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Review Article: Nature-Based Solutions for Climate Resilience Through Innovative Approaches and Stakeholder Engagement

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Abstract Nature-based solutions (NBS) offer promising pathways for climate change adaptation and reduction of water-related risks. However, their integration faces socio-institutional barriers, necessitating innovative approaches and stakeholder engagement in planning, design, and evaluation. This review synthesizes insights from six studies, each putting light on the potential of NBS beyond 'grey infrastructures'. Acknowledging socio-institutional barriers as key obstacles, these studies advocate for innovative tools and stakeholder involvement in NBS planning, design, and assessment. Diverse methodologies are employed across various case studies, fostering a comprehensive understanding of benefits, co-benefits, and trade-offs associated with NBS implementation. Leveraging inputs from institutions, NGOs, and local communities, the studies highlight the importance of inclusive decision-making processes. This review underscores the imperative of early stakeholder engagement, diverse methodologies, and thorough evaluations to guide informed NBS selection, ensuring resilient and sustainable solutions in different environmental contexts.

Keywords: Nature-based solutions, Co-benefits, Participatory modelling, Stakeholder engagement

1 Introduction

In the face of escalating climate change impacts and an increasing frequency of extreme weather events, the imperative for effective adaptation strategies has never been more pressing. These recent findings (Altamirano et al. 2023; Scrieciu et al. 2023; Mulligan et al. 2021; Mayor et al. 2021; Giordano et al. 2020) highlight a pivotal moment in our climate, stressing the immediate requirement for comprehensive actions to address and prepare for these challenges. In the study by Altamirano et al. (2023), the authors emphasize that the Global Commission on Adaptation (GCA) has firmly labeled climate change as a significant menace, causing extensive and harmful impacts on humanity, ecosystems, and global finances.

This review article delves into the relatively new subject of NBS, recognizing their crucial role in supporting resilience and addressing the multifaceted challenges posed by climate change impacts. The escalating frequency and severity of natural disasters, with 2017 marking the second-costliest year for such events (Altamirano et al. 2023), emphasize the necessity for innovative, nature-inspired approaches to mitigate risks and foster sustainable adaptation strategies.

Drawing from a spectrum of disciplines including environmental science, hydrology, and system modeling, this review presents a comprehensive examination of stakeholder engagement, co-benefit analysis, and methodologies crucial for devising and implementing NBS. It underscores the crucial role of active stakeholder participation in aligning NBS initiatives with societal needs and local contexts, fostering greater social acceptance and effectiveness in implementation strategies.

Furthermore, the present article comments on the dynamic interplay between stakeholders, ecosystems, and NBS implementation using robust analytical tools such as Causal Loop Diagrams (CLD), Multi-Criteria Decision Analysis, and Participatory System Dynamic Modeling that are described in the articles mentioned before. These methodologies serve as crucial lenses through which to understand and navigate the intricate web of co-benefits, trade-offs, and systemic impacts associated with NBS implementation.

In both the works of Mulligan et al. (2021) and Altamirano et al. (2023), the post-pandemic era emerges as a potential turning point for an economic reset, emphasizing the need to implement NBS. This era is portrayed as a moment demanding an economic overhaul and echoing the urgent call to 'build back better', a slogan that underscores the importance of addressing both environmental and social concerns, ensuring environmental improvements benefit everyone, the economy works inclusively, and there are lots of high-quality job opportunities for all. One of the most compelling aspects of this discussion is the recognition of the fragility of the pre-pandemic economic system, which was marked by cycles of growth and decline, along with growing social inequality.

Mulligan et al. (2021) further caution against ongoing environmental deterioration, stressing the urgent requirement to reshape our strategies to avert a less hospitable future for humanity. Moreover, the authors provide a stark portrayal of the environmental toll on densely populated areas, particularly in Europe. It vividly paints a picture of crowded, polluted cities juxtaposed against ecologically depleted rural landscapes. The impact on physical and mental health due to pollution and the lack of access to natural spaces becomes a focal point, emphasizing the far-reaching consequences of environmental degradation on human well-being.

In Mayor et al. (2021), the authors discuss the pressing concern of significant economic losses resulting from flooding. In the European context, projections indicate that by 2050, these losses can be predominantly attributed to the dual effects of escalating asset values in flood-prone regions and the compounding impacts of climate change. Traditional infrastructure measures that can help to prevent major losses are costly, requiring substantial investment. As an alternative, NBS are gaining traction, focusing on nonstructural and nature-centric approaches to tackle water-related hazards, although they face implementation challenges and funding barriers. The authors emphasize the need for robust business models to attract investment for NBS, highlighting the current lack of comprehensive data on the environmental, economic, and social benefits of these solutions. They point out the necessity for user-friendly tools to develop strong business cases for NBS, especially at larger scales such as disaster risk reduction and climate change adaptation. Existing frameworks often overlook scalability and institutional trade-offs, leading to limitations in assessing the full value and potential revenue streams of NBS. To address these gaps, the authors introduce and detail the Natural Assurance Schemes (NAS), a tool developed under the H2020 NAIAD project. NAS aims to characterize value creation from service providers (implementing NBS) to beneficiaries and identify viable business models for NBS strategies focused on disaster risk reduction and climate adaptation. The NAS canvas tool structures the elements essential for generating business models around NBS, aiming to catalyze economic resources for implementation and facilitating eco - disaster risk reduction and climate adaptation services.

Altamirano et al. (2023), predominantly focus on addressing and bridging the gap that exists in the execution and application of NBS specifically concerning water security. The primary objective of this research is to devise and formulate a comprehensive implementation strategy for NAS. Within the context of a climate and water crisis, the authors emphasize the significance and relevance of NBS in mitigating the risks associated with drought and its subsequent impacts on the agricultural sector. In order to substantiate their claims, the authors present an illustrative case study concerning Medina del Campo Groundwater body in Spain. This case forms an integral part of a broader initiative involving the implementation of the Financing Framework for Water Security (FFWS). The authors mention two other distinct case studies in separate articles, which will not be addressed in our review.

Giordano et al. (2020) raise the importance of stakeholder involvement in assessing NBS, as different stakeholders perceive and value NBS benefits differently, potentially leading to conflicts and impeding policy implementation. The focus on NBS revolves around their potential to enhance ecosystems and generate environmental, economic, and social advantages critical for climate adaptation and mitigation. Yet, existing evaluation frameworks for NBS effectiveness have limitations in fully analyzing their multifaceted benefits, often neglecting socio-cultural, economic, and cross-sectoral impacts. Moreover, these frameworks are static, failing to consider changes in NBS and their operating conditions over time. With these thoughts in mind, the authors proposed a methodology based on Fuzzy Cognitive Maps (FCMs) to assess NBS effectiveness, detect stakeholder value differences, analyze trade-offs, and manage potential conflicts. This methodology was developed within the EU-funded project NAIAD and implemented in the Lower Danube River basin.

Colleta et all. (2021), kicks off by highlighting a growing concern: the increasing frequency and intensity of natural disasters, particularly water-related ones like floods and droughts. These disasters are wreaking havoc on communities and infrastructure; they are amplified by factors like climate change, urbanization, and land-use alterations. In response, European policies are leaning towards a 'working with nature' approach, focusing on NBS as innovative methods rooted in nature to tackle these challenges. These innovative approaches, inspired or supported by nature, offer environmental, social, and economic benefits crucial for climate adaptation, ecosystem conservation, and sustainable growth. While these benefits drive NBS implementation, most methods focus on post-assessment rather than integrating these advantages from the beginning. Limited frameworks propose starting NBS design with a co-benefits analysis. Engaging stakeholders actively in NBS design, as shown by various studies, enhances social acceptance. This research proposes an approach involving stakeholders from the outset, using methods that detect potential impacts and trade-offs of NBS, aiming to identify the most suitable solutions aligned with strategic objectives. The study adopts an innovative methodology that involves Causal Loop Diagrams (CLDs) within a Multi-Criteria Decision Analysis, aiming to address key questions about stakeholder understanding, learning processes, and the description of NBS' effects on the system. The approach, developed within the EU-funded project NAIAD, focuses as well on the Lower Danube case study in Romania. Ignoring such differences and potential trade-offs might hinder an effective NBS design, leading to conflicts and barriers in implementation.

In Scrieciu et al. (2023), the authors discuss the role of NBS in the Lower Danube, emphasizing the importance of co-benefits in enhancing social acceptance and addressing water-related risks. It highlights the need to co-define co-benefits during the NBS design phase and describes the use of hydraulic models and GIS infra-territorial indicator methodology to assess flood risk vulnerability. The article also addresses the impact of anthropic interventions and climate change on the Lower Danube wetlands, emphasizing the need for wetland restoration projects and NBS implementation. The authors examine initiatives such as the 'Program for Ecologic and Economic Reshape of the Danube Floodplain' and subsequent NBS projects carried out by the National Administration Romanian Waters. The NAIAD Project is mentioned as a key initiative for facilitating local collaboration and stakeholder engagement in decision-making and policy setting. The authors aimed to develop a NAS for the Lower Danube Case Study to improve flood and drought management and capitalize on NBS co-benefits. They outlined the steps for physical risk assessment, NBS design, and damage assessment in vulnerable areas. The research conducted in the Lower Danube case study focuses on understanding the role of

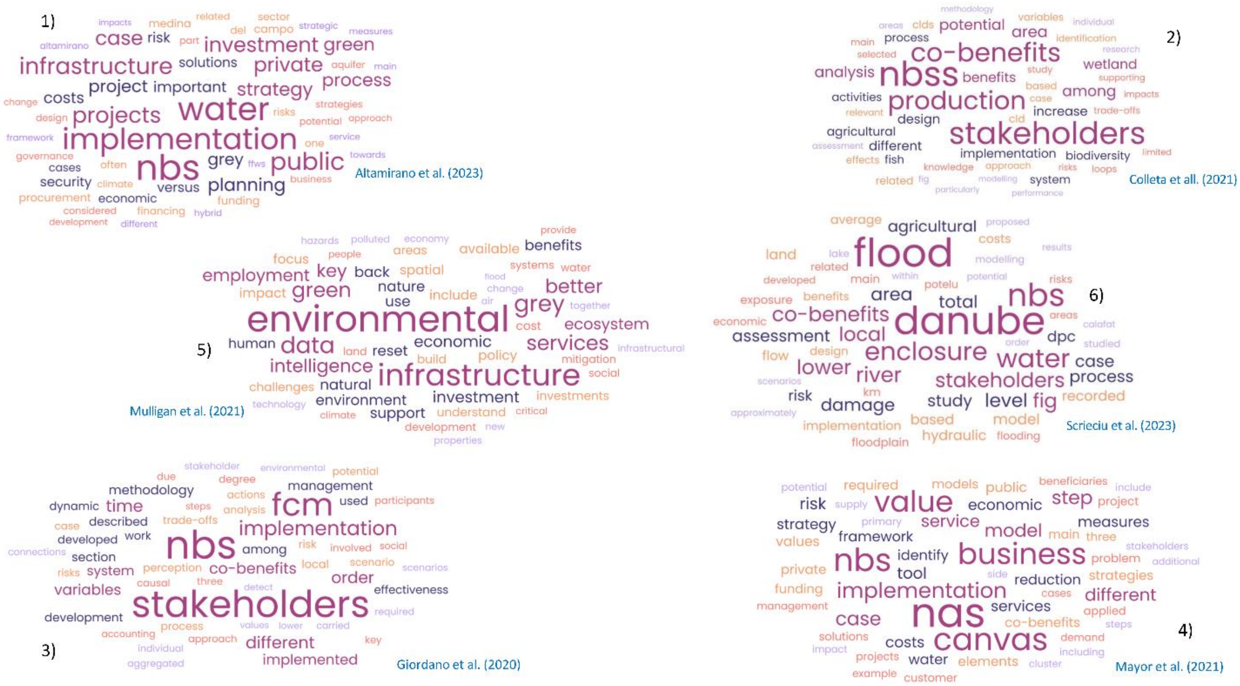

Figure 1: Wordclouds depicting prominent terms in the six cited articles. The size of each word corresponds to its frequency within the context, visually highlighting the key themes and concepts discussed.

NAS in complex natural, economic, and social contexts, with a specific focus on the Dabuleni-Potelu-Corabia (DPC) enclosure. The authors also emphasize the importance of stakeholder participatory processes and the integration of local knowledge with scientific models to facilitate effective NBS adoption and water risk management.

We decided to incorporate word clouds (Figure 1) generated from each of the discussed articles as a dynamic method to enrich the visual narrative of this review article. The word clouds provide a brief, but comprehensive overview of the thematic terrain covered in the combined content. By grouping key terms and frequently occurring words, this graphical representation offers a bird's-eye view, reinforcing concepts and recurrent themes. By examining these word clouds, it's evident that the authors predominantly discuss concepts such as NBS, stakeholder involvement, green infrastructure, and project implementations. These findings provide the readers with a distinct path to pursue to deepen their understanding of this particular range of topics.

For this review article, we identified six recent NBS articles involving at least one individual from GeoEcoMar to showcase our knowledge and contribution to this important subject. We go beyond theoretical contributions by developing practical frameworks designed to help stakeholders make well-informed decisions about adopting environmentally friendly measures and infrastructure. Furthermore, we will present each methodologies underpinning these frameworks and provide insights into their structure.

2 Material and methods

All the case studies mentioned in the six articles captured for Figure 1 have been centralized in the table below (Table 1). Additionally, we have highlighted the main issues identified by the authors within each paper and outlined the primary approach used to tackle the subject.

Table 1: Outlined case study locations, primary environmental issues, and corresponding approaches utilized across cited articles

ARTICLES	CASE STUDIES	MAIN ISSUES	MAIN APPROACHES
Altamirano et al. (2023)	Medina del Campo Groundwater body (GWB), Spain	Droughts, groundwater exploitation	FFWS
Colleta et all. (2021)	Potelu wetland in the Lower Danube, Romania	Floods, Droughts	Multi-step methodology
Giordano et al. (2020)	A large area of the Lower Danube, from Calafat to Zimnicea, Romania	Floods, Droughts	FCM
Mayor et al. (2021)	Medina del Campo Aquifer, Spain	Droughts	NAS
	Lez basin, France	Floods	
	Rotterdam, Netherlands	Pluvial Flooding	
Mulligan et al. (2021)	Thames Gateway, OxCam Arc and Strand Aldwych, UK	Air pollution, Thermal extremes, Floods	'Build back better' strategy
	Carasuhat Wetlands, Romania	Biodiversity loss	
	Castilla Leon and Rivas VaciaMadrid, Spain	Floods, Droughts	
	Bologna, Italy	Air pollution, Thermal extremes	
Scrieciu et al. (2023)	Dabuleni-Potelu-Corabia Enclosure, Lower Danube, Romania	Floods, Droughts	NAS

2.1 COMPARATIVE INSIGHTS FROM THE SIX STUDIES

The methodology outlined in the conference paper of Mulligan et al. (2021) details a comprehensive approach to 'build back better' by emphasizing the need for investment-specific intelligence to maximize nature's benefits while minimizing human impact. The key steps involved in this process are as follows:

1. Understanding Baseline Conditions:
- Evaluating environmental, economic, and employment baselines provided by green and grey infrastructure within the area of interest.
- Assessing human exposure to ecosystem services, dis-services, environmental hazards, and the economic costs associated with these infrastructures.

2. Exploring Investment Alternatives:
- Examining a spectrum of investment options, ranging from traditional grey infrastructure to various grey-green blends and fully green infrastructural development.

3. Simulating Impact:
- Using simulations to assess the potential impact of different interventions on ecosystem and infrastructural services and dis-services, specifically focusing on their distribution and effect on people.

4. Cost-Benefit Analysis:
- Calculating the economic costs versus benefits of the interventions, considering cost savings, damage avoidance, and opportunity cost savings for each.

5. Employment Assessment:

- Estimating the income generated through employment opportunities created or sustained by the interventions.

These spatial assessments of benefits, costs, and income enable a comparison of interventions, providing intelligence for investment decision-making, planning, and evaluation processes. The ReSET project aims to utilize environmental intelligence and tools developed by the consortium to progress in these areas, focusing on environmental hazards in urban areas and flood mitigation, climate change, and biodiversity conservation in rural areas.

The consortium has developed several tools over the years to facilitate this work, including web-based spatial policy support systems, DIY environmental monitoring tools, and software environments for spatial decision support systems. These tools will be refined and integrated to support 'build back better' investments, validated in specific demonstration areas while being adaptable for global application using routinely available data.

Additionally, the ReSET project plans to leverage artificial intelligence techniques, particularly ResNet50 ANN, for image classification tasks such as distinguishing grey infrastructure from green spaces in urban areas and identifying key grey infrastructure in rural settings. Overall, the methodology presents a holistic approach leveraging data, simulations, economic analysis, and AI to guide investment decisions aimed at sustainable and environmentally friendly infrastructure development.

In Giordano et al. (2020) the authors outline a methodology focused on NBS for water-related risk management, emphasizing active stakeholder engagement throughout the process. Employing a 'snowballing' sampling approach, diverse stakeholder categories participated to mitigate bias and ensure representation. Central to this methodology is the utilization of FCM and Problem Structuring Methods (PSM). These methods facilitated an in-depth understanding of stakeholders' perceptions, preferences, and concerns regarding water-related risks and the potential impacts of NBS implementation. Through individual stakeholder interviews, valuable insights were gathered and translated into FCMs, mapping out the causal relationships and key concepts. The methodology further employed scenario analysis using these FCMs, simulating the expected impacts of NBS implementation on various variables. Special attention was given to accounting for time scales and delays in co-benefits production, a critical consideration for understanding system dynamics. The validation of FCMs involved stakeholder discussions to refine and enhance their representation of stakeholders' perceptions. Finally, the methodology engaged stakeholders in defining NBS scenarios and conducted a trade-off analysis to anticipate and address potential conflicts arising from unequal distribution of co-benefits among stakeholders due to NBS implementation. This comprehensive approach integrates stakeholder perspectives, FCM analysis, scenario simulations, and trade-off assessments to offer a holistic understanding of NBS effectiveness in managing water-related risks while highlighting stakeholder perceptions and potential conflicts in implementation.

The methods chapter of Colleta et all. (2021) details a participatory approach divided into three core steps. Initially, stakeholders are engaged through semi-structured interviews to gather diverse insights on water-related risks and potential benefits associated with sustainable environmental practices. This information is synthesized into Individual FCM representing stakeholders' perceptions of the system, crucial for identifying key elements and potential co-benefits. Subsequently, collaborative workshops involve group activities to collectively rank co-benefits and select NBS aligned with these priorities. The third step focuses on constructing CLD illustrating relationships among system variables, aiding comprehension of system dynamics under various conditions, including NBS implementation. CLD facilitate qualitative analysis of feedback loops, revealing co-benefits' production mechanisms and potential side-effects. Alongside CLD, a Performance Matrix quantitatively evaluates NBS' performance concerning selected benefits and co-benefits, integrating fuzzy logic to incorporate stakeholders' qualitative knowledge. This process enables estimation and comparison of NBS performance, aiding stakeholders in formulating recommendations for decision-makers, emphasizing the maximization of benefits and co-benefits while addressing water-related risks in the study area.

The materials and methods chapter of Mayor et al. (2021) details the development of the NAS Canvas, a framework designed to identify and describe business models specific to NBS addressing climate adaptation and risk reduction. This canvas is an adaptation of the traditional business model canvas, tailored to the unique context of NBS.

The NAS canvas is structured around six blocks: Problem, Service, and Value; Supply Side; Demand Side; Supply-Demand Interactions; and Impact; Further Steps Towards Defining the Business Case. Each block contains clusters or steps that sequentially describe various aspects crucial for understanding and implementing NAS strategies.

- **Problem, Service, and Value:** Defines the problem addressed by the NAS and articulates the primary and secondary values provided by the solution.
- **Regulatory Context:** Considers relevant regulations or their absence in regard to the identified issues or goals.
- **Supply Side:** Identifies agents responsible for implementation, required activities, resources, and key partners involved.
- **Mapping the Costs of the Service:** Details the different types of costs associated with implementation.
- **Demand Side:** Identifies stakeholders affected by the problem, segments customers, and evaluates their willingness to pay.
- **Mapping the Ability/Willingness to Pay:** Identifies revenue streams and funding sources.
- **Supply-Demand Interactions:** Describes the relationship between the service provider and the customer, communication channels, and interfaces.
- **Impact:** Establishes Key Performance Indicators (KPIs) to measure the efficiency of the NAS strategy.

Beyond the traditional business model elements, **Block 6** further outlines crucial steps necessary to prepare a solid business case and lay the groundwork for NAS implementation and funding:

Further Steps Towards Defining the Business Case:

- **Financing Mechanism:** Identifies the type of financing formula needed to acquire required funds or capital investment.
- **Governance Model:** Describes collective action arrangements for NBS implementation, management, and maintenance, including models like Public-Private Partnerships.
- **Success Conditions:** Identifies determinant factors essential for successful NAS strategy implementation, drawn from similar examples.
- **Barriers to Implementation:** Highlights potential constraints or hurdles that could impede the feasibility or success of NAS strategy execution.

The NAS canvas provides a structured approach to comprehensively describe and understand the components of an NAS business model. It was applied to three demonstration cases in European sites, with data collected through assessments, interviews, and participatory workshops, and the economic analysis carried out to estimate primary and secondary values and costs.

From Altamirano et al. (2023), we gleaned the primary methodological concepts dispersed throughout its chapters, given the absence of a dedicated section explicitly outlining the methods and materials. The text encompasses a comprehensive methodology for financing water security and structuring investable propositions centered on natural infrastructure, outlining the FFWS. The paper addresses the transition from adaptive planning to investment planning, emphasizing the importance of justifying investments in NAS while optimizing the use of public and private funds. The framework guides stakeholders in developing implementation arrangements for water security projects and natural assurance schemes, incorporating governance structures, funding and financing strategies, and procurement approaches. Th paper differentiates between green (natural-based) and grey (conventional) infrastructure projects, highlighting the challenges in investment planning processes primarily designed for grey infrastructure. The comparison underscores the context-specific nature of green infrastructure and its uncertain performance, risk factors, and cash profiles compared to conventional grey infrastructure. The authors further introduce steps for designing implementation arrangements, emphasizing the need to define services created by projects, devise funding strategies, determine financing instruments, and establish procurement strategies. They explore various forms of investment in natural infrastructure, including public procurement contracts, private stewardship investments, collective investment vehicles, and environmental/ecosystem markets. The case study on the Medina del Campo aquifer in Spain illustrates the application of the FFWS. They delve into the strategic, economic, commercial, financial, and management aspects of the project. The strategy aims to mitigate drought risk, improve water quality, and reduce flood risks while emphasizing the importance of behavioral change among agricultural water users. They examine the winners and losers concerning the economic impact, detailing funding sources, governance structures, and implementation arrangements for the project. Overall, the paper guides stakeholders through a structured process to plan, finance, and implement NBS for water security, offering insights into navigating the complexities of integrating natural infrastructure into traditional investment planning processes.

Scrieciu et al. (2023) does not have a dedicated chapter specifically for methods and materials; however, the authors discuss these elements across multiple sections within the paper. The chapter on NBS design process outlines the emergence and significance of NBS as an effective alternative to conventional infrastructure in mitigating climate-related risks in both urban and rural settings. The paper delves into the challenges facing successful NBS implementation, particularly the lack of stakeholder engagement, emphasizing the necessity of involving local communities in the design and implementation phases. It describes a stakeholder engagement process conducted in the Lower Danube case study within the NAIAD project, aiming to understand the role of natural assurance schemes within complex natural, economic, and social contexts. The methodology includes phases such as identifying main beneficiaries, aligning NBS principles with regulatory directives, and conducting a stakeholder engagement process through interviews and workshops. Stakeholders ranked benefits and co-benefits, identifying key NBS like wetland restoration and river renaturation. The paper proceeds with hydraulic modeling of the DPC enclosure, assessing scenarios for restoring the floodplain, considering total and partial flooding. It outlines the intricacies of the hydraulic model, calibration processes, and proposed scenarios' impact on water flow, flood reduction, and associated costs.

The economic assessment section examines the 2006 flood damage through literature review and GIS-based indicators. It details the estimated damage costs, displaced population, affected constructions, and agricultural loss in the Lower Danube area, emphasizing vulnerability mapping as a decision-making tool for disaster assessment. Overall, the chapters present a thorough methodology for designing NBS, incorporating stakeholder engagement, hydraulic modeling, and economic assessments to address climate-related risks in the Lower Danube region.

3 General findings

In the last chapter, Mulligan et al. (2021) start by acknowledging the long-standing existence of environmental modeling and simulation, tracing its roots back to the 1970s. The recent developments highlighted encompass the exponential growth of available data, the evolution of data science techniques, the increased accessibility of cutting-edge digital technologies, and the rise of AI-enabled approaches, all against the backdrop of increasingly complex sustainability challenges. The chapter pinpoints several key challenges that still confront environmental intelligence initiatives:

1. **Problem Assessment:** Environmental issues are often complex and multifaceted, necessitating enhanced communication between stakeholders and environmental scientists. This collaboration aims to grasp the diverse dimensions of problems and ensure that technological solutions align with actual demands.
2. **Problem Focus:** There is a risk of technology-centric projects losing sight of the actual environmental or social issues they aim to address. The emphasis should remain on using technology as a means to an end, enabling research and innovation, rather than becoming the central focus itself.
3. **Usability:** Despite the development of numerous tools in applied environmental science, their widespread adoption remains low. Difficulty in use or a lack of clear identification of users and use-cases can hinder their uptake. Co-designing with stakeholders becomes crucial for ensuring usability.
4. **Integration and Maintenance:** The abundance of data, while beneficial, poses challenges in terms of accessibility, varying formats, and standards. There is a need for robust APIs and adaptive integration methods to bring disparate data together in a maintainable manner.
5. **Scalability and Relevance:** Environmental tools should demand minimal user input while offering comprehensive support globally. Achieving a balance between a global understanding of processes and locally relevant data and policy options is pivotal for diverse applications.
6. **Accessibility:** Reducing costs, enabling local maintenance, and ensuring accessibility to data and model infrastructure are vital for ensuring the legacy and continued utility of these tools

The results chapter of Giordano et al. (2020) presents tan assessment of implementing NBS to address flood and drought risks in the Lower Danube region. The study highlights the multifaceted nature of these risks, emphasizing the need for a combined approach that considers floodplain reconnection, wetland restoration, and the impacts of climate change, urbanization, and anthropic pressures. The chapter illustrates the intricate process of stakeholder involvement, starting from the selection of key actors, conducting interviews, and developing a shared understanding of NBS. The methodology employed, including the use of FCM, facilitates the perception and assessment of co-benefits associated with NBS implementation. The delineation of stakeholders' problem understanding and objectives through FCM, coupled with scenario simulations, helps in visualizing potential impacts of different strategies over short, medium, and long terms. This predictive modeling is crucial for gauging the effectiveness of the proposed NBS, even before their implementation. The detailed analysis of different scenarios (e.g., wetland restoration, river renaturation) sheds light on the varying impacts on community well-being, economic variables, and environmental factors. This granular understanding allows stakeholders to choose and refine strategies that align with their objectives and priorities.

The identification of potential trade-offs among stakeholders based on their perceived benefits is a critical highlight. It underscores the necessity of early engagement, continuous communication, and managing expectations to mitigate conflicts and ensure smoother NBS implementation. Overall, Colleta et all. (2021) exemplifies a systematic and inclusive approach to assess, simulate, and evaluate NBS effectiveness in addressing complex environmental challenges. The detailed analysis of stakeholder perceptions, coupled with scenario simulations, provides valuable insights for decision-makers to fine-tune strategies and navigate potential conflicts during implementation. The results and discussion chapters focus assessing the effectiveness of NBS in the Lower Danube case study, specifically the Balta Potelu Pond area in Romania. The study delves into stakeholder engagement, co-benefit identification, CLD construction, and an assessment of NBS using qualitative and semi-quantitative methods. It involves stakeholders actively, seeking their input through interviews and workshops, aiming for a shared conceptual understanding. It identifies key issues such as water-related risks, economic activities, environmental concerns, and barriers to restoration due to land ownership complexities and community resistance. The research reveals the importance of reducing flood and drought impacts and identifies co-benefits like eco-tourism, biodiversity, fishing, and agriculture. Stakeholders prioritize these co-benefits, aligning them with potential NBS like wetland restoration, retention areas, river renaturation, and reforestation. The CLD creation illustrates the complex interactions among variables, highlighting feedback loops affecting biodiversity, agricultural production, fish production, eco-tourism, and human well-being. It indicates potential trade-offs between agricultural and fish production due to the impact of wetland restoration. The assessment using CLD and a Performance Matrix outlines the effects of different NBS on benefits and co-benefits. It demonstrates the potential positive impact of wetland restoration on reducing water-related risks but suggests a potential negative effect on agricultural production. The paper emphasizes the value of qualitative modeling, particularly CLD, in capturing stakeholder knowledge and fostering interaction. It highlights how qualitative models effectively represent stakeholder views and contribute to a shared understanding of complex systems. The study's strength lies in elucidating the dynamics and potential trade-offs among co-benefits, thereby enhancing awareness of NBS' effectiveness, and fostering equitable distribution of benefits among stakeholders. The discussion acknowledges the qualitative nature of the analysis and its limitations. It suggests the need for more quantitative tools and recognizes the importance of considering market conditions in agricultural production analysis for a more comprehensive assessment.

The results section of Mayor et al. (2021) presents an in-depth analysis of three case study scenarios employing NBS to address water-related risks, specifically, drought and flood risks, in different geographical locations. Each case study offers insights into the unique business models adopted for the implementation of NBS strategies, highlighting their specific features, stakeholder engagements, funding mechanisms, and impacts. The first case study, focusing on the Medina del Campo Aquifer in Spain, illustrates a large-scale NAS strategy. It emphasizes the multifunctional nature of NBS, addressing not only drought risk reduction but also the restoration of aquifers to comply with environmental directives. The partnership between public and private entities stands out as a crucial aspect for effective implementation, showcasing the necessity of collaborative efforts for achieving desired impacts.

The second case, situated in the Lez sub-catchment in France, addresses flood risk through urban-focused NBS measures. Here, the discussion revolves around the significance of co-benefits in justifying investments, surpassing the primary value of risk reduction. Various funding mechanisms, including taxes and insurance funds, were leveraged, highlighting the role of financial instruments in supporting NBS initiatives. The third case, located in the Spangen district in Rotterdam, Netherlands, highlights a small-scale urban NAS aimed at flood risk reduction. What distinguishes this case is the empirical data-driven assessment post-implementation, demonstrating the substantial value of risk reduction and co-benefits, further justifying investments from the municipality and Water Authority. Moreover, the discussion on keys for success and barriers for implementation across these cases underscores common factors such as funding availability, stakeholder cooperation, proven efficacy of measures, and the role of political will or an enabling environment. Moving to the discussion section, it reflects on the increasing importance of innovative business models for financing and mainstreaming NBS implementation, as recognized by various governmental institutions and projects funded under Horizon 2020. It delves into the development of tools to describe NBS-related business models, showcasing the NAS canvas's unique attributes compared to other tools. The canvas's ability to quantify values, costs, and impacts in a comprehensive yet simplified manner makes it a valuable communication tool. The adaptability of the NAS canvas across different project stages and contexts, its usability for various stakeholders, and its capability to accommodate non-monetary values emerge as key strengths. Additionally, the discussion stresses the critical role of institutional arrangements and governance structures in the successful implementation of NBS, emphasizing the significance of stakeholder involvement and co-creation processes in validating business models.

The discussion in Altamirano et al. (2023) explores the evolution of NBS implementation, stating that many projects, primarily led by advocacy or academic organizations, prioritize raising awareness over demonstrating revenue potential. To move forward effectively, a reevaluation is necessary to present a strong investment case to both public and private sectors. However, a critical gap exists between NBS projects and the structured business approach required to secure funding. These projects often lack the necessary planning due to the inexperience of advocacy-driven organizations in investment processes, leading to a distinction between scientific/advocacy projects and those attractive to investors. Implementation challenges emerge, emphasizing the importance of considering lifecycle costs, expertise distribution, and differing management styles between NBS and traditional infrastructure projects. Innovative contracting practices, especially those accommodating multiple revenue streams and hybrid infrastructure, are seen as more appealing for funding and sustainability. The recommendations emphasize the need for a different mix of expertise and coaching to balance awareness and investment potential in NBS projects. Moreover, mission-driven research programs are proposed, involving advisory boards for accountability and engagement of key stakeholders in shaping the viability and impact of NBS initiatives. Overall, the discourse underscores the need for a paradigm shift, involving diverse stakeholders and innovative practices to transform NBS projects into financially attractive and sustainable ventures.

Scrieciu et al. (2023) delve into the NAIAD project's exploration of NBS and the pivotal lessons gleaned from its implementation in mitigating local water-related risks. It emphasizes an integrated assessment framework designed to encapsulate stakeholders' preferences for co-benefits. Three key insights emerge: Firstly, the process demands a rich tapestry of knowledge, acknowledging individual risk perceptions and divergent problem framings. This approach champions a nuanced, inclusive procedure without immediate consensus. Secondly, the Lower Danube experiences underscored the profound impact of co-benefits in securing social acceptance for NBS. Stakeholders displayed greater enthusiasm for socio-economic gains, such as eco-tourism, fishery production, and addressing depopulation over mere flood damage reduction. Hence, integrating co-benefits into the NBS design phase itself proves crucial. Thirdly, ensuring equitable access to these co-benefits assumes paramount importance. Detecting potential trade-offs and conflicts early in the NBS design phase becomes vital to ensure fair distribution of benefits. Additionally, the chapter highlights attempts within the NAIAD project to assess insured damage and calibrate specific damage curves for the Lower Danube region in the face of water-related risks. Employing a GIS-based approach to evaluate flood risk vulnerability in the absence of robust insurance data, the initiative aimed to pinpoint highly exposed areas, primarily agricultural regions, and estimate damage costs linked to affected dwellings.

However, challenges persist, particularly in local damage assessment due to insufficient data on insured losses, impeding precise estimations of incurred and avoided damages. The utilization of GIS-based indicators endeavors to alleviate this issue by identifying highly exposed areas and estimating costs linked to damaged and destroyed properties, especially in agricultural zones. In summary, the chapter's insights highlight the significance of embracing diverse perspectives, integrating co-benefits into NBS design, and addressing data gaps to effectively implement and evaluate NBS for managing local water-related risks.

4 Conclusions

The methodologies discussed in Mulligan et al. (2021), Giordano et al. (2020), Colleta et al. (2021), Mayor et al. (2021), Altamirano et al. (2023), and Scrieciu et al. (2023) converge to highlight a comprehensive approach to implementing NBS for environmental challenges. These methodologies stress the importance of considering multiple facets, including stakeholder engagement, predictive modeling, economic assessments, and business models, in crafting effective strategies. Stakeholder involvement emerges as a recurring focal point across these methodologies. Giordano et al. (2020) and Colleta et al. (2021), Scrieciu et al. (2023) emphasize understanding stakeholders' viewpoints and preferences, fostering shared understanding, and ensuring fairness in benefit distribution. Techniques like scenario simulations, FCM, GIS-based analyses and CLD are employed to anticipate the impacts of NBS implementation, aiding decision-makers in visualizing outcomes and potential trade-offs. Mayor et al. (2021) and Altamirano et al. (2023) delve further into economic assessments and business frameworks tailored for NBS, stressing the need to quantify values, costs, and revenue streams associated with these solutions. Addressing challenges like tool usability, data integration, scalability, and accessibility emerges as crucial for advancing methodologies and attracting investments to NBS projects. Mulligan et al. (2021) stress the importance of investment-specific intelligence in maximizing nature's benefits while minimizing human impact, offering a robust methodology that integrates data, simulations, economic analysis, and artificial intelligence to guide sustainable infrastructure development. Overall, these methodologies underscore interdisciplinary collaboration, the importance of diverse data sources, and the necessity of evolving methodologies to meet evolving needs. They collectively contribute to informed decision-making, effective NBS implementation, and progress toward sustainable environmental solutions while acknowledging the need for further advancements in this field.

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