needs

[4,5]. Given increasing challenges of climate change, biodiversity loss, pollution, and socio-environmental inequities, landscape architecture now operates at the intersection of design, planning, art, aesthetics, social science, and ecology, creating spaces that are functional, resilient, and culturally meaningful [6]. It has increasingly been framed as a response to industrial legacy and growing urbanization, becoming a crucial tool for repairing, cleaning, and transforming (post-)industrial sites, and integrating ecological and social systems into the urban fabric [7–9].

According to the International Federation of Landscape Architects [10], landscape architects “plan, design and manage natural and built environments, applying aesthetic and scientific principles to address ecological sustainability, quality and health of landscapes, collective memory, heritage and culture, and territorial justice”. Landscape architecture operates across scales, from large complex projects (e.g., national parks, greening of cities, urban parks) to smaller-scale projects (e.g., residential gardens, streetscapes). Landscape architecture also serves as a mediator between nature and culture, producing meanings, values, and human experience through spatial design [7,8]. It is essential for co-creating urban landscapes where design is based on ecological principles and social considerations [6,11,12]. This synergy underpins the implementation of nature-based solutions (NBS), where landscape architecture translates climate adaptation and socio-ecological resilience strategies into tangible, culturally legible spatial forms [13,14]. Defined as actions to protect, sustainably manage, and restore natural or modified ecosystems, NBS address societal challenges effectively and adaptively while providing human well-being and biodiversity benefits [15].

There is a strong movement toward integrating principles of urban ecology, biodiversity, and social science into landscape architecture practice [7]. Incorporating ecological knowledge into site design can enhance urban biodiversity and ecosystem services while making ecological processes visible to stakeholders. Co-creation and participatory approaches promote social inclusion, justice, and community resilience [16–18]. Cross-disciplinary research shows that reconciling divergent visions of urban nature across professional, geographical, and cultural contexts supports effective NBS implementation, emphasizing the need for interdisciplinary collaboration and context-sensitive design [19]. The interdisciplinary nature of contemporary landscape architecture, encompassing planning, design, and management across multiple scales, makes it a central mechanism for delivering ecological, social, and climate-responsive urban solutions [6,7,20].

Despite these advances, a critical research gap remains: although NBS are widely discussed in policy and ecological frameworks, there is limited understanding of how governance arrangements and co-creation processes enable their translation into landscape architecture practice across contrasting Global North and South contexts. Cities in the Global South face rapid urbanization, native biodiversity loss, and socio-environmental inequities that differ from Global North contexts, requiring contextually adapted NBS approaches [21–23]. Even though governance-oriented research has clarified institutional pathways for NBS adoption [17,24,25], less attention has been paid to how these NBS strategies can be physically realized and socially negotiated and accepted through landscape architecture. We acknowledge that the Global North/South distinction, while analytically useful, risks oversimplifying heterogeneity within each category. Cities within the Global South exhibit vastly different governance trajectories, colonial histories, and urbanization patterns, while the Global North encompasses diverse institutional contexts. We therefore employ this binary as a heuristic device to foreground systemic inequities in NBS knowledge production and implementation, while remaining attentive to intra-regional diversity through case selection and cross-case comparison.

To address this gap, the research investigates how NBS are operationalized through landscape architecture practice and how these processes differ across Global North and South contexts. Specifically, the research questions are:

- (a) How can landscape architecture effectively translate NBS from governance and ecological frameworks into successful spatial design practice?
- (b) How do institutional, cultural, and ecological contexts shape the implementation of NBS through landscape architecture across regions?
- (c) What context-specific strategies emerge from comparative analysis of NBS implementation through landscape architecture?

Drawing on the recent academic literature, project-based experiences, and insights from conference sessions organized by the authors, this paper proposes an integrated approach applicable across diverse socio-ecological settings. Unlike single-context studies, the comparative North–South perspective highlights how institutional capacity, cultural perceptions of nature, and knowledge systems shape NBS implementation in fundamentally different ways.

The study contributes a novel transdisciplinary analytical framework linking landscape architecture, urban ecology, co-creation and NBS governance, addressing the gap between policy-oriented NBS discourse and spatial implementation using several case studies (realized projects) in different cities. The proposed multi-scalar framework integrates systemic planning with site-level ecological design and socio-cultural context. It emphasizes co-creation and cross-sector collaboration as enabling conditions for translating NBS into spatial practice. The framework supports social and environmental resilience while enhancing inclusivity, justice, and biodiversity outcomes within NBS realization.

Overall, the study advances understanding of NBS implementation by bridging policy-oriented frameworks, ecological performance, spatial design practice, and socio-cultural dimensions.

The paper is structured as follows: Section 2 presents the research methodology; Section 3 reviews conceptual foundations linking NBS to landscape architecture, offering a comparative analysis of Global North and South perspectives by examining governance structures, co-creation processes, and NBS implementation strategies; and Section 4 discusses limitations and implications for integrated practice and policy, proposing a new comprehensive approach applicable to both Global North and South contexts.

2. Materials and Methods

2.1. Research Process

This study adopts a comparative qualitative research design, integrating conceptual analysis, a narrative literature review, and case-informed insights drawn from research projects and conference-based work. The research process is organized around four interconnected steps (Figure 1). It begins by establishing a conceptual foundation, mapping key terms underpinning the study (i.e., NBS, landscape architecture, co-creation, and socio-ecological resilience) to identify overlaps, disciplinary blind spots, and terminological ambiguities (step 1). This conceptual groundwork informs the subsequent coding phase, in which narrative review materials and experiential data from research projects and conference sessions are organized according to four analytical dimensions: governance, socio-cultural and political aspects, ecological conditions, and knowledge systems (step 2). Building on these dimensions, a cross-context comparison between Global North and South cases is conducted (step 3). This analysis focuses on structural asymmetries such as funding and regulatory mechanisms, context-specific innovations including informal greening and community-led initiatives, and shared implementation challenges related to maintenance capacity and aesthetic resistance. These patterns, divergences, and opportu-

nities inform a new multi-scalar conceptual framework (step 4). This framework integrates macro-scale governance, meso-scale spatial planning and green infrastructure networks, and micro-scale ecological and aesthetic materialization on sites. Throughout this process, iterative synthesis ensures that theoretical development remains grounded in practice-based findings and cross-context comparisons.

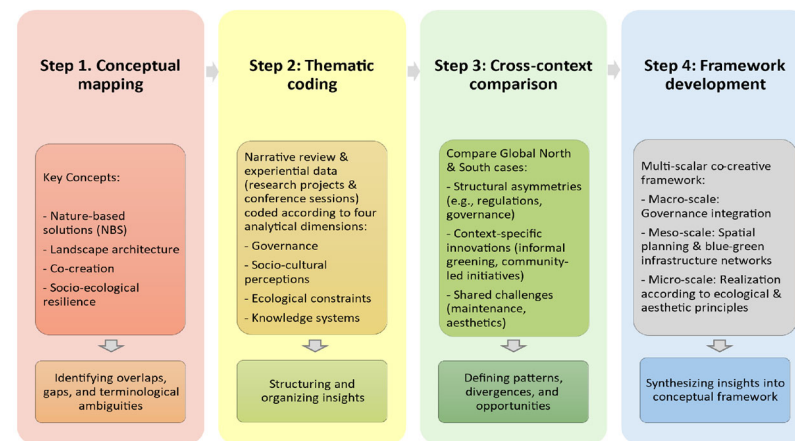


Figure 1. Research design (Source: authors).

The three methodological components—narrative literature review, project-based insights, and conference sessions—function complementarily within this analytical framework. The narrative literature review establishes the theoretical background, identifying key concepts, governance arrangements, and implementation pathways for NBS. Project-based insights provide empirical grounding, offering concrete examples of how NBS are translated into spatial design decisions, implementation strategies, and maintenance regimes across diverse geographic and cultural contexts. Conference sessions serve as a platform for external validation and iterative refinement, enabling us to test emerging findings against practitioner expertise and current scientific debates (Section 2.2.3, Table S1 in Supplementary Materials). These three sources are triangulated through thematic coding and cross-source comparison, ensuring that the resulting conceptual framework is both theoretically grounded and practice-informed.

To ensure transparency and reproducibility, we develop a structured case study selection and analysis (Section 2.2.4), which guides the identification, documentation, and cross-case comparison of NBS implementations. This approach is applied consistently across all cases identified through the literature, project insights, and conference contributions. Thematic coding was carried out by the first author, with iterative review and category refinement conducted jointly by all three authors through regular discussion sessions. Inter-coder reliability was ensured through consensus-based validation, where emerging categories were discussed and revised collectively until agreement was reached. Interpretive bias was managed through systematic triangulation across literature, projects, conferences, and by explicitly documenting coding decisions and their justifications. Selected cases and their contributions to the analytical framework are summarized in Table S2 in the Supplementary Materials. The cases span diverse geographic contexts (Australia, Brazil, China, Colombia, Germany, India, Mexico, New Zealand, Russia, South Africa, Spain, Türkiye, USA, and others), representing both Global North and South perspectives, and cover a wide range of NBS intervention types from building-scale green roofs and public parks to regional Indigenous governance systems for green infrastructure.

2.2. Methods Used

2.2.1. Narrative Literature Review

A narrative literature review follows established principles for structured yet interpretive synthesis across interdisciplinary knowledge domains [26–28] with the aim to:

- (1) Synthesize critical insights on NBS across governance, ecological, and design-related disciplines, where NBS has been approached through diverse conceptual lenses.
- (2) Examine how NBS are translated from governance frameworks into spatial practice through landscape architecture implementations across Global North–South contexts.

This approach is appropriate because NBS scholarship spans multiple disciplines (e.g., urban ecology, environmental governance, sustainability science, and landscape architecture), each employing distinct terminologies and epistemologies. Rather than applying a systematic review protocol, this approach enables critical integration, conceptual clarification, and theory-building across heterogeneous sources.

The review is based on two interlinked knowledge domains:

- *Governance-oriented and socio-ecological system research*, focusing on policy integration and implementation of NBS;
- *Ecological design with an emphasis on biodiversity-oriented research*, covering urban ecology, biodiversity, and site-level design translation.

These domains are jointly analyzed to construct a conceptual interface between system-scale planning and site-scale implementation.

Source selection prioritizes conceptual relevance, interdisciplinary contribution, and explicit engagement with implementation processes rather than solely theoretical positioning. The emphasis is placed on identifying patterns, tensions, and emerging themes across disciplines. The review focuses on four thematic areas:

- (1) NBS governance and implementation pathways;
- (2) Integration of landscape architecture principles;
- (3) Urban biodiversity and ecosystem services;
- (4) Co-creation and participatory approaches.

Peer-reviewed publications from Scopus, Web of Science, and Google Scholar (primarily 2015–2026) are analyzed through an iterative narrative synthesis process. This is complemented by the gray literature (e.g., project reports and websites, policy briefs, and NBS-related platforms), identified via Google Scholar and targeted searches of relevant databases. This dual sourcing ensures that the review captures both established academic findings and practice-based insights from recent and ongoing NBS implementations. All sources were read and coded manually: first, texts were organized according to the four thematic areas listed above; second, additional themes that emerged during reading (e.g., colonial legacies, aesthetic perceptions, maintenance challenges, and Indigenous knowledge) were added as new categories. The resulting coding structure was used to compare and triangulate findings across the literature, project insights, and conference contributions. This cross-source comparison helps identify converging patterns and persistent gaps, directly informing development of the proposed conceptual framework.

2.2.2. Project-Based Insights

The study incorporates reflective analysis of implemented NBS-related projects based on collaborations between science, policy and practice. These experiences illustrate how sustainability-related challenges and objectives are translated into spatial design decisions, implementation strategies, and maintenance regimes.

Project evidence is selected based on relevance to NBS implementation, ecological design innovation, and co-creation processes. To mitigate potential selection bias, we de-

liberately select projects representing diverse geographical, governance, and socio-ecological contexts, encompassing cases from both the Global North and South. This diversity ensures that our analysis captures a broad spectrum of NBS governance arrangements and implementation challenges, rather than reflecting a narrow or self-referential sample. Key insights are drawn from several related international Horizon 2020 and Horizon Europe projects: CONNECTING Nature (COproductionN with Nature for City Transitioning, Innovation and Governance) (2017–2022), RECONNECT (Regenerating ECOSystems with Nature-based solutions for hydro-meteorological risk rEduCTion) (2018–2024), and EmpowerUs (Socio-economic Empowerment of coastal communities as users of the sea to ensure sustainable coastal development) (2022–2025). The projects demonstrate NBS potential for addressing socio-environmental challenges while enhancing biodiversity, community well-being, and place attractiveness across European and international demonstrator and collaborator sites (Living labs). They contribute critical perspectives on co-creation pathways, governance integration, and stakeholder engagement across European and Global South demonstrator sites.

Additional projects include a range of national and local-scale long-term research and design initiatives on urban greening, biodiversity-friendly design, low-impact design, and climate adaptation in various regional contexts (e.g., urban lawns, climate change adaptation and mitigation, road and parking lot surface, institutional greening, building-scale interventions, integration of scientific and community knowledge into design practice in cities). Among them are “Smart technologies for monitoring, modeling, and assessing ecosystem services of green infrastructure and soils to support decision-making in sustainable urban development under conditions of global change” (2023–2025), “Shades of urban greening: Understanding the social, design and environmental impacts of plant foliage colour in hot cities” (2023), “Sustainable Campus as a Living Laboratory” (2022–2024), “Lawn as an ecological and cultural phenomenon in Perth” (2022–2025), “Biophilic resilient city models in the time of climate change (2018–2020)”, “Environmental management for sustainable territorial development: theory and practice” (2016–2018), “Lawn as ecological and cultural phenomenon: Search for sustainable lawns in Sweden” (2013–2017), “Landscape and human wellbeing: identification, assessment and communication in the field of ecosystem services” (2014–2016), “Low impact urban design and development” (2003–2009), and “Ecology and cultural history in urban rivers” (2000–2003). These projects were conducted in Argentina, Australia, China, Germany, Italy, Japan, New Zealand, Russia, South Africa, Spain, Sweden, Türkiye, Vietnam, and the USA. They inform our understanding of biodiversity-positive design, maintenance and long-term stewardship challenges, multifunctionality, and aesthetic acceptance across Global North and South contexts. Indigenous knowledge projects in Australia, South Africa, Colombia, Ecuador, and New Zealand contribute critical perspectives on the integration of Indigenous knowledge systems and decolonizing design approaches. These cases enable systematic investigation and comparison of socio-cultural dimensions of NBS, diverse landscape architecture traditions, and integration of scientific and community knowledge into design of outdoor spaces across varied geographical and cultural contexts.

Collectively, these projects provide an empirical foundation for analyzing co-creation processes, governance mechanisms, and the translation of ecological and cultural knowledge into site-specific NBS interventions.

2.2.3. Conference and Knowledge Exchange Sessions

To complement the literature-based and project-based evidence, the analysis includes insights from international conferences and sessions organized and moderated by the authors. Among them are the 7th Urban Biodiversity and Design Network/URBIO Conference in Leipzig, Germany (URBIO 2022), the 8th URBIO Conference in Columbia,

USA (URBIO 2024), the 9th URBIO Conference in Perth, Australia (URBIO 2025), the 4th International Conference on Smart and Sustainable Cities in Moscow, Russia (SSC 2024), and the Society for Urban Ecology (SURE) World Conference in Istanbul, Türkiye (SURE 2025) (Table S1 in the Supplementary Materials). These conferences are selected because they are prominent international forums that attract diverse participants from multiple institutional, disciplinary, and regional backgrounds, including both Global North and South contexts. This diversity ensured that the insights gathered extend beyond the authors' own networks and capture a wide range of practitioner and researcher perspectives. Conferences brought together scientists, policymakers, practitioners, planners, and civil society representatives from both Global North and South contexts, enabling identification of recurring implementation barriers and design innovations for NBS. These conference sessions functioned as active sites of knowledge co-production, where emerging findings from the literature review and project analysis were presented, discussed, and critically interrogated by diverse expert audiences. The structured thematic sessions addressed NBS co-creation, urban biodiversity, landscape design implementation, and governance integration across diverse geographic contexts, allowing us to systematically gather feedback on preliminary analytical dimensions. This external validation helped identify blind spots in our early analyses and revealed context-specific challenges and innovations that were not yet well documented in the peer-reviewed literature.

Each conference contributed to the analytical framework in distinct ways. Specifically, URBIO 2022 provided foundational insights into the integration of biodiversity into landscape architecture practice and highlighted co-creation challenges. URBIO 2024 offered in-depth discussions on community engagement, rewilding, and translational ecology, which were particularly relevant for our co-creation pathway analysis. URBIO 2025 emphasized integration of Indigenous knowledge systems and shared language across landscape design and ecological professions—insights that informed our treatment of epistemic plurality and decolonizing NBS. SSC 2024 contributed perspectives on green infrastructure and climate resilience from Eastern European and Asian contexts, broadening our comparative base. SURE 2025 provided a large-scale global forum that reinforced convergent challenges across North and South contexts, particularly regarding governance fragmentation and justice concerns, alongside transdisciplinary exchanges on green and blue infrastructure integrating landscape architecture and urban design perspectives.

Across these conferences, we systematically analyze thematic sessions and specific contributions addressing NBS, co-creation, urban biodiversity and design, and the translation of ecological knowledge into spatial practice. For each conference, the following materials are systematically analyzed: (a) conference proceedings and abstract books [29–33] (see Table S1 in Supplementary Material), which provide structured summaries of research questions, methods, and findings across all accepted contributions; (b) presentation content from all thematic sessions relevant to NBS, landscape architecture, and co-creation, captured through detailed note-taking; (c) discussion notes from Q&A sessions and panel debates, documenting emergent themes, points of contention, and practice-based insights not captured in written abstracts; and (d) workshop outputs, including visual documentation, participatory mapping exercises, and summary reports. All collected materials are analyzed using a structured thematic coding approach aligned with the study's four analytical dimensions: governance and institutional pathways; socio-cultural and political contexts; ecological conditions and biodiversity outcomes; and co-creation and participatory processes. Initial coding identified emergent themes within each conference, followed by focused coding to synthesize patterns across conferences. This cross-conference synthesis is particularly valuable for identifying recurring challenges (e.g., maintenance capacity, aesthetic resistance, funding constraints) and innovative solutions (e.g., Indigenous knowledge integration, community-led monitoring, biodiversity-positive de-

sign approaches) across diverse geographical contexts. These inputs are triangulated with findings from the narrative review and project-based insights to ensure methodological consistency and cross-source validation. Collectively, this evidence base reinforces the need for integrating ecological knowledge into design practice and informs our comparative analysis of various contexts shaping NBS implementation. The analytical process is outlined in Table S1 in Supplementary Materials, summarizing conference characteristics and specific themes that were systematically analyzed.

2.2.4. Case Study Selection and Analysis

To guide the selection and analysis of case studies drawn from the aforementioned conferences and projects, the following inclusion criteria are established:

- (1) Geographical focus on a specific city or settlement in the Global North or South;
- (2) Explicit engagement with NBS, green infrastructure, or landscape architecture and urban planning initiative(s);
- (3) Use of co-creation, participatory, or stakeholder engagement methods;
- (4) Methodological detailing of the approach(es) employed.

Case studies that focus solely on biophysical or technical aspects of NBS or green infrastructure development without a participatory or co-creation component are excluded, as well as those lacking socio-ecological or institutional context. This selection approach ensures that the analyzed cases meaningfully inform the study's comparative analysis of NBS implementation across diverse Global North and South contexts.

Table S2 in the Supplementary Materials summarizes the selected cases, with information on: (i) geographic location and scale, (ii) type of NBS intervention and landscape design approach, (iii) governance context, (iv) participatory methods and co-creation processes, (v) ecological and socio-cultural outcomes, and (vi) source of evidence (the literature, project insights, conference presentation). To facilitate cross-case comparison, the cases are coded according to the four thematic analytical dimensions established in Section 2.1 (governance, socio-cultural and political aspects, ecological conditions, and knowledge systems). This coding enables systematic identification of patterns, divergences, and shared challenges across Global North and South contexts. The coded case data are then triangulated with findings from the narrative literature review and conference insights to develop the multi-scalar conceptual framework presented in Section 3.3.

3. Results

3.1. Conceptual Foundations: Linking NBS with Landscape Architecture

The term *NBS* refers to “actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, providing human well-being and biodiversity benefits” [15,34]. Early scientific uptake has been dominated by environmental research in a European urban context, often focusing on addressing challenges such as climate change adaptation and mitigation or biodiversity loss, revealing a gap between the concept's holistic ambition and its practical application. Yet, NBS do not function as a distinct science field in the environmental domain, but rather as a “boundary concept” operating at the intersection of science, policy, and practice [35]. While the concept of NBS is closely linked to previously established concepts such as ecosystem services and blue–green infrastructure, it carries the ambition of delivering social, economic, and environmental benefits together [15]. NBS represent a key approach to developing multifunctional urban blue–green infrastructure that integrates ecological performance with social, cultural, and design functions, enabling translation of ecological knowledge into landscape architecture practice.

NBS are inherently *interdisciplinary*; their implementation requires the integration of a wide range of scientific, technical, and social research fields aimed at utilizing natural processes to address societal challenges. The core scientific fields involved include [11,18,35–39]:

- *Urban ecology* for restoring degraded ecosystems, enhancing biodiversity, and informing spatial design decisions such as habitat connectivity, species selection, and structural diversity in planting design, as well as managing (semi-)natural systems;
- *Hydrology and water management* for addressing water storage and purification, flood regulation, groundwater recharge, and wetland rewetting;
- *Soil science and geomorphology* for soil–water conservation, erosion control, and carbon sequestration;
- *Biology and biodiversity science* for studying species diversity and supporting habitat protection and species conservation (e.g., in cities, forests, wetlands, grasslands, coastal areas);
- *Technical sciences (environmental and civil engineering)* for designing green–blue–gray hybrid solutions (e.g., green roofs, sustainable urban drainage systems (SUDS), and coastal infrastructure);
- *Sociology, psychology, and geography* to examine human–nature interactions, social justice, and equity in access to green spaces;
- *Public health* to investigate the impacts of green spaces on mental and physical health;
- *Political science and governance studies* to analyze policy and institutional frameworks needed for NBS project implementation;
- *Economics and business management* to assess economic viability, cost–benefit dynamics, and innovative financing mechanisms.

To ensure NBS are contextually appropriate, their planning and design require a *transdisciplinary approach* that integrates scientific evidence with local communities' and Indigenous knowledge and practitioner expertise to co-create context-specific solutions [35,40,41]. Transdisciplinary partnerships are critical for assessing and defining problems and aligning solutions with sustainability visions and local community needs. They also enable co-production of knowledge to establish project frameworks and intervention designs that balance scientific rigor with local values, helping address inclusivity, justice, and implementation barriers [16,17,35].

Understanding how landscape architecture synthesizes these diverse fields is crucial as these disciplines translate the ambitious concept of NBS into tangible and multifunctional interventions. Figure 2 presents the conceptual foundation of our integrated approach, mapping key components that bridge NBS and landscape architecture, including NBS principles, disciplinary bridges (governance, co-creation, environmental knowledge), and multi-scale design dimensions. Specifically, it clarifies the building blocks of an integrated NBS–landscape architecture approach and provides the conceptual foundation for the operational framework presented in Section 3.3.

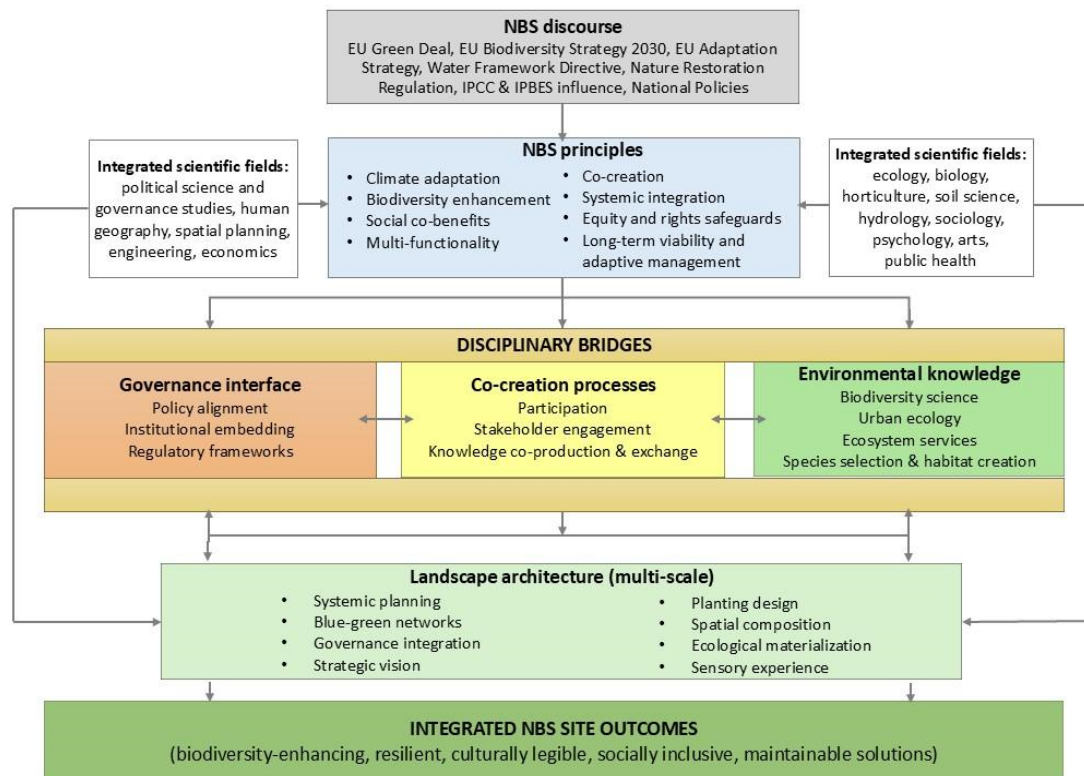


Figure 2. Integrative conceptual framework bridging NBS and landscape architecture (Source: Authors).

Landscape architecture operates across regional and urban scales (macro-meso-micro scales), integrating blue–green infrastructure, climate adaptation planning, and biodiversity networks [6,8]. Within NBS discourse, it aligns ecological performance with planning instruments and cross-sector governance [13,14]. Studies demonstrate that NBS depend on long-term institutional support, inclusive collaboration, and adaptive governance frameworks [17,18,25,42]. Therefore, landscape architecture offers strategic structures needed to embed individual projects within wider ecological frameworks, policy contexts, regulatory systems, and infrastructural networks. Yet this systemic integration is not merely technical or administrative; it also operates through aesthetic expression [7]. Appropriate visual and spatial language of blue–green networks (e.g., alignment of urban forests, legibility of public parks) communicates ecological goals and shapes public perception. In this sense, landscape architecture translates the governance and ecological goals into forms that citizens can see, experience, and value, making systemic strategies visible and tangible.

However, the legacy of colonialism further complicates this picture: former colonial cities across Global North and South contexts exhibit remarkable homogeneity in their urban biotopes and landscape design languages. This is reflected in shared planning principles, planting designs, and aesthetic preferences exported from Europe [43]. Such uniformity—from urban lawns to hedgerows and street tree alignments—has produced globally replicated urban landscapes that often erode native biodiversity and local/Indigenous ecological knowledge (Figure 3) [44]. For NBS implementation, this means that design practitioners must confront not only contemporary governance challenges but also deeply embedded colonial legacies, including landscape architecture styles that shape perceptions of what urban nature “should” look like across diverse contexts [19,21–23,45]. As shown in Figure 3, this globally replicated aesthetic, rooted in European templates, manifests visually in the striking similarity of lawns and planting designs across cities worldwide, presenting a fundamental obstacle to ecologically responsive NBS implementation.



Figure 3. Global homogeneity of urban lawns in (a) Central Park in New York (USA), (b) Johanna Park in Leipzig (Germany), (c) public park in Istanbul (Türkiye), (d) Zhongshan Square in Dalian (China), (e) Kings Park in Perth (Australia), and (f) public park in Buenos Aires (Argentina) (Photos: D. Dushkova and M. Ignatieva).

Landscape architecture operates at different scales and involves principles of planting design, spatial composition, and experiential qualities [2,8,46,47]. However, its role extends beyond mere aesthetic arrangement: planting design materializes ecological principles through species selection, planting composition and structure, and substrate engineering, which determine whether NBS deliver promised biodiversity outcomes (one of the core NBS principles emphasized by IUCN [15]). This materialization is key to moving beyond the use of NBS as a “buzzword” toward delivering its intended multi-functional benefits [15,40]. Yet, a growing body of research cautions that NBS are not inherently just or beneficial. Their capacity to deliver equitable outcomes or, conversely, to reinforce existing inequalities, depends critically on how they are designed, sited, governed, and for whom they are intended [17,35,48]. Without explicit attention to inclusivity and justice, well-intentioned greening interventions can increasingly drive green gentrification (e.g.,

by increasing property values and apartment rents), exclude vulnerable and marginalized communities, or impose aesthetic norms that disregard local and Indigenous ways of knowing and valuing nature [21,22,35,41]. Figure 4 illustrates how well-intentioned greening interventions can reinforce patterns of green gentrification. High-profile urban parks, while delivering ecological and recreational benefits, are frequently linked to rising property values, luxury development, and socio-spatial inequality, proving that NBS are not inherently just or beneficial without explicit attention to inclusivity and justice. For example, the transformation of the former Eilenburger railway station into Lene-Voigt-Park in Leipzig (Germany) upgraded the surrounding neighborhood by creating a multi-functional neighborhood-enhancing green space that increased the area's image and attractiveness [24]. Studies demonstrated that the park operated as a trigger for structural, socio-ecological, and symbolic upgrades in combination with real estate market developments [24,29]. Similar dynamics have been observed in other cities, particularly in the case of the High Line in New York (the USA), where the conversion of former railway infrastructure into a flagship urban park significantly increased nearby property values and accelerated luxury development, contributing to displacement of lower-income residents [29,30]. This pattern is also evident in Zaryadye Park in Moscow (Russia), which is often discussed as a signature project linked to overtourism, rising land values, and socio-spatial inequalities [32]. A further example is the Barangaroo Reserve in Sydney (Australia), a major waterfront redevelopment that combines the creation of a high-quality multifunctional park with extensive high-end commercial and residential development. It has been characterized in planning debates as an instance where public green space enhancement is closely intertwined with luxury urban restructuring, rising land values and socio-spatial exclusion [31]. Crucially, these examples show that green gentrification is context-dependent, shaped by governance arrangements, property markets, and planning frameworks rather than an automatic consequence of greening.



Figure 4. Examples of green gentrification associated with urban greening and park-led redevelopment: (a) Lene-Voigt-Park in Leipzig (Germany), (b) High Line in New York (USA), (c) Zaryadye Park in Moscow (Russia), and (d) waterfront redevelopment in Barangaroo Reserve in Sydney (Australia) (Photos: D. Dushkova).

Landscape architecture is closely related to aesthetics, which play a central role in public acceptance of green infrastructure [7]. This is particularly relevant for NBS that intentionally rely on more “naturalistic” or low-maintenance vegetation structures, which may visually diverge from conventional, culturally embedded expectations of tidy, controlled urban landscapes [48–50]. Without specific design strategies that align ecological functions with cultural expectations, biodiversity-promoting interventions risk being perceived as neglected [44,51,52]. Nassauer’s concept of “cues to care” [51] has considerably influenced ecological design by arguing that people accept ecological “messiness” more readily when it is framed by visible signs of human intention and order/minimal intervention. Such signs (e.g., neat edges, mown margins, pathways, structural plantings, art objects and information boards) serve as signals that apparently wild landscapes are deliberately tended rather than abandoned [51,53]. This approach explains why spontaneous vegetation is often perceived as messy and undesirable, revealing how aesthetics and ecology are entangled: what looks “untended” is often rejected, even when it supports greater biodiversity [44,54–56]. As shown in Figure 5, these design cues (edges, pathways, interpretive signage/information boards) can effectively frame apparently wild landscapes as deliberately tended rather than abandoned, thereby increasing public acceptance of ecologically complex and “messy” NBS interventions.



Figure 5. Urban rewilding as NBS with visible “cues to care”—interpretive signage indicating ecological management in (a) Tempelhof Felder (former airport) in Berlin (Germany) and (b) Central Park in New York (USA) (Photos: D. Dushkova).

However, recent studies have challenged Nassauer’s concept by arguing that ecological processes are defined by function rather than form, meaning that healthy ecosystems often appear messy, and that perceptions of nature are culturally constructed, not universally given [2,19,55–58]. Such critiques suggest that the “cues to care” approach may privilege human aesthetic preferences over ecological integrity, framing “wildness” within a human-centered perspective that demands order as reassurance [56]. For NBS implementation, this tension is acute: biodiverse interventions must negotiate between ecological authenticity and cultural legibility, particularly in Global South contexts where aesthetic expectations may differ markedly from Western society norms.

Thus, appropriate design translates NBS through ecological planting systems and habitat structures that support biodiversity, as well as culturally legible forms. This dual role (ecological performance and cultural communication) positions landscape architec-

ture and its tools (e.g., design and management) as the critical interface where abstract NBS policies encounter local communities with context-specific aesthetic expectations, cultural traditions, and relationships with urban nature [19,44,52]. The challenging task remains: to develop design languages that simultaneously enhance biodiversity, reduce maintenance burdens, and cultivate new aesthetic sensibilities capable of appreciating the “messy” vitality of functional ecosystems [2,49]. Recent studies reinforce this view, arguing that design should actively mediate between scientific ecological knowledge and diverse cultural understandings of nature, particularly by incorporating Indigenous and local perspectives that have long been marginalized [13,17,19,22,35].

Bridging landscape architecture and NBS therefore requires more than scalar integration. It involves reconciling (a) systemic ecological thinking with site-specific cultural mediation, (b) global biodiversity targets with local aesthetic traditions, and (c) scientific knowledge of ecosystem function with community understandings of what urban nature (and native ecosystems) should look like [14,20]. This integration is essential for moving beyond technical fixes toward genuinely transformative, systemic and justice-oriented NBS that are both ecologically robust and socially inclusive [17,25,38].

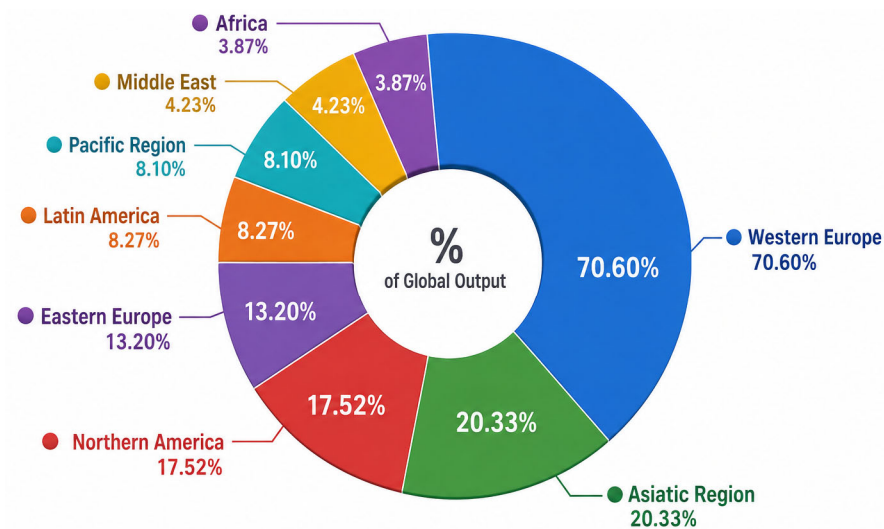
The following sections will apply this integrative lens through a comparative North–South perspective, examining how these tensions and opportunities manifest across different contexts and what transferable lessons they provide.

3.2. Global North and South Perspectives: A Comparative Overview

Rather than treating the Global North and South as homogeneous blocs, our analysis identifies three cross-cutting axes of difference that cut across the binary: (1) governance capacity—ranging from strong institutional frameworks with dedicated NBS funding to fragmented governance with limited regulatory enforcement; (2) colonial history—distinguishing post-colonial contexts, where imported landscape aesthetics and planning paradigms continue to shape urban nature, from contexts with stronger Indigenous governance continuities; and (3) urbanization trajectory—differentiating rapidly urbanizing, informally growing cities from those with more stable demographic and spatial development patterns. These axes allow for comparison of the cases not merely by geographic location but by structural conditions that shape NBS implementation. The subsections below are organized around these three axes, examining how each dimension shapes NBS knowledge production, co-creation processes, and implementation challenges across diverse contexts.

3.2.1. Geographic Bias in NBS Research and Knowledge Co-Production

This section examines how colonial history and governance capacity shape geographic biases in NBS knowledge production, revealing persistent epistemic asymmetries that constrain global applicability of current NBS frameworks. Research on NBS has historically been dominated by scholarship from and about the Global North, often framing urban challenges and solutions through a Western (European or North American) perspective [59–61]. Foundational frameworks such as the IUCN Global Standard for NBS [15] and early conceptualizations of NBS [34,38] were developed with global applicability in mind. However, their empirical grounding and case study bases remain disproportionately focused on the Global North, despite recent efforts to broaden geographic representation through global case study collections [62]. Figure 6 visualizes this geographic bias in NBS knowledge production, highlighting the empirical and epistemic disparities that constrain the transferability of NBS frameworks across diverse socio-political contexts global applicability of NBS frameworks.



Total exceeds 100% owing to overlap from co-authorship among authors, institutions, countries, and regions.

Figure 6. NBS research distribution worldwide—percent of global output, overlap from co-authorship (diagram made by authors based on data/numbers from [63]).

Along the colonial history axis, this imbalance is also reflected in landscape architecture paradigms, where Eurocentric landscape architecture styles (French formal, picturesque and gardenesque) emphasize human-centered recreational spaces, often overlooking local ecological and cultural priorities in the Global South (Figure 7) [3,23,43].



Figure 7. Example of formal landscape design emphasizing geometry and ornamentation and demonstrating how European legacies have shaped urban landscape aesthetics globally, often at the expense of local ecological and cultural priorities—(a) Zwinger Palace Park in Dresden (Germany), and (b) Botanic Garden in Christchurch (New Zealand) (Photos: D. Dushkova and M. Ignatieva).

This uneven knowledge production, shaped by colonial history and governance capacity, has resulted in hegemonic narratives and Eurocentric scientific worldviews focused on human priorities. These narratives may reinforce exclusionary environmental practices when applied in other contexts [22,23,64–66]. Consequently, dominant NBS research often overlooks local and Indigenous community understandings of nature, including different ways of knowing and learning about the environment, thereby limiting its effectiveness across diverse socio-ecological contexts. Throughout the analyzed case studies, traditional and Indigenous knowledge emerged as a foundational yet often undervalued resource for NBS, particularly in Australian, New Zealand, Latin American and Asian contexts. In the Andean region of Colombia and Ecuador, the ancestral philosophy of *Alli Kawsay* (Buen Vivir/Good Living) informs Indigenous economies and governance

practices centered on circularity, communality (minga), and respect for Mother Nature. It offers an alternative to extractive development models (mining), contributing to preservation of biodiversity-rich territories [33].

Cabanek et al. [67], using Perth (Western Australia) as a case study on the land of Noongar people (the Traditional Owners of the greater Perth region), argue that “Indigenous people have a long history of deploying NBS, however, not many countries have recognized this knowledge as necessary for building a sustainable economy and sustainable living environments, especially in cities” [67] (p. 2). Noongar’s Six Seasons concept was translated into landscape architecture projects by constructing Six Seasons Gardens in cultural centers and local parks (Figure 8). Aboriginal knowledge and art were also incorporated into the design of school gardens and public children’s playgrounds.



Figure 8. Indigenous ecological knowledge systems: (a) the Noongar six-season calendar representing a relational understanding of nature embedded in cultural and seasonal cycles—a sign in the Botanical Garden in Perth (Western Australia), and (b) Aboriginal knowledge and art incorporated into Waalbiirniny Waabiny Boodja (Perth Children’s Hospital Greenspace,) Perth (Australia), showing how Indigenous perspectives can be translated into contemporary landscape architecture, offering an alternative to Eurocentric aesthetic templates (Photos: D. Dushkova and M. Ignatieva).

However, meaningful integration of traditional knowledge requires not merely the extraction of Indigenous practices as design templates. Instead, it requires fundamentally reconceptualizing urban planning and design frameworks to recognize the spiritual, relational, and intergenerational dimensions of human–nature relationships embedded in Indigenous worldviews [31,33,68].

Along the governance capacity axis, this limitation extends to NBS evaluation practices, where comparability of outcomes across contexts remains constrained, alongside persistent uncertainty regarding ecological and social performance [60,69,70]. This reflects deeper differences in how nature itself is understood across knowledge systems, which directly affects evaluation frameworks and design logics [61,64]. For instance, in Western science, a tree is mainly seen as a biological organism or habitat for multiple flora and fauna species. However, in some Indigenous perspectives (e.g., a Cottonwood tree by Lakota Indians, a Kauri tree by the Māori people, the Baobab tree by various African cultures), the same tree may be seen as a living being with relationships, spirits, or community value, providing protection, healing, wisdom and connections to the spiritual world.

This relational understanding of nature aligns with broader Indigenous and decolonial approaches identified in the case studies, in which nature is not treated as a passive behind-the-scenes actor but as a fundamental part of the socio-ecological system embedded in cultural, spiritual, and territorial relations [19,30,31]. In contrast, dominant NBS assessment frameworks often remain rooted in technocratic and object-based metrics (e.g.,

ecosystem services quantification), which limits their ability to capture relational, multi-species, and culturally embedded values of nature [18,65].

The intersection of colonial history and governance capacity is evident in how global guidelines for NBS interventions and associated landscape planning and design recommendations often reflect dominant Global North framings and priorities. These framings may not adequately account for institutional, financial, and socio-ecological realities of Global South contexts, limiting their applicability and effectiveness. They also have been criticized for under-representing local socio-ecological realities and justice concerns, potentially reproducing inequitable power dynamics and obscuring deeper structural issues in climate governance [18,22]. Current debates on transformative change further stress that biodiversity loss and climate vulnerability are rooted in systemic drivers such as colonial land regimes, extractive economies, and uneven governance capacities that cannot be addressed through technocratic greening alone [28,71]. Emerging scholarship, therefore, calls for anti-racist, decolonial, and transdisciplinary approaches that center justice and equity, ensuring that NBS planning and landscape architecture do not reproduce environmental injustice or reinforce social inequities [17,35,61,72].

Further, a synthesis of the recent literature and conference contributions on urban biodiversity and design outcomes from NBS in the Global South highlights significant research gaps. While many projects show positive biodiversity benefits, methodological limitations (e.g., absence of baseline biodiversity assessments and long-term monitoring) constrain robust evaluation of ecological outcomes [18,22,61]. This reflects broader concerns in the NBS evaluation literature regarding inconsistent metrics and insufficient integration of ecological and social indicators and long-term monitoring frameworks, limiting comparability and scalability of outcomes [36,60,69,70,73]. These findings emphasize the need for improved evaluation frameworks that integrate climatic, ecological, social and design indicators tailored to the Global South context that are capable of capturing both intended and unintended outcomes [22,23].

3.2.2. Co-Creation, Participation, and Equity in NBS Realization

This section examines how co-creation processes are shaped by governance capacity, colonial history, and urbanization trajectory, revealing divergent approaches across contexts and identifying convergent challenges.

Co-creation and participatory processes are implemented differently across the Global North and South, reflecting distinct social, political, and ecological contexts as well as divergent institutional and power structures.

In the Global North, participation and co-creation are increasingly advocated as mechanisms for translating NBS into spatial planning and design practice [16,35,40]. They frequently rely on structured stakeholder workshops, citizen science, modeling tools, and expert-driven decision-making, where local communities contribute to design, implementation, stewardship, and monitoring processes. Such approaches seek to integrate ecological expertise with public preferences and perspectives in designing urban parks, urban forests, alternative lawns, and other types of multifunctional green infrastructure [17,30,74]. In this context, landscape architecture acts as a mediating practice translating ecological and governance-oriented NBS frameworks into spatially and socially acceptable urban interventions. Evidence from Europe, North America, and Australia shows that long-term participatory processes improve social legitimacy, public acceptance, biodiversity outcomes, and long-term stewardship of green infrastructure [31,33,39]. For example, structured co-design in urban contexts has been applied to urban trees [74], play biotopes [75], street verges and public parks [20], and urban lawn alternatives [44,45], combining ecological expertise with landscape design and community preferences to balance multifunctionality and public use. Similarly, early and iterative stakeholder engagement

through workshops, surveys, and citizen science improves design legitimacy and reduces resistance to urban greening and climate adaptation measures [16,42,48].

In contrast, participatory approaches in the Global South frequently operate under conditions of immediate socio-political and infrastructural pressures and resource constraints, including informal settlements, contested land tenure, limited institutional capacity, and marginalization of vulnerable populations [18,21,76]. In these contexts, co-creation extends beyond knowledge exchange and consultation toward negotiations over rights and access to land, livelihood needs, environmental justice, and distribution of ecosystem benefits [17,22,41]. Landscape architects and urban designers therefore play a critical role in mediating trade-offs between ecological functionality and urgent social priorities. Their task is to translate participatory insights into site-specific design solutions that align social and cultural needs with ecological objectives [6,14,20]. Effective NBS co-creation in this context requires integrating Indigenous and local knowledge, adapting methods to cultural norms, and addressing power asymmetries among stakeholders [35,39,61].

The axes of colonial history and urbanization trajectory are evident in how participatory NBS processes in the Global South are closely intertwined with socio-economic and land tenure complexities as well as ecological design considerations [18,62]. In South Africa, multi-stakeholder engagement integrates community priorities into green infrastructure design, explicitly addressing informal settlement needs and ecosystem services such as shading, water infiltration, and livelihood support [21]. The ICLEI Africa programs test participatory methods including walking workshops, photovoice, and a human rights-based approach, showing that context-sensitive community involvement is a key success factor [30]. In Latin America, community narratives and Indigenous knowledge underpin co-design processes (adaptation strategies) that reflect socio-ecological histories rather than imported technical models [30,64,76]. Studies from Chile and Brazil show that perceptions and acceptance of conservation-based green infrastructure and climate adaptation projects depend on landscape attributes and climate change beliefs [29]. Research on green space distribution and pollinator diversity in Mexico highlights the need for community engagement and education to improve perceived ecological value in marginalized areas [30]. In Colombia, pronounced spatial inequalities in access to urban green spaces and their climate-regulation capacity reveal marked asymmetries concentrated in downtown and southwestern areas inhabited by vulnerable and low-income populations, indicating broader environmental injustice in Latin American cities [33]. In Ecuador and Colombia, Indigenous perspectives support the preservation of biodiverse territories against mining and climate change, linking co-creation to Indigenous governance and environmental justice [33].

Along the urbanization trajectory axis, case studies from Asia further demonstrate the diversity of co-creation approaches and the growing integration of digital tools, citizen science, and local ecological knowledge into NBS planning. In India, social network analysis of lakes shows that community actors increasingly shape conservation and NBS uptake through bridging roles that connect knowledge and resources beyond formal state governance [30]. In China and Vietnam, research using participatory surveys, interviews, citizen science, and AI-assisted mapping assesses perceptions of vegetation, lawns, and biodiversity in urban communities [29,30]. In Indonesia, local knowledge is integrated into GIS-based multi-criteria decision analysis for community resilience mapping. In Türkiye, studies emphasize both the ecological potential and the associated risks of incorporating ruderal vegetation into urban green infrastructure [31]. In Iran, an adaptive governance framework integrates institutional conditions (e.g., regulatory frameworks, governance coherence, land tenure systems, community norms, resource availability) with NBS indicators (e.g., ecosystem health, social co-benefits, economic viability, stakeholder inclusion, adaptive management) to improve implementation in developing contexts [33].

Across the Global South, inequalities in access to green infrastructure, exposure to climate risks, and environmental quality strongly shape NBS outcomes, demonstrating that NBS effectiveness cannot be separated from broader socio-economic goals and governance conditions.

In both contexts, meaningful co-creation enhances social legitimacy, strengthens long-term sustainability, and reduces risks of reinforcing socio-economic inequities [17,18,35,41,77]. However, the form, intensity, and objectives of co-creation differ substantially along the three axes: governance capacity shapes the degree of formalization; colonial history influences the role of Indigenous knowledge and community-led approaches; and urbanization trajectory determines the urgency of livelihood and land tenure negotiations. Co-creation ranges from formalized and institutionalized governance procedures, living labs and citizen engagement platforms in the Global North to community-led, rights-based, and grassroots approaches, including negotiations, in the Global South.

These examples underline that co-creation is not a uniform template but a context-dependent process that benefits from diverse tools (e.g., qualitative ethnography, citizen science, design studios, stakeholder mapping, photovoice, social network analysis, web-based surveys). Successful co-creation in the Global South depends on long-term collaborations with grassroots organizations, where participatory monitoring, iterative feedback loops, and shared decision-making secure equitable access to benefits and strengthen community agency [18,41,62]. It also requires addressing land tenure uncertainty, building trust through bridging actors, integrating local ecological knowledge, adapting to various perceptions of nature, and aligning technical NBS design with social and institutional realities. All of these requirements must be adapted to local political, economic, and cultural contexts to support both ecological and social resilience.

These insights, along with the analysis of the mentioned projects, reinforce regional differences while also revealing convergence trends. In the Global North, co-creation is increasingly institutionalized through structured governance frameworks, living labs, and digital and modeling tools that formalize stakeholder input into planning and monitoring processes. In contrast, Global South contexts emphasize negotiation over access, rights, and livelihoods, relying on community-led and practice-based knowledge rather than formalized procedural frameworks. Across both contexts, there is a clear shift from one-off participatory events toward long-term iterative co-production of knowledge, alongside persistent challenges in integrating Indigenous and local knowledge into formal urban planning and evaluation systems.

Figure 9 synthesizes a comparative analysis of co-creation processes. It contrasts institutionalized, structured co-creation approaches common in the Global North (formalized governance, living labs, citizen engagement platforms) with community-led, rights-based approaches often found in the Global South (negotiations over land tenure, livelihoods, and environmental justice). The figure also highlights convergent trends, including long-term iterative co-production and challenges in integrating Indigenous and local knowledge.

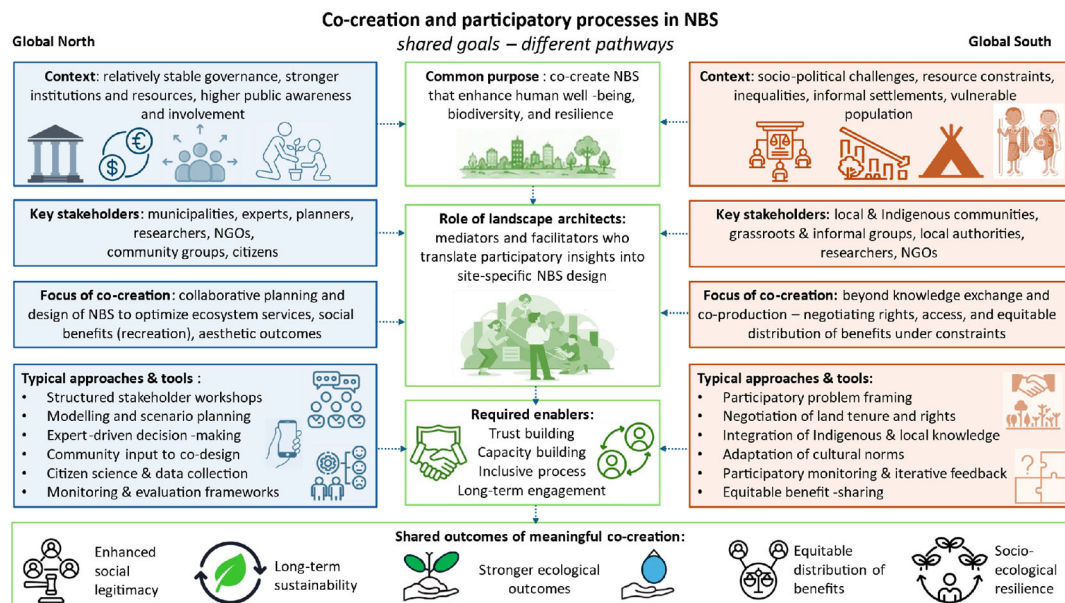


Figure 9. Pathways of NBS co-creation across the Global North and South (Source: authors with free icons from <https://www.magnific.com/app> (accessed on 6 June 2026)).

3.2.3. Unifying NBS-Related Challenges Across the Global North and South

This section synthesizes how the three axes—governance capacity, colonial history, and urbanization trajectory—converge to create shared challenges across diverse contexts while acknowledging that their expression varies locally.

NBS outcomes are shaped not only by design and participation processes but also by structural conditions such as governance capacity, cultural landscape perceptions, and socio-spatial inequality. These underlying constraints explain why similar NBS interventions can produce divergent ecological and social outcomes across regions. As a result, NBS evaluation frameworks must move beyond technical performance metrics toward integrated assessments that explicitly include justice, access, and lived experience.

The tension between ecological function and cultural legibility (e.g., exemplified by resistance to “messy” biodiverse landscapes) appears globally, though its expression is shaped by local aesthetic histories [44,47,49,51]. Therefore, the concept of “cues to care” (Section 3.1) remains particularly relevant, suggesting that visible signs of stewardship can increase public acceptance of ecologically complex landscapes [56,57]. Accordingly, there is a need to bridge strategic planning and landscape architecture with site-specific realization, even though resources and governance capacities for achieving this integration vary significantly [13,14,78,79].

Along the governance capacity axis, traditional lawn monocultures, despite their global ubiquity, have been criticized for limiting biodiversity and ecological resilience. Several studies promoted experimentation with biodiverse lawn alternatives across different regions (e.g., in Australia, China, Germany, France, New Zealand, Sweden, the USA—see [12,43–45]). These approaches demonstrate the ecological potential of lawn alternatives, revealing latent biodiversity often overlooked in conventional designs. Similar design innovations (e.g., “low-impact design”, “biodiversity-positive design”, “plant signatures”, and rewilding approaches) in Europe, Australia, and North America offer alternatives to conventional picturesque–gardenesque aesthetics while delivering multifunctional ecosystem services [2,20,54,55,57,79,80]. These initiatives collectively reveal that dominant global landscape aesthetics, often shaped by historical planning traditions, can obscure ecological heterogeneity and reinforce simplified notions of “order”, limiting biodiversity integration in urban systems. Such design trajectories align with broader calls

for biodiversity-positive design and multifunctional green infrastructure that integrates ecological performance with cultural meaning.

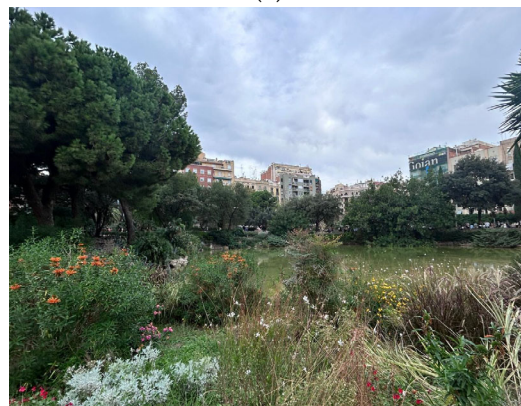
Figure 10 illustrates a diverse range of biodiversity-positive designs and examples of multifunctional green infrastructure. It demonstrates how NBS interventions across different geographic and cultural contexts—from Europe and Australia to China and South Africa—reimagine urban green spaces by integrating ecological functions, cultural meaning, and diverse aesthetic expressions.



(a)



(b)



(c)



(d)



(e)



(f)



Figure 10. Examples of biodiversity-positive design and creating multifunctional green infrastructure demonstrated through various-scale NBS interventions: (a) green roof on a building in St. Petersburg (Russia), (b) green balcony in Monaco (Monaco), (c) naturalistic plantings in Barcelona, Spain; (d) community garden in Leipzig (Germany), (e) Western Australian native plantings in Collier Park Golf, Perth, Australia, (f) one of the best examples of water-sensitive design, habitat restoration and cultural narratives—Waitangi Park, Wellington, New Zealand, (g) flower-rich meadow restoration in a public park within the Fengxi New City Balma River Project Design, Xian, China, (h) eco-circles for food production and biodiversity conservation in a school yard of Potchefstroom, South Africa (Photos: D. Dushkova and M. Ignatieva).

Along colonial history and the urbanization trajectory, similar shifts in the Global South draw on different cultural and material resources. Among them are integration of food-producing landscapes into urban greening, revival of Indigenous planting practices, and hybrid green infrastructure that combine ecological restoration with livelihood support [21,22]. Here, biodiversity enhancement is closely intertwined with food security, water management, and informal economies, reflecting distinct development imperatives [23,62].

What unites these diverse experiments is a shared recognition that landscape planning and design must accommodate the “messy” vitality of functional ecosystems while remaining culturally legible and socially acceptable [49,50,56]. However, this requires moving beyond replication of Northern aesthetic templates toward place-based landscape architecture approaches that recognize ecological processes and diverse ways of knowing and valuing nature [22,23,61]. Across the three axes—governance capacity, colonial history, and urbanization trajectory—these convergences are underpinned by broader systemic constraints, including institutional path dependencies, fragmented governance structures, and the dominance of simplified ecological indicators in planning and assessment systems. Such factors not only shape design outcomes but also reinforce persistent gaps between strategic NBS ambitions and on-the-ground implementation and maintenance realities across regions.

Ultimately, bridging divergent contexts and convergent challenges demands integrating ecological science, participatory governance, and culturally adaptive landscape design into a cohesive strategy supporting just and transformative urban sustainability transitions [35,71]. This implies shifting from project-based NBS implementation toward systemic urban transformation frameworks that explicitly integrate ecological function, social justice, and long-term governance capacity.

3.3. Proposed Multi-Scalar NBS Framework

Insights from both the Global North and South highlight the critical role of landscape architecture in translating NBS knowledge and participatory insights into tangible, site-specific interventions. Case studies from the Global North provide strategies for structured co-creation, multifunctional urban design, and aesthetic integration. By contrast,

those from the Global South emphasize the need for negotiating socio-political realities, informal land tenure, and integrating various knowledge systems. Together, these case studies underline that resilient and equitable NBS emerge at the intersection of ecological science, participatory governance, and responsive landscape architecture, providing a model for globally informed yet locally grounded urban sustainability.

Building on these findings, the operationalization of NBS can be visualized through a proposed multi-scalar, iterative framework that explicitly integrates landscape architecture and governance (Figure 11). In this sense, NBS function as a framework for structuring multifunctional urban green infrastructure across scales. This framework emphasizes five interconnected steps of the NBS co-creation process: (1) co-assessment, (2) strategic co-planning, (3) co-design (site-level translation), (4) co-implementation, and (5) co-monitoring and evaluation. Linking these steps creates a continuous feedback loop where ecological, social, and landscape architecture knowledge informs adaptive interventions, bridging top-down planning with bottom-up participatory processes. This ensures that lessons learned at the implementation and monitoring stage feed back into strategic planning, thereby reinforcing resilience, inclusivity, and biodiversity outcomes [14,16,40].

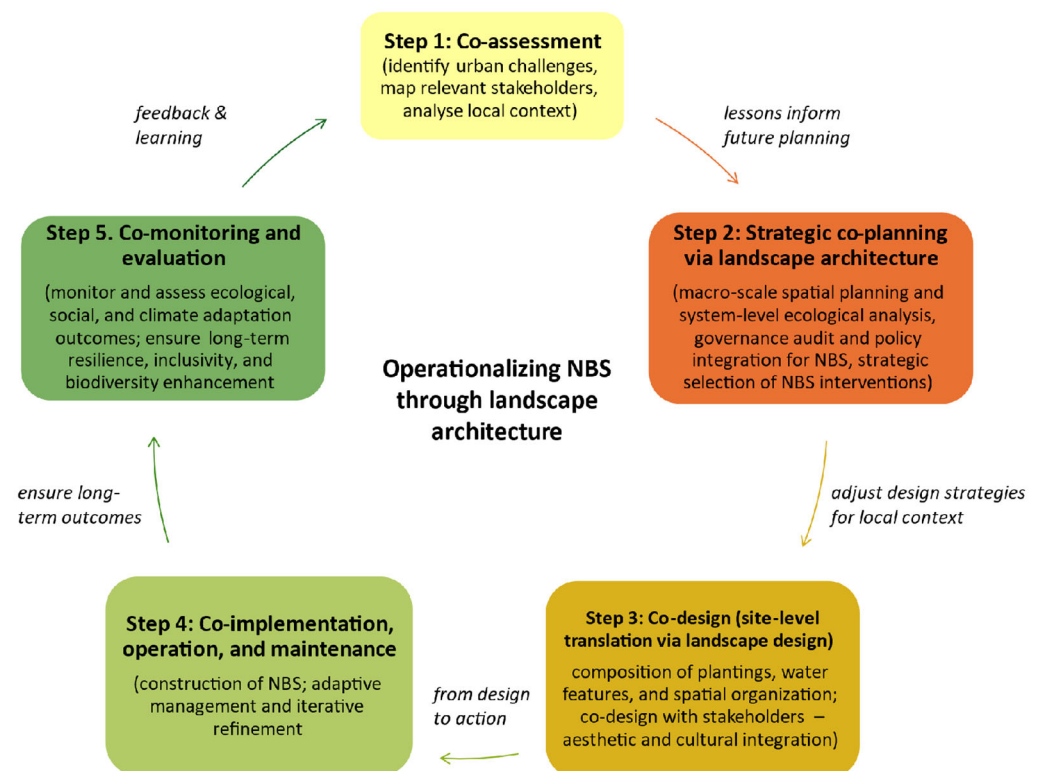


Figure 11. Stepwise multi-scalar approach bridging NBS with landscape architecture and governance. This figure operationalizes the conceptual building blocks from Figure 2 into a practical, sequential pathway for implementation; the five interconnected steps create continuous feedback loops that bridge top-down planning with bottom-up participatory processes (Source: authors).

For a *context-specific and locally relevant operationalization of NBS*, the proposed framework should be tailored based on the following ecological, socio-cultural, governance, design, and monitoring considerations:

- (1) *Context-specific ecological diagnosis*, reflecting climatic extremes, native species baseline conditions, ecosystem dynamics, and ecological characteristics of local biomes [44,80];

- (2) *Socio-cultural landscape analysis*, which incorporates local governance structures, community priorities, cultural values, and social equity considerations shaped by rapid urban growth and structural inequalities [18,23,72];
- (3) *Governance alignment*, accommodating formal and informal institutions, multi-stakeholder decision-making, and co-management approaches [35,41,76];
- (4) *Design translation*, in which ecological and socio-cultural knowledge is converted into site-specific landscape architecture interventions, including planting composition, spatial organization, water features, and cultural integration [6,14,19,20];
- (5) *Adaptive monitoring and management*, ensuring iterative evaluation of ecological, social, and aesthetic outcomes, with lessons feeding back into future planning, design, and maintenance [14,39,40,81].

This tailoring process operationalizes NBS across scales, connecting macro-level governance and ecological planning with micro-level site design and emphasizing continuous feedback and adaptation to local contexts. The framework highlights that landscape architecture functions as an integrative medium that translates scientific knowledge, community input, and governance requirements into actionable interventions [1,5,7,8].

Integrating these insights through a landscape architecture and governance lens enables NBS interventions to be locally relevant and globally informed, bridging ecological functionality, aesthetic performance, regulatory alignment, and social legitimacy. Our previous studies demonstrated that operational success depends on multi-scalar assessment, co-creative governance, design translation, and iterative monitoring [16,17,44]. The framework integrates these dimensions, providing a practical pathway toward achieving resilient and equitable urban sustainability in both Global North and South contexts. In practical terms, this framework enables the translation of ecological knowledge into design decisions such as species composition, habitat structuring, soil and water management, and spatial configuration of green infrastructure elements.

The framework's novelty lies in revisiting five NBS realization steps through a governance and co-creation lens, specifying conditions that enable NBS translation into landscape architecture practice. Indigenous knowledge, colonial legacies, aesthetics, and biodiversity are treated as contextual factors that enrich the core governance and co-creation analysis. This refocused scope allows for greater depth in examining how institutional arrangements, stakeholder engagement, and participatory processes shape NBS implementation across diverse contexts. Specifically, the framework is novel in five respects: (i) it positions landscape architecture as the integrative medium operating across all five phases; (ii) it systematically bridges governance, ecology, and design across macro-, meso-, and micro-scales; (iii) it is empirically grounded in systematic comparison across Global North and South contexts, revealing context-sensitive tailoring; (iv) it explicitly integrates aesthetics and cultural legibility as substantive dimensions of all five phases; and (v) it emphasizes iterative feedback loops and non-linear adaptation.

4. Discussion

4.1. Critical Reflection on Applying the Newly Proposed Multi-Scalar NBS Framework

Synthesizing insights from both Global North and South contexts, the proposed multi-scalar iterative framework enables NBS to be translated into practice through landscape architecture and governance (Figure 2). The framework links five interconnected steps/phases within the NBS co-creation process (Figure 11) through continuous feedback loops, synthesizing ecological, social, and landscape design knowledge and informing adaptive interventions. Its successful application requires context-specific tailoring to ecological conditions (e.g., climatic extremes, native species baselines), governance capacities (e.g., formal and informal institutions), cultural meanings and values (e.g., aesthetic pref-

erences, various knowledge systems), and socio-economic realities (e.g., informal economies, housing affordability, land tenure) [17,82]. Landscape architecture thus functions here as an integrative medium that translates scientific knowledge, community input, and governance requirements into actionable, site-specific interventions promoting just sustainability transitions [11,13,20].

As outlined in Section 3.3, the framework's primary contribution lies in specifying the governance and co-creation conditions that enable NBS translation into landscape architecture practice.

NBS implementation is not a linear or purely technical process, but a negotiated socio-ecological practice shaped by competing values and interests, uneven power relations, and institutional constraints [18,60,83]. From this perspective, the five-step structure (Figure 11) should be understood as an adaptive cycle or spiral rather than a fixed sequence. Co-assessment and co-planning are continuously reshaped by monitoring outcomes, while co-design and co-implementation are revised in response to ecological feedback and social negotiations. This cyclical logic aligns NBS implementation with broader resilience thinking and adaptive governance approaches, where uncertainty and change are treated as natural rather than exceptional conditions [34,73,81]. Instead of assuming seamless transfer from science to policy and practice, the proposed framework emphasizes that translation occurs through iterative reinterpretation across scales, actors, and knowledge systems.

A further critical reflection is that the framework explicitly challenges the persistent disconnect between strategic planning and site-level design in urban sustainability practice. While landscape architecture operates as a bridging discipline, in practice, these scales are often institutionally separated, leading to a loss of ecological intent during implementation and post-construction stages [11,14]. By embedding design thinking throughout all five phases of co-creation [16] (Figure 11), the framework strengthens vertical integration across governance levels and reduces the risk of implementation and management gaps commonly observed in NBS projects.

The framework foregrounds knowledge plurality, integrating scientific, practitioner, Indigenous, and local knowledge systems. This transformative process enables different epistemologies to reshape problem definition and solution formulation [65,66]. In this sense, co-creation becomes a space where ideas of "nature", "value", and "success" are negotiated rather than predefined.

However, structural tensions may limit the operational feasibility of the proposed framework. Among them are institutional capacity, fragmented governance, weak regulatory mechanisms, and challenges of sustaining iterative and participatory ambitions [42]. Similarly, power asymmetries between stakeholders can result in selective participation, where certain voices dominate decision-making processes despite formal inclusivity [83]. The framework thus requires not only methodological adaptation but also institutional and political commitment to inclusive and equity-oriented governance.

In addition, the framework has important implications for landscape architecture practice. It expands the role of designers from spatial problem-solvers to mediators of socio-ecological complexity, responsible for translating abstract policy goals into materially and culturally meaningful NBS interventions [13,14,20]. This requires new competencies, including facilitation of participatory processes, cross-disciplinary communication, and critical awareness of social and environmental justice issues.

Finally, the framework reconceptualizes NBS as a context-sensitive and politically embedded process of sustainability transformation rather than a standardized solution [17,35]. In doing so, it supports a shift from project-based greening interventions (pilot paradox) toward long-term, systemic urban transformation pathways grounded in ecological integrity, social justice, and cultural relevance.

4.2. Limitations and Future Research Directions

This study has several limitations. First, the narrative review methodology, while appropriate for synthesizing interdisciplinary knowledge across landscape architecture, design, and NBS scholarship, may not capture the full breadth of empirical evidence that a systematic review would provide. The reliance on English-language publications further reinforces the very geographic bias this paper critiques, potentially excluding relevant studies published in other languages, particularly from Global South contexts where local knowledge may be documented outside mainstream academic channels.

Second, the project-based insights draw primarily on the authors' direct experiences and networks, which may introduce selection bias toward cases and collaborations that align with the authors' research trajectories. To mitigate this, we deliberately selected projects representing diverse geographical, governance, and socio-ecological contexts, encompassing cases from both the Global North and South, and triangulated these insights with literature-based evidence and conference inputs. Similarly, the conference reflections, while offering valuable practice-grounded insights, may represent the perspectives of participants who attended these specific events. To address this, we engaged with multiple international conferences with different regional foci and participant compositions, ensuring a broad range of perspectives. Although we triangulated project insights with literature and diverse conference inputs, systematic case study selection protocols were not employed.

Third, despite our comparative Global North and South framing, the analysis remains constrained by the uneven availability of documented evidence. Overall, cases from the Global South are underrepresented in the peer-reviewed literature, and those that exist often originate from collaborations with Global North institutions, potentially influencing how both problems and solutions are conceptualized and framed. This reflects broader epistemic asymmetries in knowledge production [22,64]. Furthermore, the rapid urbanization and socio-political dynamics of various Global South cities limit the temporal validity of documented cases, as they can quickly become outdated.

A further limitation concerns the governance dimension. While our analysis addresses institutional capacity, participation, power distribution, and land tenure, other governance aspects (e.g., funding arrangements, maintenance responsibility, accountability, decision-making authority) remain underexplored due to limited documentation across the cases analyzed. These dimensions represent critical gaps in current NBS governance research and practice, requiring dedicated investigation in future empirical studies.

Finally, the proposed multi-scalar framework is a preliminary conceptual synthesis derived from the triangulated evidence of the literature, projects, and conference insights, rather than a prescriptive or empirically validated model. Its operational feasibility, particularly regarding resource requirements for co-creation processes and long-term monitoring of NBS, especially in the Global South, requires further empirical testing across diverse socio-ecological and governance contexts.

Despite these limitations, the triangulation across the three methodological pillars (literature, projects, and conferences) strengthens the validity of our findings and ensures that the proposed framework is both theoretically grounded and practically informed.

Building on these limitations and the manuscript's findings, we identify several priority areas for future research:

1. *NBS implementation through landscape architecture integration.* NBS discourse has historically been dominated by ecological, governance, and policy frameworks [38,73], yet this paper demonstrates that landscape architecture is the "umbrella" discipline where abstract NBS ambitions are translated into tangible, multi-functional interventions. This reinforces the role of urban ecology as not only an analytical field but also a design driver

shaping green infrastructure and landscape interventions [11]. Landscape architecture provides the strategic structure embedding NBS within ecological corridors, governance frameworks, and infrastructural networks at regional and urban scales [6,14]. Site-specific design materializes ecological principles through species selection, spatial composition, and culturally legible interventions at the site scale [12]. Their integration is not merely scalar but epistemological, linking systemic ecological thinking with site-specific cultural mediation, and global biodiversity targets with local aesthetic traditions and ecosystem needs. Without this integration, NBS risk remaining merely technical solutions rather than delivering genuinely transformative outcomes that are both ecologically robust and socially inclusive.

2. *Decolonizing NBS knowledge production and epistemic plurality in NBS research and practice.* Research must actively center scholarship from and about the Global South, including non-English publications, Indigenous knowledge systems, and practice-based documentation from informal settlements and community-led initiatives [61,72]. Collaborative North–South research partnerships should be structured to ensure equitable epistemic authority, moving beyond extractive models of case study documentation toward genuine co-production of knowledge [22,35]. Persistent geographic bias in NBS knowledge production has direct implications for landscape architecture practice. Research on NBS remains dominated by scholarship from and about the Global North, framing urban challenges and solutions through Eurocentric lenses that often marginalize Indigenous and local knowledge [59,60]. This bias extends to landscape architecture paradigms, where colonial legacies have produced globally replicated urban habitats and homogeneous landscapes that suppress native biodiversity and local ecological knowledge [43,83]. Consequently, global guidelines for NBS interventions may prioritize perspectives of the Global North, impose disproportionate governance burdens on Global South contexts, and overlook local socio-ecological realities. Addressing this requires deliberate efforts to decolonize both NBS research and practice by centering diverse knowledge systems and ensuring that landscape architecture reflects locally meaningful relationships with nature rather than imported aesthetic templates.

3. *Long-term and comparative evidence generation for NBS outcomes across contexts.* There is a need for long-term monitoring of NBS implementations that track ecological, social, and aesthetic outcomes over time. Such studies should employ mixed methods capable of capturing both biodiversity indicators and community perceptions, particularly examining how public acceptance of “messy” biodiverse landscapes evolves with exposure and stewardship [44,50,56]. Comparative research across multiple Global South cities, using standardized yet culturally adaptable protocols, would strengthen the evidence base for context-sensitive design. Developing robust, context-sensitive evaluation frameworks that integrate ecological, social, and aesthetic indicators remains a critical priority [18,62,73]. Participatory monitoring approaches that involve communities in data collection and interpretation, including citizen science and Indigenous knowledge integration, require further methodological development and testing across Global North and South contexts.

4. *Operationalizing social and environmental justice in NBS design.* Further empirical research is needed on how landscape architects and designers can operationalize anti-racist and decolonial principles in site-specific decisions: species selection, spatial configuration, material choices, and participatory processes [41,72]. Action research that documents how designers navigate trade-offs between ecological function, cultural legibility, and social inclusion would provide practical guidance for both practitioners and decision-makers.

5. *Esthetics and cultural legitimacy of biodiverse landscape design.* The tension between ecological function and cultural acceptance requires deeper investigation across diverse cultural contexts. Research should examine how aesthetic preferences for urban nature

are formed, how they intersect with colonial legacies of landscape design, and whether alternative design languages (e.g., “cues to care”, rewilding, Indigenous planting systems) can reshape public expectations toward greater appreciation of biodiversity [49,51,57]. Cross-cultural studies comparing aesthetic responses to identical NBS interventions would illuminate the cultural specificity of landscape preferences.

6. Governance conditions and institutional capacity for multi-scalar NBS implementation. The proposed multi-scalar framework assumes institutional capacity for coordination across governance levels and sustained community engagement. Future research should examine the governance conditions enabling such integration, particularly in contexts with fragmented institutional landscapes, limited technical capacity, or contested land tenure [39,42]. Specific attention should be paid to funding arrangements, maintenance responsibility, accountability, decision-making authority, and power distribution—governance dimensions that remain critically underexplored in NBS scholarship. Comparative policy analysis could identify regulatory and financial mechanisms that support or constrain landscape architecture’s role in NBS implementation.

7. Advancing participatory and transdisciplinary methods for context-sensitive co-creation. Co-creation is context-dependent yet globally significant for inclusive and equitable NBS. Participatory processes manifest differently across the Global North and South, reflecting distinct social, political, and ecological contexts. In the Global North context, co-creation often incorporates structured stakeholder workshops and expert-driven optimization of ecosystem services and recreational benefits. In contrast, in the Global South, participation processes must address issues of informal settlements, contested land tenure, and immediate livelihood priorities, functioning as a mechanism for negotiating rights and equitable benefit distribution [22]. Despite these differences, meaningful co-creation across both contexts enhances social legitimacy, fosters long-term sustainability, and prevents NBS from inadvertently reinforcing socio-economic inequities. Effective co-creation requires methods adapted to cultural norms, integration of Indigenous and local knowledge systems, and explicit attention to power asymmetries among stakeholders [18].

8. Shared socio-ecological challenges and enabling conditions for NBS implementation across Global North and South contexts. Despite divergent contexts, the Global North and South share similar challenges in NBS implementation. The tension between ecological function and cultural legibility, exemplified by resistance to “messy,” biodiverse landscapes, appears globally, though its expression is shaped by local aesthetic histories [54]. The concept of “cues to care” remains relevant across the contexts, suggesting that visible signs of stewardship can increase public acceptance of ecologically complex landscapes [51,56]. Similarly, the need to bridge strategic planning with site-specific design and realization is relevant for both the Global North and South, although the resources and governance capacities to achieve this integration differ significantly. Across diverse NBS interventions, from urban rewilding initiatives in Europe to food-producing landscapes in Africa, there is a shared recognition that landscape design must support healthy, functional ecosystems while remaining culturally legible and socially acceptable.

5. Conclusions

This paper demonstrates how NBS are operationalized through landscape architecture and governance. These domains are deeply intertwined. Landscape architecture translates abstract policy ambitions into tangible, multifunctional interventions and embeds NBS within governance systems, ecological networks, and green infrastructure planning. It materializes biodiversity and cultural legibility at the site scale through planting composition, spatial organization, and experiential qualities. Governance provides the institutional frameworks that enable or constrain this translation. Effective implementation depends on governance arrangements that enable sustained co-creation across scales and

knowledge systems. In this context, landscape architecture functions as an integrative medium across all five phases of co-creation (co-assessment, co-planning, co-design, co-implementation, and co-monitoring), transforming strategic objectives into ecologically and culturally grounded site-specific interventions.

Our analysis further reveals that NBS knowledge production is both geographically imbalanced and epistemologically constrained. Global North perspectives dominate, marginalizing Indigenous and local knowledge and reproducing Eurocentric planning and design perspectives. Decolonizing NBS research is therefore essential for achieving context-sensitive and socially just sustainability transitions. Landscape architecture success hinges on governance arrangements—institutional capacity, regulatory frameworks, and participatory processes. These arrangements shape how ecological knowledge, community priorities, and design decisions interact across different scales.

Co-creation emerged as both context-dependent and fundamental for effective NBS implementation, yet its meaning and function diverge markedly across contexts. Governance capacity, colonial legacies, cultural perceptions of nature, and urbanization trajectories fundamentally shape these divergent pathways. In the Global North, co-creation operates within structured governance frameworks to optimize ecosystem services and stewardship. In the Global South, it frequently functions as a mechanism for negotiating basic rights—land tenure, livelihoods, and environmental justice, under conditions of institutional fragmentation and socio-economic inequality. Across both contexts, meaningful co-creation requires culturally adapted methods that address power asymmetries and integrate diverse knowledge systems.

Despite differing regional conditions, several shared challenges were identified across the Global North and South, including tensions between ecological function and cultural legibility, fragmented governance, and the disconnection between strategic planning and site-scale realization. Emerging context-specific strategies include biodiversity-positive design, rewilding approaches, multifunctional green infrastructure, integration of Indigenous knowledge systems, culturally adapted participatory methods, and hybrid approaches combining ecological restoration with livelihood support. These strategies offer important alternatives to conventional greening paradigms and challenge Eurocentric aesthetic templates while centering locally meaningful relationships with nature.

The findings demonstrate that NBS cannot succeed solely as a science and policy approach; instead, they must be spatially translated through culturally responsive and ecologically informed design processes and maintenance.

The proposed multi-scalar framework synthesizes these insights by linking co-assessment, planning, design, implementation, and monitoring of NBS through iterative feedback loops, connecting governance with site-level interventions through context-specific tailoring processes. The framework's contribution lies in centering governance arrangements and co-creation pathways as the primary analytical dimensions. This focus does not disregard ecological considerations. Rather, our analysis identifies these dimensions as the principal constraining variables that most critically determine whether NBS progress from policy ambition to transformative, context-sensitive practice. NBS implementation is not a linear technical process but a set of adaptive socio-ecological dynamics and outcomes shaped by institutional capacity, participatory processes, ecological conditions and socio-cultural contexts. Reaching transformative NBS' potential therefore requires embedding landscape architecture and governance as mutually reinforcing domains: landscape architecture translates governance ambitions into material form, while governance provides the institutional frameworks that enable design action. Together, these domains must synthesize environmental knowledge with co-creation processes and institutional frameworks through transdisciplinary and context-sensitive approaches that support resilient, biodiverse, and socially inclusive urban futures.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/land15081342/s1>, Table S1: International conferences and thematic sessions from which selected contributions are included in the study; Table S2: Overview of selected case studies and their contribution to the proposed framework.

Author Contributions: Conceptualization, D.D.; methodology, D.D.; validation, D.D., M.I. and E.D.; formal analysis, D.D.; investigation, D.D., M.I. and E.D.; resources, D.D.; data curation, D.D.; writing—original draft preparation, D.D.; writing—review and editing, D.D., M.I. and E.D.; visualization, D.D. and M.I.; supervision, D.D.; project administration, D.D.; funding acquisition, D.D. All authors have read and agreed to the published version of the manuscript.

Funding: The research is prepared within the UFZ Integration Platform “Societal Transformations towards Sustainability”, Research Units “Ecosystems of the future” and “Environment and Society”, as well as with the support of the RUDN University Scientific Projects grant system and Strategic Academic Leadership Program (Diana Dushkova and Elvira Dovletyarova).

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

Acknowledgments: We extend our warmest thanks to all contributors to the URBIO conferences held in Leipzig (2022), Columbia (2024), and Perth (2025), as well as the SSC International conference in Moscow (2024) and the SURE World Conference in Istanbul (2025). The case studies presented, the productive discussions on implementation challenges and successes, and the strong commitment to transdisciplinary collaboration demonstrated at these events have significantly informed and enriched the conceptual development of this work. We are especially grateful to the researchers, practitioners, policymakers, and community representatives who generously shared their practical experiences, innovative co-creation approaches to NBS and green infrastructure development, and critical reflections on navigating institutional opportunities and constraints. The diversity of perspectives, local knowledge, and collaborative spirit fostered across these gatherings has substantially contributed to the ideas and insights presented in this paper. We are deeply grateful to our colleagues for their thoughtful reflections and constructive feedback, which helped strengthen this manuscript. We also thank three anonymous reviewers for their constructive feedback, which helped us strengthen the manuscript through methodological clarification, sharper analytical focus, and improved coherence. Our sincere appreciation goes to Victoria Novikova-Dickey for her invaluable assistance in refining and proofreading the final version of the manuscript.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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