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Making a case for nature-based solutions for a sustainable built environment in Africa

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Abstract

The potential of using nature-based solutions to address issues of climate change has continued to gain momentum, especially in developed nations. However, the same cannot be said for developing countries, particularly in Africa, where the knowledge and awareness of natural solutions are low, and research on their application within the built environment is scant. Using a sciento-metric and narrative review of published literature, this paper makes a case for research exploration on nature-based solutions for a sustainable built environment in Africa. The findings revealed an opportunity for significant research contributions on nature-based solutions in addressing flood risk management, climate change and urban planning, water quality and carbon emission, sustainable development, and green infrastructure and urban development. These areas are the critical focus of past studies explored. Also, the findings offer guidance for further studies to be conducted in less explored areas, such as carbon sequestration, greenhouse gases, energy utilisation, indoor comfort, and numeric models for using nature-based solutions within the African context. The findings of the study offer an excellent theoretical background to direct researchers and practitioners who seek to attain and promote sustainable built environments through nature-based solutions, especially in Africa.

KEYWORDS
built environment, climate change, disaster management, flood risk, nature-based solutions, sustainable development

1 | INTRODUCTION

Similar to other continents, Africa is faced with the adverse effects of rapid changes in climatic conditions. Increasing cases of natural disasters attributed to climate change are being recorded within the continent, with approximately 4% of the population of the continent being severely affected by droughts and floods between 2021 and 2022. This situation places an encumbrance on people's livelihoods and, by extension, their survival (Global Centre on Adaptation, 2022). Further observation shows that the major disasters on the continent, between 1970 and 2019, were droughts and floods experienced in countries such as Algeria, Chad, Ethiopia, Mozambique, Sierra Leone, Somalia and Sudan (Statista, 2023). In 2022, Sguazzin (2022) submitted that approximately 15 million people lost their homes because of disasters related to weather, with Nigeria, Burkina Faso, Ethiopia, Somalia and Sudan being the worst affected countries. However, signs of other forms of disasters are imminent. For instance, in March 2023, the United Nations Children's Fund (UNICEF) reported that millions of

children were at risk with the increase in cholera cases in Malawi and Mozambique following the occurrence of Tropical Cyclone Freddy (UNICEF, 2023). In June 2023, South Africa experienced an earth tremor that shocked many residents in the Gauteng Province. In the same month, severe flooding was experienced in KwaZulu-Natal Province that led to the loss of lives and properties (Davies, 2023; Reuters, 2023). Also, early in September 2023, Morrocco witnessed a massive earthquake, which left thousands of people dead (Alsaafin, 2023). These occurrences emphasise the need for strategies to help to reduce the impact of adverse natural disasters and create effective adaptation in this era of climate change. Moreover, practitioners in the built environment who play a major role in the provision of infrastructure, have the responsibility to ensure the delivery of resilient and sustainable structures that can withstand the impact of these adverse effects of climate change. One such strategy that has proven to be effective and efficient in addressing these current climatic and biodiversity crises is nature-based solutions (NbS).

NbS, as described by the World Bank, encompasses a spectrum of actions that are centred on protecting, managing sustainably, and restoring natural ecosystems (World Bank, 2022). This comprehensive approach is designed to address a multitude of pressing challenges that societies face today, including, but not limited to, impacts of climate change, the enhancement of human health and well-being, ensuring food and water security, and effectively reducing the risks associated with disasters. Bona et al. (2023) noted that NbS can be crucial in sectors, such as water management, forestry, agriculture, urban areas and coastal areas. As such, the built environment and its allied profession, which are crucial to the development of urban areas, have the opportunity to deliver sustainable and resilient projects through implementing NbS. According to Pearlmutter et al. (2020), NbS can be introduced into built environment projects by using green building materials, systems, practices and sites. Momentous benefits lie in the use of natural solutions within the built environment, including the attainment of the United Nations (UN) sustainable development goals (SDGs), especially SDGs 11 and 13, directed at attaining sustainable cities and communities, as well as contributing to climate action (European Commission, 2021). Through the incorporation of NbS, there is an opportunity in the built environment to enhance the appreciation of recreation and aesthetics, encourage healthy and high-quality lifestyles, increase the value of land and properties through green features, and improve comfort (Bona et al., 2023). Bridges et al. (2021) also noted that policy-makers, practitioners and the public in most developed countries are increasingly recognising the efficacy of the NbS concept in achieving the twin engineering objectives of sustainable development of the built environment and protection of the natural environment.

Albeit the benefits of NbS mentioned above, there is little evidence to support the utilisation of nature-driven concepts and solutions in delivering built environment projects, particularly in Africa, where disasters that can be addressed through NbS are becoming prominent. Diep et al. (2022) noted that, while NbS continues to gain recognition globally, evidence of its implementation within communities in Africa is low. Similarly, Dupar et al. (2023) submitted that NbS is only gradually gaining recognition among African leaders. The research attention given to the application of NbS for a sustainable built environment on the continent is slow-paced, considering the current adverse impact of climate change on countries within the continent. The few available NbS-related studies emanating from the continent have been piece-meal and have placed emphasis on diverse issues regarding climate change. For instance, Lokidor et al. (2023) explored NbS from the perspective of sustainable flood management in East Africa and noted that, despite the increased attention attracted to this natural solution in the last decade, studies from Africa have remained limited. In the paper referred to, emphasis was placed on NbS for flood risk management studies conducted in East Africa and some success factors required for the effective use of NbS in managing flood risk in the region were identified. Earlier, Kalantari et al. (2018) explored NbS in combating flood-drought risk in urban areas in East Africa. Again, in relation to flood risk management, Enu et al. (2023) reviewed the potential of NbS to mitigate flood risk in Sub-Saharan Africa and concluded that the use of NbS within the region in addressing flood risk was low. Also, Acreman et al. (2021) explored the effectiveness of NbS in solving Africa's water problems and observed that, while local knowledge is needed, policy and planning for NbS are crucial to solving water-related risks in Africa. From the perspective of urban green spaces, Giombini and Thorn (2022) explored the opportunities for the use of NbS in the capital city of Namibia in South-Western Africa, while Thorn et al. (2021) explored the use of NbS for climate-resilient infrastructure in peri-urban, Sub-Saharan Africa. From a people's perspective, Diep et al. (2022) explored the views of individuals regarding NbS used in informal settlements in East Africa with a focus on projects across Nairobi and Dar es Salaam. It was concluded that there is a need for key participants involved in NbS projects to support the replication, scaling up and institutionalisation of NbS. Nykia and Dinka (2022) conducted a biblio-metric analysis of NbS studies within the African continent that were published and indexed in Web of Science. Based on the study, it was concluded that there is a need to overhaul institutions and policies, while financial assistance should be provided for more research about NbS to be undertaken by African researchers to supplement the studies already conducted in developed countries.

One consistent observation within the studies mentioned above is the need for more studies about NbS within the African continent. Moreover, it can be observed that the existing studies have been focused on using NbS to solve specific issues such as flood risk and water management, urban spaces, and informal settlements, among others. It has become necessary to view NbS studies from a wider perspective to identify crucial, unexplored areas and to set the direction for more NbS studies within the African continent. Moreover, in the wake of the realisation in diverse countries globally that nature offers solutions to age-long problems of mankind, and that using nature-inspired initiatives would lead to more sustainable benefits, it is timely to make a case for NbS for a sustainable built environment as a way of mitigating the effects of adverse climatic changes on construction infrastructure within the African continent. To this end, NbS studies were analysed in this study, using a sciento-metric approach, to determine scholarly connections, performance and trends within these studies. Furthermore, in this study, through network

visualisation and a narrative review, a future direction is delineated for NbS research within the built environment in African countries and other developing countries where such studies are deficient. It was believed that the outcomes of the study would create a clear line of focus for forward-looking research in the deployment of NbS to enhance built environment projects undertaken within developing nations, particularly in Africa. Moreover, the findings could serve as an excellent platform for wider debate and directing future NbS studies in the built environment.

2 | OVERVIEW OF NATURE-BASED SOLUTIONS

Since NbS gained prominence at the beginning of the 21st century, several definitions and descriptions of the concept have been proposed. NbS was defined by the United Nations Environment Assembly (UNEA, 2020) as encompassing actions that address social, economic and environmental challenges effectively and adaptively while, simultaneously, protecting, conserving, restoring and sustainably managing natural or modified terrestrial, freshwater, coastal and marine ecosystems. These actions provide benefits for human well-being, ecosystem services, resilience and biodiversity (UNEA, 2020). The International Union for Conservation of Nature (IUCN, 2020) described NbS as an innovative approach towards conserving nature while protecting, managing and restoring the environment and, in the process, delivering benefits that are tangible and sustainable for the people. The Federal Emergency Management Agency (FEMA) characterised NbS as sustainable planning, design, environmental management and engineering practices that integrate natural features or processes into the built environment to foster adaptation and resilience (FEMA, 2021). According to Kalantari et al. (2018), NbS is notable for its adaptive nature, enabling its use to be of benefit to both human welfare and biodiversity conservation simultaneously. NbS also embodies the fusion of human innovation with the inherent resilience and functions of ecosystems. According to this philosophy, it is recognised that ecosystems, from forests and wetlands to coastal areas and urban green spaces, provide services that are crucial for sustaining life on earth (Goodwin et al., 2023). From purifying air and water to regulating climate and supporting pollinators, these services underscore the vital link between humanity and the natural world (Kalantari et al., 2018). By leveraging these attributes of ecosystems, NbS exemplify an approach that harmonises human needs with ecological imperatives.

According to Pereira et al. (2023), NbS can be understood as strategies that harmonise human development and environmental conservation through the strategic integration of nature. These strategies encompass diverse practices, from enhancing natural infrastructure, such as wetlands and forests, to integrating green spaces within urban environments. Van Rees et al. (2023) added that the essence of NbS lies in recognising that nature is not merely a resource to be exploited, but a foundation upon which sustainable and resilient societies can be built. By working with, rather than against, nature, these solutions engender long-term benefits for both people and the ecosystems that support them. Also, different examples and applications of NbS have been noted in past studies. These include: marshes, dunes and reefs that protect coastal property and infrastructure against storms and chronic erosion (Jordan & Fröhle, 2022); forests and wetlands that store floodwaters, provide wildlife habitat and filter water for downstream communities (Hovis et al., 2021); and natural spaces that improve water and air quality, reduce urban heat, store carbon and provide health benefits in urban environments (Hayes et al., 2022). NbS also enhance the resilience of built and natural systems in a changing environment (e.g., increasing weather and climate extremes). Unlike conventional "grey" infrastructure that is static in the environment and designed to optimise a narrow set of functions and conditions (Sun et al., 2020), natural infrastructure systems can recover from extreme events, self-adjust to on-going environmental changes and continuously deliver a wide range of social and economic benefits (Jordan & Fröhle, 2022). Evidence also indicates that NbS can be equally as cost-effective as conventional approaches, or more so, particularly considering the life-cycle costs of projects (Lafortezza et al., 2018).

3 | METHODOLOGY

An interpretivist philosophical stance was adopted for the study, using a sciento-metric and narrative review of existing studies, with the unit of analysis being each publication. This approach is inductive and rooted in the grounded theory strategy and longitudinal time horizon. The paucity of works on NbS within the built environment, particularly in the African context, necessitated this approach, which has gained considerable interest in other aspects of built-environment research. From an operational perspective, Figure 1 illustrates the specific details of the sciento-metric review conducted. The sciento-metric review (a branch of biblio-metrics) is a quantitative approach to text-mining scientific publications. It is a computer-assisted approach to reviewing the available body of knowledge to examine core research or authors and their relationship within a given research field (De Bellis, 2009). Also, a sciento-metric review provides a visual perspective of the structural and dynamic aspects of existing scientific research contained within a body of knowledge (Olawumi & Chan, 2018). Sciento-metric review offers the opportunity to identify leading contributors (authors, countries, funding bodies, sources) through performance analysis, to examine impactful contributions (citations, co-authorships, bibliographic coupling) and their areas of focus and trends through scientific mapping and network visualisations (Donthu et al., 2021). Furthermore, this approach enables researchers to identify systematic, literature-related discoveries that might be overlooked in manual review studies (Zhong et al., 2019). Thus, a sciento-metric review was adopted to understand the concept of NbS further from the perspective of past studies and create a clear direction for future studies within the built environment. Based on the sciento-metric analysis conducted, a narrative review was further considered to be necessary to highlight the core discussions from the identified NbS studies that were extracted. The narrative review entailed summarising different primary studies and drawing

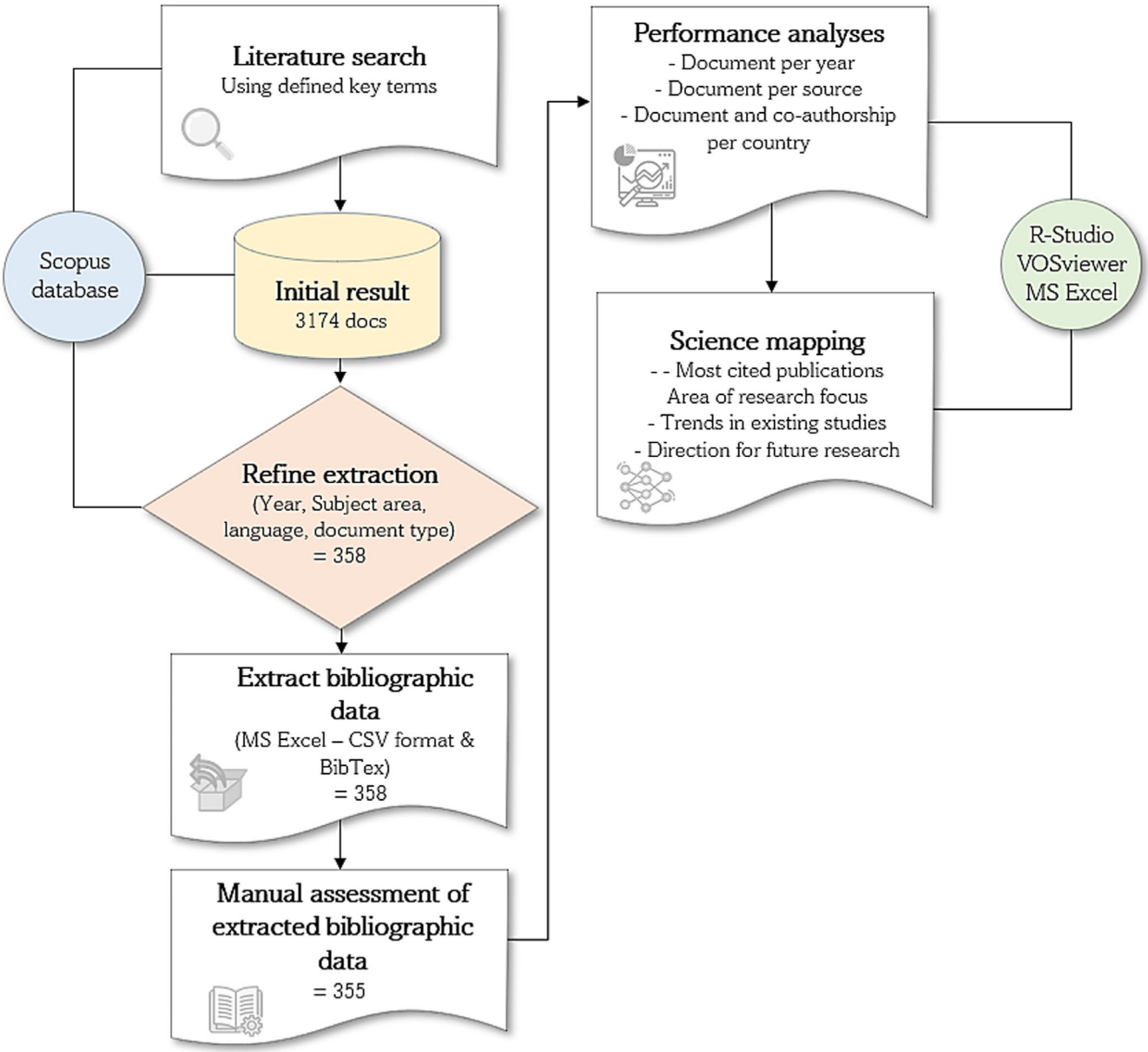

FIGURE 1 Outline of the research framework.

conclusions from a holistic viewpoint. These conclusions were shaped mostly by the experience of the researcher and the existing theories (Dinther et al., 2011).

In conducting the review, the database for bibliographic data extraction and the ideal key terms for data search were first determined. The Scopus database was selected because it has attracted significant attention among researchers in the field of science. Moreover, the database overlaps considerably with other databases, such as Web of Science (Aghimien et al., 2020; Guz & Rushchitsky, 2009). Also, selecting the optimal search terms is crucial to the reliability of the outcomes of sciento-metric reviews (Chen & Xiao, 2016). As a result, three common ways of writing "NbS" in the studies reviewed in the preliminary investigation were used to search titles, abstracts and keywords, using two major Boolean operators ("OR" and "AND"). The search protocol used to gather bibliographic data included: Title-Abstract-Keywords: "Nature-based solutions" OR "Nature-base solutions" OR "Nature base solution" published in the last 10 years (i.e., 2013 to 2023). The selected 10-year period was based on the need for recency in the extracted data. This initial search revealed 3174 documents across diverse fields of study. The next step was to refine the search to gather documents that were related to the built environment. In doing this, the subject area was limited to Engineering to gather documents that were more specific to the built environment, while the document type was restricted to journals and conferences. These two document types were selected based on past submissions that they both have higher rigour in their review process (Aghimien et al., 2020; Zheng et al., 2016). The language of publication was also set to English, as this is the preferred language of most journals. Based on these refined parameters, 358 documents were found, and their bibliographic data were downloaded onto a comma-

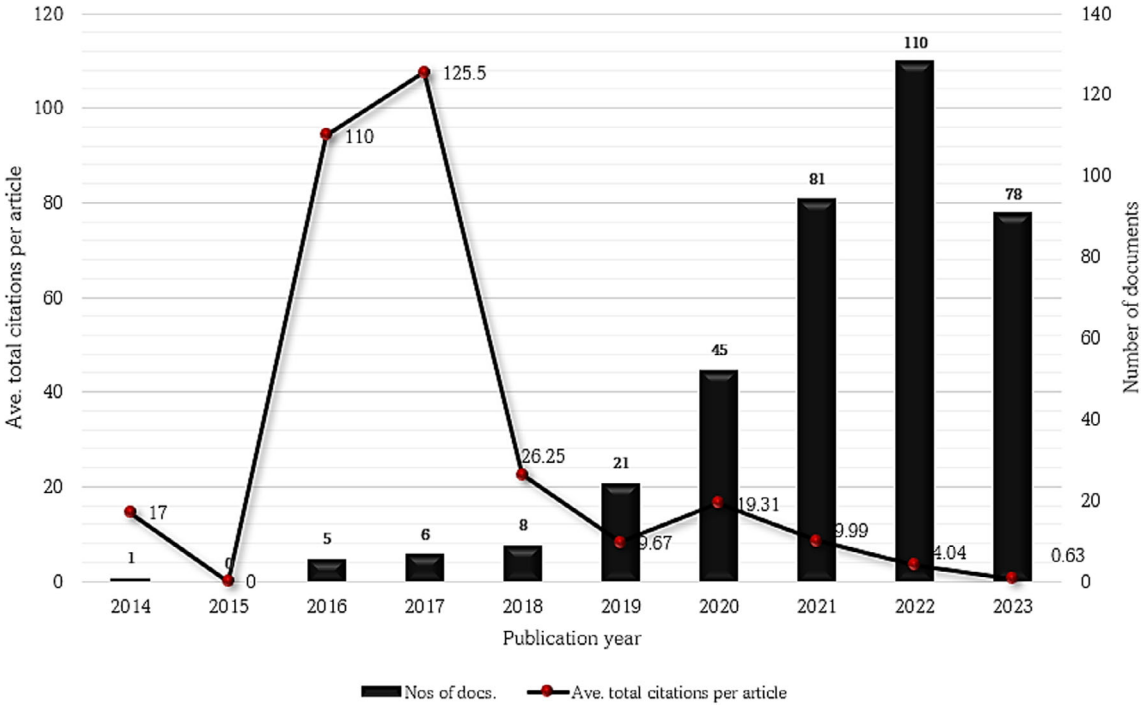

FIGURE 2 Publication per year.

separated values (CSV) file and a Bibtex format for further review. The downloaded CSV file was cleaned manually to ensure no overlaps or missing information before proceeding with the data analyses. This approach produced usable bibliographic data for 355 publications (323 journal articles and 32 conference papers).

The analyses of the extracted bibliographic data were conducted using Microsoft Excel, R-Studio and the visualisation of Similarities Viewer Software (VOSviewer). To understand the area of focus of these extracted documents and the trends in these research studies, a visualisation of the mapped keywords in the documents was conducted using VOSviewer Software. Also, Bibliometrix in *R*-Studio was used to determine the word frequency and to create a word cloud of the significant keywords from the extracted documents. Based on the analysis conducted, the results were presented in terms of the performance analysis (year, country, sources), scientific mapping (top-cited documents), and network analysis (network visualisation). The narrative review was employed to present the core information in the different areas discovered from the network analysis based on the extracted data.

4 | FINDINGS AND DISCUSSIONS

4.1 | Performance analysis of NbS studies

4.1.1 | Documents per year

To understand the interest attracted to this area of research, the documents per year were evaluated. The results shown in Figure 2 revealed that no documents were extracted for the years 2013 and 2015, with only one for 2014. However, since 2016, there has been a steady increase in the number of publications in this area of research. A surge of publications occurred in 2019, with 21 documents compared were the eight documents published in 2018. There has been significant interest in this area of study during the period from 2020 to 2023. There was a reduced number of publications ($n = 78$) in 2023 compared with the year 2022 ($n = 110$) because the search was conducted in August 2023. It was possible that more papers were published before the end of the year. Figure 2 also shows the average total citations (TC) per article in each year. The line graph shows that the highest average TC per article of 110 and 125.5, was recorded in 2016 and 2017, respectively. It was not surprising to see fewer average TC per article for publications during the period 2018 to 2023. The average TC per article in these years will increase as forthcoming publications cite these documents.

4.1.2 | Documents per sources

The extracted documents originated from 96 sources. Table 1 shows the top10 most relevant sources. It is immediately evident from the table that all top sources were journal outlets, with the first set of articles published in 2016. This could be attributed to the earlier observation of there being more journal articles ($n = 323$) compared with conference papers ($n = 32$). This implied that more conference gatherings might be needed to promote further awareness of NbS, especially among built environment experts. The result in the table showed that the journal, *Sustainability*, published as an open-access journal of MDPI, had the highest number of published documents ($n = 83$), followed by the *Journal of Cleaner Production* ($n = 36$)

TABLE 1 Top ten sources.

Sources	2016	2017	2018	2019	2020	2021	2022	2023	*n*	TC	*h*-index	*m*-index
Sustainability	1	1	0	2	5	32	31	11	83	501	11	1.375
Journal of Cleaner Production	1	2	2	1	6	8	10	6	36	1804	17	2.125
Frontiers in Marine Science	0	0	0	0	0	6	11	5	22	88	5	1.666
Sustainable Cities & Society	0	0	0	1	5	2	7	2	17	335	10	2.000
Sustainable Mediterranean Construction	0	0	0	5	3	2	1	0	11	94	2	0.400
Water Research	0	0	1	0	1	2	4	3	11	112	5	0.833
Building and Environment	0	0	1	0	1	0	3	5	10	120	4	0.667
Buildings	0	0	0	0	0	0	1	6	7	3	1	0.500
Journal of Flood Risk Management	0	0	0	0	0	1	3	3	7	21	2	0.667
Water Resources Management	0	0	1	0	1	2	1	2	7	47	4	0.667

Abbreviations: *n*, number of publications; TC, total citations.

published by Elsevier. A careful review of the scope of these journals showed that they both encourage original research in sustainability and the environment. Thus, it was reasonable to find more papers about NbS being published by these journal outlets. This further reinforced a strong relationship between NbS and a sustainable built environment. Further scrutiny of the most relevant sources based on their citation counts and Hirsch index (*h*-index) revealed that the *Journal of Cleaner Production* (*h*-index = 17; TC = 1804), *Sustainability* (*h*-index = 11; TC = 501), and *Sustainable Cities and Society* (*h*-index = 10; TC = 335) had the highest impact measure. An interesting observation was that, despite having fewer publications than the *Sustainability* journal, the *Journal of Cleaner Production* had the highest number of citations. This implied the possibility of the latter journal reaching a much wider audience than others. The high impact factor of the *Journal of Cleaner Production*, when compared with others, could be another indicator for researchers to rely on its output. It is important to note that the *h*-index presented in this case was based on the impact of the extracted documents. This *h*-index shows the number of NbS articles (*h*) published by these journals, which have been cited in other papers at least *h* times. Also, the *m*-index shows the *h*-index divided by the number of years since the first NbS-related publication by the source. This result showed that, for NbS studies relating to sustainable and resilient infrastructure, the sources identified would be the best references for researchers.

4.1.3 | Documents and co-authorship per country

In understanding the countries from where these studies about NbS came, and also to identify countries in which the findings of this research could be most useful, the contributions per country were assessed. Since it was difficult to distinguish the specific country in which some of the extracted studies were conducted because of cross-country and continent collaborations among authors, the countries of the corresponding authors were explored to gain insight into where the studies were conducted. The extracted documents came from 51 countries, and 18 of these countries produced only 1 document. It was possible that these were once-off collaborations. To be certain that a country has contributed to the existing NbS discourse, Table 2 shows the results for countries with a minimum threshold of five documents. At the top of the list were: China ($n = 39$, TC = 377), Italy ($n = 29$, TC = 328), United Kingdom ($n = 25$, TC = 182), Spain ($n = 22$, TC = 272), and USA ($n = 20$, TC = 68). An interesting outcome of this result was the contribution of African countries to the larger NbS discourse in the built environment. The result showed that only four African countries (i.e., Algeria, Egypt, Kenya, and South Africa) had authors who had researched and published studies about NbS, which had been indexed in the Engineering section of Scopus. In past studies, South Africa and Kenya were also noted as major contributors to the NbS discourse (Enu et al., 2023; Nykia & Dinka, 2022). It is emphasised that, while other studies from the African continent might exist, the country of affiliation of the corresponding authors might not have been within the African continent, as in the case of many of the extracted documents. This might have affected the number of African countries, which was evident in the result presented.

Table 2 also shows the details of collaborations. For each country identified, the number of documents with at least one co-author from a different country is indicated by the figure for multiple countries publication (MCP). On the other hand, the single country of publication (SCP) shows the number of documents that were published by the author(s) from just one country. Thus, the result in the table shows that all the countries identified had at least one publication that someone from a different country co-authored. Leading this pool of collaborators were China, Italy and the United Kingdom. The MCP ratio indicates the strength of international collaboration. The closer the ratio is to 1, the higher the international collaboration of the country (Aria & Cuccurullo, 2017). Considering the figures in the MCP-ratio column, it could be concluded that Ireland, Portugal, China and the United Kingdom were among the highest international collaborating countries. However, countries such as the USA, Poland, Canada, and India could broaden their research activities through international collaborations.

TABLE 2 Countries of publications.

Country	*n*	SCP	MCP	MCP ratio	TC	Av. art. Citations
China	39	20	19	0.487	377	9.7
Italy	29	19	10	0.345	328	11.3
United Kingdom	25	13	12	0.480	182	7.3
Spain	22	17	5	0.227	272	12.4
USA	20	17	3	0.150	68	3.4
Germany	19	11	8	0.421	247	13.0
Australia	18	13	5	0.278	211	11.7
Poland	12	10	2	0.167	16	1.3
Netherlands	11	7	4	0.364	185	16.8
France	10	8	2	0.200	51	5.1
Portugal	9	4	5	0.556	36	4.0
Brazil	8	3	5	0.625	50	6.2
Canada	8	7	1	0.125	86	10.8
Greece	8	5	3	0.375	31	3.9
India	6	5	1	0.167	48	8.0
Ireland	5	2	3	0.600	27	5.4

Abbreviations: MCP, multiple countries publication; *n*, number of publications; SCP, single country of publication.

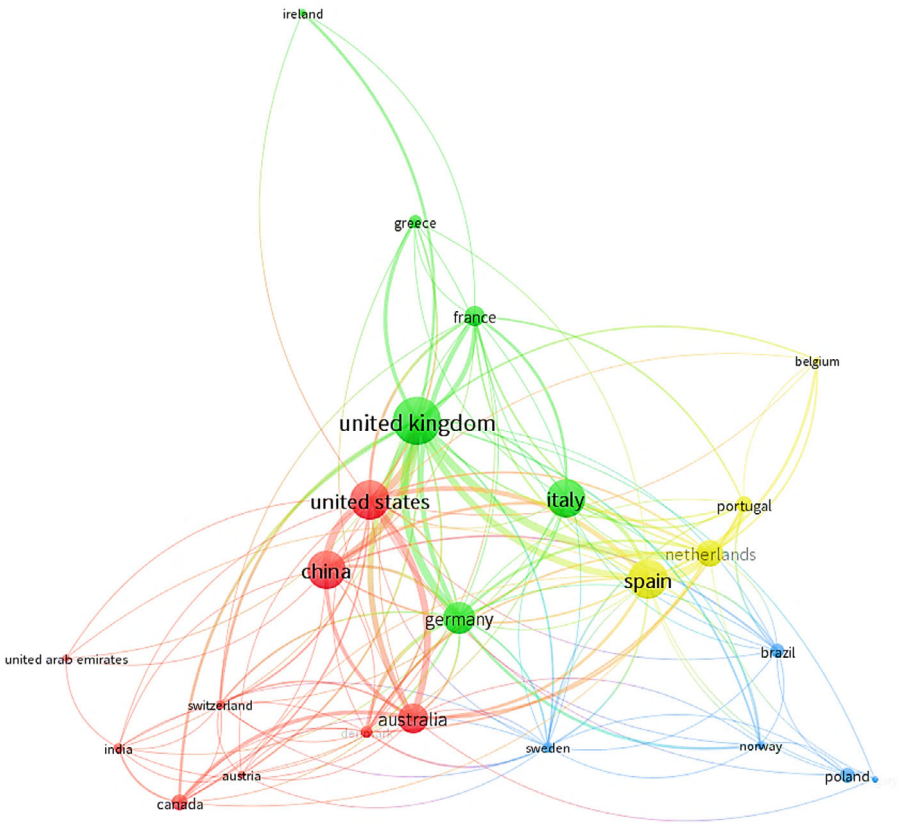

FIGURE 3 Co-authorship per country.

Further analysis illustrated in Figure 3 showed the co-authorship relationship between these countries. The Figure shows that the United Kingdom, which had a total link strength (TLS) of 81, strongly collaborated with Italy, Germany, France, Greece and Ireland. With a high TLS of 52, the USA had a strong co-authoring relationship with China, Australia, Switzerland, Austria, India, Canada, Denmark and the United Arab Emirates. A co-authoring relationship was also evident between Spain, Netherlands, Portugal and Belgium and between Norway, Poland, Sweden, Hungary and Brazil. These results further reinforced the need for this current study and the opportunity for researchers to contribute to the NbS discourse from an African perspective through international collaboration.

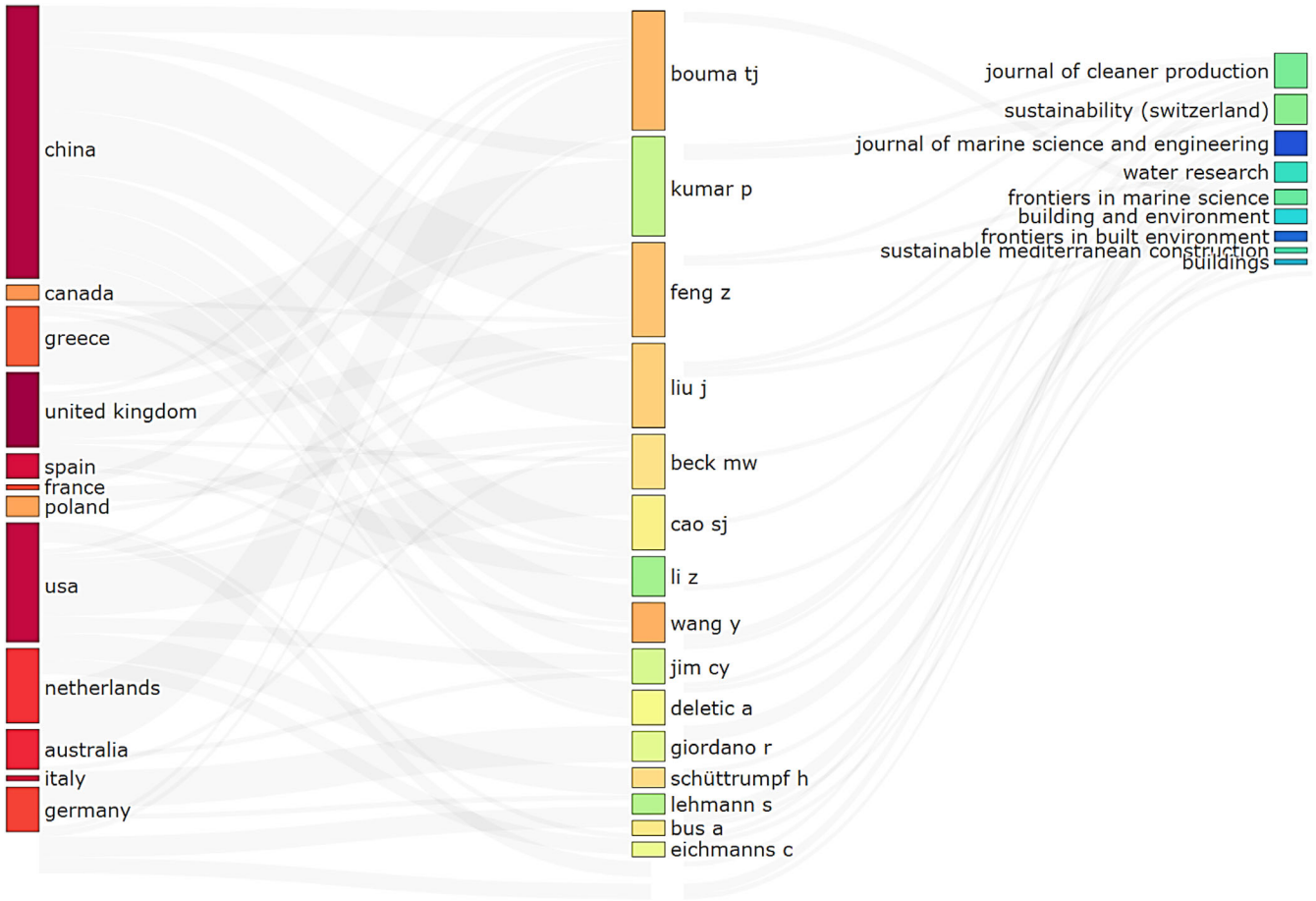

FIGURE 4 Three-field plot of authors, countries and sources.

4.1.4 | Contributing authors

Regarding the contributing authors, the extracted documents had 1354 authors, while only 20 documents had single authorship. Wang, Y. had the highest number of documents ($n = 5$) with TC of 39 and *h*-index of 4. The first NbS-related paper by this author was published in 2017. Also prominent in terms of number of publications were Bouma, T.J. ($n = 4$, TC = 58, *h*-index = 3), Liu, J. ($n = 4$, TC = 84, *h*-index = 3), Schüttrumpf, H. ($n = 4$, TC = 24, *h*-index = 3), and Feng, Z. ($n = 4$, TC = 26, *h*-index = 2). Figure 4 shows a three-field plot of the countries, authors and sources. The statistics show a strong link between the most published countries, authors and sources.

4.2 | Scientometric mapping of NbS studies

4.2.1 | Most cited documents

The citation count of an author or document is regarded as the bibliometric performance of the document or author and their impact on their field of study (Hirsch, 2005). Thus, the result in Table 3 shows the top cited documents (i.e., documents with at least 50 citations), their TC, TC per year, and normalised TC. While some of these documents were mostly about NbS, related areas were addressed in others, such as green infrastructure, green economy, circular economy, urban planning, and policy, among others, with NbS being mentioned as either part of their keywords or in their abstracts. Studies with a core focus on NbS as part of their titles were reported by Fink (2016), La Rosa and Pappalardo (2020), Magliocchetti et al. (2021), Pontee et al. (2016), Ren et al. (2019) and Wamsler et al. (2020). These top-cited papers ($n = 14$) had accumulated 1838 citations with an average TC per year of 24.4. The work of D'amato et al. (2017), in which circular economy, green economy and bio-economy were compared, was top of the list. These three aspects of sustainability were compared and contrasted to promote the concepts of sustainability. It was discovered that, for issues related to environmental sustainability, a green economy could be an over-arching concept that encompasses elements of circular and bio-economy and other ideas, such as NbS. This document accumulated 525 citations. A review of the green economy and its related concepts, done by Loiseau et al. (2016), also gained 362 citations. In the study, the major theories and concepts relating to green economy were identified and described. In so doing, the purpose of the study was to contribute to the definitions and relationships of concepts related to green economy, as a condition for operationalising green economy. An interesting observation from the result shown in Table 3 is the methodology adopted by these past

TABLE 3 Most cited documents.

Publication	Title	Source	Focus	Approach	TC	TC/year	Normalised TC
D'amato et al. (2017)	Green, circular, bio-economy: A comparative analysis of sustainability avenues	Journal of Cleaner Production	Circular economy, green economy and bioeconomy	Review	525	75	4.18
Loiseau et al. (2016)	Green economy and related concepts: An overview	Journal of Cleaner Production	Identifying and describing the main theories and concepts related to a green economy and to illustrate their links to sustainability	Review	362	45	3.29
Garfí et al. (2017)	Life Cycle Assessment of wastewater treatment systems for small communities: Activated sludge, constructed wetlands and high-rate algal ponds	Journal of Cleaner Production	Use of LCA to compare conventional wastewater treatment plant with two nature-based technologies	Experimental	191	27	1.52
Henry et al. (2020)	A typology of circular start-ups: Analysis of 128 circular business models	Journal of Cleaner Production	Circular business model strategies and innovations adopted by newly- established firms	Review of documentary evidence and interview	143	36	7.41
Magliocchetti et al. (2021)	Small rivers and landscape NbS to mitigate flood risk	Sustainable Mediterranean Construction	Using nature-based solutions to provide to green and blue infrastructures that will mitigate hydro-geological risk linked to climate change	Case study	89	30	8.91
Wamsler et al. (2020)	Environmental and climate policy integration: Targeted strategies for overcoming barriers to nature-based solutions and climate change adaptation	Journal of Cleaner Production	Integration of nature-based approaches for climate change adaptation into municipalities' daily planning practices and associated governance	Applied participatory analysis	70	18	3.62
Taillardat et al. (2020)	Climate change mitigation potential of wetlands and the cost-effectiveness of their restoration	Interface Focus	Meta-analysis on wetland carbon dynamics	Review	63	16	3.26
Pontee et al. (2016)	Nature-based solutions: Lessons from around the world	Proceedings of the Institution of Civil Engineers: Maritime Engineering	Emerging coastal management approaches for the reduction of coastal flood and erosion risks	Case study	61	8	0.55
Lin et al. (2020)	Water as an urban heat sink: blue infrastructure alleviates urban heat island effect in mega-city agglomeration	Journal of Cleaner Production	Exploring the cooling effect and efficiency of blue spaces	Experimental	59	15	3.06
Ronchi et al. (2020)	Integrating green infrastructure into spatial planning regulations to improve the performance of urban ecosystems. Insights from an Italian case study	Sustainable Cities and Society	Performance standards approach based on Ecosystem Services provision	Case study	59	15	3.06

TABLE 3 (Continued)

Publication	Title	Source	Focus	Approach	TC	TC/year	Normalised TC
Marando et al. (2022)	Urban heat island mitigation by green infrastructure in European Functional Urban Areas	Sustainable Cities and Society	Urban green infrastructure in reducing the urban heat island effect	Case study	56	28	13.87
Fink (2016)	Human-nature for climate action: Nature-based solutions for urban sustainability	Sustainability (Switzerland)	The role of nature and nature-based solutions in addressing climate change on a city scale	Review	56	7	0.51
La Rosa and Pappalardo (2020)	Planning for spatial equity – A performance-based approach for sustainable urban drainage systems	Sustainable Cities and Society	Use of sustainable urban drainage systems as a nature-based solution to address urban issues	Case study	53	13	2.74
Ren et al. (2019)	A nature-based reservoir optimisation model for resolving the conflict in human water demand and riverine ecosystem protection	Journal of Cleaner Production	The available ratio of water resources of natural or semi-natural rivers for ecologically feasible regions	Case study	51	10	2.58

studies. The result indicates an opportunity for methodological contribution by built environment researchers with a focus on more quantitative methods to provide empirical evidence about NbS for sustainable built environments.

4.2.2 | Visualisation of research focus of NbS studies

In order to determine the key areas of focus, first, the top-ten, most common terms from the extracted bibliographic data were identified, and a word cloud was created using the 50 most common terms, as shown in Figure 5. These terms were: climate change ($f = 82$), nature-based solution ($f = 50$), sustainable development ($f = 44$), sustainability ($f = 40$), urban planning ($f = 32$), ecosystems ($f = 30$), urban area ($f = 28$), water management ($f = 28$), floods ($f = 27$), decision-making ($f = 25$). These common terms gave an idea of the area of concentration of the extracted NbS-related studies.

To map the research focus of the extracted publications further, VOSviewer was adopted. All the extracted documents revealed 3256 keywords used by authors and journals during indexing. Using VOSviewer helped to group this large number of keywords into more coherent clusters, using a set co-occurrence threshold. Since there is no rule regarding the minimum threshold to be used (Aghimien et al., 2022), a minimum co-occurrence threshold was set at eight, as this gave the best clarity and optimisation of the visualisation map as suggested by Darko et al. (2020). Based on the set threshold, 78 keywords co-occurred eight times, and these were grouped into five clusters with a TLS of 3382 and 1376 links, as shown in Figure 6.

Cluster 1, arbitrarily named *NbS for flood control*, can be seen in the red nodes. This cluster had 20 co-occurring keywords. Among these keywords were: flood, flood control, flooding, flood risk management, runoff, storms, coastal protection, coastal engineering, risk assessment, risk perception, and sea level. Based on the latent similarities of these keywords, this cluster was named *NbS for flood control*. NbS in combating natural disasters, such as floods, has been highlighted in various studies. Thaler et al. (2023) explored natural flood management to support sustainable flood risk management. It was noted that this approach impacted physical conditions, social interaction, financial resources and institutional settings. Also, Van Hespen et al. (2023) assessed the role of mangrove forests as NbS in protecting coastal areas from floods. It was noted that using NbS for protection from coastal flooding could be both sustainable and cost-effective. Reaney (2022) explored spatial targeting of NbS for managing flood risk in river catchments and observed that most NbS for reducing flood hazard were designed to store and slow the flow within catchments. For these NbS to be effective as designed, it was necessary to identify the optimal locations for implementing them. Also, Basu et al. (2021) proposed a theoretical framework that could be used to assess the performance of green roofs as NbS for mitigating flooding within urban areas. It was stated that climate change, poor soil permeability and infiltration caused by rapid urbanisation had made many cities susceptible to flooding. Pontee et al. (2016)

FIGURE 5 Word cloud of most common keywords.

explored the lessons learnt from NbS applications worldwide, particularly concerning coastal floods and erosion risks. It was observed that, although created or enhanced by man, NbS adopted tended to mimic the characteristics of natural features (hence the name). These solutions include beaches, dunes, salt-marshes, mangroves, and sea grasses, among others, and were designed either to control or to reduce erosion and flooding. As noted earlier, NbS studies from within Africa have also placed emphasis on the use of this concept to combat flood risk, which has become prevalent in the continent (Enu et al., 2023; Kalantari et al., 2018; Lokidor et al., 2023). From the perspective of building resilient cities, Mabrouk et al. (2023) explored the use of NbS in urban planning in Egypt. Based on the study, it was found that the use of NbS strategies, such as low-impact development tools, could be very effective in reducing flood run-off. In Ghana, Yiwo et al. (2022) also noted the need for the use of NbS to build flood resilience and effectively manage flood risk. Considering the studies mentioned above, in which flood risk management, mangrove forests as NbS, spatial assessment of river catchments as NbS, and green roof construction as NbS for reducing flooding were explored, it was evident that NbS played a crucial role in the reduction and management of flood risk.

Cluster 2, arbitrarily named *NbS in climate change and urban planning*, is indicated within the green nodes (Figure 6) and had 19 keywords. Among these keywords were: nature-based solution, climate change, climate change adaptation, urban planning, urban growth, urban design, urban development, adaptation, adaptive management, and resilience, among others. This cluster was subsequently named *NbS in climate change and urban development*. Zikhathile et al. (2023) noted that the effect of climate change on earth's sustainability is devastating, and this has become a growing concern for countries worldwide. Ensuring effective planning, particularly in urban areas that are susceptible to the adverse effects of climate change, has become critical. Pancewicz et al. (2023), in an effort to strengthen the resilience of cities to climate change, explored the use of NbS within local communities in Poland. It was noted that, while cities within the country were introducing sustainable urban lifestyles through NbS, the full potential of the opportunities presented by these solutions were not being utilised. Similarly, Małecka-ziembińska and Janicka (2022) submitted that NbS was one of the recent means of addressing climate change through the use of the power of nature to combat the emissions of greenhouse gases. However, NbS had not gained much attention in Polish municipalities because of the poor awareness and knowledge of the concept, and this necessitated the need for effective education about this aspect of addressing climate change in the country.

Wamsler et al. (2020) viewed NbS and climate change adaptation from the perspective of the environment and climate policy. How nature-based approaches were integrated into the planning and governance of municipalities in Sweden to address climate change adaptation was examined in the study. It was noted that critical planning for nature-based adaptation could be challenging, as this process requires trans-disciplinary approaches with interaction among various stakeholders. However, five strategies for overcoming this challenging process were proposed, namely: "targeted stakeholder collaboration; strategic citizen involvement; alteration of internal co-operation structures; outsourcing; and concealed science policy integration" (Wamsler et al., 2020: 3). In South Africa, Knight (2023) explored NbS in building coastal resilience. It was noted that coastal landforms are green infrastructure that could reduce the impact of climate change, while providing environmental services as intended. Within the railway sector, Blackwood and Renaud (2022) explored the challenges in the use of NbS for adaptation to climate change. It was observed that lack of evidence, safety issues, constraints on land-use, constraints on time, stakeholder dependencies, uncertainty in climate changes, and limited cost–benefit analysis were all key challenges. Evidently, NbS offered solutions to address issues of climate change, and planning was essential if these solutions were to be incorporated into cities and societies effectively. Małecka-ziembińska and Janicka (2022)

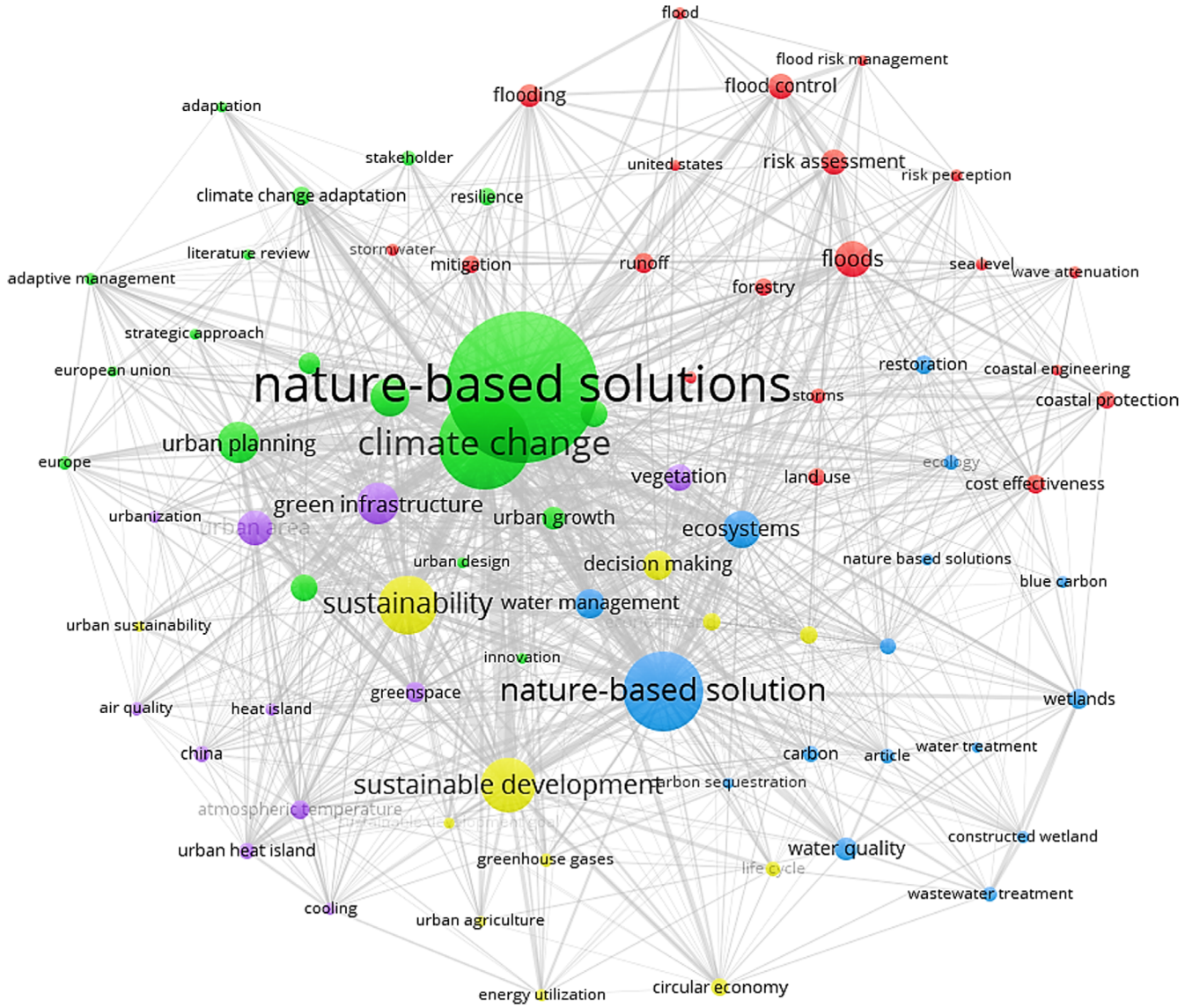

FIGURE 6 Network visualisation of co-occurring keywords in NbS-related publications.

mentioned earlier that the green benefits offered by NbS, which could address the issue of climate change, should be standard in planning of land-use, particularly in the current human-centred era.

Cluster 3, arbitrarily named *NbS in water quality and carbon emission*, is presented in the blue nodes (Figure 6) and had 16 keywords. Among these keywords, were: nature-based solution, water quality, water treatment, waste-water treatment, water management, wetlands, constructed wetlands, ecosystem, ecology, blue carbon, carbon, and carbon sequestration. This cluster was subsequently named *NbS in water quality and carbon emission*. Tsatsou et al. (2023) noted that urban centres are faced with the challenges of water management and scarcity. This has necessitated the need for water circularity and NbS in urban areas. To this end, a circular water NbS was proposed, including green roofing, living walls, indoor plants, permeable paving, rain-garden and bio-swale. To improve water delivery, particularly in urban areas, Bogatinoska et al. (2022) noted that a participatory approach that enables all stakeholders to congregate and share ideas was crucial. However, diverse participatory methods have been used in designing NbS together with stakeholders. Thus, a step-wise, participatory framework, applied in four countries (Netherlands, Belgium, France, and United Kingdom), was proposed in the study. In Portugal, Freitas et al. (2021) adopted a multi-disciplinary approach in assessing NbS for water delivery in urban areas. It was observed that old, underground structures, such as ancestral networks of water sources and springs, could benefit socio-economic, environmental and heritage drivers of water delivery. Muñoz Veloza et al. (2022) explored two NbS, that is, blue-green roofs and rain gardens, as means of increasing water availability in informal settlements, while mitigating climate change in the process. Using recycled materials, prototypes for these two NbS were built in El Pozón, Colombia, and were observed to improve indoor thermal comfort, while enabling easy storage of rainwater for domestic use and cultivation of affordable food for people

in private gardens. Based on the study, it was concluded that NbS could be a method for dwellers in informal settlements to tackle the effects of global warming. Also, Acreman et al. (2021), using a systematic review, showed that the use of NbS had the capability to improve water quality in Africa and to address the water shortage in some parts of the continent.

Xiao et al. (2023) also explored NbS as a means for attaining carbon neutrality in resilient buildings and communities. This became necessary because the building industry has been noted as being a principal culprit of carbon emissions, accounting for almost 40% of CO_2 emissions globally. It was noted that using NbS, such as urban trees, green roofs and facades, which are urban green infrastructures, could be a viable means of addressing this negative impact of the building industry on the environment. Similarly, Xi et al. (2022) noted that NbS could prove to be effective in regulating urban ecosystems, particularly through increased green infrastructure. In Canada, Grossi et al. (2023) noted that urban trees absorb CO_2 emissions through the process of photosynthesis. Furthermore, in the study, several parameters for carbon neutrality through sequestration of tree emissions were presented. Similarly, Xi et al. (2023) noted that transportation was a principal contributor to urban heat islands and heat waves, which could increase urban carbon emissions. However, these problems could be addressed through the effective use of NbS, such as roadside green belts, which tend to block traffic-related pollutants. In South Africa, Raw et al. (2023) explored the need for restoration to enhance carbon sequestration. It was noted that blue carbon systems, including mangroves, sea-grasses and salt marshes, could help to mitigate the impact of climate change because of their efficiency in sequestering CO_2 within the atmosphere. Similarly, Masisi et al. (2022) explored bamboo as an NbS in combating climate change in Tanzania. The use of bamboo was explored because it is a versatile, woody grass that can survive in degraded lands. It was concluded that bamboo "can produce a tradable amount of carbon under carbon offsetting schemes and serve as an effective strategy for forest landscape restoration opportunities" (Masisi et al., 2022: 8). The studies mentioned above all indicate the immense usefulness of NbS in attaining net zero carbon emission and improving the delivery of high-quality water.

Cluster 4, arbitrarily named *NbS for sustainable development*, is shown in the yellow nodes (Figure 6), with 11 keywords. These keywords included: sustainability, sustainable development, circular economy, economic and social effects, life-cycle, urban sustainability, sustainable development goal, decision-making, urban agriculture, and economics. This cluster was subsequently named *NbS for sustainable development*. Neumann and Hack (2020) noted earlier that NbS were designed to achieve sustainability through attaining economic, social, and environmental benefits. Ommer et al. (2022) stated that the use of NbS had gained popularity because of its ability to provide some co-benefits in terms of economy, society and the environment. In support, Ramísio et al. (2022) submitted that NbS takes into consideration the wellbeing of people, the growth of socio-economic indicators and rules of governance. Thus, introducing NbS into urban infrastructure development created a fresh perspective on urban sustainability, quality of life, and adaptation to climate change. Fink (2016) noted that using NbS, such as green infrastructure, which is a cost-effective approach to improving adaptation to climate changes and promoting human well-being, can be effective in promoting sustainability within societies.

Considering the economic dimension of sustainability, Loiseau et al. (2016) explored green economy to identify major theories and concepts relating to green economy. Based on the study, it was found that NbS, among other frameworks, was closely related to the attainment of a green economy. Di Cosola et al. (2021) explored NbS and renewable energies in achieving the agenda of the UN's SDGs in a quest for urban transition. It was noted that urban centres had become synonymous with issues of unsustainability such as air pollution, resource consumption and inequality. Thus, introducing nature-based technologies that could help to transform these urban centres and attain sustainable development was essential. Another essential study was the work of Keesstra et al. (2023), in which NbS was explored as an opportunity to attain sustainable food systems in societies. Food production was noted to be germane to societal well-being and ecological sustainability. To this end, three types of NbS were observed in the study, namely: intrinsic NbS, which adopts existing ecosystems; hybrid NbS, which adapts ecosystems; and inspired NbS, consisting of totally new ecosystems. The use of inspired NbS was observed to have the highest impact on the attainment of sustainable food production. Considering the impact of NbS on environmental, societal and economic development, it was evident that careful attention given to solutions drawn from nature could be a positive step towards achieving the SDGs in countries worldwide.

Cluster 5, arbitrarily named, *NbS in green infrastructure and urbanisation*, is shown in the purple nodes (Figure 6), with 11 keywords. These keywords included: green infrastructure, urban area, vegetation, green space, heat island, urban heat island, urbanisation, cooling, atmospheric temperature, and air quality. This cluster was subsequently named *NbS in green infrastructure and urbanisation*. Frantzeskaki et al. (2022) noted the importance of NbS for resilient infrastructure in cities. Also, Ronchi and Salata (2022) assessed the role of the design of urban space, using NbS in green infrastructure. The findings of the study conducted in Italy provided opportunities to define environmental policies and strategies that could prove to be effective in the design of urban space and in the decision-making process for the attainment of sustainable development goals. In proposing NbS as a viable option for addressing issues of climate change in Canada, Anderson and Gough (2022) focused on the regulatory environmental impact analysis of green infrastructure. Based on the study, it was noted that using NbS through green infrastructure offered an approach to achieving the country's build-back better plan and localising the SDGs, while addressing the various impacts of climate change. Magliocchetti et al. (2021) attempted to restore landscape ecosystems that would benefit society significantly. To achieve this, the possibility of forecasting green and blue infrastructures through NbS to reduce the hydrological risk caused by climate change was explored in the study. Based on the study conducted in two small settlements in Argentina and Italy, a methodological tool was proposed that could

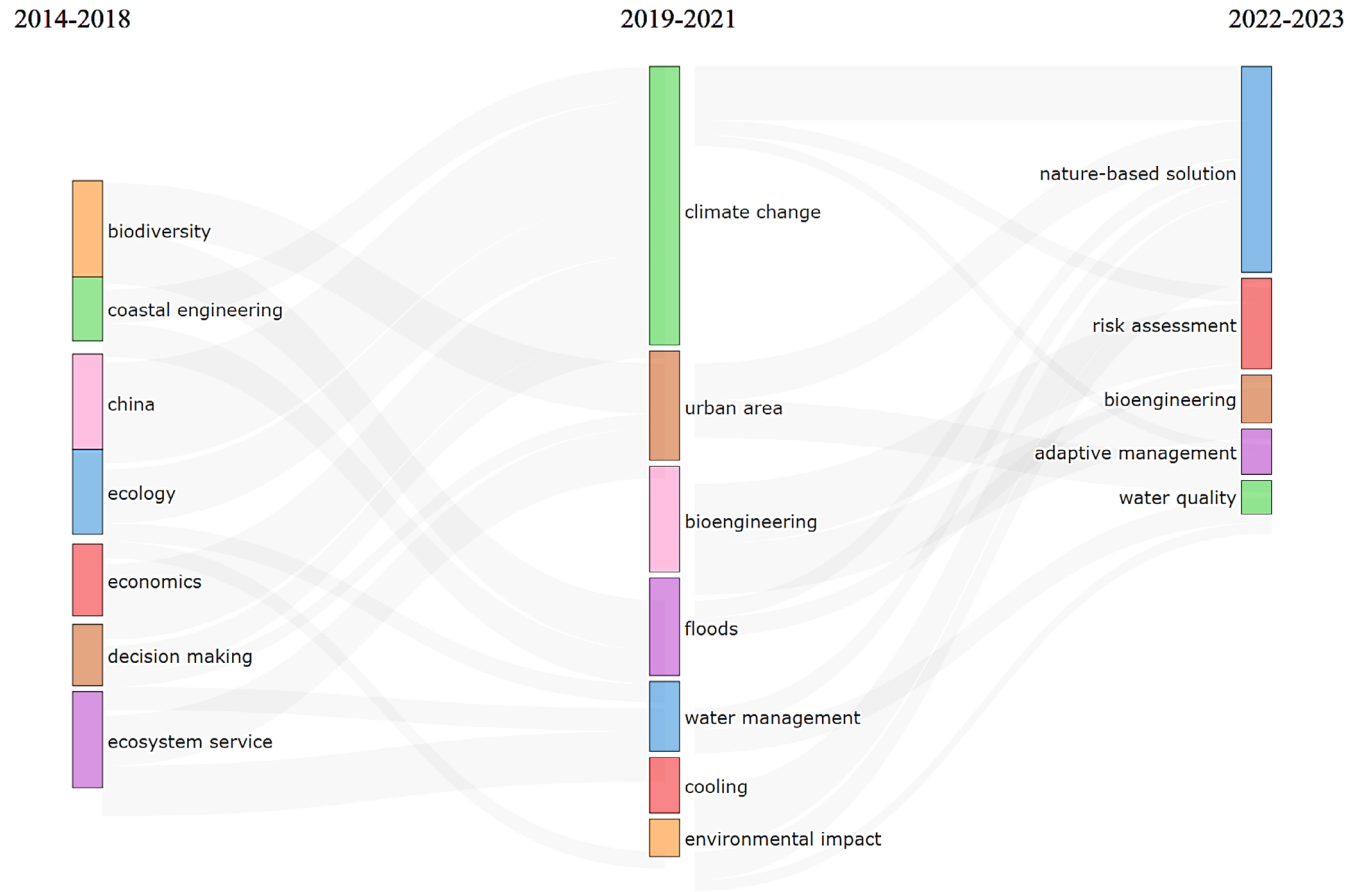

FIGURE 7 Thematic evolution of common NbS-related terms.

assist in the identification of a wide range of possible interventions to mitigate these risks through territorial and urban planning of suitable "green and blue infrastructures" achieved through different uses of NbS. In view of these benefits of NbS for infrastructure and urban development, Bona et al. (2023) noted that a huge opportunity existed for NbS to be adopted in buildings and the built environment, but these were not prioritised because of a lack of effective monitoring of the potential successful outcomes of available NbS.

4.2.3 | Visualisation of trends and direction for future studies in NbS research

Figure 7 shows the thematic evolution of common terms within a three-year range. While terms, such as "coastal engineering", "biodiversity" and "ecology", were common between 2014 and 2018, "climate change", "urban area", "bio-engineering", "floods", "water management", "cooling" and "environmental impact" were more prominent between 2019 and 2021. From 2022 to the present, NbS became more evident, together with risk assessment, bio-engineering, adaptive management and water quality. This showed that the term "NbS" has continued to gain prominence in recent studies.

Figure 8 shows the visualisation map overlay derived from VOSviewer. This map shows the trend in the focus of research. The map shows only keywords that co-occurred eight times, beginning in 2020. Based on the map, and in affirmation of the results from the thematic evolution of common terms, it was evident that terms, such as "floods", "ecosystems", "water quality and management", "climate change", "urban area" and "planning", were all prominent during the period from 2020 to 2021. However, since 2022, there has been more focus on: "nature-based solutions", "adaptation", "adaptive management", "greenhouse gases", "energy utilisation", "carbon sequestration", and "numerical models". These keywords are shown in the yellow nodes of the map.

It has been noted that the closer keywords are to each other, the higher their co-occurrence (Van Eck & Waltman, 2014). Thus, examining the occurrence and TLS of the keywords in the yellow nodes (i.e., the recent area of focus) showed which areas were receiving adequate attention and which could be researched further. Thus, areas such as adaptation and adaptive management ($f = 8$, TLS $= 21$), carbon sequestration ($f = 8$, TLS $= 32$), numeric models ($f = 9$, TLS $= 29$), energy utilisation ($f = 9$, TLS $= 40$), cooling ($f = 9$, TLS $= 47$) and greenhouse gases ($f = 10$, TLS $= 43$) were all current areas but with less attention. Therefore, the emphasis in future studies within the built environment domain, particularly in African countries where such studies are scant, could be placed on these research areas to achieve a sustainable built environment through NbS. For example, adaptive management, which entails making decisions and necessary changes in preparedness for future circumstances based on new information and changes (United States

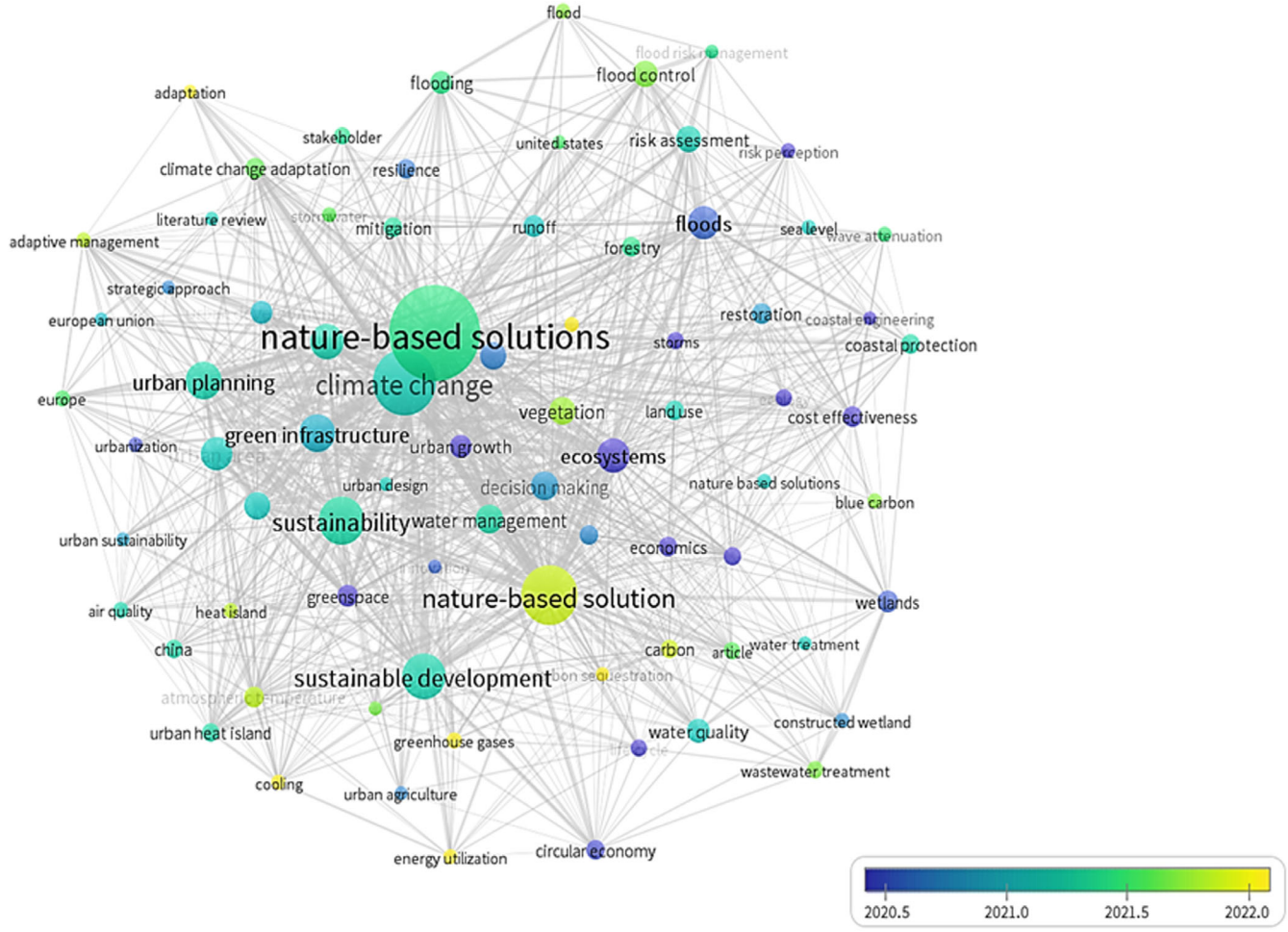

FIGURE 8 Overlay visualisation of co-occurring keywords in NbS-related publications.

Agency for International Development, 2015) has not gained significant traction within the built environment. In construction, for instance, where projects are unique and dynamic, adaptive management could help to prepare and make reasonable decisions to address unforeseen issues that might result from the delivery of such projects. Exploring the deployment of NbS within the built environment from the perspective of adaptive management could serve as a much-needed solution towards addressing unexpected problems that are common in construction projects. Also, Hutton (2021) noted that carbon sequestration can assist in transforming buildings from net-negative to net-positive structures. Carbon sequestration entails capturing and storing carbon dioxide from the atmosphere with the aim of reducing climate change. The built environment has continued to be identified in studies as a principal culprit of greenhouse gas emissions through day-to-day use of energy for lighting, heating and cooling, as well as the use of energy in material manufacturing, transportation and construction (Budds, 2019). This has made this industry unsustainable in many countries around the world. As the African continent begins to grasp the issue of climate change and several agendas for adapting and mitigating its adverse effects (Dupar et al., 2023), future studies, therefore, could be undertaken within African countries to explore how the implementation of NbS from the onset could help to address issues of greenhouse gas emission, promote energy usage and carbon sequestration to achieve carbon neutrality within buildings and society as a whole. This was important because the findings of the review conducted showed only two studies (Masisi et al., 2022; Raw et al., 2023) from within Africa, in which carbon sequestration was explored from the perspective of NbS. Furthermore, since the concept of NbS fairly new within the built environment, researchers could focus on developing and refining numerical models that could provide accurate predictions of the performance of NbS implementations. These models could contribute to a better understanding of how NbS interacts with various sustainability factors. This understanding, in turn, would enable informed decision-making and the formulation of more effective strategies to enhance resilience against climate risks in African countries and beyond.

4.3 | Implication of the findings

The findings of the review of extant literature showed a lack of adequate research about NbS within the built environment in Africa. In previous NbS-related studies within the continent, the need has also

emphasised for more studies that will lead to the improved use of this beneficial concept and to supplement findings from studies already conducted in other developed countries (Lokidor et al., 2023; Nykia & Dinka, 2022). Thus, by exploring past studies from a global perspective, the findings of the current study offer researchers within the African continent other areas that can be explored with a view to promoting the NbS discourse and contributing significantly to the attainment of a sustainable built environment. Also, the results showed that there were limited international collaborations on NbS research from an African perspective, as developed countries tend to collaborate with each other to a greater extent. This reflected the limited awareness of NbS on the African continent. To address this trend, there is a need for researchers to enhance collaborations with other scholars globally to share ideas, research techniques and cultural orientations regarding the ways in which NbS could be deployed. Through effective collaborations, researchers and scholars on the continent could leverage the distributed intelligence of other leading scholars on best practices and current trends of NbS in addressing global issues. Another approach to promote NbS research in Africa would be to arrange more NbS-related conferences, workshops, technical working groups, symposiums and seminars constantly to increase the scholarly and practical discussions about ways to maximise the potential of natural systems to address climate change and other major challenges. Through these events, African scholars would be presented with opportunities to network with leading professionals from academia and practising professionals, which could encourage the widespread adoption of NbS knowledge at a continental level in addressing environmental, social and economic challenges. Moreover, these opportunities would provide built environment professionals, decision-makers and communities with information on how and where to apply NbS and measure their numerous benefits.

Figure 9 shows a summary of the focus of NbS research and suggestions for future studies. By exploring the concept of NbS in the context of the built environment, from a global perspective, several implications could be drawn from the various clusters of keywords identified from past studies. In the first focus area of research, where NbS for flood control was examined, the potential of incorporating natural features, such as mangrove forests and green roofs, into flood risk management was emphasised. Considering the continuous issue of flooding that has afflicted some African countries, exploring NbS for effective flood management is crucial. While several studies in Africa have focused on NbS for flood risk management, as evident in the first cluster presented, built environment experts should consider holistic management approaches that encompass physical conditions, social interactions, financial resources and institutional settings that can assist in effectively managing the envisaged risk associated with flooding and its impact on built infrastructure. The second focus area of research identified, which entailed climate change and urban planning, underscored the role of NbS in fostering resilient urbanisation. Evidently, African countries face similar problems to the rest of the world in terms of adverse climatic changes. Therefore, there is a need for decision-makers, policymakers, and urban planners to prioritise the integration of NbS strategies to enhance the capacity of cities to adapt to the impacts of climate. Nykia and Dinka (2022) noted the need to overhaul institutions and policies to use NbS effectively within African cities. Moreover, the alignment of sustainability goals with urban infrastructure signified the potential for NbS to shape urban landscapes that promote ecological and human well-being.

In the third focus area of research, the potential use of NbS to improve urban water systems and mitigate carbon emissions by integrating natural systems, such as constructed wetlands and urban trees, was highlighted. This reinforced the need to make the transition towards more ecologically conscious and sustainable urban development paradigms within the built environment. With the water shortage and drought being persistent issues among many African countries (UNICEF, 2023), designs, methods and technologies that are aligned with nature cannot be overlooked. Practitioners and stakeholders involved in the delivery of water infrastructure in these countries could draw firstly from the opportunities in nature to address their water-related problems even before seeking assistance from other approaches. These could include encouraging the construction of blue-green roofs, living walls, indoor plants, and permeable paving, among others, as observed by Tsatsou et al. (2023). The fourth focus area of research (i.e., sustainable development) underscored the triple bottom-line benefits of NbS. The integration of economic, social and environmental co-benefits suggested that urban development strategies in Africa should prioritise NbS to achieve sustainable and inclusive growth. The fifth focus area of research, in which the potential use of NbS to mitigate urban heat effects and improve air quality was highlighted, implied that built environment practitioners could prioritise the integration of green infrastructure and vegetated spaces to counteract heat island effects and enhance urban liveability. The importance of green infrastructure in the African continent is gradually gaining recognition, with priority being given to this type of infrastructure by African leaders with a focus on achieving zero land degradation and restoring catchment and coastal ecosystems (Dupar et al., 2023). Thus, built environment experts involved in delivering infrastructure must also prioritise green properties.

The emergence of these five focus areas of research underlined the inter-disciplinary nature of existing research about NbS. Thus, to realise the potential of NbS adequately in the built environment in Africa, there is a need for effective and efficient collaboration among ecologists, engineers, policymakers, sociologists, urban planners and other relevant stakeholders. These cross-disciplinary collaborations could foster innovative approaches that address the complex challenges faced by urban environments holistically. This is essential, as the importance of a participatory and multidisciplinary approach in developing appropriate NbS to effectively address key climatic and ecological issues has been noted in past studies (Bogatinoska et al., 2022; Freitas et al., 2021). The implication of these findings was that researchers seeking to make more meaningful contributions to the existing discourse about NbS for a sustainable built environment in Africa would benefit more from a cross-disciplinary research approach. Furthermore, these five areas of research offer the opportunity to consolidate knowledge and its effective transfer. Educational initiatives targeted at communities, urban planners, local governments

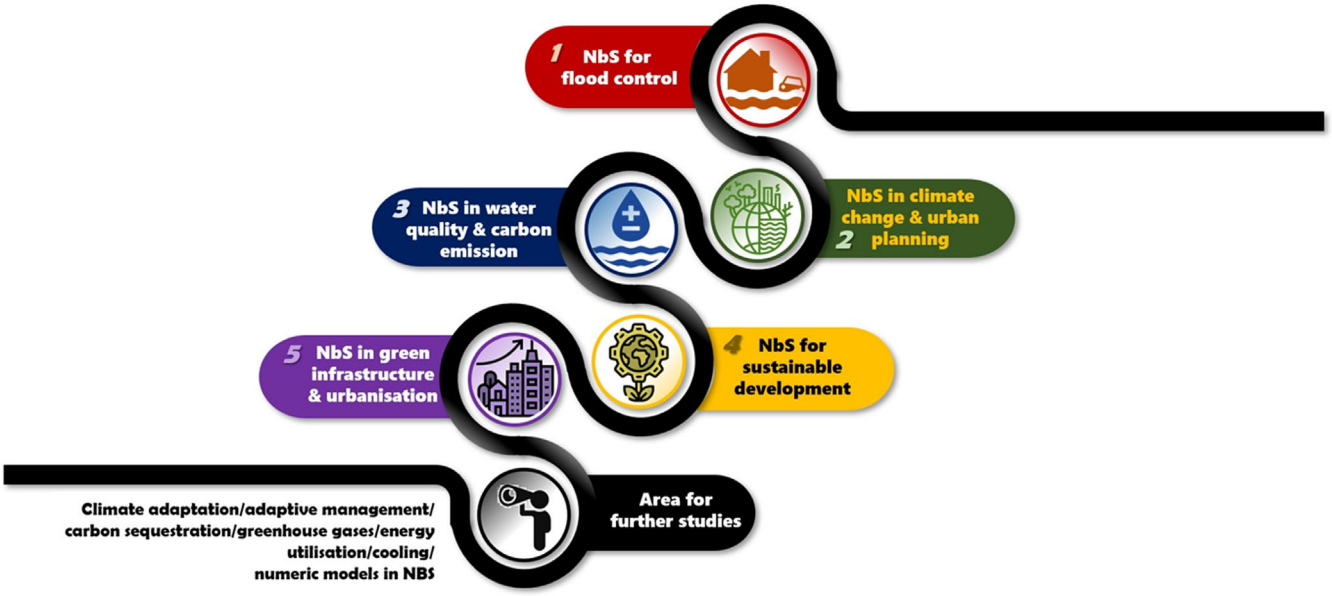

FIGURE 9 Summary of NbS research focus and suggestions for future studies.

and other stakeholders within the built environment could be used to facilitate the dissemination of best practices and lessons learned from these different areas of research in past studies. These initiatives could greatly assist in bridging the gap between research outcomes and practical implementation. Also, these five areas of research, identified in this study, provide valuable insight into policy formulation and implementation. Policymakers and other stakeholders within the built environment could leverage the findings to devise targeted strategies that foster the incorporation of NbS within plans to adapt to climate, sustainability frameworks and urban planning regulations. In addition, the areas of research identified in this study provide a robust foundation for establishing long-term monitoring and evaluation mechanisms for NbS projects. By categorising projects according to their clusters, policymakers and researchers could assess the effectiveness and impact of different NbS interventions over time, refining strategies and maximising potential outcomes.

5 | CONCLUSION AND RECOMMENDATIONS

The current issues afflicting the African continent, such as devastating droughts, rising sea levels, population displacements, water scarcity, and changing weather patterns, among others, are expected to be exacerbated by climate change in the coming decades. With the population of the continent projected to increase by another billion people by 2050, the adoption of NbS could play a crucial role in mitigating the impacts of climate change. Additionally, NbS could contribute to strengthening communities, boosting local economies and ensuring the preservation of ecosystem services and biodiversity. This importance of NbS towards combating issues of climate change has led to an emerging popularity of the concept among researchers in both developed and developing countries. However, it has been noted that few studies about NbS have emerged within the African continent, and the need for financial support for researchers to explore this area has been noted. Thus, exploring existing NbS studies from a global perspective to provide direction for NbS research that is specific to Africa and to augment the existing studies emerging from the continent was deemed to be timely. Therefore, in this study, a case was made for NbS for a sustainable built environment in Africa by identifying scholarly connections, performance, and trends within past NbS studies and determining a future direction for research about NbS within the built environment in African countries.

Based on the findings, it was concluded in this article that literature regarding the use of NbS within the built environment in Africa is scant, and there are limited external collaborations about NbS research from an African perspective. It was also concluded that the concepts of NbS have been explored from five major perspectives, namely: flood risk management; climate change and urban planning; water quality and carbon emission; sustainable development; and green infrastructure and urban development. These clusters offer opportunities for more contributions from researchers within the built environment in Africa. Significant contributions can be made to the existing NbS discourse by exploring NbS for sustainable built infrastructure in relation to any of these identified focus areas of research. Based on the trend in existing studies, it was also concluded that, in comparison with the other areas of research, less focus has been placed on carbon sequestration, greenhouse gases, energy utilisation, indoor comfort and numeric models for the use of NbS. Again, these areas offer opportunities for researchers within the built environment to contribute to NbS implementation in Africa.

Practically, the findings of this study lead to key synergistic recommendations to help to scale up research and the deployment of NbS throughout the continent, and the need for aggressive action to

deploy the concept cannot be over-stated. The acceptance and implementation of NbS require a collective approach because the government (federal, state and local), experts, partners and agencies, all have a role to play. Adequate knowledge and awareness of NbS created through research would create a future where natural infrastructure becomes the *preferred option to combat climate change*, build resilient infrastructure and create prosperous communities. Thus, there is a need for more financial support for researchers in the built environment who are willing to explore NbS within the African continent. Governments and research institutions in diverse African countries could champion this by prioritising and investing in research and development designed to improve the use of NbS. Similarly, built environment researchers should explore international collaboration to broaden their understanding of the concept of NbS and use this knowledge to explore their local context. To further promote NbS for a sustainable built environment, there is a need for more conferences, workshops, technical working groups, symposiums and seminars organised by organisations and institutions within the continent to explore NbS for local problems. These programmes would help grow the scholarly and practical discussions about ways to maximise NbS systems that would address the turbulent climate problems of the continent. Theoretically, this study provides a foundation upon which empirical studies can build to promote the knowledge and deployment of NbS in Africa. As a limitation, care must be taken in generalising the results of this study, as the data used were obtained solely from the Scopus database. Although significant commonalities exist between Scopus and other platforms, future studies could go further to deploy other databases to obtain a broader view of NbS research and provide direction for research about the built environment in Africa. Future studies could also combine several databases to compare results with this study, thus allowing inferences and theories to be drawn. Furthermore, the Scopus database is updated regularly, which means that the number of articles identified might increase when this article is published.

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