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Co-building trust in urban nature: Learning from participatory design and construction of Nature-Based Solutions in informal settlements in East Africa

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While the amount of research on NBS is growing rapidly, there is a lack of evidence on community experiences of NBS design and implementation, particularly from low-income and informal settlements of African cities. This article adds new empirical evidence in this space through grounded analysis of NBS “niche” projects co-developed by intermediary organizations and communities in five sites across three settlements in Nairobi and Dar es Salaam. Findings are organized around four established NBS knowledge gaps: (1) NBS-society relations; (2) Design; (3) Implementation; (4) Effectiveness. We find that across the five studied sites, residents’ perceptions and valuation of urban nature has changed through processes of co-design and co-implementation, enabling community ownership of projects, and hence playing a crucial role in NBS effectiveness over time. The integration of gray components into green infrastructure to create hybrid systems has proven necessary to meet physical constraints and communities’ urgent needs such as flood mitigation. However, maintenance responsibilities and cost burdens are persisting issues that highlight the complex reality of NBS development in informal settlements. The cases highlight key considerations for actors involved in NBS development to support the replication, scaling up and institutionalization of NBS. These include the need to: (i) develop forms of engagement that align with co-production values; (ii) capture communities’ own valuation of and motivations with NBS development for integration into design; (iii) elaborate technical guidance for hybrid green-gray infrastructure systems that can be constructed with communities; and (iv) help define and establish structures for maintenance responsibilities (especially governmental vs. civil society) that will enhance the environmental stewardship of public spaces.

KEYWORDS

Nature-Based Solutions, informal settlements, hybrid infrastructure, water management, East Africa, urban nature, co-production, niche experiments

Introduction

NBS for water management in Africa's informal settlements

Cities are characterized by nestedness and interdependencies of social, ecological, and technological “systems” (McPhearson et al., 2016). Urban development interventions that do not adequately consider the interrelationship of urban systems when attempting to address specific issues create and compound socio-environmental risks (Leck et al., 2018). Cities and towns in Africa face such patterns of risk accumulation, notably due to governance barriers that translate into poor planning not accommodating rapid urbanization (Lusugga Kironde, 2006; UN-Habitat, 2020), high levels of poverty and particularly in informal settlements (Hove et al., 2013; Smit et al., 2017), lack of access to basic services such as water and sanitation (Chitonge, 2014; UCLG., 2014), and loss of green space and functioning ecosystems (Mensah, 2014; Güneralp et al., 2017).

Nature-based approaches that include Green Infrastructure (GI) or Green/Blue Infrastructure, ecosystem-based adaptation, Sustainable Urban Drainage Systems (SUDS), and more recently Nature-Based Solutions (NBS), have attracted attention for their potential to simultaneously address multiple challenges. Many have considered such approaches as offering key opportunities to tackle water-related issues while increasing biodiversity, air quality, public health, and providing recreational space, and thereby support resilience-building. Since they are most exposed to climate stressors, and particularly floods, droughts and heatwaves that compound pre-existing risks (Trisos et al., 2022), nature-based approaches are relevant for informal settlements. The few who have considered NBS and related concepts for informal settlements in Africa have shown that many barriers prevent their application in practice (Parkinson, 2002; Mguni et al., 2016; Charlesworth et al., 2017; Reed, 2017; Douglas, 2018; Wijesinghe and Thorn, 2021).

While there is a gap in both the research and practice of NBS in the context of informal and low-income urban settings worldwide (Breen et al., 2020; Hamel and Tan, 2022), this is particularly true for African cities (du Toit et al., 2018; Thorn et al., 2021). Major barriers to the uptake of NBS projects include a lack of information on temporal and spatial scales of NBS (Acreman et al., 2021), of design and performance data (Thorn et al., 2021), and of recognition of vital functions of NBS (Maranga, 2021). Dysfunctional land markets, constraints of space, gaps in basic services, inadequate policy systems and unclear mandates mean that NBS development require differentiated approaches in such settings that are not well understood and can lead to the (re-)production of socio-environmental issues (Haase et al., 2014; Jiusto and Kenney, 2016; Mguni et al., 2016; Roy et al., 2018; Wijesinghe and Thorn, 2021). This gap also means there is a lack of cross-learning between different city contexts (Thorn et al., 2021).

Scaling up NBS with niche experiments

Hyman and Pieterse (2017) argue that de facto hybrid (formal and informal) service delivery systems that undergird African cities can unlock a transition to future infrastructure systems that are progressively inclusive and sustainable. Besides, Bulkeley (2006) has shown that strategies to implement urban sustainability often rest on the development of exemplar projects from which lessons can be learned and applied within the urban arena or transferred between cities. In the context of water management, Herslund et al.'s (2018) study of GI in African cities demonstrates that sustainability transitions can be driven by “niche innovations” that build internal momentum to challenge the “regime” (i.e., the locus of established institutions and their configurations, networks, rules and techniques). Yet, Herslund et al. (2018) and Diep et al. (2019) raise the question as to whether such niche experiments can sustain themselves while informing and influencing larger-scale planning and design. A range of barriers to the implementation and upscaling of NBS needs to be better understood. According to Kabisch et al. (2016), they include disconnects between short-term actions and long-term plans, sectoral silos, and the paradigm of growth which puts pressure on urban green spaces. This also includes “fear of the unknown” which relates to perceived uncertainties and risks (Kabisch et al., 2016). These barriers are particularly important for contexts of urban informal settlements characterized by the physical and spatial manifestation of land conflicts, urban poverty, and intra-city inequality.

Recent studies have analyzed community-based adaptation strategies in African cities, for example in Cape Town (South Africa) (Fox et al., 2021), Windhoek (Namibia) (Wijesinghe and Thorn, 2021), and Mombasa (Kenya) (Suleiman Haji, 2021). These studies show the need for better involvement of the civil society in project development and governance to ensure sustainable and inclusive processes and outcomes. Wijesinghe and Thorn (2021) particularly argue that a lack of collaborative governance for action in integrated slum upgrading strategies have frustrated residents whose needs have remained unmet, and further led to conflicts. They further highlight unclear delineation of GI maintenance mandates as a fundamental issue. Although not specifically for the context of Africa, Dodman et al. (2018) also indicate the need for supported community climate action through collaborations with local governments. Mguni et al. (2015, 2016) argue that the local scale allows for the creation of spaces of innovation (“SUDS niche experiments”) with active engagement of local communities.

More specifically in relation to NBS for water management, Mulligan et al. (2020) have explored the effectiveness and sustainability of localized hybrid green-gray infrastructure for urban drainage constructed in Kibera, one of Nairobi's largest informal settlements. They call for further practice on the evaluation of NBS, notably regarding the effectiveness of

specific drainage techniques to help build the evidence base for replicating and scaling up NBS. They highlight that this requires setting and evaluating technical performance goals (such as runoff reduction under different rainfall scenarios) as well as social and economic outcomes (e.g., in improving equal access to green spaces and related opportunities). They raise the need to understand the role that participatory processes can play in effecting these outcomes, a point that we explore in detail in this paper.

Participation, co-production, and governance of NBS in informal settlements

The importance of community participation in projects in multiple contexts is widely recognized, despite considerable debate regarding what participation means in practice. A recent review of multiple NBS across multiple cities by [Kiss et al. \(2022\)](#) concludes that tokenistic forms of participation dominate citizen engagement across a variety of NBS contexts and, in addition, that collaborative multi-stakeholder forms of engagement do not automatically lead to enhanced ecological functions. “Deeper” forms of engagement, by contrast, were shown to strengthen and diversify both expected and unexpected social outcomes, including social learning, an enhanced sense of belonging, environmental stewardship, and inclusiveness and equity ([Kiss et al., 2022](#)). These forms of engagement can materialize in different ways, from co-design workshops, to specialized meetings and field visits.

Co-production strategies have gained attention as distinct approaches to service provision that can spur transformative urban governance, as opposed to participation approaches that do not address embedded injustices ([Castán Broto et al., 2022](#)). Since co-production has been used in several specific cases to build state-society alliances for community change and socio-spatial transformation ([Siame and Watson, 2022](#)), it is considered of significance in the context of the niche experiments examined in this paper to explore avenues for the uptake of NBS. In informal settlements, a heightened awareness of power and access deficiencies means that many advocate for an express focus on the integration of knowledge systems related to residents’ specific experience of place, environment, and social networks, as well as for promoting the decision-making agency of residents in development processes ([Mulligan et al., 2020](#)).

Co-production approaches can help understand and manage human-nature relationships and thereby reduce undesired outcomes of socio-ecological management ([Palomo et al., 2016](#)). Yet, human-nature relationships in informal settlements are particularly complex, due to a range of factors. Flood risk in informal settlements is in many cases rooted in historical environmental injustice and worsening socio-economic segregation, exacerbated by rapid urbanization and

climate change. In order for NBS to provide useful services, enhance equity, and address issues of power and environmental injustice, “deeper” forms of engagement where citizens control or are delegated more power, are crucial ([Kiss et al., 2022](#)). Learning from examples where such forms of engagement have been attempted in a context which is under-studied hence can provide important opportunities that include improving project conception, delivery, and impact.

Aims and objectives

This article aims to leverage learning from the practice of NBS for water management in informal settlements in two cities in East Africa. We provide a detailed case investigation of the implementation of NBS projects for water management in five sites across three informal settlements in the cities of Nairobi (Kenya) and Dar es Salaam (Tanzania). Several NBS for water management were built as part of participatory processes with residents in the first phase studied in this paper (2019–2020). The projects are led by two nonprofit “intermediary organizations.” “Intermediary” here refers to organizations that bridge between actors involved in situations where direct interaction is compromised by various socio-political factors ([Kivimaa et al., 2019](#)). This overlaps with the notion of “boundary organizations” where actors operate at multiple scales or levels of governance, and narrow the gap between science and decision-making ([Kirchhoff et al., 2015](#); [Gustafsson and Lidskog, 2018](#)). We consider this intermediary role to be particularly important in the context of informal settlements where governance responsibilities are often unclear and gaps in the provision of services persist.

We pay particular attention to the ways participatory approaches for the design and construction of NBS may influence residents’ relation to urban nature. We explore how different project stages—early engagement, design, implementation, and post-implementation—have helped explore and collectively shape community members’ (or residents) understanding of and relationship with urban nature. This helps evaluate the effectiveness of the projects as niche experiments in mitigating risks and providing co-benefits in informal settlements. Ultimately, this serves the purpose of contributing to knowledge gaps in the practice of NBS in informal settlements, thereby providing decision-makers with evidence of challenges and opportunities as to how NBS can make a difference in a neighborhood.

Methods

A case study approach

In this paper we study the multi-year program “Nature-Based Solutions to Water Management Challenges in Urban

Informal Neighborhoods” (2019–2022) which has been funded by Sida and SwedBio at the Stockholm Resilience Centre/Stockholm University (Sweden). The overarching goal of the program is to address some of the most urgent challenges posed by climate change, rapid urbanization, and the loss of green space in Africa’s informal settlements. It aims to build evidence from experiences of co-design and co-construction of local NBS that can inform the expansion and institutionalization of NBS. [Figure 1](#) shows the location of the five settlements in which the program has been conducted in Nairobi and Dar es Salaam. [Figure 2](#) illustrates the types of NBS projects implemented across the five case study areas.

The program has been led by two non-profit intermediary organizations: Kounkuey Design Initiative (KDI) in Kenya and the Centre for Community Initiatives (CCI) in Tanzania. Both organizations are dedicated to improving the provision and access of basic services by the urban poor. They promote participatory and community-centered methods and procedures to provide local populations with an “improved practical understanding of NBS approaches and impacts, equipping them to engage with and even lead other similar green infrastructure projects” (KDI, 2021; p. 18). The CBOs involved in the projects are groups committed to address environmental issues and support socio-economic development, as well as groups managing local schools in both cities. Although not explored in detail in this paper, the project has also involved the development of a Monitoring, Evaluation and Learning (MEL) framework comprising of seven overarching categories and 66 qualitative and quantitative indicators. The MEL was co-developed by resident groups, NGOs, local governments, and evaluation experts at the Stockholm Resilience Centre.

In this paper, we follow a case study approach (Harrison et al., 2017) to capture grounded evidence from the series of NBS implemented across the five sites. While the overall approach to the set of interventions in the two cities is similarly focusing on participatory processes, the socio-political and environmental contexts in which the interventions take place are significantly different. Therefore, we draw parallels and contrasts between project experiences and thereby support knowledge-building on challenges and opportunities for NBS in urban settings in East Africa. Instead of claiming that the cases are exemplary, we rather aim to demonstrate that first-hand testimonials from residents and project implementers provide valuable learnings for other NBS initiatives in the region and similar contexts elsewhere.

We seek to address knowledge gaps identified by Kabisch et al. (2016) who associate them with the aforementioned barriers to the implementation and upscaling of NBS (fear of the unknowns, disconnects between short-term actions and long-term plans, sectoral silos, and the paradigm of growth). We pay particular attention to the notion of “fear of the unknowns” because of its relevance in the contexts explored here. We use Kabisch et al. (2016) categorization of “knowledge gaps” to guide the analysis of case studies and explore the extent to which they

support knowledge-building for the uptake of NBS. These four key categories of knowledge gaps relate to: (1) NBS and society relations; (2) Design; (3) Implementation and; (4) Effectiveness.

The first category, “NBS and society relations,” here relates to the impacts of NBS projects on human-nature interactions, notably to encourage residents’ long-term involvement. This includes understanding changes in people’s perceptions toward NBS throughout their experiences with the projects, for example resulting in an increase in access to urban nature or because of potential impacts such as forced displacement. The second category focuses on “design” through knowledge integration from different disciplines such as architecture, urban planning, and engineering. In relation to the cases explored in this study, it helps evaluate co-design approaches for multifunctional NBS, including for the purpose of meeting local needs articulated by community members. The third category relates to the range of instruments and actors required for NBS project “implementation.” This includes the technical knowledge and working force required for the implementation of infrastructural projects, but also for elements such as the relevant legal and administrative instruments. Lastly, “effectiveness” highlights the long-term performance of NBS. It reviews the provision of different types of ecosystem services at multiple scales, while acknowledging the difficulty of assessing certain forms of causality (e.g., between urban green space and human health). This category also explores local ownership and knowledge transferability.

Data collection and analysis

Focus Group Discussions (FGDs) and surveys were used to collect information from different stakeholder groups, i.e., communities and intermediary organizations directly or indirectly involved in project implementation. For the application of these methods, guiding questions were developed under Kabisch et al.’s (2016) four “knowledge gaps.” Two FGDs were conducted with community members, many of which are part of the Community-Based Organizations (CBOs) involved in the NBS projects deployed in the studied areas. FGDs took place in Kibera (Nairobi, Kenya) and in Mji Mpya (Dar es Salaam, Tanzania) in March 2022. Questions designed around the four knowledge gaps guided discussions. Facilitation was done in both Swahili and English. In Nairobi, sixteen participants took part in the FGD, four of whom were women. Even though women were underrepresented, the ones present actively participated in discussions. The FGDs were recorded, transcribed and translated into English. In Dar es Salaam, the FGD involved 4 men and 4 women from Mji Mpya and was supplemented with a Key Informant Interview (KII) with a teacher from Mapinduzi Primary School. All participants took part in FGDs on a voluntary basis and consented to their responses being published anonymously.

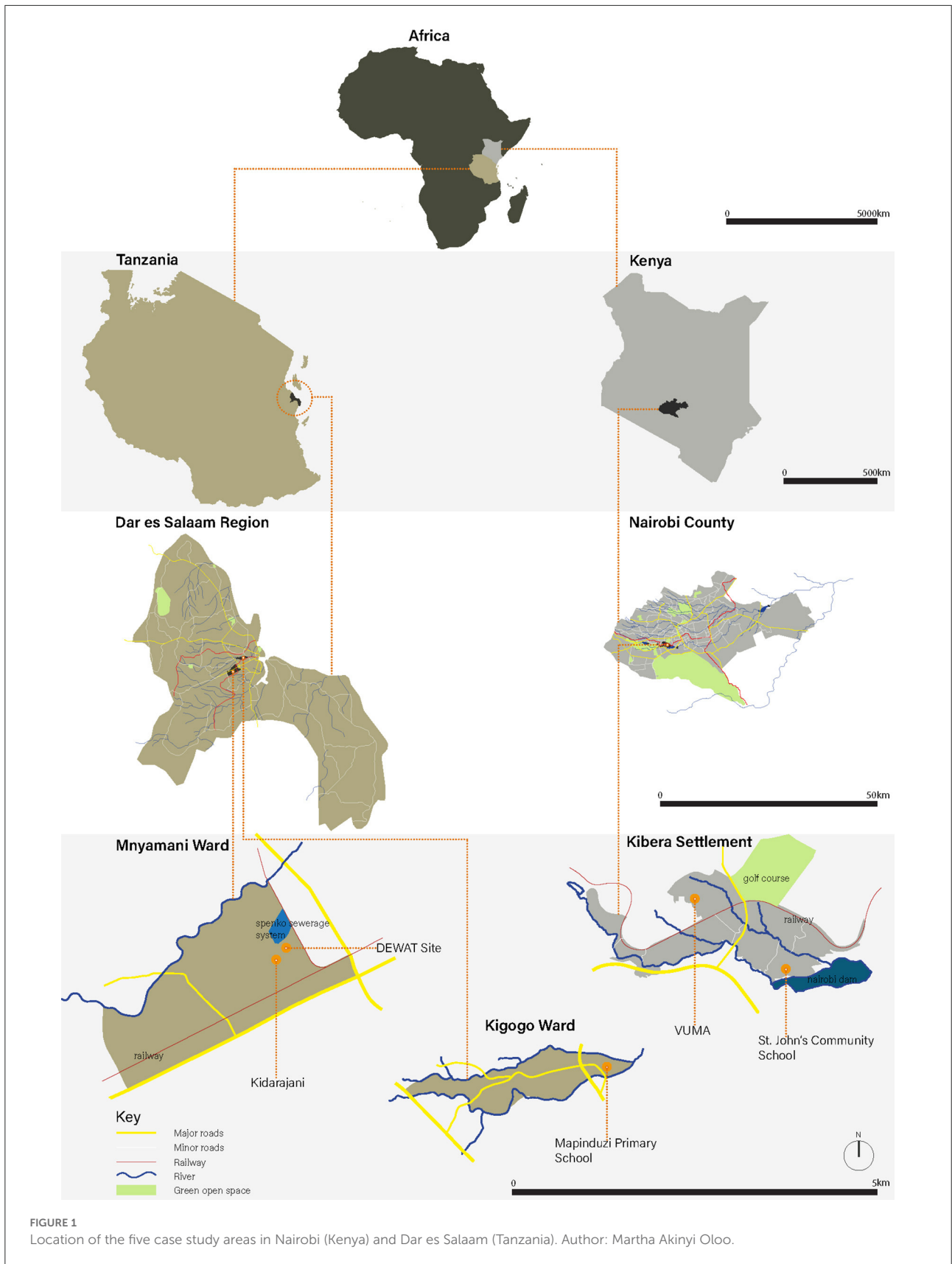


FIGURE 1
Location of the five case study areas in Nairobi (Kenya) and Dar es Salaam (Tanzania). Author: Martha Akinyi Oloo.

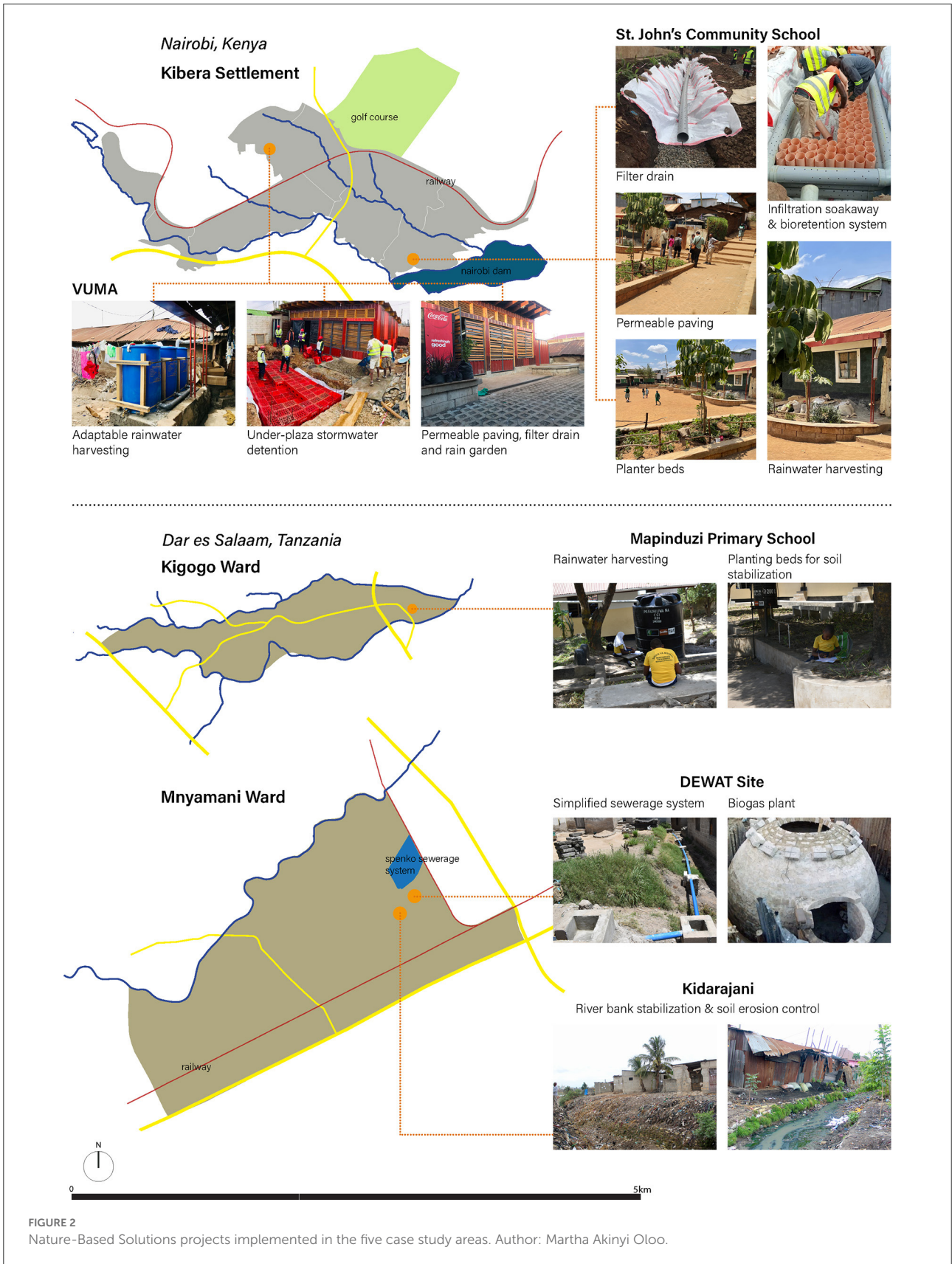


TABLE 1 Number of survey respondents per intermediary organization's team.

	Nairobi	Dar es Salaam
Design/engineering/construction	2	1
Planning	2	1
Research	1	2
Community Engagement	2	-

Online surveys were conducted to collect data from landscape architects, engineers, and community organizers from both intermediary organizations involved in the NBS projects explored in this study. Responses were received from 11 individuals, seven of which worked on the NBS projects in Nairobi, and four of which in Dar es Salaam (Table 1). Not every respondent participated in every project phase, which explains the unevenness of responses per question. The survey used a combination of open- and closed-ended questions. Questions were framed in neutral terms to minimize the introduction of biases. Responses were anonymized and all participants consented to their responses being used in the final study. Primary data was also supplemented with project reports made available to the authors by KDI and CCI.

Authorship of the present paper was split between academics who have not been directly involved in the program, and practitioners who have played a direct role in the program delivery. Research design and analysis have therefore been in part informed through a “participant-observer” position. An identified advantage of this approach relates to the proximity of the researchers with the subject. We argue there is research value in this proximity in terms of deepening the understanding of contextual issues to answer research questions. However, this also presents risks of confirmation bias, e.g., in using responses to confirm previously held beliefs, and in lacking objectivity, notably due to the activist and advocacy nature of the intermediaries' work. Particular attention was therefore paid to possible assumptions and ways to account for such biases (Asselin, 2003).

Definitions and concepts

While the scope of this paper is not to provide extensive definitions and justifications of the nomenclature used herein, there is a need to provide working definitions around the key terms and concepts used in this paper. We approach “urban nature” as “nature”—i.e., living (biotic) systems that contain plants and non-human animals - in urban environments. Urban nature is multilayered and exists across a range of scales and degrees of human management (Bratman et al., 2012; Gandy, 2022a). Contradictions can emerge from the dissociation of “nature” from “non-nature,” as well as of “human” from “non-human” (Gandy, 2010, 2022b). However, this demarcation here supports the understanding of the way they perceive, approach,

and support non-human nature in the process of producing urban spaces.

NBS are defined as actions to address societal challenges that support and are supported by nature. NBS encompasses other concepts such as “ecosystem-based adaptation” which is commonly used as a term in the context of African cities. Urban NBS aim at leveraging the value of urban nature, for example in improving health, and mitigating the effects of climate change (van den Bosch and Ode Sang, 2017; Keeler et al., 2019). Yet, NBS is another contested concept. To some, “greenness” is a determinant factor to qualify an action as an NBS or not. For example, Sowińska-Swierkosz and García (2022) consider that interventions that use wind, wave or solar power, but which are not directly based on functioning ecosystems, should not be considered part of NBS. However, the establishment of “fully green” NBS might face multiple barriers in contexts like those of informal settlements, including in terms of immediate effectiveness in providing ecosystem services (Depietri and McPhearson, 2017; Anderson et al., 2022). Therefore, hybrid systems that contain green/blue elements (functioning ecosystems) and gray elements (engineered infrastructure) are considered relevant NBS in the cases explored in this paper.

The term “informal settlements” is used to refer to areas generally characterized by the confluence of low-income areas with areas where municipal infrastructure and social services are lacking. In these areas, lack of infrastructure for basic services associated with the “absence” of formal institutions (such as the state) results in the embeddedness of urban poverty and the accumulation of socio-environmental risks (Satterthwaite et al., 2020). The way we approach NBS allows the consideration of locally established practices in the informal settlements of interest in this study, where communities and civil society organizations have jointly provided water management services outside the formal sphere. These have benefitted residents by filling service gaps through the use of ecosystems, yet without necessarily referring to them as NBS. We argue that the effective and innovative aspects that characterize these practices make relevant the consideration of these interventions as NBS niche experiments. While we recognize that distinguishing “the regime” from “the niche” can be as onerous as attempting to demarcate the “formal” from the “informal,” we show the value of highlighting the complex reality of NBS by drawing lessons for similar contexts where comparable practices also exist within heterogeneous governance structures.

Case studies

Nairobi and Dar es Salaam city contexts

An estimated 55 to 60 percent of Nairobi's population live in informal settlements, many of which are located in close proximity to the city's major watercourses (Ono and Kidokoro, 2020). This condition was created through selective

settlement of desirable and higher lying areas by Europeans in the colonial era, leaving low-lying, riverine, and swampy areas to “natives” (Hake, 1977). Kimari (2021) argues that the urban environmental form today is still heavily shaped today by “divide and rule” policies and exclusions reminiscent of the colonial administration. Lack of access to public space and services, coupled with insecure land tenures, lead many residents to build housing on slopes adjacent to rivers. Almost all residents of Nairobi’s informal settlements are acutely threatened by flooding, given the widespread absence of adequate drainage and solid waste disposal systems. In settlements such as Kibera, measures to reduce local risk to flooding are hence often taken at the community level by community or faith-based organizations or traditional hierarchies present in the settlement (Mulligan et al., 2017). Heavy rainfall often results in dirt tracks temporarily transformed into rivers. High levels of population density and informality complicate the protection, creation, and maintenance of urban green space and functioning ecosystems. The conjunction of these issues accentuates the need for community engagement in water management.

As a low-lying coastal city, Dar es Salaam is particularly vulnerable to climate change, a vulnerability which manifests itself most strongly in informal settlements (Morin et al., 2016). In Dar es Salaam, the proportion of people living in informal settlements is even higher than in Nairobi and is estimated to be of 70 per cent (Nyssölä et al., 2021). With informal settlements in Nairobi resembling comparatively small patches within planned areas, informal settlements in Dar es Salaam make up the majority of the land area (Sirueri, 2015). Sirueri (2015) points out that informal settlements in Dar es Salaam tend to have a medium density of population, whereas most informal settlements in Nairobi have a high density of population.

Similarly to Nairobi, informal settlements in Dar es Salaam are largely located on floodplains, thereby exposing residents to extreme physical and existential risks. Governmental action in flood-prone areas has historically consisted in demolishing existing infrastructure and relocating populations, leaving thousands of residents without adequate housing (Schofield and Gubbels, 2019). Local governments are often unwilling to adequately respond to the needs of communities in areas considered outside their planning mandate. Residents of informal neighborhoods in both cities are therefore confronted with considerable socio-environmental challenges that include that of water management. In this context, NBS that are co-designed, implemented and maintained by residents potentially represent a cost-effective solution to address the drivers of multiple urban vulnerabilities.

Case study projects

The “Nature-Based Solutions to Water Management Challenges in Urban Informal Neighborhoods” program

BOX 1 Public engagement with communities for implementation of NBS projects in Kibera through Requests for Proposal, Nairobi (Kenya).

In September 2019, KDI and CCI initiated a “Request for Proposal (RFP)” process in the three selected settlements to identify community partners and specific sites for the NBS interventions. This included reaching out to existing CBOs and self-help groups in the selected informal neighborhoods. Public fora and community meetings (*barazas*) were held in central locations to inform communities about the requirements for the RFP and basic principles behind NBS. Flyers and posters were distributed, and social media were used for greater outreach. Groups were given one month to submit project proposals on paper or online. Next, the intermediaries evaluated the submitted proposals against 18 selection criteria. Numerous proposals were shortlisted for site visits and group interviews, during which spaces for potential interventions and the groups’ level of formalization and organization were discussed. The final decision was made using a point-based system.

In December 2019, the intermediaries held awarding meetings to inform CBOs about their selection. Design workshops with the CBOs, but also different resident and stakeholder groups, started in January 2020 and focused on: (1) identifying challenges in water management; (2) discussing the concept of NBS; and (3) choosing the type(s) of NBS to be implemented. Photographs and illustrations were used to create an understanding of NBS. Workshop attendance was initially high, for example VUMA co-design workshops were attended by an average of 30 people at Vuma and 55 at St John’s. Covid-19 restrictions that came into effect during the project period reduced maximum attendance to 20.

A Memorandum of Understanding (MoU) was established between the CBOs and the intermediaries to formalize the mutual commitment and responsibilities in terms of finance, labor, and governance of NBS. In the co-design phase, residents visited the locations for proposed interventions to get a better sense of scale and functionality. The intermediaries shared design options and highlighted potential construction and maintenance challenges. Residents in turn asked questions and made design suggestions and inputs. Key design and investment choices were made by democratic vote with groups members.

Sources: Ohler (2020) and Kirimi and Ohler (2021).

has been implemented in partnerships with two CBOs in Nairobi, and a school and a CBO in Dar es Salaam. Box 1 provides a description of the Requests for Proposal that led to the creation of these partnerships with CBOs and the selection of sites for NBS in Nairobi. A list of the sites, NBS interventions, and CBO groups is provided in Table 2. In Nairobi, the first community partner is the youth group “Vijana Usafi na Maendeleo” (VUMA) from Makina Village in the Northwest part of Kibera. Despite their remote location from the settlement’s watercourses, as many as 40 percent of the households of the village are directly affected by flooding due to the low-lying nature of the area and the poor drainage system in place (KDI, 2022). NBS selected and implemented for surface water management include rainwater harvesting, rain gardens, stormwater detention, permeable paving, and filter drains.

The second community partner, St. John’s Community School, is active in Silanga Village in Southeast Kibera, adjacent to the Nairobi Dam. In their proposal, parents and local residents indicated that the school was highly exposed to

TABLE 2 Summary of NBS implemented in each site in phase 1 (2019–2020).

City	Settlement	Site	Community partner	NBS implemented
Nairobi	Kibera	Makina Village	VUMA	<ul style="list-style-type: none"> • Rainwater harvesting • Under-plaza stormwater detention • Permeable paving • Filter drain • Rain garden
		Silanga Village	St. John's Community School	<ul style="list-style-type: none"> • Planter beds • Filter drains • Bioretention system • Infiltration soakaway • Permeable paving
Dar es Salaam	Mji Mpya, Mnyamani ward	Kidarajani (River bank or soil erosion control site)	PANAKUNA CBO	<ul style="list-style-type: none"> • River bank stabilization
		DEWAT site	PANAKUNA CBO	<ul style="list-style-type: none"> • Biogas Plant • Simplified sewerage system
	Kigogo Mbuyuni	Mapinduzi Primary School	Mapinduzi Primary School	<ul style="list-style-type: none"> • Planting beds for soil stabilization • Rainwater harvesting

flooding and sewage overflow as the compound lacked sufficient drainage and infiltration options (Ohler, 2020; p. 12). In both cases, the need for change was well-known to VUMA and St. John's communities. NBS selected and implemented for surface water management were therefore proposed so they could include rainwater harvesting, rain gardens, planter beds, bioretention zones, and filter drains.

In Dar es Salaam, CCI partnered with Mapinduzi Primary School in the informal settlement of Kigogo Mbuyuni (Kigogo Ward). The school is built in a low-lying area affected by erosion. Teachers and students used to be entirely dependent on water from a borehole providing insufficient amounts for irrigation and sanitation purposes. Rainwater harvesting and planting beds for soil stabilization were identified as relevant NBS to help address these issues.

CCI also partnered with PANAKUNA in Mji Mpya (Mnyamani Ward) which faced several challenges, including lack of sanitation, localized flooding, and poor solid waste management due to waste disposal into a nearby river. The CBO prioritized the development of means to tackle soil erosion and flooding issues at the riverbank (Kidrajani). The project also involved developing Decentralized Wastewater Treatment (DEWAT) through a simplified sewerage system, as well as the construction of a biogas plant decomposing waste material including sludge and enabling energy recovery and nutrients

through anaerobic digestion. Similarly to the others, this site therefore planned the construction of NBS and new gray infrastructure. This resulted in hybrid systems for water, waste and riverine ecosystem management. In addition, the CBO also built a bridge and installed solar streetlights to support safe mobility between neighborhoods.

Findings

This section lays out the key findings and results from the analysis of FGDs with residents and surveys with intermediaries after project implementation. The results are structured according to Kabisch et al.'s (2016) four thematic categories: (i) NBS-society relations, (ii) design, (iii) implementation, (iv) effectiveness. Table 3 provides a summary of the key findings. The subsequent sections explore each of the "knowledge gaps" with more detail and evidence from data collection.

NBS and society relations (pre-project)

During FGDs, residents of the four case study sites reported that a range of drivers have influenced their involvement in the projects. In VUMA (Nairobi), respondents

TABLE 3 Community experiences of participation in NBS projects for water management in informal settlements in Nairobi and Dar es Salaam.

Key findings

NBS and Society relations pre-project (drivers for participation, expectations, concerns)	<ul style="list-style-type: none"> • There was initially limited familiarity with the concept of NBS or how it applies in practice among residents; • Drivers for residents' participation in the projects have included addressing localized flood risks, lack of water access and improving environmental cleanliness, as well as learning technical skills; • Some residents had expressed skepticism about the functionality of NBS pre-implementation, sometimes as compared to gray infrastructure (e.g., for erosion and flood control). Residents indicated this changed for the majority of them post-project implementation; • Though the intermediaries had a policy of not displacing residents or removing existing residential structures, residents at St. John's (Nairobi) were concerned about displacement before the project started; • Curiosity about whether NBS could be effective was high, in particular in areas where gray infrastructure has failed to provide climate mitigation.
Design (knowledge exchange on design opportunities and constraints)	<ul style="list-style-type: none"> • The inclusive aspects of the design workshops gave space for different segments of communities, including children, to participate, not just in the school projects, but with those in more public spaces; • Residents have valued getting exposure to different design techniques, e.g., alternative designs for gutters to work with the typical roofing materials and structure; • Creating a safe space for children to play was considered important for several residents; • Residents have identified design issues: e.g., entrance of floodwater needing a trench, also issues "at the back," needs for a bridge and gabions, issues with manholes not letting water flow through, blockages";
Implementation (knowledge exchange on implementation opportunities and constraints at local scale)	<ul style="list-style-type: none"> • "Seeing is believing": the construction phase of projects was a major determinant for resident's understanding of how NBS for water management materializes in practice; • Both women and men participated in the construction of NBS projects; • Several residents took initiatives to ensure safety during construction (including to protect against COVID-19 risks); • Residents employed during implementation have valued learning techniques through engagement in different construction activities; • Evidence of emergence of local conflicts, notably with landlords and neighboring communities who feared the projects could affect their structures.
Effectiveness (learning on short-term and longer-term benefits and issues, maintenance)	<ul style="list-style-type: none"> • All FGD and survey respondents (100% of responses) agree in saying NBS have been effective in mitigating local flood risks. • In the two Nairobi sites, further NBS benefits highlighted during FGDs include education opportunities and youth involvement more broadly, but also improved living conditions due to cost-savings resulting from flood mitigation. • In one of the Nairobi sites (St. John's), a maintenance committee was formed and trained with support from intermediaries, for example to help unblock channels and maintain gardens. • Some maintenance challenges were reported, for example due to lack of finances to buy materials to repair systems.

explained their priority was to address local flooding issues. They also saw an opportunity to simultaneously improve accessibility to public space by the wider community through NBS. In St. John's Community School (Nairobi), residents explained they were interested in learning techniques to address water access issues, while increasing environmental cleanliness and air quality. On the latter, residents expressed a connection—including during early stages of engagement and design—between NBS and the possibility of improving socio-environmental health. Several comments illustrated concerns about water and airborne pollution harming the population, and particularly children.

At Mji Mpya (Dar es Salaam), participants explained being willing to see the effectiveness of NBS in addressing soil erosion in areas where gray infrastructure such as concrete bank reinforcement infrastructure—had been insufficient. Alongside the water management features of NBS, residents expressed the

need for other measures for community development. These included sanitation measures and interventions to improve safety, notably for women and girls.

According to FGDs, there was initially limited familiarity with the concept of NBS among community members across sites in both Nairobi and Dar es Salaam, and more particularly with the way it would be implemented in practice. One resident from St. John's commented on their expectations regarding large-scale, traditional infrastructure development:

"I was dreaming big. I imagined big trenches draining to the dam, hard construction, bridges, and infrastructure around the dam such that water could not overflow into the neighboring plots. [...] I thought bridges would be constructed so as not to jump over the trenches." (St. John's respondent, 2022-03-05)

Several participants also shared they were skeptical about the effectiveness and functionality of NBS, for example to solve water management-related challenges that the communities had been facing. In Mji Mpya, one resident also explained the need to complement NBS with gray infrastructure to prevent floods and erosion:

“I had not much doubt about the effectiveness of the NBS measures against soil erosion. But I wanted this stream to be cemented from the bottom, and then NBS measures like putting sandbags to be implemented alongside the stream.” (Mji Mpya respondent, 2022-03-10)

Survey respondents reported that initial skepticism from communities slowed down project implementation, requiring extra workshopping and consensus building. Furthermore, residents expressed clear concerns about the threat of evictions:

“According to my view as a member of the community of St. John’s, most of us were worried that we could be displaced. Rumors were going around that these people could displace us.” (St. John’s respondent, 2022-03-05)

Each of these points were further discussed during meetings and workshops between residents and intermediaries during the subsequent phases of the projects in attempts to address the concerns raised.

Design

The co-design phases of the projects aimed at engaging with participants in an interactive manner, using tools and sketches and practical examples of NBS to discuss ways to address multiple risks as well as other community needs. Workshops were designed in a way residents could share learning, suggest ideas for integration into plans co-developed with intermediaries, and ask questions. A resident from VUMA reported:

“The children, adults and youth came up with different ideas, and afterwards we all sat down, looked at the different ideas and discussed the most appropriate ones. Every design that was implemented had previously been discussed and agreed upon.” (VUMA respondent, 2022-03-05)

Based on FGDs, participants consider they acquired valuable learning during NBS design workshops. Among the different learning elements that participants considered useful, drainage and rainwater harvesting techniques were particularly valued by residents from both St. John’s and VUMA in Nairobi. In

Dar es Salaam, a member of CCI’s design team stated that once communities learned about the potential benefits of functioning NBS, their willingness to protect their environment increased. This was particularly evident at the DEWAT site and the soil erosion control works at Mji Mpya.

During workshops, intermediaries and residents also discussed the multifunctional character of NBS designs, notably in relation to unlocking benefits beyond the local scale. Intermediaries presented how local river revitalization strategies could provide ecological benefits at the scale of the watershed. Yet, the range of challenges to achieve such benefits—as opposed to focus on ecosystem services at targeted project sites—were recognized throughout discussions between residents and the intermediaries. A community member of KDI in Nairobi and a design team member of CCI in Dar es Salaam reported that limited resources and governance constraints (e.g., legal requirements) restricted the extent to which strategies could be designed during such workshops. This has therefore limited the significance of ecological impacts at river basin scale. Furthermore, co-design sessions held in the various case study sites largely helped identify the needs for gray infrastructure interventions to complement the ecological components of NBS. For example, in the case of Mapinduzi Primary School, project participants expressed the need for benches (*vimbweta*) for students and teachers to rest in the garden.

Implementation

The construction of NBS projects in both cities occurred through active involvement of community members. Several FGD respondents indicated they have valued the way community members came together to build the projects and that “unity” had been very important to them. In St. John’s community, a female respondent pointed out that both women and men participated in the construction of the projects as paid laborers, and that everyone could contribute in the way they wished and were able to do so within their capacity. Another resident explained their role in ensuring safety measures were respected throughout the construction phase of the project:

“Safety was the priority. I was in charge of personal safety. I ensured COVID-19 regulations were followed, and that everyone had the safety gear, i.e., safety boots, reflectors, face shields, and gloves and that basic medicine like painkillers were also available on site. The reflective tape also helped delineate the risk area, showing people that the place was out of bounds.” (St. John’s respondent, 2022-03-05)

The technical skills acquired have been considered useful to residents. FGD respondents from the Mji Mpya sites explained having gained knowledge on the way human waste can be turned into useful products at a reduced cost through the installation

of the biogas production system. They also reported learning how NBS can complement and/or replace hard infrastructure in practice. Several FGD participants also stated how the skills they acquired could easily be replicated. In St. John's specifically, community members explained that being directly involved in the construction of NBS was beneficial in several ways:

"I have learned how to harvest water and use it for other purposes by recycling water. I have also learned how to make proper drainage channels because it is not just digging a trench; one should use specific techniques." (St. John's respondent, 2022-03-05)

"I was involved in the design workshops and construction. I understood the project after construction began." (St. John's respondent, 2022-03-05)

"We learned the theory aspects during workshops, but I didn't quite understand at first. But when we started construction, I understood what we were being taught." (St. John's respondent, 2022-03-05)

"We were involved in all stages of the implementation of the NBS. The NBS measures are simple but have been very useful especially on reducing the recurrence of the soil erosion here." (Mji Mpya respondent, 2022-03-10)

Among challenges faced, the emergence of conflicts was notably reported by FGD respondents. A VUMA respondent explained:

"Before anything is constructed in VUMA, it is always a fight. The landlords themselves could not understand the project and the gutters were to be installed in their plots. What happened was that when you wanted to construct something, the landlords would report you to the chief claiming that you are grabbing their houses. [...] They thought that their houses were being grabbed." (VUMA respondent, 2022-03-05)

In Dar es Salaam, intermediaries (3/3) pointed out the need to better manage expectations as community members hoped that NBS could address more challenges in their neighborhood than those for which they had been planned.

Effectiveness

In both Nairobi and Dar es Salaam, the large majority of FGD participants and all survey respondents involved in the construction of infrastructure ("built works") (9/9) reported that NBS have been effective in mitigating local flood risks. The teacher from Mapinduzi Primary School at Kigogo Mbuyuni stated:

"Previously when it rained heavily, our classes were flooded with stormwater. But now we have given the storm water direction through the guttering system. No flooding has happened." (Mapinduzi Primary School respondent, 2022-03-10)

A VUMA community member commented on the way NBS for water management has provided benefits beyond flood mitigation:

"Gutters and drums were installed, and now when it rains, we use that water for domestic use and to water the vegetables we have planted there. My house no longer floods and we now have water for laundry and irrigation. Now I can go home and harvest rainwater using gutters and drums, and I can also plant some vegetables and flowers in sacks, and direct water to these sacks so that it is not wasted." (VUMA respondent, 2022-03-05)

In Nairobi, survey respondents listed improved aesthetics (3 out of 6 respondents) and groundwater recharge (3/6) as other important aspects for both residents and intermediaries. In Dar es Salaam, 2 out of 3 respondents believed that the NBS providing recreation for children, reducing solid waste pollution, and soil remediation were the most important gained benefits. For intermediaries themselves, by contrast, all three respondents in Dar suggested that the most positive aspect was recreation for children, followed by flood risk reduction and reduced solid waste pollution.

A few survey respondents from KDI in Nairobi argued that the NBS have had further socio-environmental impacts beyond the local scale in contributing to the revitalization of the river basin. This revitalization has occurred through the creation of new public recreational space requested by residents. In Dar es Salaam, survey respondents similarly agree in reporting that the Kidarajani project has contributed to the revitalization of local riverbanks.

In VUMA, one resident explained that addressing flooding led to further benefits:

"NBS has improved living standards. Previously when it flooded, you could not even buy a sofa or other household appliances. However, now that flooding has reduced, the living standards have improved and people can renovate their houses because when they previously flooded, the houses used to crumble." (VUMA respondent, 2022-03-05)

According to survey responses, the NBS approach has helped disincentivize the dumping of waste into the environment, notably because of the valuation of the NBS in reducing flood risks and the associated need to protect them. Besides, intermediaries believe that the aesthetics of a greener, cleaner, and more organized public space strongly emerged as an

influencing factor in people's appreciation of the solutions, particularly in St John's, VUMA, and Mapinduzi Primary School. In Mapinduzi School, the key informant reported that planting beds have helped reduce dust and related air pollution. FGD participants from St. John's described a feeling of pride as visitors have come to see the project. Further benefits highlighted during FGDs include education opportunities with children, as well as youth involvement in developing community projects. School teachers involved in the projects have used the project to teach children about water recycling.

Yet, the impact of NBS on pollution behavior has not been the same across sites. Preventing the wider dumping of solid and human waste into the environment was also reported as a challenge in the study sites of Dar es Salaam. The CBO "PANAKUNA" was created during the program with the purpose of supporting the management and maintenance of the NBS interventions (the DEWAT and soil erosion control sites). A maintenance committee was formed after project implementation in St. John's. Residents have assured maintenance (e.g., of trenches and trees). As explained by community members, intermediaries helped this committee in gaining further technical skills:

"KDI left when we had planted trees in the rain gardens. We maintain those trees; we make sure we water them, weed them, and manure them." (St. John's respondent, 2022-03-05)

"I learned how to maintain the project as a member of the maintenance committee after KDI handed over the project. KDI gave us the skills of maintenance such as unblocking channels and gutters and maintaining gardens." (St. John's respondent, 2022-03-05)

However, several people from both sites of Nairobi reported that significant maintenance challenges emerged:

"We face a lack of materials, for example, those needed to unblock drains. We usually ask the school's committee for assistance but sometimes there is a lack of finance. In some cases, we also lack technical knowledge." (St. John's respondent, 2022-03-05)

"We faced challenges mostly on cleaning the tanks, which are supposed to be cleaned when it is not raining. It is hard for a grown man to clean, especially getting inside, so sometimes children are sent to do it with the guidance of older people." (St. John's respondent, 2022-03-05)

All nine survey respondents involved in built works reported that communities had either "some" or a "very good" understanding of NBS following the completion of the projects, with the greatest improvements perceived in Nairobi. FGD participants were asked to provide a definition of NBS

following their involvement in projects. Several individuals made references to spiritual and religious values. For example, a participant from St. John's project described NBS as "the things we use from nature... doing things God's way ('Njia za Kimungumungu')." A VUMA resident explained seeing NBS as low-cost solutions:

"The whole NBS project has taught me that we can use the least expensive materials to solve problems we have. We don't have to use a lot of money and complex materials; for example, we have used gutters and drums in my area. You don't have to wait for a lot of money and materials to solve your problems." (VUMA respondent, 2022-03-05)

Residents further identified that the addition of gray infrastructure components to NBS strategies increased project effectiveness. For example, solar streetlights at Mji Mpya increased a sense of security, an outcome which they perceive as having critically contributed to the success of the project. The application of the MEL framework will intend to help build further evidence on effectiveness in relation to both technical and non-technical aspects of NBS.

Discussion

Co-building communities' relationships with urban nature

Results from the case study sites in Nairobi and Dar es Salaam show similarities regarding processes and outcomes from the practice of NBS and its potential to address multiple, and interconnected risks in the context of informal settlements. Testimonials from community members who participated in FGDs and respondents to surveys who are part of "intermediary" organizations show that the projects have achieved risk mitigation while ensuring longer-term objectives of integrating urban nature into different socio-environmental contexts. Residents across the case study sites reported that projects have managed to address targeted local issues through nature-based approaches including flood risks and polluted water supply, while providing additional benefits, ranging from well-being and safety to senses of community ownership and increased environmental awareness. However, continued monitoring and evaluation will be required to confirm such outcomes in the longer run.

Results show that communities' perceptions and valuation of NBS positively changed throughout project phases. Some residents clearly stated that their valuation of NBS changed through the process and that the experience of co-developing projects has had an impact on this. This concerns situations where individuals initially expressed skepticism, felt "fear of the unknowns" and/or held higher trust in traditional gray

infrastructures to address specific hazards. Testimonials indicate that perceptions toward the effectiveness of NBS in mitigating flood risks and erosion have changed for the positive. The implementation phases of projects appear to have played a significant role in this. Several FGD participants explained that involvement in the construction phase of their project has supported their learning of the ways the theory of NBS can materialize in practice. FGDs suggest that this phase had the strongest impact on the residents' learning of NBS. This is a relevant conclusion for participatory processes in NBS since it reflects the need to embody a concept that is often associated with non-material and intangible values, including within NBS epistemic communities (Schröter et al., 2014).

An important question emerges on the way observed changes in NBS-society relations could have impacted community relationships with the wider notion of urban nature. As described by one survey respondent based in Dar es Salaam, communities started to reflect on the “whys” of urban nature throughout project implementation. Individual testimonials reflected a change in perceptions toward what nature-based approaches could achieve, for example in terms of erosion control as seen in Dar es Salaam. Yet, higher trust has often remained in the effectiveness of traditional gray infrastructure to tackle hazards like flooding. Given the normalization of gray or “conventional” infrastructure investment to manage climate stressors, it is not unexpected to witness such perspectives. Indeed, this is consistent with other research demonstrating how “fear of the unknown” and a lack of access to alternative options can impede uptake of NBS (see e.g. Kabisch et al., 2016).

In relation to this, FGD testimonials and surveys confirmed that the creation of hybrid gray-green infrastructure systems aided the integration of projects into their context of implementation, notably to navigate constraints of space since gray systems often take up less physical space to deliver the same immediate function. The participatory aspects of the projects are considered to have played a significant part in this due to the early identification of local needs for non-NBS components which were discussed during the design phase of projects. Engagement of intermediary organizations with community residents helped identify possible applications of both green/blue and gray infrastructure solutions (e.g., rainwater harvesting systems and channelized drainage, respectively) to meet urgent needs which green/blue infrastructure would hardly provide on its own over the short-term. At the same time, these systems were seen as complementary from a design and engineering perspective, as well as having high levels of acceptance in the community. However, NBS hybridity may contribute to the blurriness of the definition of the concept, but also opens up many practical questions, for example on the interactions between ecological and built infrastructures, and therefore on the type of expertise and knowledge required to design and manage them.

Examining residents' reactions to the case projects has also surfaced a range of representational values specific to urban nature (as opposed to gray infrastructure) which go beyond ecological or engineering performance. For example, the aesthetics of NBS appear to have played an important role in the rapprochement of communities with NBS. This was visible in the way FGD participants noted that the gardens were being photographed by residents for their beauty. Furthermore, it is important to highlight the association between nature and spirituality or religion. Several respondents in Nairobi have made comments that emphasizes an NBS–divinity nexus. References to “God” exemplify relational attachments to nature through the divine figure in which they believe. A common theme amongst respondents was also the narration of climate disasters as an expression of divine forces. In both cases, these comments represent a form of cultural values associated to nature and were interpreted as resulting from experiences of connectedness with urban nature (da Rocha et al., 2017).

The cases confirm that early involvement of community members in project development is important to stimulate stewardship. Indicators of such stewardship could be identified among results in multiple ways. Firstly, communities have continued to manage the projects, particularly in cases where they have organized committees—with support from intermediaries—to ensure the maintenance of the NBS. Secondly, several members have replicated the same NBS in different places. Thirdly, teachers have used NBS to develop educational programs on urban nature for children. It is worth noting, however, that one intermediary working with communities in Nairobi stated that this relationship is unlikely to have changed in significant ways. Similarly, another intermediary suggested that residents would continue to “alter the environment to suit their needs.” Finally, it is important to note elements that are likely to have influenced projects and their outcomes. We recognize that the level of stewardship is likely to have been influenced by the intermediary organizations having had worked in the majority of the studied sites before these specific projects were developed. While this appears to have positively influenced outcomes, a word of caution is needed for contexts where such pre-existing relationships do not exist, and therefore prevent the “depth” of engagement.

Maintenance responsibilities

Maintenance of NBS or other local infrastructures by residents and CBOs in Nairobi and Dar es Salaam is a practical reality in the absence of a present local authority, in particular in the area of drainage and public works. In Dar es Salaam, although projects may have replaced burdens such as drainage clearance and minimized risks of damage from periodic flooding, maintenance works have created higher or additional responsibilities for communities and CBOs.

The complete decentralization of the physical network and governance system for wastewater (e.g., in the case of the DEWAT project in Dar es Salaam) or stormwater (e.g., in the VUMA site in Kibera) demonstrates that when community groups take on sole management of surface and sanitary water systems, as they also internalize costs and risks. Ethical questions around responsibilities therefore need to be raised in relation to the added burden this might create on already disadvantaged groups.

The additional burden (and potential public health risk) that maintenance responsibilities might represent to already disadvantaged populations remains understudied in the literature on hybrid and emergent systems. Much of the literature presumes that local populations should be directly involved in the maintenance of NBS projects. While this can be seen as beneficial for local stewardship, it raises questions about long-term responsibility, and governance models at scale. Such assumptions may risk re-producing oppressive patterns historically found in top-down and exclusive urban planning. Community-based action may sometimes build local resilience to climate change, but without addressing resilience at a larger scale, and in some cases, even impeding it.

It is important to note that the school projects in both cities benefited from the pre-existing governance arrangements for the school management and grounds. In addition, the improvement in school environment and play spaces was directly connected to increased student numbers and fees income for the school, providing a direct resource and incentive for upkeep and expansion of the interventions. Given the relatively large open space and surface area of schools as compared to other structures in informal areas, as well as the quasi-formal status of some schools, a focused but extensive schools program for NBS could be a strategy for scaling NBS, encouraging local (and future) NBS stewardship, and drawing the attention and investment of municipal and national bodies on education.

From “niche experiments” to governance lessons

The question remains as to whether niche experiments can sustain themselves and motivates institutional investment into NBS (Herslund et al., 2018; Diep et al., 2019). The survey responses and project documentation suggest that municipal actors and the water and sewerage utility in Dar es Salaam showed more interest in the projects than in Nairobi since these actors visited the NBS areas. This may either reflect a greater interest in NBS among Dar es Salaam governmental representatives, stronger institutional engagement in the settlements of interest, and/or a closer working relationship between CCI and the authorities. Different

responses from the local governments might also relate to the fact sectors including sanitation and drainage are managed by different types of agencies within different governance structures, and therefore respond differently to such projects. It is noteworthy, however, that the project team in Dar es Salaam, despite appreciating the efforts, argued that the governmental representatives did not believe that the approaches they witnessed could easily be scaled up.

Yet, such visits are considered important given the potential of “niche experiments” in leading to wider understandings and uptake of NBS, in particular by governments which hold the responsibility of improving public infrastructure at scale. The choice of a small scale for the projects is nevertheless strategic since it enables easier design, implementation and maintenance, but also limits risks of population displacement. However, the limited scale of the NBS developed for the sites also means the ecological impacts of the projects at larger scale have been limited. A balance must therefore be found to enable the integration of these different factors.

Better monitoring and evaluation frameworks are needed to support decision-making for NBS. Many monitoring and evaluation frameworks created in academic settings are overly complex and very difficult to apply in practice. They are typically not designed for smaller scales, and not with the specific considerations of informal settlements. The MEL framework co-developed in this program was tailored for both scale and context and iterated during multiple tests. Nevertheless, survey responses from the intermediary organizations indicated it represents a significant workload: above and beyond the challenges of developing and building the NBS. Intermediaries deemed it too ambitious and technical, causing difficulties to mobilize the required expertise within limited timeframes. Consistently collecting NBS data against multiple indicators across multiple sites and cities, as well as the distribution thereof, is a difficult endeavor for which organizations do not always have the internal capacity. This has been particularly challenging for indicators that require on-site testing (e.g., on heatwaves, surface runoff, groundwater quality, etc.), or require longer time frames such as evidence of economic benefits and gentrification.

The usefulness of data collection therefore remains to be analyzed in comparison to other factors influencing the enabling conditions for NBS planning and implementation. In a subsequent phase of the studied program, project partners will investigate the potential of NBS in providing alternatives to traditional hard infrastructure solutions through neighborhood-level planning together with municipal government partners. This will aim at increasing advocacy for NBS practice in East Africa. It will be informative to understand whether intermediary organizations are able to produce robust and transferable data in this context, and whether this data would be accepted for use by governmental partners or other decision-makers. If adapted to local capacities, the use of monitoring and evaluation frameworks like MEL could help

leverage practical knowledge of NBS, and guide resource investment into NBS in the studied cities in East Africa and beyond.

NBS for water management in informal settlements: Knowledge gaps

There is a need to continue building understanding of good practices and barriers in the implementation of NBS in complex contexts like informal settlements. Through the elaboration of this study, a series of (re)emerging “knowledge gaps” have shown the need to capture results in a concise way in order to inform future research and practice. With this in mind, [Figure 3](#) provides a list of specific knowledge gaps identified in NBS for water management in informal settlements. These are organized according to [Kabisch et al.’s \(2016\)](#) four categories of knowledge gaps.

A significant gap identified relates to the need for critical reflections on governance structures—and related political implications—through which NBS projects are implemented. This is significant in relation to NBS management, to negotiate responsibilities and mobilize resources in an equitable way. Better approaching questions of scale and related governance actors is also detrimental for the wider socio-ecological impact of projects, but also for ecologically sustainable and socially inclusive aspects. Political ecology theories that explore multi-scalar socio-environmental management can illuminate analyzes by surfacing critical power and political dynamics in NBS in those regards.

We also see a number of important technical and design questions to pursue on a research and practice front, including the need for design guidance tailored to informal contexts, and for greater exploration of hybrid green-gray infrastructure systems. A novel discussion amongst the authorship is the possibility of stronger cooperations with faith-based organizations which have advanced human-nature projects in rural and urban settings, and, in the same vein, exploring concepts of divinity and religion with respect to urban natural asset stewardship and care. This relates to a wider research frontier around the consideration of interior aspects of human-nature dynamics that affect the operationalization of NBS, and disaster risk management more broadly ([Wamsler et al., 2022](#)).

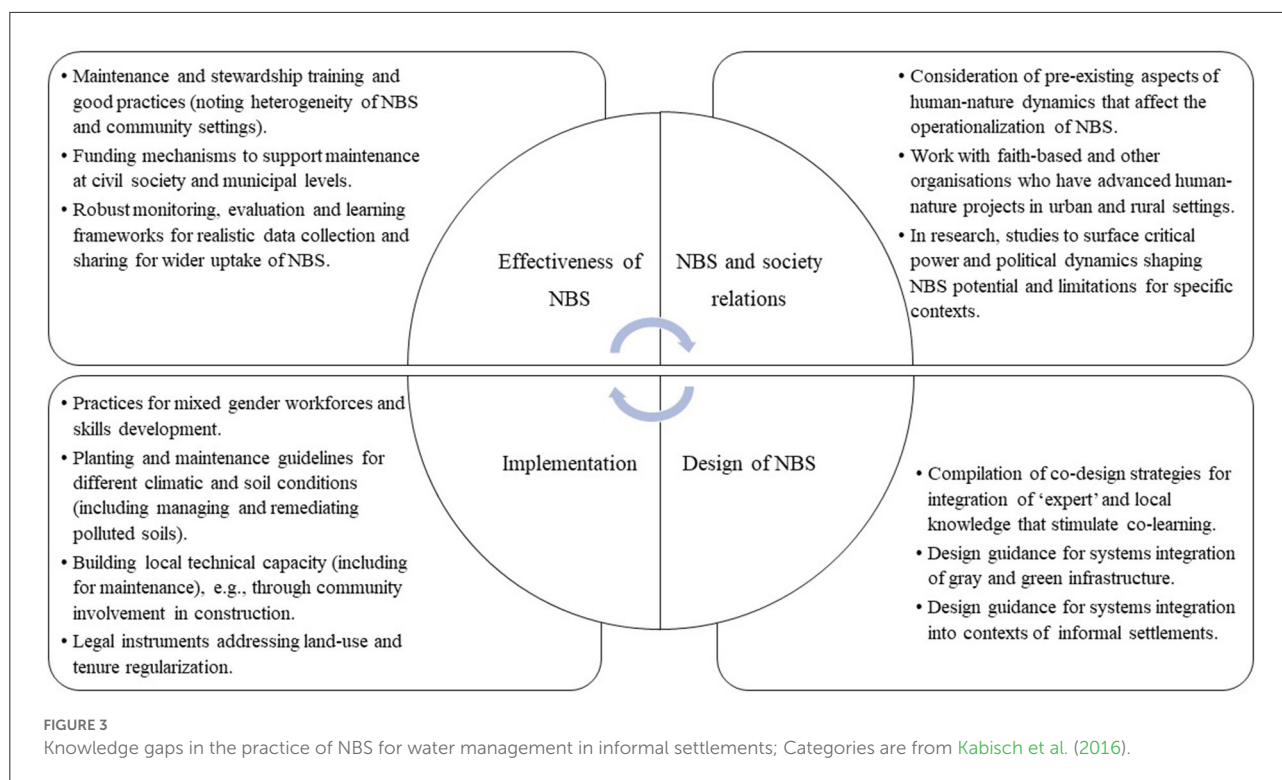
Conclusion

NBS have the potential to address multiple socio-environmental risks in East African cities but their practice is not well understood. Investment into NBS that respond to local needs and aspirations can help cities move away from governance lock-in mechanisms that do not include justice goals. This is particularly important for the context of urban informality which raises complex questions that are not

necessarily found in the “formal” city, particularly in relation to gaps in basic services and land tenure creating barriers to governmental actions. NBS niche experiments can be deployed to explore ways through which socio-technical transitions take place outside “entrapped” governance structures. Based on the results of this study, we therefore suggest that NBS niche experiments can support the development of new learnings, here in relation to new ways of creating partnerships and socio-material configurations. Explored in various study sites across Nairobi and Dar es Salaam, NBS initiatives for water management provide a range of insights into opportunities and challenges to the socio-spatial and ecological integration of NBS into complex urban contexts.

Two high-level lessons on NBS integration into the contexts of the cases studied in this paper can be highlighted. Firstly, evidence shows that the NBS projects have changed communities’ perceptions and valuation of urban nature to a point where they better trust the effectiveness of urban nature in providing multiple benefits. The cases show that intermediary organizations can play an important role of knowledge brokers in such engagement process to facilitate dialogue and ensure shared understanding among different groups. Focus Group Discussions with residents of several of the case study sites indicated that communities were generally unclear about what NBS entail before project implementation. Some explained being skeptical before projects were implemented, particularly in relation to their effectiveness in mitigating flood risks. Many community members stated having higher trust in gray infrastructure to address such risks. Still, many were curious about NBS and engaged with projects, often with the broad expectation that the ecology of their local environment would improve. Participatory processes supported the understanding of complex relationship between people and urban nature, notably to identify and navigate their “fear of the unknowns.”

Secondly, results show that co-production approaches that ensure early, consistent and deep forms of engagement at every step of project development supports trust in NBS through better understanding of the way their functions can be articulated. Co-design phases have enabled knowledge-sharing and multi-purpose designs for NBS strategies that are relevant to their context of implementation. The implementation phases of projects appear to have been even more valuable for residents in engaging with NBS practices and replicate learning elsewhere. Testimonials indicated an increased understanding of the way NBS can achieve multiple benefits with a relatively smaller capital investment as compared to typical gray infrastructure. During FGDs in Nairobi, several individuals indicated a positive relation to nature when they referred to NBS in religious and spiritual ways. These different elements are considered to reflect a higher trust in urban nature, not only in what it can achieve, but also how it integrates socio-spatially in their own environment and helps them meet short- and long-term needs and aspirations. Nevertheless, many of these results need to be carefully evaluated, including the way in which benefits are



assessed over the long-term. The maintenance of NBS projects is particularly challenging since communities often lack resources.

As participatory approaches can support inclusivity and decision-making, the way they are conducted throughout project development is crucial to involve communities since they play a fundamental role in the sustainability of projects. However, other governance mechanisms are required to ensure the effectiveness of NBS in providing ecologically sustainable and socially just outcomes in the longer term. These can be grouped into two further lessons. On the one hand, that systems of shared management responsibilities are required, notably with regard to maintenance. In the cases studied, communities mostly bear the burden of maintaining NBS. This reiterates well-known - but yet unaddressed - concerns related to equity and justice, and demonstrate the need for better involvement of duty bearers and state actors. On the other hand, the context of informal settlements where gaps in basic services continue to persist confirms that NBS cannot be implemented on their own and need to be completed with gray infrastructure to create hybrid gray-green systems. This is particularly important in the context of informal neighborhoods where density and hazards require immediate localized solutions. New projects should integrate pre-existing systems (both NBS or otherwise) developed and managed by local organizations. Intermediary organizations play a key role in this by bringing different forms of knowledge together in the making of niche experiments, which can eventually become advocacy tools for change.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

LD and JM led the study, co-designed the theoretical framing and data collection tools, conducted data analyses, and wrote and edited the manuscript. MO co-designed and delivered the FGDs in Kibera, translated and analyzed FGD results, produced the figures, and participated in the writing of the manuscript. LG co-designed and delivered the FGDs in Kibera, co-designed and delivered online surveys and analyzed survey results, conducted the literature review, and participated in the writing and editing of the manuscript. MR delivered the FGDs and KII in Dar es Salaam, analyzed FGD results, and participated in the writing of the manuscript. TN provided oversight and reviewed the manuscript. All authors contributed to the article and approved the submitted version.

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