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Nature-based Solutions for sustainable flood management in East Africa

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Abstract

Africa's population is expected to triple by 2050, owing to rapid urbanisation and overall demographic trends. The combined pressures of urbanisation and climate change impact the ecosystem and the services it provides. As a result, additional dangers such as increased flooding, and environmental disruption have risen. Therefore, devising adaptive solutions to mitigate flood risk impacts while also building community resilience is needed. Evidence suggests that Nature-based Solutions (NbS) can potentially alleviate floods and mitigate climate change impacts while also delivering other societal benefits. Despite rising NbS popularity following its recognition in the last decade, studies on its recognition in Africa remain limited. For this reason, this paper reviewed NbS studies conducted in East Africa (EA) to evaluate opportunities and barriers surrounding NbS adoption in EA. Academic literature published from January 2012 to May 2022 was reviewed using a comprehensive search of the SCOPUS database. Results show 14 papers have been published during the period, with the majority being post-2020. In addition, the majority of the articles focused on cities and peri-urban settlements, while public awareness, clear guidelines on performance monitoring, stakeholder inclusion, and diverse demonstration projects were highlighted as potential success factors for the adoption of NbS in EA.

KEYWORDS

East Africa, ecosystem services, flood risk, nature-based solutions, sustainable flood management, urbanisation

1 | INTRODUCTION

Growing evidence on the impacts of climate change and its links to natural disasters underlines the need for decision-makers to devise sustainable solutions to address the impacts, while building communities' resilience to adapt (Liu & Russo, 2021). Successful integration of flood management infrastructure into urban drainage is critical for developing resilient communities. However, the approach has traditionally focused on hard-engineered structural measures that aim to rapidly remove water from urban areas (Lashford et al., 2020).

Hard engineering often uses traditional piped drainage, whereas in rural, fluvially dominated areas, rivers have been straightened and dams added to provide flood management (Lashford et al., 2016).

The main objective of this paper was to identify the context in which Nature-based Solutions (NbS) are used in East Africa (EA), with the specific aims of (i) assessing the types of NbS adopted and location in, (ii) evaluating opportunities surrounding NbS adoption other than sustainable flood management and (iii) barriers and constraints impeding NbS adoption in EA. Many communities in EA depend on locally available natural resources for their livelihoods and well-being and NbS projects can help to support and sustain these communities while also addressing environmental challenges (Egoh et al., 2012). The academic literature published from January 2012 to May 2022, a decade following the recognition of NbS and growing interest in their potential in mitigating climate change impacts and flood risk was reviewed using a comprehensive academic literature search of the SCOPUS database. These aims will expand our understanding of the recognition and existing practises on NbS in a specific geographical region with a limited amount of research undertaken over the study period but also enable the identification of major research gaps and a way forward for a region that is in much need of representation. It is also notable to mention that EA is impacted by not only climate change but also a growing population thus, researching solutions for sustainable flood management is increasingly important.

This paper starts with a brief discussion on the paradigm shift in approaches to flood management, followed by the emergence of NbS, methodology, its adoption in EA and its specific benefits.

2 | PARADIGM SHIFT IN FLOOD MANAGEMENT AND THE EMERGENCE OF NbS IN AFRICA

Africa is urbanising at a rapid rate, with current projections suggesting that the population will triple by 2050, with the percentage of the population living in urban areas doubling during the same period (Lumbroso, 2020; UN-Habitat, 2020). The increase in drought due to climate change impacts added to the urban population growth will put more strain on existing water resources which will directly impact ecosystem services (ES) for example water supply, food, habitat, recreation, clean air and the tourism they provide (Kumar et al., 2020). Additionally, current climate change projections over some African catchments, especially those in EA, suggest the possibility of extreme rainfall events in the future (Endris et al., 2019). As a result, related risks, including increased flood risk and extended droughts, pose significant impacts on human well-being, health, economy, society and the environment (Kabisch et al., 2017). Such consequences are severe, and recovery is slow in low-income countries due to underlying issues such as poor housing, extreme poverty levels, inadequate stormwater and sewer drainage system (Douglas, 2018).

Devising adaptive and innovative solutions to mitigate flood risk impacts, while also building community resilience is therefore needed. Evidence suggests that NbS has the potential to reduce flood risk, and mitigate climate change impacts while also delivering other benefits such as biodiversity, sustainability and increased water and food security among others (Seddon et al., 2020). Unlike structural flood control measures, NbS is reported to be cost-effective, enables site-specific adoption and can be implemented in diverse environmental conditions and at different spatial scales (Kumar et al., 2020). Therefore, it is accessible and affordable for poor communities and builds resilience to future flood risk at the household/community level in developing East African countries.

While hard-engineered structures have played a vital role in alleviating risks from natural hazards, their design must evolve to account for the changing climate and the potential for more extreme events (Sayers et al., 2013). Thus, their continued use in the 21st century and beyond might be inadequate to protect society and the environment from the increasing impacts of climate change (Debele et al., 2019). Such engineered structures were traditionally built with the primary goal of protection from floods only and consequently offer little or no co-benefits, for example, to the ecosystem (Mercer et al., 2010). For example, river flood defences such as river straightening, channelisation and other modifications such as River Great Ouse & Flit in the UK, have wide-ranging environmental impacts, as they can modify river flow dynamics and damage associated floodplain ecosystems causing cumulative ecological consequences, a typical example of problem shifting rather than problem-solving (Beale et al., 2022; Gurnell & Grabowski, 2016). Additionally, flood defences and channelisation in urban promote rapid floodwater delivery downstream, causing flooding of the unprotected floodplain areas downstream, a typical example of problem-shifting rather than a problem-solving scenario (Rubinato et al., 2019). The environmental cost of damage caused to floodplain ecosystems has resulted in the recent shift to integrated river basin management measures. Kumar et al. (2020) argued that initial construction and maintenance of large-scale structural

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measures (e.g., embankments and dams) are costly, limiting their use in low-economic countries. It is for this reason that flood management strategies have shifted from reactive approaches to sustainable and integrated strategies.

Fletcher et al. (2015) discussed the evolution of urban drainage terminologies and highlighted the transition from hard engineering to more holistic approaches. They discussed and defined several key terms, including Sustainable Urban Drainage systems (SuDs) and Green Infrastructure (GI). The term SuDs was first used in the UK in the late 1980s and was defined as a series of management approaches that incorporated environmental and societal issues to manage runoff sustainably, preferably at the source, to offer multiple benefits including water quality improvements as well as water quantity reductions (Ashley et al., 2015). The application of SuDS for stormwater management was formally accepted in 2000 in the UK, with a practical document guiding its design first released in 2007 and updated in 2015 (CIRIA, 2017). The term Blue-Green Infrastructure (BGI) was first used in the United States and is defined as a linkage between blue (water) and green (vegetation) infrastructure, integrated to perform grey infrastructure functions, for example, water storage, treatment/purification, restoration of destroyed habitats among others (European Commission, 2019). The concept is thought to go beyond stormwater management, inspiring urban layout, and design, promoting the inclusion of green space hubs and corridors and acknowledging the benefits and contributions of such green spaces to the ecosystem (Fletcher et al., 2015). These holistic approaches such as SuDS and BGI are typical examples of NbS, an umbrella term for all integrated ecosystem approaches, overlooked by Fletcher et al. (2015). More recently, NbS has become a catch-all term globally to group sustainable approaches that tackle a series of 21st century challenges, which will be explored in the following section (Ramírez-Agudelo et al., 2020).

Policies such as Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) promoted advancement in policy frameworks for economically sustainable solutions to tackle climate change impacts (United Nations, 2015). Consequently, the shift in policy paradigm resulted in alternative approaches to managing the impacts of climate change, broadly captured as NbS (Cohen-Shacham et al., 2016; Nesshöver et al., 2017). The origin of NbS has been linked to indigenous knowledge and practises, including working with nature to mitigate flood risk and promoting biodiversity and ecosystem management. NbS are not new practises since they have been practised for millennia by local and indigenous people for different purposes before their first mention and/or recognition by the World Bank and International Union for Conservation of Nature (IUCN; Berkes et al., 2000). A good example is artificial terpen, mounds that slowly raise the low-lying grounds (terps singular form) created along the coastal regions of the Netherlands, Germany and Southern Denmark to provide safety during river flooding or storm surges, and were in use from 500 BC (Sayers et al., 2013).

The World Bank published its first report in 2008 on the potential and benefits of NbS for climate change mitigation and adaptation of the Bank's biodiversity protection efforts (World Bank, 2008). Due to the World Bank report, the International Union for Conservation of Nature (IUCN) integrated NbS principles into its 2013–2016 programme as a means of reducing the effects of climate change, ensuring sustainable energy, food production and guiding economic growth (Cohen-Shacham et al., 2016; UN-Water, 2018). Examples of NbS benefits include but are not limited to reducing flood risk (Samuels, 2022), building resilient and liveable cities, restoring and protecting important ecosystems, for example, coastal and mangrove habitats, mitigating climate change impacts and promoting long-term food security (Raymond et al., 2017). Evidence shows that NbS has been researched under different terminologies globally and the most used in Africa are GI, Urban Green Infrastructure/spaces (UGI), SUDs, and Forest Landscape Restoration (FLR) (Owusu et al., 2021; Tauhid & Zawani, 2018). Despite the successful demonstration of projects in Europe, Asia and the United States, the adoption and implementation of NbS in Africa remain limited (Debele et al., 2019; Douglas, 2017).

Although studies on the use of NbS for urban planning in Africa are increasing, most are focused on South Africa (Cilliers et al., 2012), Ethiopia and Tanzania (Herslund et al., 2018) and Sub-Saharan Africa (du Toit et al., 2018). Additionally, limited review papers have been published on the adoption of NbS in other African countries, such as those in East Africa. For example, Egoh et al. (2012) published the first paper on ES provision and its role in supporting African livelihoods. Even though the paper extensively focused on ES, sustainability, biodiversity and conservation, it links directly to NbS. Others, such as Cilliers et al. (2012) and Mensah (2014) published review papers concentrating on the adoption, challenges and management of GI and urban green spaces in African cities. Nassary et al. (2022) reviewed urban green infrastructure for climate change adaptation in global south cities, of which Tanzania and Kenya were included. However, none of the above has comprehensively detailed NbS studies conducted in East Africa.

TABLE 1 NbS demonstration projects across Europe and Asia.

Project title	Subject	Reference
Connecting nature	The commencement and growth of economic and societal initiatives and the broad application of NbS in urban areas	Connecting Nature (2019)
Transitioning towards urban resilience and sustainability (TURAS)	Providing examples of increasing urban resilience, including the creation of urban green walls that can be installed practically anywhere and at a minimal cost to local governments	Faivre et al. (2017)
Green infrastructure and urban biodiversity for sustainable urban development and green economy (GREEN SURGE)	Developing guiding principles on improving and integrating green/grey infrastructure, connectivity and inclusive approach in urban planning	Faivre et al. (2017)
Operation potential of ecosystem and research application (OPERA)	Exploring the benefits potential of combining NbS with the existing traditional solutions along the 9.3 miles coastline of Barcelona as a cost-efficient strategy for building resilience to climate change	IUCN (2020)
NATURVATION	Evaluating the accomplishments of the NbS in cities.	European Commission (2017)
Sponge cities	Promoting social cohesion, administrative merging, digital evolution, ecosystem sustainability and recuperation	Xia et al. (2017)

Abbreviation: NbS, nature-based solutions.

3 | METHODOLOGY

A systematic literature review (SLR) was conducted using the SCOPUS database to identify suitable publications as it has been used by other studies (Acreman et al., 2021; Ramírez-Agudelo et al., 2020). The SLR collects, and brings together published scientific knowledge that has gone through a rigorous peer review process under the keyword combination 'Green Infrastructure', 'Nature-Based Solutions', 'Urban Green Spaces', 'Sustainable Urban Drainage Systems', 'Forest Landscape Restoration', 'Ecosystem-Based Adaptation' and 'East Africa' for 'Flood Risk Management'. The search for peer-reviewed papers was conducted in May 2022. In terms of exclusion criteria, a delimited search period used only peer review articles from January 2012 to May 2022. Additionally, articles with an access fee, those written in a language other than English and those published outside East African administrative boundaries were excluded. Also, articles from the Democratic Republic of the Congo were excluded as it joined EA 2 months at the end of the search period.

The 10-year study period was significant for the following reasons. First, the timeframe followed the World Bank's (2008) recognition of the role of NbS in climate change mitigation and biodiversity conservation (World Bank, 2008), and the subsequent inclusion and adoption of NbS by the International Union for Conservation of Nature (IUCN) between 2013 and 2016 (Cohen-Shacham et al., 2016). Second, there was a distinct paradigm shift in policy frameworks including DRR and the Paris CCA that promoted the adoption of NbS for climate change mitigation (United Nations, 2015). Third, within the same period, more research and innovation funding was launched to finance and support programmes focusing on NbS, for example, Horizon 2020 (H2020), funded by the European Commission (EC) (European Commission, 2017). Furthermore, multiple successful demonstration projects were carried out across Europe, the United States and Asia. Examples of those projects include are but not limited to the list in Table 1.

Inclusion criteria selected articles from Kenya, Uganda, South Sudan, the United Republic of Tanzania, Rwanda and Burundi, explicitly presenting NbS for flood risk management and water management. The initial search generated 2032 peer-reviewed papers, of which only 34 papers focused on East African countries, as shown in Figure 1. The excluded papers were outside of East Africa administrative boundaries and considered out of scope, as they did not mention NbS or other search words implementation, and water management issues in

FIGURE 1 East African countries (highlighted in blue) with the newly joined Democratic Republic of the Congo (DRC). African boundaries outline source: OpenAfrica website available via https://open.africa/dataset/africa-shapefiles.

the process. Literature was screened for its suitability, based on the title, abstract and focus of the paper, thus, 14 out of the initial 34 papers met the inclusion criteria for this study. Results are discussed in the following section.

4 | NBS IN EAST AFRICA

This section describes past NbS projects in EA and the literature search findings in more detail, presenting possible opportunities for implementing NbS and barriers impeding its wider implementation in EA. Figure 2 shows the number of papers on NbS in East Africa with most research focussing on Kenya, followed by Tanzania, one of the fastest-growing countries in sub–Saharan Africa (Kalantari et al., 2018). It is of note that Uganda, with the highest annual urbanisation rate of 5.1% in the world (Mukwaya et al., 2010), only had one published paper on NbS during the search period.

Furthermore, 14 papers were published during the period, the majority being post-2020. In addition, the articles focused on urban cities and peri-urban settlements (Thorn, Hejnowicz, et al., 2021). This leaves informal

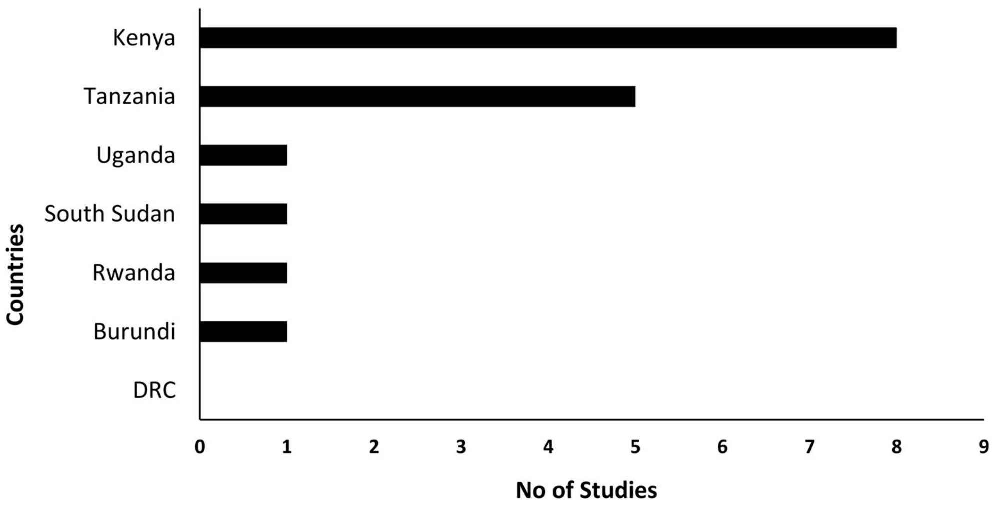

FIGURE 2 NbS studies distribution over East African countries organised in descending order. Kenya leads with eight studies, followed by Tanzania. NbS, nature-based solutions.

TABLE 2 Distribution of NbS studies in East Africa from January 2012 to May 2022.

East Africa countries	Reference	Terminology used
Kenya	Agol et al. (2021), Kilonzi and Ota (2019), Kiplagat et al. (2022), McCartney et al. (2019), Mulligan et al. (2020), Nassary et al. (2022), Quandt (2020), Tauhid and Zawani (2018)	Urban green space, GI, EbA, NI, ES, Agroforestry
Uganda	Xueqin Lia et al. (2022)	GI
Tanzania	Kalantari et al. (2018), Nassary et al. (2022), Owusu et al. (2021), Thorn, Biancardi Aleu, et al. (2021), Xueqin Lia et al. (2022)	NbS, GI, FLR
South Sudan	Xueqin Lia et al. (2022)	GI
Rwanda	Cohen-Shacham et al. (2016)	FLR
Burundi	Ndayizeye et al. (2020)	ES

Abbreviations: ES, ecosystem services; FLR, forest landscape restoration; GI, green infrastructure; NbS, nature-based solutions; NI, natural infrastructure.

settlements and rural areas under-researched, although statistics show 80% of the East African population resides in rural areas (Kalantari et al., 2018), while 70% of the population in Tanzania inhabit informal settlements (Owusu et al., 2021). Furthermore, apart from the three studies that adopted the term NbS, other studies used different terminology, with GI and FLR being the most popular Table 2.

Similarly, natural infrastructure (NI) defined as the same as GI has been used to refer to NbS types such as wetlands, forests and grassland (McCartney et al., 2019). A detailed definition of terminologies used is given in Table 3. Integrated ecosystem approaches aimed at restoring degraded ecosystems, such as ecosystem-based adaptation (EbA) have been utilised too. EbA is defined as the utilisation of biodiversity and ES to assist society to adapt to climate change impact (Convention of Biological Diversity, 2010).

4.1 | Opportunities

Aside from the general benefits outlined by Ashley et al. (2015) regarding water quantity, quality, amenity and biodiversity, there are specific opportunities for implementing NbS in EA. Implementation of NbS at any spatial scale has the potential to alleviate flood risk, encourage water reuse, promote food security and build community resilience among other possibilities in EA.

4.1.1 | Encouraging water reuse and promoting food security

A rising population in African countries increases water demand (Falkenmark, 1990). This in turn leads to water stress and scarcity, compounded by a changing climate which creates problems in many African countries (Chitonge, 2020; Douglas, 2018). However, Cohen-Shacham et al. (2016) showed that NbS can potentially augment water supply, which could be beneficial in water-scarce countries since many NbS can retain water either above or below the surface, and therefore less water is lost through runoff (Zölch et al., 2017). For

TABLE 3 Definition of the terminologies and acronyms used in Table 2.

Approach (acronym)	Definition	Reference
Forest landscape restoration (FLR)	Actions aimed at restoring deforested or degraded forested areas thus renewing their ecological integrity and boosting human well-being.	Mansourian and Vallauri (2013)
Ecosystem-based adaptations (EbA)	The utilisation of biodiversity and ES is part of a broader adaptation plan to assist society to adapt to climate change impacts.	CBD (Convention of Biological Diversity) (2010)
Natural or green infrastructure (NI/GI)	Green in this context refers to vegetation. Interconnected natural, blue, and green infrastructure designed and sometimes integrated with grey infrastructure to perform diverse functions such as but not limited to water storage, purification, aesthetic, recreation, air quality and so forth.	European Commission (2019)
Ecosystem services (ES)	Direct and indirect benefits human beings obtain from ecosystems e.g., food, fibre, water, climate regulation, flood control, recreation and so forth.	Birkhofer et al. (2015)
NbS	A collection of integrated ecosystem-associated approaches inspired by and copied from nature, which must sustainably minimise flood risk and impacts while offering other societal benefits	Cohen-Shacham et al. (2016)
Agroforestry	Various approaches aim at conserving healthy soil through sustainable agriculture, for example, mixed farming, and planting trees between crops.	Torralba et al. (2016)

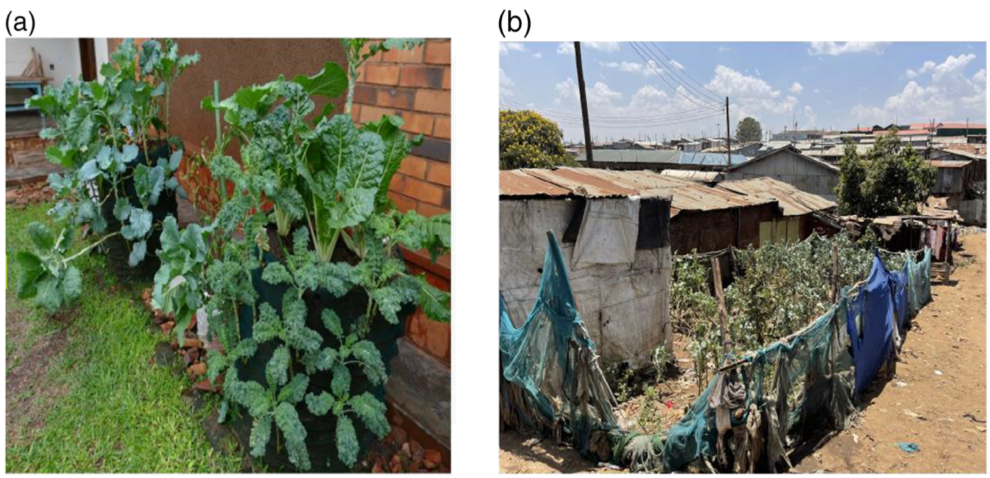

FIGURE 3 (a) Shows how sack gardens are used in urban areas in Uganda to grow vegetables for households *Source*: orocha.org. (b) Shows a kitchen garden utilised in Kibera informal settlement to grow vegetables. *Source*: Author February 2022.

instance, increasing the use of rainwater harvesting during the rainy season can ease water supply difficulties, thus saving water costs during this period (Mati et al., 2006). According to Mati et al. (2006), Dar es Salaam in Tanzania has the potential for harvesting approximately 5,000,000 m^3 of rainwater annually from buildings, which can address some of the UN Sustainable Development Goals (SDGs) specifically SDG 6, to ensure the availability and sustainable management of clean water and sanitation, and also the Sendai framework for disaster risk reduction (2015). Reusing greywater from households for watering sacks and kitchen gardens promotes the recycling of water traditionally disposed of on footpaths and in ditches, creating pools of standing water around households (Charlesworth, 2017; Mulligan et al., 2020). Sack farming involves filling a bag with soil and manure before planting vegetables both on top and on the sides; this is particularly important in areas where water is scarce, and/or there is limited access to arable land (Figure 3). According to Simon (2013), most open spaces in African cities are for urban agriculture, which contributes approximately half of the food consumed in cities such as Dar es Salaam in Tanzania and Kampala in Uganda. Similarly, tree planting, if there are locally available trees, can supplement food security alongside other benefits such as carbon sequestration, climate change adaptation and flood reduction (Owusu et al., 2021). Strategies such as these tackle the UN's 2030 global agenda to end poverty in all forms, achieve zero hunger by addressing food security, mitigate climate change and promote the Paris CCA.

Furthermore, collecting and storing runoff through approaches such as constructed wetlands is reported to support and promote rain-fed agriculture, which may benefit countries such as Rwanda, where 90% of agricultural activities are rain-fed (Billman, 2014). This provides a particular opportunity in areas where a conventional drainage system is absent, for example, informal settlements and refugee camps (Mulligan et al., 2020). Moreover, reducing standing water through NbS has wider benefits in terms of reducing water-borne disease and improving human and environmental health (van den Bosch & Ode Sang, 2017). As mentioned by (Mulligan et al., 2016) and (Earl et al., 2018), encouraging standing water can increase the presence of disease vectors, for example, mosquitoes, and therefore the spread of malaria.

4.1.2 | Building community resilience

Successful NbS projects require a holistic and multi-sectoral approach to fully optimise their impact, and to address social challenges at the required scale (Faivre et al., 2017). Scientists, practitioners, the public, indigenous people and private sectors should be engaged to develop diverse knowledge that is useful in the planning and implementation of NbS (Cohen-Shacham et al., 2016). Past literature suggests that projects with participatory approaches that foster stakeholder inclusion (i.e., their views and values) in decision-making are more likely to succeed, because of fair representation and outcomes (Zafra-Calvo et al., 2020). Not only is such engagement morally and ethically right, but it helps to prevent negative intervention effects for Indigenous People and Local Communities (IPLCs), and it underpins the effectiveness of NbS for multiple reasons, including the sharing of ecological knowledge about their local environment and its management and recovery (Mercer et al., 2010). Thus, it recognises both local and experimental knowledge, ideas, interests and values through consultation, participatory approaches, NbS training, bottom-up initiatives, adaptive governance/management, co-creation, co-design and so forth (Cohen-Shacham et al., 2019).

Furthermore, NbS can be integrated into the community or informal settlements, as part of upgrade initiatives as showcased by Thorn, Hejnowicz, et al. (2021). For example, the integration of GI into existing traditional practises has encouraged an appreciation of small-scale GI ownership in the Kibera informal settlement, in Kenya (Mulligan et al., 2020). Another example is the successful use of detention ponds to alleviate urban runoff in Dar es Salaam's Metropolitan Project (Mguni et al., 2016), and the flood mitigation plans by 20 non-governmental organisations to fit drains in informal settlements in Kampala (Tukahirwa et al., 2010). All these upgrade projects not only help to build community resilience to the existing problems such as flooding but also provide communities with more effective ways of managing runoff which can encourage community cohesion.

4.2 | Barriers and challenges limiting the adoption of NbS in EA

While the benefits and opportunities presented by integrating NbS in EA are evident, the implementation of such measures remains limited. Based on the reviewed literature, this section discusses the challenges impeding widespread adoption and implementation of NbS in EA.

4.2.1 | Lack of understanding of performance, design and standards

There is an overall lack of understanding regarding the performance and requirements of NbS in EA, primarily as a result of little understanding among stakeholders, such as political decision-makers. This is underpinned by the limited availability of monitored data regarding the performance of different approaches, with few published best practise case studies in the region, (Table 2; Debele et al., 2019). However, when data are available, decision-makers often have inadequate technical ability, training, or experience of the approach, due to the limited implementation of NbS, to apply such methods (Zuniga-Teran, de Vito, et al., 2020; Zuniga-Teran, Staddon, et al., 2020). A lack of awareness among policymakers (e.g., at the municipality level) can impede the progression and adoption of NbS, by prioritising more conventional methods of water management (Sarabi et al., 2020).

Current NbS policies, frameworks and existing knowledge gaps on NbS design hinder its transformation into practise (Cohen-Shacham et al., 2019; Lechner et al., 2020). For example, several studies have outlined the role of NbS in managing natural hazards (e.g., flooding, climate change impacts; Faivre et al., 2017) as well as the importance of a multi-stakeholder and inclusive approach relevant to the specific natural hazard (Kabisch et al., 2016; Raymond et al., 2017). However, the knowledge-base about NbS has largely been academic in nature, with limited information and proof about its functionality and advantages (Nesshöver et al., 2017). The main advantage of NbS over traditional solutions is its multi-functionality, cost-effectiveness, long-term sustainability and adaptability and climate resilience (Kabisch et al., 2017). Yet there is insufficient evidence to demonstrate the linkage between NbS types and co-benefits in the diverse tropical climatic conditions exhibited in EA, thus hindering the uptake of the NbS (Charlesworth & Mezue, 2016).

4.2.2 | Limited public awareness and maintenance

Adoption of NbS requires regular maintenance to maximise its benefits (Seddon et al., 2020). For instance, wetlands, which, if not properly monitored and managed, can serve as a breeding ground for mosquitos that transmit malaria in tropical countries, posing a health risk to communities (Horwitz & Finlayson, 2011). Additionally, poor lasting maintenance is a barrier in peri-urban areas, as there is no clear single stakeholder responsible for managing NbS (Douglas, 2018; Mulligan et al., 2020). Furthermore, regular maintenance of the existing conventional drainage system in EA cities is a challenge, due to unregulated solid waste dumping, obstructions and unkempt vegetation, thus, some fear integrating NbS can compound existing pressures on the drainage network (Opeyemi et al., 2016).

As discussed in Section 4.2.1, creating awareness among the general public is equally important. Lack of public awareness, understanding and negative community perception, typically inhibit NbS uptake (Wamsler et al., 2020). In addition, cultural constraints, which dictate community preferences and expectations in Africa, have been reported (Lechner et al., 2020). For example, planting trees and forest management in some communities is a cultural practise passed down through the generations (Naima & Richard, 2016). This was further supported by Owusu et al. (2021) who reported an inverse relationship between non-incentive and communities/individual household's interest in participating in FRL projects in Tanzania. Monetary incentives are the income generated from selling tree products, such as timber, whereas non-monetary incentives are derived from perceived benefits such as a source of food, medication, sacred/worship areas and ecology. The same situation occurred regarding forest management in Cameroon, where non-monetary incentives triggered community participation (Nuesiri, 2015).

4.2.3 | Space constraints and land/property ownership problems

A few reports identified land ownership as a legal impediment to NbS adoption (Samuels, 2022; Sarabi et al., 2020). For instance, private real estate landowners would prioritise profitability over sustainability goals (Dhakal & Chevalier, 2016). For challenging environments such as refugee camps and informal settlements, reports show space (i.e., land ownership, space constraints) limitation dictates what NbS solutions can be implemented in such areas (O'Donnell et al., 2020). A good example is Kibera informal settlement in Nairobi, where the Kenyan Government owns the land (Meredith & MacDonald, 2017). Residents live in shacks rented to them by the shack owner, who controls activities in and around the shacks, thus limiting the adoption of NbS at a household level (Mulligan et al., 2020). Therefore, small-scale NbS demonstration projects in the refugee camps and informal settlements, to learn how to negotiate the inherent restrictions of space, contentious land tenure and local maintenance are needed.

5 | SUMMARY AND KEY RECOMMENDATIONS

This article has provided a literature analysis on NbS studies undertaken in EA, underlining NbS benefits in alleviating flood risk, boosting food security, promoting ecosystem regeneration, amenity, greywater management and biodiversity functions. NbS has the potential to augment water supply, promote urban agriculture and enable inclusive decision-making and flexibility to be integrated into the planned or ongoing upgrade plans in East African cities. Despite the mentioned benefits, the choice of the type of NbS to be adopted is site-specific, which necessitates consideration of both local/scientific knowledge, socio-cultural factors, technical requirements, environment practicality and political context. This paper also showcased and addressed the potential of NbS to achieve global agenda, for example, UN 2030 SDGs on ending poverty in all forms, achieving zero hunger, climate change mitigation and increasing access to clean water and sanitation, and the Paris CCA. Furthermore, the paper also enabled a review of the existing practises on NbS in the region, thus providing a series of future research themes that are necessary to provide sustainable flood management in a region that will be impacted not just by climate change, but by an increasing population. Based on the reviewed papers, this study has identified that there is inadequate evidence of NbS projects in challenging environments, for example, informal settlements and refugee camps in East African countries. As a result, the following recommendations have been made:

i. As indicated by Samuels (2022) on further local studies on NbS, a need for pilot/demonstration projects in informal settlements and refugee camps, which are monitored pre-and post-implementation of NbS, to better understand its potential for alleviating flood risk in these challenging environments.

ii. The review reaffirms the scarcity of peer-reviewed papers between 2012 and 2022 in East Africa, which is consistent with the findings of du Toit et al. (2018). The 14 presented papers were geographically and thematically biassed, with a concentration on peri-urban and urban areas. The underrepresentation of rural areas might be attributed to insufficient motivation, support, finance or interest to do this in a region that allegedly requires it more than others.

iii. Clear guidelines are vital for successfully meeting or responding to area-specific challenges (Zuniga-Teran, de Vito, et al., 2020; Zuniga-Teran, Staddon, et al., 2020). Similarly, recognising and appreciating local conditions is also critical in developing, monitoring and evaluating frameworks, currently lacking in the NbS context (Faivre et al., 2017). This will be useful in minimising trade-offs between goals and the measures required to achieve them, enabling synergies to be realised. Additionally, this will ease a better understanding of NbS and promote engagement across local communities, researchers and policymakers.

iv. While NbS has been described as an umbrella for diverse ecosystem approaches, GI and FLR are the most popular used terminologies. Future research should focus on a holistic review of the numerous terminologies being used or adopted for different purposes across all spatial scales that fall within the NbS umbrella.

v. Engaging local communities in the design, development and delivery phases of the project is a critical component of any NbS development process as suggested by Kabisch et al. (2016).

vi. There is a need for explicit guidelines on the management and maintenance of NbS projects. In the case of informal settlements and refugee camps, local communities should be given that responsibility, thus, promoting ownership and acceptance in these areas.

vii. There is a need to recognise, document and reframe existing NbS practises and policies to promote NbS in EA. For example, the Kenyan policy of cutting one plant two trees as NbS because its execution fulfils NbS contribution to flood risk mitigation and climate change adaptation.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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