Official Journal of the World Water Council
Water Policy

Water Policy Vol 00 No 0, 1 doi: 10.2166/wp.2025.238

Mainstreaming stormwater NBS: A study in transition governance

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ABSTRACT

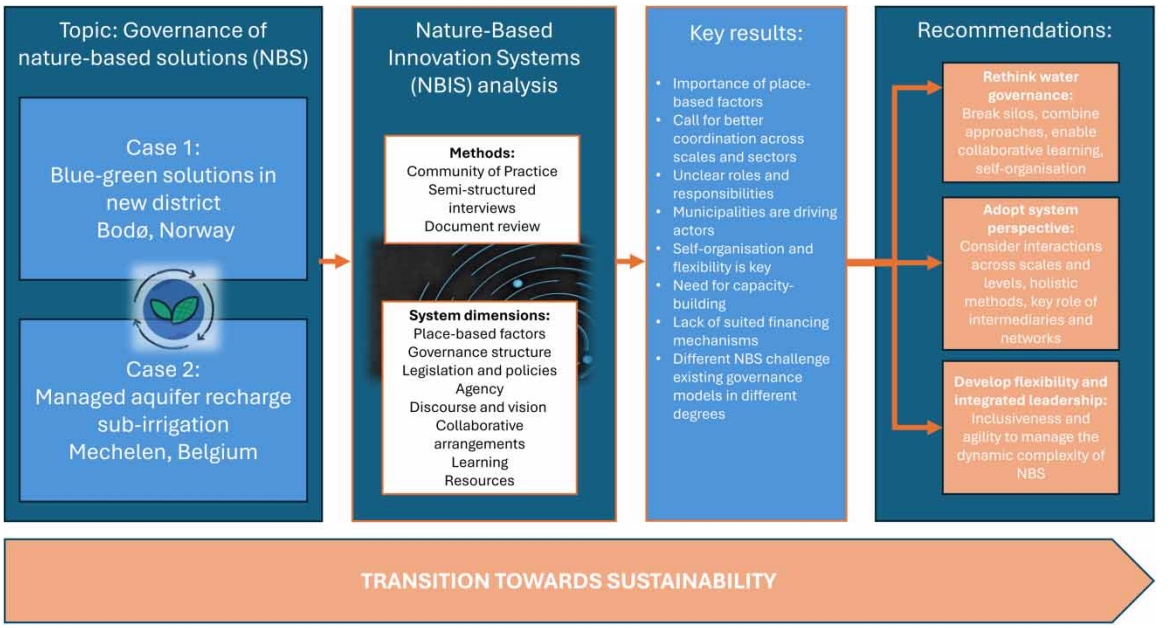
Sustainability transitions challenge established governance models, in terms of balancing short- and long-term objectives, adaptation and mitigation, local and global perspectives, and fostering innovation, while maintaining stability. Recent research calls for more knowledge on managing such trade-offs and tensions. We address this gap through a study on stormwater management, where current efforts to mainstream nature-based solutions (NBS) challenge existing governance systems. NBS are increasingly promoted to sustainably manage ecosystems. However, their governance, at the interface between social, technical, and ecological systems, comes with multiple challenges. The paper sheds new light on these challenges, based on interviews and workshops in two European case studies. The nature-based innovation system framework is applied, to assess system-level interactions influencing the uptake of NBS, and their governance implications. In line with recent studies on transition and transformative governance, we show that governance enabling NBS must provide increased coordination and collaboration across sectors and levels, inclusion of diverse stakeholders and knowledge systems, and new financing mechanisms. Furthermore, we highlight the need for flexibility and context-sensitivity. In the studied cases, place-based dynamics are influential, and self-organisation to address tensions and experiment with new instruments and business models is an important enabler.

Key words: Adaptation, Governance, Nature-based solutions, Stormwater, Sustainability, Transition

HIGHLIGHTS

- Nature-based innovation system (NBS) challenges boundaries between existing sectors, domains, and logic.
- An appropriate governance model depends on the context and type of NBS.
- Case studies highlight self-organisation based on local capabilities in two European cities.
- Municipalities need practical and adaptive instruments to promote stormwater NBS.
- System perspective and recognition of co-existing, complementary logic is key to enhancing NBS governance.

GRAPHICAL ABSTRACT



1. INTRODUCTION

The world is experiencing severe water challenges: half of the global population is facing grave water shortages, and flooding is increasing (UN Water 2024). As water cuts across all sectors, this crisis calls for systemic change (Global Commission on the Economics of Water 2023). Literature on socio-technical sustainability transitions (e.g., Köhler *et al.* 2019), social-ecological transformations (e.g., Olsson *et al.* 2006), and transformative adaptation (e.g., Pelling 2011) provide relevant perspectives. Distinct, but overlapping, these increasingly call for new governance, to enable the fundamental changes needed to develop more sustainable interaction patterns.

Nature-based solutions (NBS) are promoted as a key tool for addressing the water crisis, as '*actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges (e.g. climate change, food and water security or natural disasters) effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits,*' (Cohen-Shacham *et al.* 2016, p. xii). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services and the Intergovernmental Panel on Climate Change both highlight the potential of NBS to address the twin challenges of biodiversity and climate change. For urban water management, NBS are seen as promising, especially for flood and drought protection, removing pollutants in runoff, and addressing the water-food-energy nexus (e.g., via water retention, food production, and temperature regulation) (Biswal *et al.* 2022). The concept is partly overlapping with others, e.g., water-sensitive urban design, 'sponge cities', Green Infrastructure, and sustainable drainage systems (SuDS). While this may cause confusion, it has also added momentum (Nesshöver *et al.* 2017). Furthermore, the potential of NBS to contribute towards social sustainability in cities, via enhanced relations, community resilience, and inclusive governance is associated with added value (Palomo *et al.* 2021). Currently, NBS is strongly incorporated in international agreements (UNEP 2022). Within the EU, they are crucial to achieving major policy objectives, including the EU Biodiversity Strategy for 2030 and the EU Adaptation Strategy. However, the uptake of NBS remains limited.

NBS for stormwater management is part of a solution space containing a multiplicity of solutions that incorporate technological, ecological, and social aspects to varying degrees. For example, conventional sewer pipes are largely technological (although their deployment may have ecological and social impacts), whereas NBS, such as blue-green corridors and managed aquifer recharge, rain gardens, and swales, incorporate ecological and social processes to a larger extent (Figure 1). They can help solve urban challenges (e.g., flooding, water scarcity, liveability, land use, conservation of biodiversity) individually, but are better integrated (Remme *et al*. 2024). As NBS consists of ecological processes interacting with technological and social components, their management tends to cut across sectors, involving actors with different visions, knowledge, and resources. Thus, NBS governance is complex, and one of the dimensions we need to understand better (Dorst *et al*. 2022; Kauark-Fontes *et al*. 2023). This paper aims to shed new light on the prevailing challenges in governance of stormwater NBS, and how they currently are understood and tackled in two European cities. The research questions we address are:

(1) What are some of the main tensions and trade-offs in the governance of stormwater NBS?
(2) What key steps are needed to develop governance models enabling the transition towards more sustainable stormwater management, incorporating NBS?

Our analysis is based on interactions with two water living labs (LLs) in Flanders (Belgium) and Bodø (Norway). To analyse the complex socio-technical-ecological interactions influencing efforts to mainstream stormwater NBS, we apply a recently developed framework called nature-based innovation systems (NBIS) (van der Jagt *et al*. 2020). Besides providing new empirical knowledge, the discussion contributes to the current discourse on water and transition governance.

The following section outlines relevant insights from previous research. Section 3 describes the materials and methods we apply. Section 4 presents the key findings from the LLs, on the factors enabling or constraining NBS in their contexts. Section 5 discusses how the findings relate to current literature on NBS and transition

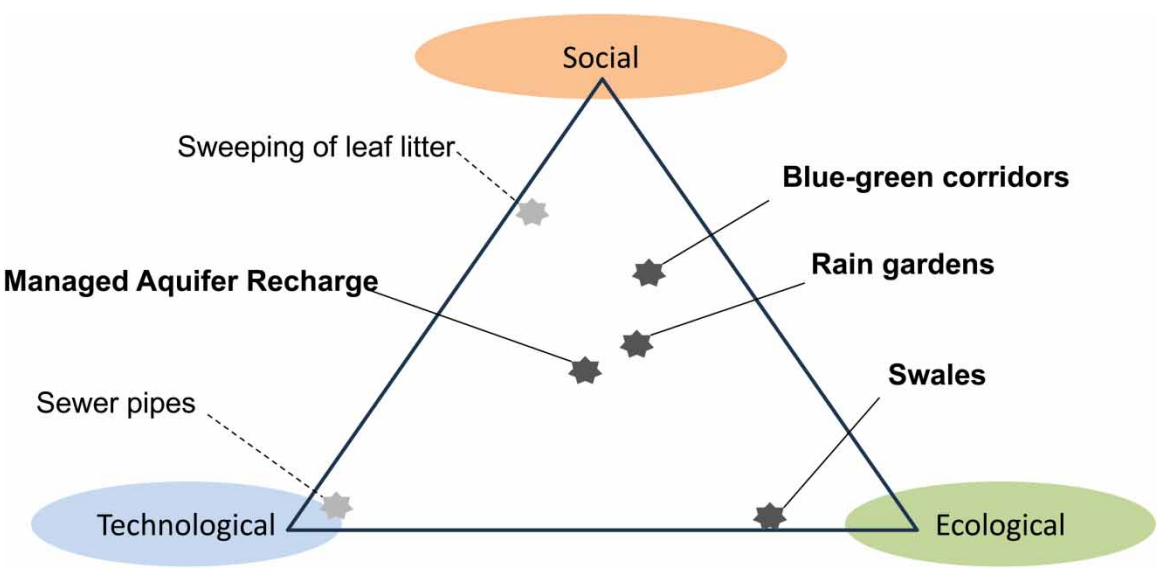


Fig. 1 | Illustration of stormwater solution space. The light grey stars exemplify conventional solutions. NBS in focus in this paper is represented by dark grey stars (figure modified from Remme *et al*. 2024, p.3).

governance, highlighting their implications for practice. Section 6, finally, provides a summary conclusion, with pointers for further research.

2. THEORETICAL BACKGROUND

Despite the increasing recognition of NBS as a tool for sustainable water management, there is an implementation gap (Hölscher *et al.* 2023). First, the design and management of NBS come with trade-offs. NBS vary in the degree to which they are managed with and for local communities and must strike a balance between reducing exposure (e.g., to flooding) and sensitivity (e.g., enhancing and diversifying ecosystem services), and supporting adaptive capacity (Seddon *et al.* 2019). Trade-offs between short-term and longer-term costs and benefits, and between stakeholder groups experiencing these differently, are also challenging (Seddon *et al.* 2020; Boulomytis *et al.* 2024). For example, Zuniga-Teran *et al.* (2020) find that attention to socio-economic aspects (e.g., disproportional access to green space and their ecosystem services) is a critical yet under-appreciated factor in NBS implementation.

Prior studies have identified multiple barriers to the implementation of NBS, including a lack of sense of urgency, political will, and long-term commitments; misalignments between short-term plans and long-term goals; functionality and performance uncertainties; and lack of supportive policies and legislation (Sarabi *et al.* 2020; Zuniga-Teran *et al.* 2020; Novaes & Marques 2022). These barriers are exacerbated by a lack of skilled knowledge brokers, training programs, and standards; silo mentalities coupled with risk aversion, resistance to change, and limited public awareness; lack of financial resources and incentives; and property ownership complexities and space constraints (Sarabi *et al.* 2020; Zuniga-Teran *et al.* 2020). In terms of finance, key challenges are the lack of integrated accounting and valuation methods and appropriate models for funding the implementation of NBS (Toxopeus & Polzin 2023). Though combined public–private funding has proven successful in some cases (Zuniga-Teran *et al.* 2020), knowledge of funding models is still limited. Furthermore, low private sector engagement is reinforced by limited public resources, policy implementation, and limited documentation of NBS performance (Boulomytis *et al.* 2024; Ferrario *et al.* 2024).

The barriers to NBS implementation relate to overarching discussions regarding water governance. In many parts of the world, water governance has tended to be top-down and state-driven (Kauark-Fontes *et al.* 2023). A dominant institutional logic, referred to as 'hydraulic', is linked to grey infrastructure, engineering perspectives, and public ownership (Fuenfschilling & Truffer 2014), as opposed to other logics associated with market orientation and more water-sensitive approaches (Fuenfschilling & Truffer 2014; Dorst *et al.* 2022; Boulomytis *et al.* 2024). The balance between these logics varies across continents and countries, but a prominent hydraulic logic is often considered a hindrance to the implementation of NBS. For example, Dorst *et al.* (2022) find that NBS tends to bounce against established socio-technical regimes, which are deeply embedded and resistant to change. This cuts across three domains: (1) urban development, (2) regulation and policymaking, and (3) finance. These are still characterized by high trust in engineering practices, leading to regime rationality which tends to exacerbate silos, eschew 'soft' NBS benefits, and incentivise engineering-heavy innovation (Dorst *et al.* 2022; Boulomytis *et al.* 2024).

Recent scholarship emphasizes the need to move beyond governance models which give precedence to the hydraulic logic (Dorst *et al.* 2022; Mercado *et al.* 2024). Franco-Torres *et al.* (2021) frame this as a shift from a mechanistic to a more organic urban water paradigm, recognizing the dynamic and close link between water and societal needs and values. Such a shift requires a governance system capable of managing and adapting to uncertainty. To this end, recent scholarship has advocated flexible, polycentric governance (Pauleit *et al.* 2017; Kauark-Fontes *et al.* 2023). Several studies argue that adaptive approaches are necessary to integrate NBS in urban planning (Nicholson-Cole & O'Riordan 2009; Dorst *et al.* 2022; Kauark-Fontes *et al.* 2023). Adaptive

governance aims to develop institutions for the management of common resources which also improve social arrangements. One of its key characteristics is the use of networks to coordinate adaptive management learning across governance levels while working within – and simultaneously shaping – the complex social system that sets governance goals (Folke *et al.* 2005). Studies in adaptive governance further highlight the need for social justice and common visions, incorporating local capabilities and flexibility to address both short- and long-term challenges, while managing tensions between national strategies and local contexts (Nicholson-Cole & O'Riordan 2009).

Based on experiences from 10 European cities, Hölscher *et al.* (2023) identified three main strategies for addressing the NBS implementation gap: (1) institutionalising a systems approach, (2) institutionalising inclusive collaboration, and (3) institutionalising reflexivity and continuous learning. These three strategies resonate with other studies. For example, Raymond *et al.* (2017) and Kabisch *et al.* (2017) argue that NBS implementation requires engaging with multiple actors and new tools for assessing the co-benefits of NBS. Participation and collaboration are also key for negotiating interests, gaining recognition for NBS, and realising their place-based transformative potential (e.g., Bos *et al.* 2015; Frantzeskaki 2019; Dorst *et al.* 2022; Mercado *et al.* 2024). Zuniga-Teran *et al.* (2020) note that as NBS creates new green urban commons, it is crucial that they are aesthetically appealing, co-created with local stakeholders, and managed in an inclusive way (see also Cousins (2021) and Cooper *et al.* (2024)). To strengthen these aspects, there is a need for more research on stakeholder perceptions, trust, and collaboration around NBS (Frantzeskaki 2019; Thodesen *et al.* 2022). Collaboration is also crucial for reflexive and continuous learning: the implementation of NBS requires further piloting and experimentation (Zuniga-Teran *et al.* 2020; Gerlak *et al.* 2021), with emphasis on the dynamic relationships between NBS and their context (Franco-Torres *et al.* 2021). The emphasis on reflexive learning, monitoring, and experimentation also resonates with recent work on the transformative governance of biodiversity (Visseren-Hamakers *et al.* 2020).

NBS may be considered a boundary concept (Dorst *et al.* 2019). The number and diversity of concepts contained under the umbrella of NBS (see Nesshöver *et al.* 2017) make the concept well-suited for collaboration across disciplines and practices. Simultaneously, it allows the concept to be translated into practice in multiple ways, either supporting or challenging existing logic and interests (Krauze & Wagner 2019; Seddon 2022). Several contributions emphasize the potential of NBS to mask, depoliticize, and reinforce technocratic structures of stormwater governance (Cousins 2018; Finewood *et al.* 2019). However, they also relate NBS to a shift towards neoliberal urban environmental governance, where control is exercised through devolution, decentralization, and delegation to non-state actors (Fuenfschilling & Truffer 2014; Cousins 2018). NBS is intrinsically linked to a water-sensitive logic, but the diversity of types and concepts means that their exact relationship to the hydraulic logic will differ. This might complicate the governance – and mainstreaming – of NBS. Thus, a more granular approach might be necessary. Engaging with the governance of different types of NBS in specific contexts might increase our understanding of NBS characteristics, as well as the merits and shortcomings of NBS governance in the specific setting. Over time, this may promote a more systemic governance approach, advancing sustainability via combinations of NBS and conventional stormwater solutions tailored to the needs and capabilities of specific regions and communities.

Our paper heeds the call for more research on place-specific approaches and how to leverage the social and economic enablers of NBS (Wong *et al.* 2020; Tsatsou *et al.* 2023). We apply van der Jagt *et al.*'s (2020) NBIS framework to explore how systemic and place-based factors shape the mainstreaming of NBS in specific cases. Building upon the technological innovation systems (TIS) approach (Bergek *et al.* 2008), NBIS employs a systems perspective to analyse the actor networks and strategies influencing the development and diffusion of nature-based innovations. Compared to TIS, NBIS places more emphasis on agency, discourse and visions, collaborative

arrangements, and crucially, place-based factors. This reflects the (often) urban context of implementation and the multidimensional nature of NBS. In the following section, we present the applied materials and methods and describe the NBIS framework in more detail.

3. MATERIALS AND METHODS

Our study is grounded in a 4-year project aiming to accelerate the transformation to water-smart societies through the co-development of innovative solutions in six European case studies. Though the cases did not necessarily exhibit all characteristics of the Urban LLs discussed in literature – as a specific intervention type delivering sustainability goals for cities (Bulkeley *et al*. 2016) – they were defined as LLs within the project, due to their aim to design, demonstrate and assess the impacts of water innovations in real-time. Each LL was built around a water utility and/or municipality, technology providers, and knowledge partners while engaging wider stakeholders through Communities of Practice (CoPs). CoPs are networks connecting experts, locals, end-users, and other stakeholders to share best practices and co-develop knowledge on a given topic (Wenger *et al*. 2002). In combination, LLs and CoPs are well-suited for transdisciplinary research. Whereas the other LLs in the project centred on other topics, this paper focuses on those in Flanders and Bodø, which had stormwater management as one of their focus areas.

LL Flanders aimed to assess alternative water sources to reduce the demand for freshwater resources, thus increasing the resilience of natural water systems. Characterised by a mix of densely urban, suburban, and agricultural areas, Flanders is grappling with severe water scarcity and drought risks, combined with increasingly frequent heavy rainfalls. The region is densely populated (490 inhabitants per km^2), and the population keeps growing, due to in-migration. The demonstration is in Mechelen, in the sub-municipality of Hombeek, where a culvert under the railway became inadequate to address flooding issues, resulting in the construction of a 1,400 m^3 buffer basin. The buffer basin enables managed aquifer recharge: a control system regulates the storage of stormwater and manages flooding while providing water for reuse in agriculture through sub-irrigation.

Bodø is located just north of the Arctic Circle. It has a cold and windy four-season climate, and increased precipitation with more flooding is expected. The population is stable, at approximately 54,000. While fishery and aviation have been the main industries, the city's large airbase closed in 2022. LL Bodø focused on several water-smart opportunities associated with the relocation of the civilian airport, which enables new sustainable city development. The integration of NBS for stormwater management in early city planning was the focus of the local CoP.

To be able to consider both place-based and structural conditions interacting with the efforts to mainstream NBS, we selected the NBIS as an analytical framework. To our knowledge, this framework has not been applied in empirical case studies until now. The NBIS comprises the institutions, networks, and actors that initiate, advance, and diffuse NBS, as well as eight system dimensions, or key processes, derived from NBS research literature (van der Jagt *et al*. 2020, p. 207):

- *Place-based factors*: Built environment (urban (infra)structures and amenities), natural processes and endowments (local climate, soil, flora, fauna), societal conditions (demography, socio-economic conditions), cultural frames of reference (social practices, norms, attitudes)
- *Governance structure*: The formal system of decision-making (rules, processes, roles, responsibilities)
- *Legislation and policies*: Legislation and policies which support NBS or disincentivise alternatives
- *Agency:* Leadership and power (will and ability to act, champions/frontrunners, commitment (individual and organisational support for NBS))

- *Discourse and vision:* Presenting NBS as a solution for pertinent challenges
- *Collaborative arrangements:* Networks and partnerships, participation (participatory processes, citizen engagement)
- *Learning:* Education and training, research, experimentation (piloting, testing, or new governance arrangements), monitoring and evaluation of NBS impacts
- *Resources*: Knowledge and human capital (explicit and tacit knowledge, skills), financial factors (funding, incentives, demand), technologies (for implementing NBS)

Assessing these dimensions provides insight into the extent to which the system can leverage transformative change, although exogenous factors such as competing technologies or macro-economic trends also influence the scope for mainstreaming NBS.

Our main source of data was a set of physical, full-day workshops within the CoPs, organised around the assessment, implementation, and mainstreaming of case-relevant NBS. The number, dates, and titles of the workshops are listed in Table 1.

In addition, we conducted 11 stakeholder interviews, and a desk study of relevant reports (on NBS in the case countries), public policies, strategies, and (municipal) plans (full list with references is provided in the Supplementary material). Interviewees were selected in consultation with the LL owners, and with an aim to include different stakeholder categories. In Bodø, they included three representatives of different municipal departments, two property developers, two consultancies, and one national authority. In Flanders, we interviewed three stakeholders, representing the municipality, a wastewater company, and a relevant knowledge and innovation centre focused on the agricultural sector. Furthermore, a public water company validated the insights shared by the municipality. The interviews were semi-structured and focused on the interviewees' views and experiences with planning and/or implementation of NBS, in relation to the eight system dimensions of the NBIS framework. In the case of Bodø, we also draw on participant observation at a public dialogue meeting on the development of the new district (organised by the municipality with around 50 participants, March 2024).

Table 1 | List of CoP workshops where mainstreaming of NBS was a key topic discussed with stakeholders.

Date	Case study	Workshop title	Participants (public sector)	Participants (private sector)
17.02.2022	Flanders	Practical lesson to accelerate and scale up circular and smart water use	12	9
29.03.2022	Bodø	Shared collaboration arena for managing surface water	10	14
28–29.08.2022	Bodø	Course in blue-green structures creation value	34	21
18.10.2022	Flanders	Decoupling the human water chain and the water system	5	8
23.11.2023	Flanders	Innovative financing, management, and collaboration	5	16
06.06.2024	Flanders	Lessons learned, LLs as a resource in open innovation ecosystems, and the transition to a water-smart society	19	34
25.06.2024	Bodø	Surface water management in municipal building approvals	12	6

4. KEY FINDINGS

4.1. Place-based factors

In the Flanders case, the densely built environment with limited space for surface water management, together with increased flood risk and overloaded stormwater systems, are important drivers for NBS. The growing population and increasing water demand from different sectors have resulted in water availability concerns. According to the interviews, a growing recognition that stormwater should be stored and reused further enabled the integration of water conservation and reuse. Thus, existing infrastructure, natural endowments, and social factors interact in conducive ways. The LL actors also faced certain tensions, e.g. concerns about maintaining space for agriculture versus the need for stormwater management. However, this was managed by including managed aquifer recharge as an additional source of sub-irrigation water.

In Bodø, the last decades have seen warming, and increased precipitation with more high-intensity rains is expected. Average precipitation is high (1,134.0 mm/year), and the public tends to take water for granted. Moreover, Bodø is built upon rock and dense clay, so infiltration is limited, and drains are periodically clogged by snow and ice. Thus, climatic conditions are key drivers. However, the rough climate also poses challenges to the operation and maintenance of NBS. Thus, some stakeholders doubted the long-term sustainability of NBS. Existing infrastructure, i.e. old pipe network with limited capacity has been a driving factor. Within the existing urban centre, limited availability of space is a hindrance. However, the new district under development, following a 900 m shift of the main landing strip of Bodø's civilian airport, provides a window of opportunity for NBS, such as green corridors retaining water and safe floodways. Here, interviewees noted that the NBS functionality must be carefully balanced with the preservation of natural and cultural heritage, given the old airport's centrality in local history and identity.

Both cases highlight the importance of place-based factors, often overlooked in governance research. These include both shortcomings of existing water infrastructure and its interaction with other infrastructures (railway and airport). Moreover, they exhibit trade-offs between different interests and concerns (e.g., reducing exposure and increasing adaptive capacity), shaped by the local contexts.

4.2. Governance structures

In Flanders, various institutions collaborate in managing stormwater (and other aspects of water management). The Flemish Environment Agency monitors water quality and sets guidelines for sustainable water management. Provincial governments implement regional water plans, while municipalities assess their stormwater management needs, oversee stormwater infrastructure, and implement measures to reduce flood risk, manage runoff, and protect water quality. In Flanders, the watercourse manager, Province of Antwerpen, proposed the construction of the buffer basin. Water and wastewater companies (either public or private) typically develop and operate such infrastructure, working alongside municipalities to realise broader policies and regulations.

In Bodø, the Norwegian Water Resources and Energy Directorate is responsible for stormwater. The Ministry of Climate and Environment coordinates water management across sectors, whereas municipalities are responsible for implementing solutions, with additional guidance from county governors. Several interviewees saw silos as a problem, noting that public agencies and municipal administrations can be poorly coordinated. For example, existing planning procedures might constitute a hindrance, as dialogue between departments and institutions tends to take place late in the process. Whereas interdisciplinary collaboration could foster NBS as a 'win-win' solution, there were neither incentives nor capacity for this. The need to prioritise more acute problems (e.g., maintenance backlogs) posed a barrier to NBS investments.

While the formal structures are quite similar, these findings indicate that the regional level took a more active role in the Flanders case, whereas local coordination challenges were more prominent in Bodø. Furthermore, the latter case illustrates trade-offs between short- and longer-term costs and benefits, arising due to a combination of place-based and structural conditions.

4.3. Legislation and policies

Water in Flanders is managed in the context of the EU Water Framework Directive and Floods Directive through the Decree on Integrated Water Policy (2003). The Coordination Committee on Integrated Water Policy, chaired by the Flemish Environment Agency, oversees the implementation of this decree. A regional urban development ordinance (2023) further mandates rainwater retention, use, and infiltration. However, the evolving legal status of the use of rainwater and stormwater, alongside changing policies on groundwater use and rainwater infiltration, creates disparities in their practical application. Two interviewees highlighted that whereas new regulations require capturing rainwater on new properties, 'outdated' legislation and unclear guidelines on water access across boundaries hamper utilization of rainwater. This, together with the cost of individual storage, is challenging for end-users. Stormwater falling on company sites can be classified as potentially contaminated industrial wastewater, whereas rainwater from roofs may be treated differently. Trade-offs and competition between sectors necessitate clear guidelines to ensure equitable access.

Although not a member state, Norway has adopted most of the relevant EU policies. A three-tiered approach for stormwater management applies: (1) small events should be infiltrated locally, (2) medium events should be detained locally as far as possible, and (3) large events must be handled through a safe flood approach. Since 2018, National guidelines for climate and energy planning in municipalities require that non-selection of NBS must be justified. On the other hand, water cycle services shall be based on 'Best Available Technologies' and urban densification should be promoted to limit climate gas emissions. There are also tensions with other infrastructure priorities, such as parking space. A revision of the National Plan and Building Act, Pollution Act, and Water Act (2022) aimed to clarify NBS definitions and responsibilities, and the National Plan for Climate Adaptation Planning (2023) underscores the need to work with nature in stormwater management. Still, local stakeholders called for clearer expectations from national authorities (NIVA 2024).

To summarize, this dimension also exhibits multiple tensions: between policies for stormwater and groundwater, in terms of lacking clarity regarding cross-border water management; and between policy objectives for different domains. Although NBS is prioritised in policy, this is not associated with specific national implementation targets or guidelines, making it difficult to translate locally.

4.4. Agency

Municipalities in Flanders are required to develop stormwater management plans to tackle flooding, water pollution, and climate change impacts. These can include green and blue infrastructure, engaging stakeholders in planning and implementation, and strategies for retrofitting existing infrastructure, such as adapting stormwater basins for reuse. Furthermore, the interviewees stressed that municipalities' collaboration with water and wastewater companies is crucial for integrating and effectively managing stormwater. The agency of municipalities is further strengthened by their role in strategic decision-making regarding stormwater solutions. By requiring stormwater plans, and facilitating experience-sharing across municipalities, Flanders also takes an active role, promoting integrated and resilient water management across a wider scale.

In the Norwegian context, municipalities have been the driving actors for NBS, via innovative, but fragmented piloting activities. In 2015, a national white paper recommended municipal sector plans for stormwater management. This instrument provides an opportunity to introduce local requirements and is increasingly applied.

Furthermore, all planning and land-use activities shall integrate climate adaptation (Norwegian Ministry of Climate and Environment (2023)). A standard to ensure that surface water and nature conservation are addressed in early construction planning (blue-green factor) is increasingly implemented, and the national building standard requires that stormwater be managed locally. However, the distribution of responsibilities and internal collaboration in municipalities vary. Whereas some have individual coordinators, Bodø has an interdepartmental committee on surface water. NBS is also included in municipal plans, ensuring that NBS is anchored into the municipality's objectives. Still, representatives of the municipality noted that NBS activities often depend on enthusiastic individuals (NIVA 2024), and interviewees from other organisations felt that upscaling requires more concerted efforts.

Both cases highlight the key role of municipalities. In Flanders, their agency is strengthened via active support from regional authorities, and collaboration with water companies operating across municipalities. The Bodø case highlights the crucial role of individual entrepreneurs and the need for more inter-organisational collaboration to mainstream NBS.

4.5. Discourse and visions

The CoPs in Flanders emphasized the need for policies to align with current environmental needs and technological advancements while stimulating good stormwater management practices. Overall, the discourse acknowledged the multifunctional benefits of NBS. One interview highlighted the adaptability of NBS to local conditions. Another emphasized the pertinence of stormwater for agricultural sustainability. While uncertainties and operational challenges can temper these perceptions, the interviewees stated that the evolving discourse has begun valuing stormwater as a resource rather than a waste product. The city of Mechelen also highlights the transformative role of NBS. In an ongoing urban design initiative centred on the River Dijle, they organise citizens' assemblies and work towards NBS connecting enhanced liveability and inclusive governance (including the elderly, children, youth, and disadvantaged groups) with conservation of biodiversity.

In Bodø, the effort to mainstream NBS is linked to the long-term vision for the city. Most interviewees highlighted the multiple benefits of NBS, and citizens were largely positive. Still, two participants at a public meeting called for more focus on biodiversity, and others stated that the municipality should prioritise public schools and healthcare. One person indicated that ambitious urban development plans are unlikely to be followed, as large property developers eventually prioritise profit. In national discourse, the main selling points for NBS are its contribution to climate adaptation, nature conservation, and enhanced liveability.

The Flanders case thus exemplifies the ongoing reframing of stormwater as a resource and the transformational potential of NBS. However, it also illustrates a certain tension between their multi-functionality and adaptability on the one hand, and their associated uncertainties. The Bodø case shows how NBS is a key element in the city's green future vision, however contested by citizens with more immediate concerns.

4.6. Collaborative arrangements

The workshops and interviews in Flanders emphasized the value of collaborative arrangements involving many stakeholders, in helping pool expertise and other resources. Here, they mentioned both formal and informal networks. EU projects also play a crucial role, e.g. one interviewee noted that without the LL, the municipality would not have been able to establish an innovative solution in Hombeek and engage with stakeholders to the present extent. Such collaborations create room for cohesive efforts and balance different urban infrastructure needs. Knowledge partners were perceived as important intermediaries, e.g. the non-profit Research Station for Vegetable Production was crucial for engaging local farmers.

In Bodø, there were no pre-existing networks for NBS or stormwater management. As noted above, individual champions played a key role. According to the interviews, a diversity of actors should be involved in decisions to mainstream NBS. Nationally, partnership contracts are increasingly deployed, and a long-term public–private partnership – Klima 2050 – been an important centre for co-creation in stormwater management. Interviewees also discussed other forms of collaboration, e.g. the local CoP, as arenas for knowledge building and strengthening stakeholder relations. The CoP events in Bodø supported the creation of the municipal Surface Water Plan and the implementation of new legislation. Without a mutual understanding of the challenges and goals, there would have greater scepticism hindering implementation.

The consulted stakeholders thus underscored the importance of collaboration across sectors and levels in both cases. Moreover, they highlighted specific benefits from the LL activity, in terms of resource pooling and legitimation.

4.7. Learning

The stakeholders in Flanders emphasized that integration of research and practice is pivotal for learning. Such collaboration facilitates knowledge exchange and experimentation, thus fostering innovation. Educational programs, awareness initiatives, and capacity-building platforms such as blue-green flanders[1] are crucial for propagating knowledge about NBS. These initiatives help stakeholders strengthen their capacity to participate. For instance, the involvement of the Research Station for Vegetable Production in Hombeek highlighted the benefits of stormwater reuse for farmers, fostering a culture of learning and adaptation.

In Bodø, the mentioned interdepartmental committee was associated with courses and training. One consultant further noted that graduate students can be up to date on NBS and valuable sources of learning. At the national level, municipalities have implemented several pilots for stormwater NBS, e.g. Bodø secured funding for a feasibility study on the inclusion of a large continuous green corridor within the new city development. Locally, some interviewees presented the implementation of the blue-green factor as an experiment, where 'the municipality's approach has been for us to test this out together'. On the other hand, they considered monitoring and evaluation as weak points and emphasized the need for more experimental data.

These findings underscore that learning from pilots is essential to increase NBS implementation. However, the stakeholders in Flanders placed more emphasis on capacity-building for participation, whereas those in Bodø had more focus on individual learning and documentation.

4.8. Resources

In LL Flanders, financial sustainability was a critical concern. While the implementation of stormwater management plans is supported financially by government initiatives (e.g., the Blue Deal, Flanders Innovation and Entrepreneurship), interviewees saw the need for a policy providing financing and cost distribution mechanisms ensuring the long-term operation and management of NBS. Presenting research and innovation projects as 'only a piece of the puzzle', they stated that public–private partnership and innovative financing structures – e.g. green bonds, crypto-financing, land-value capture, community infrastructure levies – should be explored[2]. For their own case, neighbourhood committees and collective management approaches, e.g. with farmers, industries, and municipalities, were considered the most promising.

The CoP participants in Bodø emphasized the need for more knowledge. While guidelines and knowledge portals exist, Norway has no authoritative rules for the assessment, planning, or implementation of NBS.

[1] https://blauwgroenvlaanderen.be/

[2] https://www.uantwerpen.be/en/projects/innofins/

Interviewees felt that some public decision-makers lack practical experience and therefore are risk averse. Also, municipal employees may reject NBS even if they see merit, due to old standards and regulations. NBS financing is challenging and hitherto done through the municipality's regular budget. The Norwegian Environment Agency offers some funding for feasibility studies and has proposed a stormwater management fee to finance local measures, comprising a fixed and a variable component, based on run-off potential. This proposal is, however, debated. Bodø municipality currently prioritises integrating NBS through building approvals, which does not require new financial models. Retrofitting has a higher barrier to entry but remains a future goal. Workshop statements suggested that disparities between large and smaller developers may arise, and property developers claim NBS requirements will increase already high housing prices in the town centre (NIVA 2024). Thus, there are potential challenges, in terms of procedural and distributional justice.

The findings for this dimension highlight tension at multiple levels: between policy objectives promoting NBS and current funding arrangements; local anchoring and ownership versus national support; policy implementation versus knowledge diffusion, and trade-offs in terms of justice and socio-economic impacts. In the following section, we discuss the findings and their implications in more detail.

5. DISCUSSION: NBIS ASSESSMENT OF THE TWO CASES

Our analysis shows how specific local conditions created 'windows of opportunity' for NBS. These comprise climatic factors, urban growth, and pre-existing infrastructure, including tensions between systems for stormwater management and other sectoral infrastructures. Still, a common challenge is uncertainty regarding the long-term functionality of NBS. In Flanders, this was linked to water quality and wider ecological impacts; in Bodø, to climatic and wider infrastructure challenges. Furthermore, our findings highlight tensions regarding land use (Seddon *et al.* 2019; Cousins 2021). In both cases, NBS were designed to serve multiple uses and sustainability objectives, determined by the local context. However, their organic nature and adaptability to local conditions also bounced against existing urban infrastructural regimes (Dorst *et al.* 2022), in terms of space requirements and limited predictability and control, compared to conventional solutions. The identified uncertainties were not 'embraced' as in the new urban water paradigm envisaged in literature (Franco-Torres *et al.* 2021). Rather, they were considered barriers according to the established hydraulic logic (Fuenfschilling & Truffer 2014), with their emphasis on permanence and technological control. These findings highlight the interaction between place-based and structural factors (van der Jagt *et al.* 2020; Dorst *et al.* 2022), and the need to take a complex system perspective (Franco-Torres *et al.* 2021) in NBS governance.

Considering governance structures, regional authorities and water and wastewater companies play an active role in promoting NBS in Flanders. In Norway, there is not the same push from the regional level. Bodø and most other municipalities manage water cycle services internally. In principle, this could improve coordination, but in line with previous research (Sarabi *et al.* 2020; Dorst *et al.* 2022), we found silos and a strong engineering rationality. Thus, our findings reveal remaining tensions in governance across sectors and levels, and between different institutional logics, i.e. the water-sensitive logic associated with NBS and the 'hydraulic logic' prevailing in large parts of the water sector (Fuenfschilling & Truffer 2014). Moreover, the findings underscore how networks for coordinating management and learning across levels, as recommended in adaptive governance (Kauark-Fontes *et al.* 2023), are crucial to mainstream NBS.

In both cases, there are increasingly conducive policies, but a lack of clarity regarding roles and responsibilities, and a need for more coherence and coordination across levels, sectors, and boundaries, in line with, e.g. Novaes & Marques (2022) and Zuniga-Teran *et al.* (2020). Municipalities stand out as key actors driving NBS. However, their effort in Norway is described as fragmented and driven by individual champions (see also Gerlak *et al.* 2021), whereas the situation in Flanders is characterised by wider collaboration networks. Dependence on individual entrepreneurs is characteristic of early transition phases. As water-sensitive policies and practices

increasingly become embedded, government agencies and multi-stakeholder networks are encouraged to take over (Wong *et al*. 2020), as observed in Flanders.

In line with previous research (e.g., Frantzeskaki 2019; Tsatsou *et al*. 2023; Mercado *et al*. 2024), our study emphasizes the need for wider stakeholder involvement. A factor highlighted in both LLs is timing: there are different planning horizons, and early engagement of stakeholders may go against established procedures, as noted by Nicholson-Cole & O'Riordan (2009) and Mercado *et al*. (2024). The nature of NBS means that time is required to demonstrate their impact and cultivate trust in the investment (Boulomytis *et al*. 2024). This is a key challenge for small municipalities with limited capacity. In terms of learning, NBS is promoted by strong knowledge institutions. The province of Flanders also has a dedicated awareness initiative, as advocated by, e.g. Thodesen *et al*. (2022). The importance of experimentation is highlighted in both cases. However, monitoring and evaluation is a challenge, in line with, e.g. Seddon (2022) and Ferrario *et al*. (2024). This may also be considered a tension, between the highly local and context-dependent nature of NBS, and concern to standardise and understand their impacts on a wider scale. The need for capacity building is emphasized in both LLs.

Concerning financing, some incentives exist, but funding to ensure the long-term operation is difficult, in line with previous research (Toxopeus & Polzin 2023; Boulomytis *et al*. 2024). New financing mechanisms with increased public–private partnerships are advocated but concerns over procedural and distributive justice are also voiced, supporting Cousins (2021) and Cooper *et al*. (2024)). While neighbourhood committees seemed most promising to stakeholders in Flanders, Bodø municipality gives priority to greenfield implementation, where they can pose requirements, e.g. in terms of the blue-green factor and/or specific measures to infiltrate, retain or divert stormwater through safe floodways.

We argue that the NBIS is in a formative phase, both in the Flanders and the Bodø case. In terms of discourse and visions for urban stormwater management, learning, and policy formation, there are conducive developments. While we find remaining challenges as regards policy coherence, the strongest barriers are structural, as NBS challenges the boundaries between existing sectors and rationalities (Dorst *et al*. 2022; Tsatsou *et al*. 2023). Recognition of the value in stormwater and the transformative potential of NBS may have developed further in Flanders. Here, we see a tendency towards less governmental control in urban governance (Cousins 2018), with new coalitions and local stakeholders expressing interest in participatory managing and financing models (e.g. neighbourhood committees). In LL Bodø and the Norwegian context, there are indications of stronger silos and more focus on guidelines, training, and standards, which can be associated with an orientation towards technical, hydrologic aspects and, eventually, a (re)technologization (Finewood *et al*. 2019) of NBS. This may accelerate the mainstreaming of NBS but can potentially also draw attention away from important trade-offs and justice issues, and their transformative potential.

The results presented above speak to the differences between the two contexts as well as the types of NBS in focus. The managed aquifer recharge in Flanders is complex in terms of regulation and required social changes, whereas the NBS in Bodø is more widely deployed and less complex in these terms (Figure 1). This suggests that there is no 'one-size-fits-all' in NBS governance, and underscores the complex, multidirectional nature of transitions and transition governance. Furthermore, our results add nuance to the calls for a new paradigm in urban water governance (e.g. Franco-Torres *et al*. 2021). The multiplexity of NBS concepts (Nesshöver *et al*. 2017) and the ability of NBS to be translated into practice in different ways (Krauze & Wagner 2019) suggests that an accumulation of institutional logic, incorporating both 'hydraulic', water market and water-sensitive values and perspectives – and an increased awareness of which logic is appropriate in what settings – might be more conducive to improving NBS governance than a complete shift from one logic to another.

The broad system perspective offered by the NBIS framework was fruitful for illuminating the complex interaction between place-based and wider, structural factors in the studied cases. However, this framework is recent,

with dimensions that in the future may be better distinguished and defined. While drawing on multiple data sources and following the two LLs over four years, another limitation of this study is its narrowness in scale and time.

6. CONCLUSIONS: KEY INSIGHTS FOR GOVERNANCE TO MAINSTREAM NBS

Using NBIS as an analytical framework, this study has shed light on NBS governance in Europe. Through two case studies, we have identified tensions and trade-offs associated with the implementation of water-related NBS and illuminated some of their implications. We find that the strongest barriers are structural, as NBS challenges the boundaries between existing sectors, domains, and logic (Dorst *et al*. 2022; Tsatsou *et al*. 2023). Furthermore, the comparative discussion of the two cases highlights differences in NBS governance, related to the local contexts, and the characteristics of the specific NBS in question. The differences in governance make us question the notion of grand shifts in water governance (Franco-Torres *et al*. 2021). Rather than one paradigm or institutional logic supplanting another, our results suggest that different logic may complement each other. Still, enabling such complementarities might require rethinking. For example, mainstreaming managed aquifer recharge for irrigation in Flanders may require substantial changes in governance – in particular, towards network governance. The implementation of NBS for stormwater management in Bodø may not require radical governance shifts. However, our findings show the need for more collaboration across sectors and incremental governance improvements (e.g. in terms of planning procedures). These examples suggest that there is no one, best governance model for NBS. Rather, the diverse and context-specific nature of NBS implies that it is important to develop structures where different logic may co-exist and, ideally, cross-fertilise ideas and practices. Based on these results, we offer the following three key insights regarding the governance of NBS.

First, mainstreaming NBS requires rethinking water governance. NBS challenges prevailing institutional logic (Fuenfschilling & Truffer (2014); Dorst *et al*. 2022). For example, interviewees questioned existing land-use patterns and planning procedures and emphasised the need to break down silos. Integrated stormwater management plans can be a crucial step in this direction. The consulted stakeholders also pointed to misalignment between NBS-promoting policies and pre-existing frameworks for stormwater management (Novaes & Marques 2022; Tsatsou *et al*. 2023). At the same time, the two cases illustrate that the implementation of some NBS types may require major governance changes, while others may be accommodated via more modest adaptations. This suggests that rather than shifting from one water paradigm to another, it might be fruitful to consider different institutional logics as complementary. The diversity and context-dependency of NBS require self-organisation based on local capabilities. Via collaborative learning and co-development to identify NBS suited to a given context, local governments will be better equipped to govern NBS in a way that takes the interaction between pre-existing structures, place-based factors, and values and visions into account.

Second, NBS as a multidimensional, open innovation, calls for a system perspective. Our findings highlight synergies and potential trade-offs associated with NBS (Seddon 2022; Mercado *et al.* 2024). In both cases, informants emphasised the importance of considering interactions across different scales and sectors and deploying holistic methods to evaluate solutions and impacts. The findings also highlight the importance of negotiated knowledge and experimentation, supporting the call for inclusive governance and enabling transformative change (Visseren-Hamakers *et al*. 2021; Cousins 2021; Mercado *et al*. 2024). Furthermore, our study shows that individuals and organisations play crucial roles as intermediaries and drivers of innovation. Considering the multidimensionality of NBS, it is necessary to take a system perspective, also in financing.

Third, flexibility and integrative leadership are needed to ensure the adaptiveness and long-term sustainability of NBS. NBS are organic systems characterised by socio-ecological-technological interactions. Hence, they may change significantly over time. Illustratively, reuse and sub-irrigation was added as a second step in Hombeek,

in response to local stakeholder interests and concerns. The community of stakeholders was also expanded. This underscores the need to be prepared for uncertainty and ensure flexibility in governance (Visseren-Hamakers *et al.* 2021; Mercado *et al.* 2024). Providing municipalities with practical and adaptable instruments (e.g. for NBS financing, capacity-building, and enhanced participation) is key, to promote NBS in ways appropriate for each region and locality. Our observations further illustrate the importance of integrative leadership (Visseren-Hamakers *et al.* 2021). Without acceptance from end-users and citizens, it is difficult to reap the full benefits of NBS (Cousins 2021; Thodesen *et al.* 2022; Boulomytis *et al.* 2024).

ACKNOWLEDGMENTS

This work received support from the European Union's Horizon 2020 programme, grant agreement No. 869171. The authors acknowledge valuable contributions from the B-WaterSmart LLs and CoP participants.

DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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First received 30 August 2024; accepted in revised form 12 May 2025. Available online 16 May 2025