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Achieving the sustainable development goals through nature-based solutions amidst climate change. Evidence from scopus and Web of Science (WoS) databases

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ABSTRACT

Nature-based solutions (NBS) offer a promising tactic to mitigate climate change impacts and contribute to sustainable development. This study leverages bibliometric analysis to investigate the global research landscape on NBS and the Sustainable Development Goals (SDGs), following the PRISMA guidelines for validation. Examining publications from Scopus and Web of Science (WoS) with 132 documents, we observed a notable upward trend in research output, indicating the growing recognition of NBS as a critical strategy. The analysis revealed that India, Italy, and the UK, among others, are the leading nations in research productivity. However, the study features a substantial geographic disparity, with a limited contribution from African nations. This discrepancy highlights the need to stimulate research collaboration and funding opportunities in developing nations, particularly in Africa. The study further demonstrates the potential of NBS to contribute to achieving 2/3 of the SDGs. This finding emphasizes the transformative power of NBS in addressing global challenges. Our analysis indicates no significant statistical difference between Scopus and WoS databases regarding the number of published articles. Nonetheless, we advocate that researchers consider utilizing both databases to ensure a thorough literature review. This study advances the existing body of literature by quantitatively assessing the global research landscape on NBS and SDGs. It highlights the growing importance of NBS, identifies geographic disparities in research output, and emphasizes the need for increased collaboration and funding in emerging economies. Trends and patterns in NBS research, if understood, can inform future research directions, policy decisions, and the implementation of effective NBS.

1. Introduction

Climate change is a complex and pressing global issue that has garnered significant attention in recent years. It is referred to the long-term changes in precipitation patterns, weather events, and in temperature due to human activities [1,2], and natural systems [3], that release greenhouse gases (GHG), which alter the composition of Earth's atmosphere and enhance the greenhouse effect. This phenomenon has far-reaching consequences, including rising global temperatures, melting ice caps, sea-level rise, and extreme weather events like wildfires, hurricanes, droughts, floods to mention just but a few. The greenhouse effect is the main driver of rising temperatures and is responsible for the current rapid warming of the Earth's climate [4]. According to Gklavopoulos et al. [5], since worldwide records began in 1850, 2023 was the hottest year with 2.12°F (1.18 °C) exceeding the twentieth-century average of 57.0°F (13.9 °C). Increase in average global temperature and extreme with unpredictable weather are the most common manifestations of climate change [1]. Consequences of climate change are far-reaching and pose unprecedented threats to human civilization and ecosystems [6].

As a result, resilience has emerged as a key idea in the discussion of climate change. It indicates how well people, groups, institutions, and systems can predict, absorb, and adjust to shocks brought on by climate change [7]. To manage future uncertainties, this strategy strongly emphasizes bolstering local adaptive capacities, utilizing traditional knowledge, and guaranteeing stakeholder participation [8]. Climate

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resilience is closely related to the global objective for sustainable development, which is expressed in the United Nations' 2030 objective and its 17 Sustainable Development Goals (SDGs). The SDGs are a set of 17 global goals and 169 targets adopted by the United Nations in 2015 to address various challenges and promote sustainable development. These goals aim to end poverty, protect the planet, and ensure peace and prosperity for all by 2030 [9–11]. However, the changing climate could affect virtually every part of sustainable development, resulting in a critical need to understand how action to combat climate change may strengthen all other SDGs [12]. By making poverty, hunger, inequality, and environmental degradation worse, climate change impedes progress on a number of SDGs [13]. Particularly at risk are objectives pertaining to food security, biodiversity, clean water, and energy [12]. Therefore, in order to accomplish these goals, coordinated and climate-resilient measures are crucial.

Against this backdrop, nature-based solutions (NBS) have evolved into a paradigm shift capable of driving significant change. These are measures that maintain, manage, or restore natural ecosystems to solve societal concerns such as climate mitigation, public health, and disaster risk [14,15]. NBS can impact >90 % of the SDGs when paired with developed infrastructure [16]. Despite being a relatively new word, indigenous and local populations have long used the methods it refers to, including ecosystem-based adaptation, conservation agriculture, and green infrastructure [17,18]. NBS offer multiple benefits for people, and nature by reducing exposure to climate hazards and building adaptive capacity [18]. Recently, NBS has shown potentials for mitigating climate driven extreme events and contributing to adaptation and resilience in the context of human settlements [19].

Despite the numerous accomplishments, nature is rapidly degrading with worrisome implications. Based on the recent assessment of nature, existing patterns will impede progress towards 80 % of the assessed SDGs objectives for land, climate, water, hunger, etc. [20]. According to the SDGs report [21], only 15 % of the SDGs have been accomplished since 2015. If NBS can influence over 90 % of all SDGs [16], and we are halfway through the proposed 2030 agenda, why have just 15 % been achieved? The 2030 Agenda will become a relic of a potentially better world if we do not act now.

Previous studies, such as those by Schmidt et al. [22], mapped the areas where NBS can have the greatest local influence on the SDGs by examining how localized NBS may advance the SDGs in the Lahn river landscape in Germany. They employ a case-based, spatial planning method that includes localised indicators, a catalogue of 650 NBS practices, and spatial data analysis. Using a framework-based empirical approach, Andrikopoulou et al. [23] investigated the contribution of fluvial nature-based solutions to nine SDGs and thirty-three SDG targets at the Eddleston Water Project in Scotland. They developed and implemented a four-step method based on case study analysis and indicator-based evaluation to link fluvial flood indicators with specific SDG indicators. With a geographical focus, Hielkema et al. [24] used real implementation data and future climate modelling to evaluate NBS performance throughout Europe, Oceania, and North America. They combined quantitative and qualitative studies across 12 NBS case sites in coastal and riverine regions using a framework for evaluating the impact of climate change. To comprehend how future climatic scenarios can affect NBS effectiveness and SDG outcomes, it uses measures such as the SDG-Sustainable Index Score and the IPCC's Shared Socio-economic Pathways (SSP1–2.6 and SSP5–8.5). However this study will applying a quantitative, bibliometric analysis using Prisma guidelines for document screening from Scopus and Web of Science to assess global research trends, output, and geographic distribution on NBS and SDGs to analyze how much and where research is happening on NBS in relation to the SDGs, identifying gaps and trends in scholarly activity with Statistical comparisons of Scopus and Web of Science databases which are lacking in the previous studies.

Given this background, this study aims to analyze the global trend in terms of yearly scientific publications of documents, continents, and countries' scientific outputs, and nations' collaboration networks. The authors will also highlight some NBS practices that met the SDGs goals. Scopus and WoS are two world-leading and competing citation databases [25], and most studies relies on them [26] and Scholars like Zhu and Liu, [25], Pranckutė, [27], and Okolie et al. [28], have used them in their literature review with varying outputs in terms of the number of publications. Nevertheless, there is still inadequate information on whether there is a statistically significant difference between the two databases. Thus, we would like to test whether there exists some level of significant disparity between Scopus and WoS databases in terms of the number of publications. This study will add to the growing body of knowledge in NBS and SDGs. It will further raise a global concern about the status of SDGS and suggest ways to achieve it based on research findings.

2. Materials for data collection and research methods

Web of Science (WoS) and Scopus are the two bibliographic databases generally accepted as the most comprehensive data sources for various purposes [27]. They are the two world-leading and competing citation databases and are increasingly used in academic papers [25]. WoS formally called "Web of Knowledge" happens to be the first bibliographic database that was founded in 1960 by Eugene Garfield at the "Institute for Scientific Information". WoS was bought by Clarivate Analysis in 2016 and currently belongs to them [29,27]. The WoS integrated Arts and Humanities Citation Index, Social Sciences Citation Index, and Science Citation Index Expanded in 1997 and expanded its coverage gradually [30,31] and are well-known and widely used in academia [32]. WoS is a multidisciplinary and selective database that is composed of a variety of specialized indexes, grouped according to the type of indexed content or by theme. "The main part of WoS platform is Core Collection, which includes six main citation indexes: Science Citation Index Expanded (SCIE); Social Sciences Citation Index (SSCI); Arts & Humanities Citation Index (A&HCI); Conference Proceedings Citation Index (CPCI); Books Citation Index (BKCI); and, established not long ago—Emerging Sources Citation Index (ESCI)" [27].

Scopus is a newcomer that is contesting the WoS's dominant position [25]. Scopus is a similar multidisciplinary and selective database, which was launched by Elsevier in November 2004 [33]. According to Baker et al. [34] and Okolie et al. [35] the Scopus database is one of the leading multidisciplinary databases of peer-reviewed literature in the social sciences and is generally accepted for quantitative analyses. This database is used in most review studies [34,36,37,26]. They publish a broad range of peer-reviewed scientific articles in practically all scientific disciplines, including research papers, conference proceedings, book chapters, and books, among other things [38]. The main difference from WoS is that all Scopus content is accessible with a single subscription without possible modulations. Thus, although Scopus also includes content from many specialized databases, such as Embase, Compendex, World Textile Index, Fluidex, Geobase, Biobase, and Medline [39], their content is integrated and equally accessible [27].

This review study considered various search topics to retrieve scientific documents relating to NBS and SDG research around the globe. The bibliometric method is a good innovation in terms of literature reviews as this method tries to collect every relevant document needed for the research. The bibliometric method uses different databases such as Scopus, WoS, Dimensions among others. It can also be used in all fields of study if there are articles published in that field of study (e.g., health science, engineering, environmental and social sciences, etc.). "Bibliometric analysis is one of the most rigorous practices that has been widely recognized for analyzing the various aspects of published academic materials, including highly cited documents, most influential journals, countries, organizations, and to show a past and present structure of the concerned field through citation, co-authorship, bibliographic coupling, keyword occurrences and cluster analysis" [35,40].

To guarantee a rigorous and systematic approach to identifying, evaluating, selecting, and synthesizing bibliometric data, this study adhered to the PRISMA updated guideline of Page et al. [41], adopted by [42,43,28,44]. Bibliometric analysis were selected for this study due to their unique capacity to provide a reliable and systematic examination of the structural and evolutionary aspects of the chosen research field [45,46]. Unlike the traditional literature reviews, which often rely on subjective selection and interpretation, bibliometrics offer a quantitative and objective approach to analysis large datasets of scholarly publications. According to Sweileh et al. [47], this method pinpoints key research areas, relevant regions, leading institutions, and researchers, aiding in future planning and resources allocation. As opined by Amatebelle et al. [42], researchers can utilize this method to discern the core structure of a field, uncover emerging trends and their temporal development by identifying key research topics and highlighting areas where knowledge is lacking. The PRISMA flow diagram figure S_1 (See supplementary data) and the systematic literature review (SLR) process showing the inclusion and exclusion criteria for this study is shown in the supplementary data.

Table 1 shows the search strings that was used for the two databases. Some inclusion and exclusion rules were considered to ensure quick visibility and retrieval of documents. As expressed by Aleixandre et al. [48], a title-specific search was utilized due to its effectiveness. First, we used published documents (articles, books, book chapters, review articles) rather than notes, errata brief surveys, editorial reviews etc. Furthermore, in terms of source type, we only utilized journals and excluded undefined, trade journals and conference proceedings as some of these papers are not published later. Non-English languages such as Chinese, Portuguese, Hindi, etc, were excluded from the bibliometric review table S_1 (See supplementary data). The process of evaluation papers produced in English serves the objective of making research more accessible to a global audience, hence facilitating wider dissemination and cooperation. Furthermore, it is worth mentioning that significant bibliometric databases like Scopus and WoS are mostly focused on indexing publications writing in English [49].

The systematic literature review process consisted of five phrase, with the initial phrase focusing on establishing the search terminology. Keywords relating to nature-based solutions and the Sustainable Development Goals were utilized, with a total of (n = 351 and 284) published records retrieved, based on previous publications from Web of Science and Scopus databases. The screening stage came next. A total of 214 and 109 articles were deleted from the (n = 351 and 284) respectively that were not eligible to be reviewed at this stage. The reason for removing these documents were due to the fact that most of them are notes, errata brief surveys, editorial reviews/note, undefined, trade journals and conference proceedings and non-English language. At the eligibility stage, a total of (n = 40 and 61) papers were removed after a thorough review since some did not focus on nature-based solutions (NBS) and the Sustainable Development Goals (SDGs). At the merging stage, following the inclusion and exclusion criteria, 114 and 97 documents were accessed and downloaded in bibtex format from WoS and Scopus, respectively. The 114 and 97 documents from the two databases were merged using the syntax “combined<- mergeDbSources(WOS, Scopus, remove.duplicated = *T*)” to have (n = 211) documents. Since various databases frequently index the same journals, it is crucial to identify and eliminate duplicate records. According to Singh et al. [50], there is a high degree of overlap between Web of science and Scopus database. Duplicate removal stage, the authors tried to overcome this challenge by executing the syntax “*M*<-duplicatedMatching(combined, Field = "TI",tol = 0.95)”, see table S_2. A total of 79 duplicated documents were removed and the retained 132 document was further analyzed using biblioshiny interface (Fig. S_1). Statictical Package for Social Sciences (SPSS) version 29 software was used to run the non-parametric test of hypothesis (Mann-Whitney U-test) to test if there was any significant difference from the document accessed from the Scopus and WoS data bases. Statistical package R and Rstudio version 4.3.1 were used to combine, removed duplicate and rewritten in xlsx using the Syntax in table S_2.

Table 1
The used search strings.

Source	*Search strings used*	*Record*
Scopus & WoS	("nature_based solution*" OR "nature-based solution*" AND "Sustainable Development Goal*" OR "SDGs") AND (LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2023)) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re") OR LIMIT-TO (DOCTYPE, "ch")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (PUBSTAGE, "final"))	114 & 97, respectively.

2.1. Research methodology

Statistical analysis has become the hallmark of studies appearing in the leading journals [51], but many publications have been reported to contain serious statistical errors [52–54]. A frequent error is to use statistical tests that assume a normal distribution on data that are skewed. Using small samples for parametric tests is considered erroneous unless a test for normality had been conducted before [54]. In Student’s t-test, the expectations of two populations are compared. The test assumes independent sampling from normal distributions with equal variance. If the assumptions are violated, the use of parametric methods is discouraged, and nonparametric tests such as the two-sample Mann–Whitney U test are recommended instead. Mann-Whitney U test is a non-parametric statistical technique. It is used to analyze differences between the medians of two data sets. It can be used in place of a *t*-test for independent samples in cases where the values within the sample do not follow the normal or t-distribution. In a preliminary test, a specific assumption is checked, the outcome of the pretest then determines which method should be used for assessing the main hypothesis [54].

For the pretest, the authors first apply the analytical method using Shapiro-Francia W’ test for normal data to test the differences in the two databases, p-0.0287 $< \alpha = 0.05$ (Table S_3**)**. Practically, numbers higher than 0.05 are expected to follow a normal distribution, which is not totally true [55]. Unfortunately, the analytical method (Shapiro-Wilk and Kolmogorov-Smirnov tests) has a major drawback [56], which is why more and more attention is being paid to graphical methods. The problem is that the calculated p-value is affected by the size of the sample. Therefore, if you have a very small sample, your p-value may be much larger than 0.05, but if you have a very large sample from the same population, your p-value may be smaller than 0.05 [57]. For robustness check, the authors have to overcome this major drawback by implementing two graphical method (Quantile-quantile plot and histogram frequency distribution. Fig. S_2). It can be fully observed that the quantile-quantile plot is skewed towards the right and histogram frequency distribution does not adhere to the bell-shape normal distribution. Since normality H_O is rejected (p-0.0287 $< \alpha = 0.05$), we made use of the Two-sample Mann Whitney - U test.

2.1.1. Two-sample mann whitney - U test research hypothesis

Ho. There is no significant difference between the Scopus and WoS database with respect to the number of published articles.

H1. There is a significant difference between the Scopus and WoS database with respect to the number of published articles.

The hypotheses stated can be mathematical expressed as:

$$H_0: \; U_s = U_w \text{ OR } H_0: \; U_s - U_w = 0$$

$$H_1: \; U_s \neq U_w \text{ OR } H_1: U_s - U_w \neq 0$$

Since testing this hypothesis involves a value marked with the letter U to formulate the testing criteria and final conclusions, it is also known as the U test (U test). The value of Mann-Whitney U statistic is calculated as:

$$U_s = n_s X n_w + \frac{n_s X (n_s + 1)}{2} - R_1 \tag{1}$$

$$U_w = n_s X n_w + \frac{n_w X (n_w + 1)}{2} - R_2 \tag{2}$$

$$\mu U = \frac{n_s X n_w}{2} \tag{3}$$

$$\sigma U = \sqrt{\frac{n_s X n_w X (n_s + n_w + 1)}{12}} \tag{4}$$

$$Z = \frac{U - \mu U}{\sigma U} \tag{5}$$

Where U_s is the U value calculated from Scopus data base and U_w is the U value calculated from the Web of Science data base, R_1 is the total number of published documents from Scopus data base, R_2 is the overall number of published documents from Web of science data base, n_s is the number of samples from Scopus data base, n_w is the number of samples Web of Science data base, μU is the expected value of U, σU is the standard error of U, Z is the value for calculating the p-value and 1, 2, and 12 are constants.

2.1.2. Integrating nature-based solutions in achieving SDGs

Fig. 1 depicts the conceptual framework that leverages on NBS in achieving SDGs. NBS hold significant promise for addressing climate change while simultaneously advancing several SDGs [18].

This conceptual framework elucidates how NBS can be systematically employed to advance sustainable development [58,59]. NBS contribute to human well-being by providing ecosystem services such as clean water, air, food, and climate regulation. These services directly contribute to the achievement of multiple SDGs, including SDG 3 (Good Health and Well-being), SDG 6 (Clean Water and Sanitation), and SDG 13 (Climate Action) among others [60].

NBS can reduce vulnerability to climate change impacts [61], by reducing GHG emissions and enhancing resilience to climate impacts [62]. Utilizing wetlands for natural water filtration and flood mitigation contributes to SDG 6 (Clean Water and Sanitation) and SDG 13 (Climate Action) respectively. Sustainable agricultural practices can improve soil health and water availability [63]. Using ecosystems like mangroves and peatlands helps for carbon sequestration. Employing green belts, urban forests, and wetlands to mitigate the impact of extreme weather events.

NBS promotes biodiversity by protecting, restoring, and sustainably managing ecosystems. This aligns with SDG 15 (Life on Land) and SDG 14 (Life Below Water) while supporting goals related to poverty alleviation (SDG 1) and hunger reduction (SDG 2). Implementing agroforestry and polyculture to enhance soil health and crop resilience contributes to SDG 2 (Zero Hunger). Agroforestry practices that integrate trees into agricultural landscapes contribute to SDG 2 (Zero Hunger) by boosting food security and nutrition [63]. NBS can as well increase agricultural productivity and create jobs [61]. NBS like reforestation and afforestation supports SDG (7 & 9) by integrating different plant species which produces fuelwood that decreases the dependency on fossil fuels and creates financial benefits through the development of infrastructure and industrial systems, respectively [60]. Furthermore, mangrove restoration and coral reef protection as NBS for coastal defense illustrate the potential to achieve SDG 14 (Life Below Water) while protecting livelihoods and promoting sustainable tourism (SDG 8).

NBS such as Urban Green Infrastructure (green roofs, urban forests, and wetlands) contribute to SDG 11 (Sustainable Cities and Communities) by enhancing resilience to climate impacts and improving urban living conditions. Urban Green Spaces like creating parks and gardens to

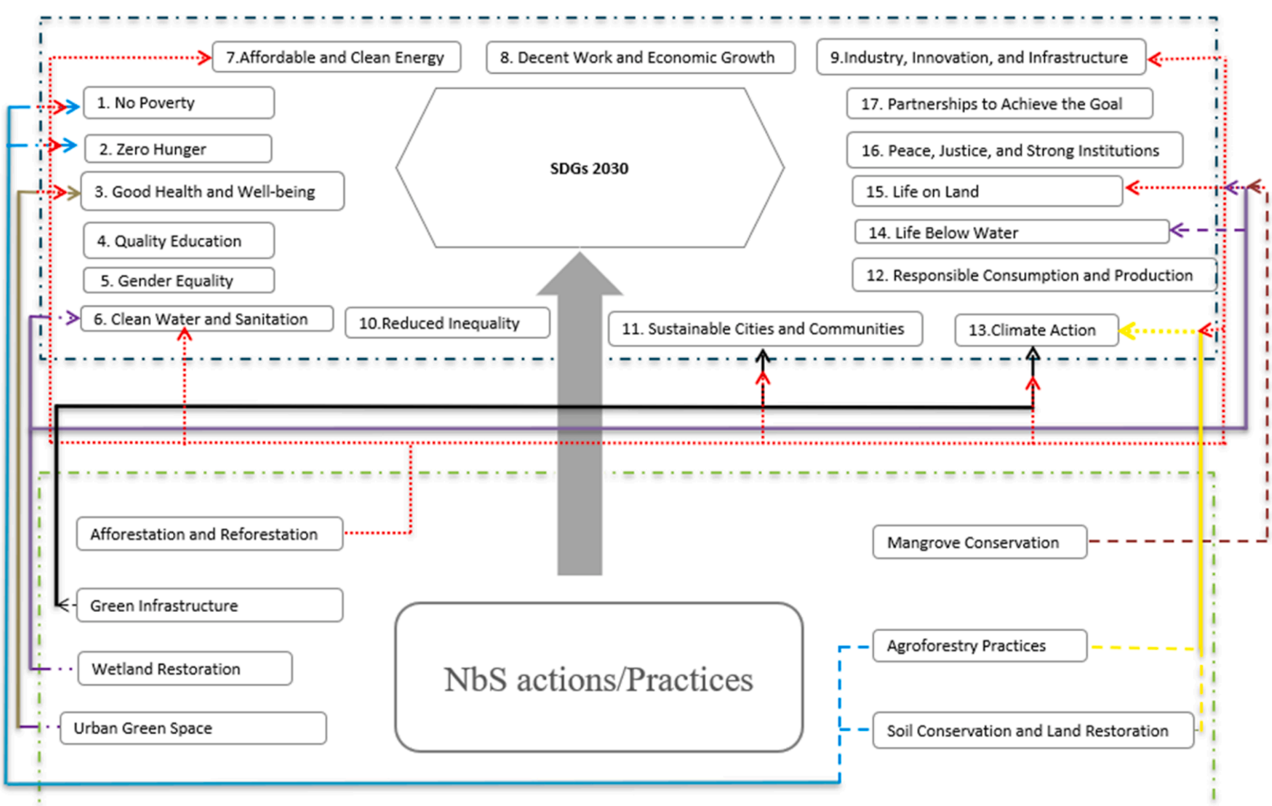

Fig. 1. Conceptual outline.

improve air quality and community well-being contributing to SDG 3 (Good Health and Well-being). It promotes natural environments for mental health and recreational activities.

3. Results and discussions

Table 2 reports on the analysis of 132 documents coming from articles, books, book chapters, and reviewed documents (90, 19, and 23) respectively, that were published in Scopus and WoS during the research period. Between 2017 and 2023, documents that were published in Scopus and WoS concerning NBS, and SDGs had an annual growth rate of 84 %. The annual growth rate of 84 % in the context of NBS & SDGs suggests that NBS are increasingly recognized for their potential to address various SDG targets, which include social, environmental, and economic aspects. NBS can influence up to 79 % of SDGs targets across all the 17 goals [16], emphasizing their fundamental roles in promoting sustainable development. This higher growth rate also indicates a growing awareness and dedication amongst stakeholders to apply NBS as helpful tactics for achieving the SDGs, primarily in global challenges like biodiversity loss and climate change. On average, 18 citations per document were recorded in the years under review. Furthermore, the study had 518 authors, with the exception of eleven who published alone. All 121 authors were part of a co-authored publication. Collaboration in research is believed to benefit both the researchers and organizations involved and increase the excellency of the study, leading to higher number of scholars publication and more citations [28]. Fig. 2 and table S_4 shows the yearly scientific output over the study period. The documents retrieved from databases show an increasing trend in publication. The scientific production changed over time, reaching its peak in 2022 with 35.61 % (47/132) of the total study output. Advancing from 2022 was a slight decrease in output of about 6.07 % in 2023 (29/132), representing 29.54 % of the total output. According to Wang et al. [64], the number of scientific publications demonstrate the quality and significance of the study.

Sunburst chart Fig. 3a shows the continents percentage distribution alongside the very contributing nations. The European continent dominates the chart with about 55 percent of the total publications. Following the European is the Asia continent which contributed 21 percent. Both the Southern America and Northern America contributed 9 percent of the total publications. Oceania and Africa contributed the least. Europe is the clear leader in terms of research productivity, contributing more than half of the total publications (55) percent. This implies a strong focus on research in Europe or favorable condition for academic work relating to NBS_SDGs for the year under review. Africa has minimal contribution, with only 3 percent of total publications, suggesting that this continent may face challenges related to research infrastructure, funding, or access to academic resources. This result aligns with the findings of Okolie and Ogundeji, [37], who reported that only a small number of documents originated from Africa in their study. African continents with 3 percent of publication may need increased funding, improved research infrastructure, and access to collaborations to boost their output. Initiatives like partnership, research grants, and scholarships with African universities could support this growth. Given that many African nations are among the most climate-vulnerable and stand to gain much from context-specific NBS measures, this under-representation may result in significant information gaps. This tendency emphasises how vital it is to encourage inclusive worldwide research participation for future studies. By increasing research funding, training opportunities, academic partnerships, and co-authorship networks, initiatives should give priority to growing capacity in under-represented countries, like Africa. Africa is highlighted due to its higher population, current development issues, greater climatic vulnerability, and geopolitical significance, even though Oceania and Africa both contributed 3 % each. To address Africa's under-representation in NBS-SDG research, critical knowledge, equity, and impact gaps must be filled where the stakes are highest. More equal knowledge generation will result, and policy decisions that are pertinent to the entire world will be better informed.

Sunburst chart Fig. 3b and Table 3 show the first ten most productive nations. Table 3 also showcases the percentage of contributions of the countries and the decisions that were made based on a systematic approach. According to the systematic approach, the data set was split into three groups (High, Medium, and Low). In the first group (high productivity group), India leads with the highest number of documents (13), accounting for 9.8 percent of the total publications, marked as "High" in the decision column. Italy followed closely with (12) documents at 9.1 percent and is also marked "high". The United Kingdom and Netherlands both produce 10 documents, each accounting for 7.6 percent of total publications also rated high for their productivity. In the second group (medium productivity group), Brazil produced 10 documents (6.8) percent and is marked as "medium" in decision-making, suggesting good but not top-tier productivity. Germany, USA, and Spain each have 7 documents (5.3) percent of the total publication and are all marked as "Medium". Each percentage indicates the proportion of total publication contributed by a specific country relative to all countries listed in the table. Korea is in the Low group with 6 documents, contributing 4.5 percent to the total. Portugal has the lowest number of documents in the table with 4 documents (3.0), also marked low for productivity. Countries like India, and Italy stand out with the highest document output, making them strong contributors in terms of research productivity. The "High" decision indicates a favorable standing in research contribution. The noticeable lack of African countries from NBS-SDG research calls for a global expansion of scientific engagement through tailored capacity-building programs, academic alliances, and expanded financing possibilities for under-represented regions, especially Africa. To close this gap, donor agencies, nonprofit organizations, and national governments must increase investment in scientific infrastructure and offer scholarships and grants to researchers from low- and middle-income countries. Promoting collaborative research networks between high-output countries and underrepresented regions can help to transfer knowledge and boost global research capacity. Finally, governments should create inclusive scientific policies incorporating varied local contexts and knowledge systems into global sustainability talks to promote locally appropriate, socially acceptable, and ecologically effective NBS.

Fig. 4 shows the first ten most relevant affiliated universities. Six out of the ten affiliated universities (Stockholm University, Newcastle university, university of surrey, Aarhus University, University of Salento, Gasgow Caledonian University) are from Europe. The preponderance of European Universities suggests that research in this area (NBS_SDGs) is heavily concentrated in Europe. This could indicate a strong academic expertise, funding availability, and research infrastructure in these regions. Two (Engineer research and development Center, University of Toronto Scarborough) are from North America. South America and Asia each have only one affiliated university (ESPOL Polytechnic University in Ecuador & Beijing Normal University) respectively. Africa and Oceania have no affiliated universities, which suggests a lack of formal university partnerships or research affiliations in this area. This

Table 2
A description of the data.

Description	*Outcome*
Duration	2017:2023
Documents	132
article	90
Book, book chapters	19
review	23
Annual Growth Rate %	84 %
Average citations per document	18
Authors	518
Single-authored documents	11
Co-Authors document	121

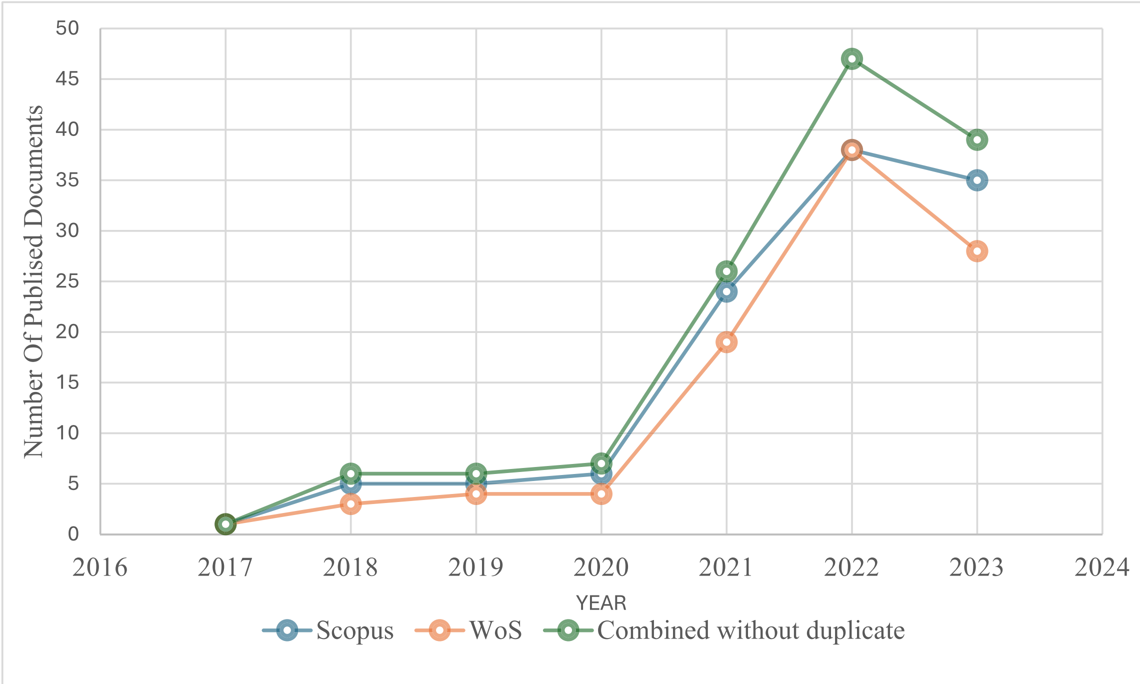

Fig. 2. Annual scientific production of SDGs & NBS for the period under review.

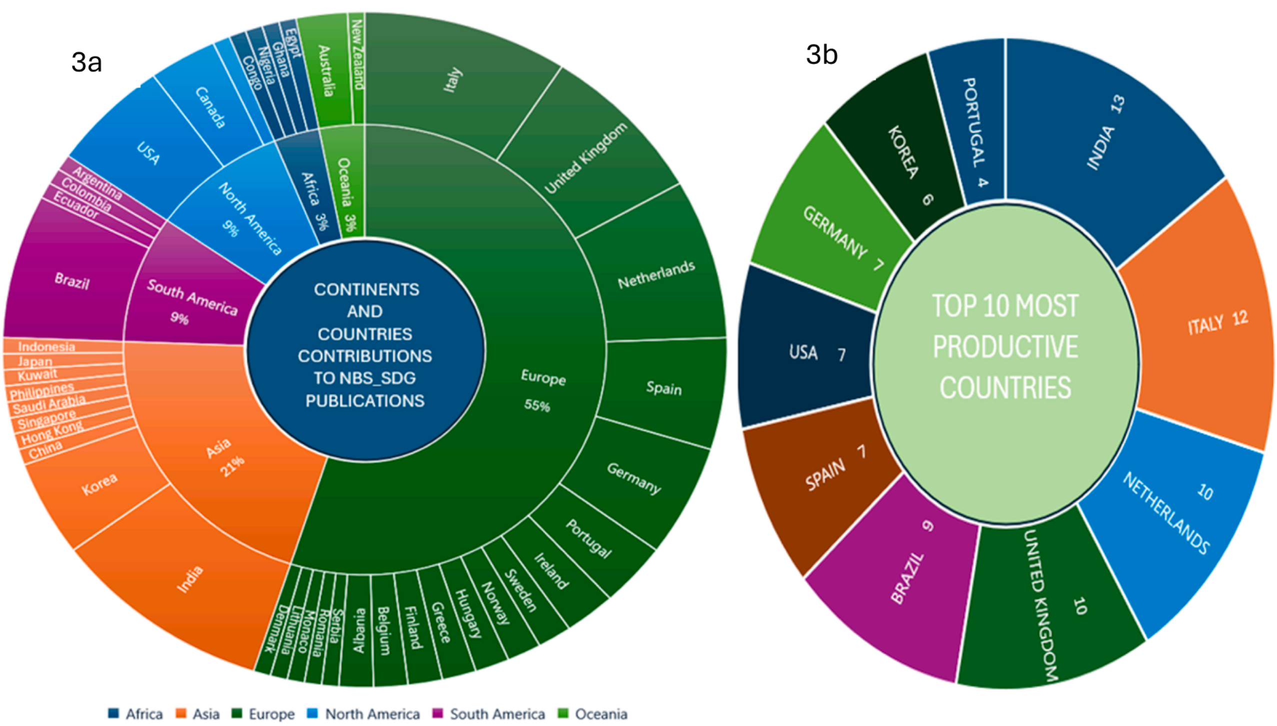

Fig. 3. a & 3b: Sunburst chart showing the continents percentage distribution and the first ten most productive nations.

indicates that these continents may not be strongly contributing to global academic output or receiving adequate recognitions. Allocating more funding to research institutes in underrepresented regions like Africa can strengthen their research capacity and encourage more participation in the field [65]. The preponderance of institutions from a few number of regions may result in skewed research agendas that ignore the particular requirements and ecological difficulties of under-represented regions, particularly Africa and Oceania, while reflecting the objectives, settings, and experiences of those locations. This hinders the creation of locally relevant NBS, which are crucial for the advancement of the SDGs worldwide. This pattern emphasises the necessity of funding the development of research capacity in under-represented areas in order to encourage greater geographic inclusion. Initiatives for knowledge sharing, capacity building, and cooperative research projects including African, Oceanian, and other under-represented universities should be supported by international

Table 3
Top ten most productive nations.

Countries	*Number of documents*	*Percentage*	*Decision*
India	13	9.8	High
Italy	12	9.1	High
United Kingdom	10	7.6	High
Netherlands	10	7.6	High
Brazil	9	6.8	Medium
Germany	7	5.3	Medium
USA	7	5.3	Medium
Spain	7	5.3	Medium
Korea	6	4.5	Low
Portugal	4	3.0	Low
Total	85 out of 132	64.4 out of (100 %)	

A systematic approach was used to decide which country published (High, Medium or Low) in terms of the number of published documents in NBS_SDGs for the period under review. (See supplementary data for further explanation on how the decisions were made).

funding agencies, governments, and institutions.

Fig. 5 demonstrates the nations collaboration network in two major clusters, the lilac purple consisting of eight nodes and the pistachio green consisting of five nodes. The more frequently the collaboration tend to co-occur, the more colorful the clusters become. A cluster is formed by nations of a similar colour [28]. United Kingdom, Italy, and Spain appears to be the central nodes in the network with many connections to other nations which suggests a Signiant role in the international collaboration. They also appear to be a regional cluster such as in Europe (Portugal, Ireland, Norway, Denmark, Netherlands, Germany, Sweden, United Kingdom, Italy & Spain) and in North America with (Canada & USA). We found that nations in Europe have deep internal collaborations than those of other nations and this finding aligns with the study of Gui et al., [66]. The strength of the connections indicates the level of research activity. Furthermore, there exist a strong bilateral relationship between certain nations like the USA and United Kingdom, Italy and Spain. We also have emerging connections between nations in different regions such as North America and China, or Europe and India indicating emerging patterns of international collaborations. The network visualizes the flow of knowledge and ideas between nations, and strong connections might indicate a high degree of information sharing and collaboration. Expanding collaborative networks to cover under-represented locations should be the main goal of future research initiatives. Diversifying the global research ecosystem and fostering more inclusive knowledge production can be achieved by supporting collaborative research initiatives, co-authorships, and institutional partnerships.

NBS hold significant promise for addressing climate change while simultaneously addressing several SDGs as depicted in Fig. 6. According to Al-Batsh et al. [67], rainwater harvesting as a sustainable solution to water scarcity and pollution, address SDG 6 by providing an additional domestic water source that meets basic human needs. The result shows that most of the rainwater samples were within Environment Protection Agency and World Health Organization guidelines for chemical parameters, thus linking to SDG 3. Similarly, Almazroui et al. [68] highlights the potential of rainwater harvesting (NBS) systems to reduce domestic water insecurity, even in arid climates, supporting the SDG 6, and further proposed a model for water harvesting which contributes to SDG13. Ambe & Obeten [69], emphasized on NBS (sustainable land use practices, biodiversity conservation, ecosystem restoration) all of which are key components of SDG 15. Reforestation, afforestation, and environmental education, proposed strategies aim to address the impairment of land productivity and biodiversity contributing to the objectives of SDG 15, which emphasize the need to prevent, halt, and reverse the degradation of ecosystems worldwide. Policymakers must acknowledge and incorporate NBS as a fundamental approach in national development plans, climate change adaptation and mitigation plans, and sectoral policies pertaining to water, agriculture, land use, and urban development, according to the evidence provided above.

Koutika et al. [70] highlighted the potentials of NBS (agroforestry, reforestation, afforestation), to address multiple challenges. These practices have been employed to enhance wood energy supply, combat food insecurity, restore degraded lands, and support climate change mitigation and adaptation. In the context of the Congolese coastal plains, sustainable management of forest ecosystem has led to improved soil health and increased tree biomass. These advancements have the potential to boost wood and fuelwood energy production, strengthen climate resilience, enhance biodiversity restore degraded lands, and improves food security. These outcomes align with SDGs (1,2,3,4,6,7, 12,13,15). Aligning with SDG (2, 13, & 15) organic farming (green manures, crop residues, animal manures, crop rotation etc.) contribute to sustainable development by prioritizing soil health and productivity, reducing GHGs emission to meet present food demand in an environmentally conscientious manner. Adopting organic farming practices can strengthen community ties, support local food system, and preserve traditional and cultural agricultural methods which aligns with SDG11 [71]. Organic farming can enhance economic opportunity for farmers by lifting them out of poverty when they maximize the use of locally derived renewable resources SDG1

Afforestation and reforestation projects in Korea have improved local biodiversity, stability, and soil quality, improving ecosystem resilience by promoting plant productivity and complex interactions within the

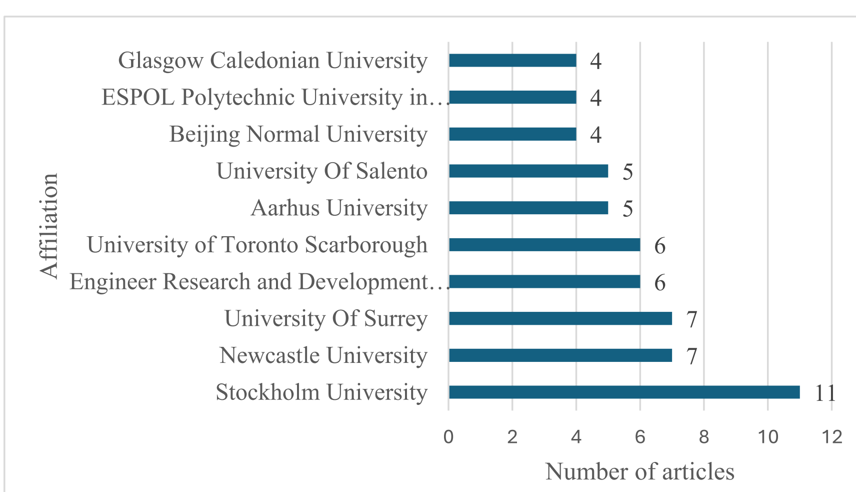

Fig. 4. First ten most relevant affiliation.

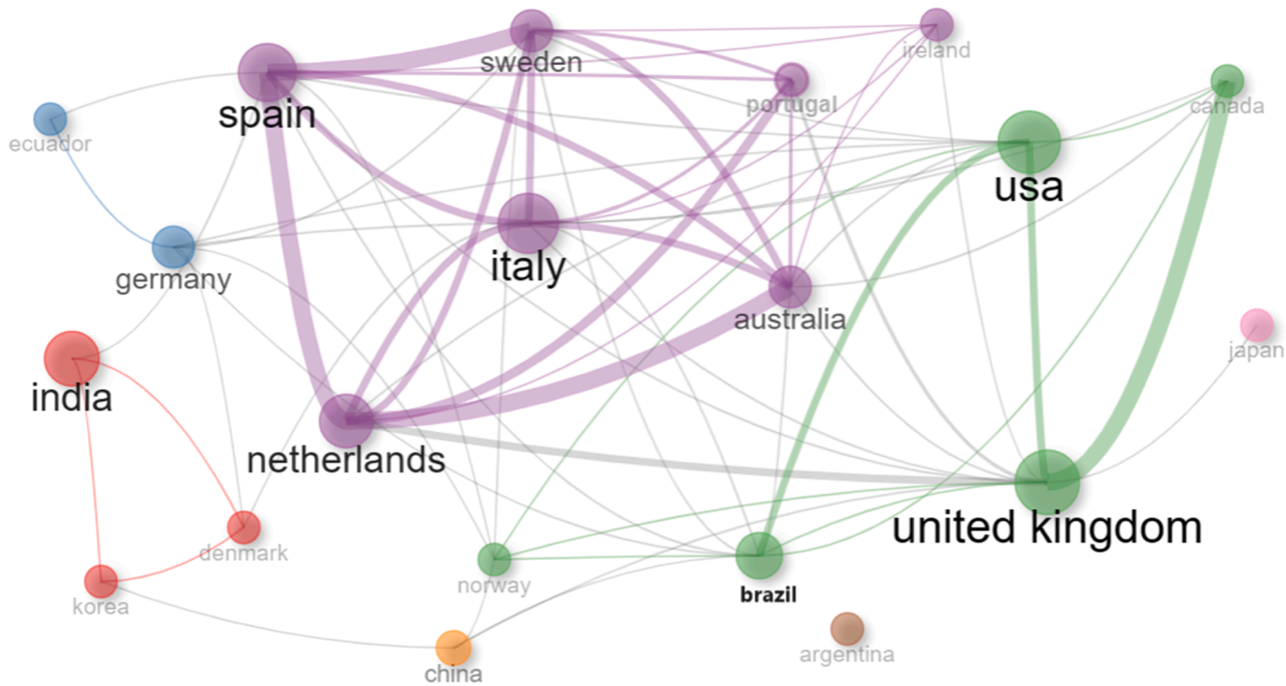

Fig. 5. Collaboration network of nations.

Fig. 6. More than two third (> 2/3) of SDGS meet by NBS.

environment. These help to decrease risk from natural hazards and human activities [72,73]. Carbon sequestration supports SDG 13 by decreasing GHG emissions, while afforestation supports SGD 15 by conserving biodiversity and terrestrial ecosystems. These projects exhibited socio-economic sustainability by employing residents in several activities such as agroforestry, cultivation, and collection of seeds which contribute to SDG (8, 2, & 1), respectively. Furthermore, the reduction in dust storms improved the quality of air and conservation of soil, benefiting both the ecosystem, and communities, supporting SDG (11 & 3) that addresses sustainable communities, and human health. Similarly, the project created financial benefits by integrating different plant species which contributed to SDG (9 & 12) through the development of infrastructure and industrial systems that connected production, distribution, and consumption of forest resources. Fuelwood production decreases the dependency on fossil fuels thereby improving SDG (7), and increased water yield in forest soil contributed to SDG (6) which centers on clean water and sanitation [60].

Utilization of NbS and "scientifically derived marine fishery advisories (MFAs)" as stated by Santhanam & Kundu, [74] can be useful for achieving SDG 14. In line with the findings of Yao et al. [75], ecosystem restoration enhanced geographical water shortages, desertification and vegetation coverage, which contributed to SDG6, SDG13, and SDG15, It equally, enhanced the food security and income level of members through technical innovation and intensive agriculture, hence facilitating the realisation of SDG2 and SDG1.

Potential barriers to adoption of NBS to achieve the SDGs includes but not limited to lack of awareness, insufficient technical knowledge, and limited financial resources [76,59]. People need more understanding of the benefits and methodologies of NBS, as well as sufficient technical knowledge and expertise in implementing NBS, with capital to fund the initial NBS investments. This conceptual framework provides a roadmap for integrating NBS into sustainable development strategies, ensuring that the world moves closer to achieving the SDGs by 2030. There are different barriers and enablers to NBS implementation. Governance and local policies steer their adoption and can either hinder or potentiate them. Bureaucracy, lack of financing models, private land ownership, lack of social acceptance, lack of knowledge, awareness of technical levels and benefits, lack of cooperation between sectors, perceived costs, social inequalities, institutional fragmentation and inadequate regulations are regarded as the main barriers to NBS implementation [77–80]. Contrarily, recognized enablers include easy access to policies, good communication, stakeholder engagement, supportive regulations, inclusion of NBS in plans, guidelines and strategies, pilot projects, awareness marketing, involvement of different institutions, financial incentives, and monitoring and evaluation [77,78, 81]. In fact, policy drivers, such as financial incentives, collaboration and communication are acknowledged as major NBS enable [79,81].

Data about the means, medians, and standard deviations of the data base used are shown in Fig. 7 and Table S_5. They show that on average, the values of the central tendency including the standard deviations of the number of published articles were higher in Scopus ($M = 16.29$, Mdn = 6, SD = 15.68) than in Web of science ($M = 13$, Mdn = 4, SD = 14.645). Data presented in Tables 4 and 5, were the results of the hypothesis using the Mann-Whitney U test. As the sample included <30 observations the normal approximation was calculated, because the exact distribution is more accurate for small sample sizes. The sample "Mean Rank (MR) and sum of ranks (SR)" from Scopus database (MR = 8.29, SR = 58) reported higher number of documents than the sample Mean Rank (MR) and sum of ranks (SR) from Web of Science database (MR = 6.71, SR = 47). Consistent with a number of earlier studies (e.g., [27,82–84]), our findings demonstrate that Scopus has a wider coverage than Web of Science. The advantage of taking the sum of rank rather than the difference in mean is that the data need not normally distributed. This pattern implies that Scopus might provide more extensive and varied coverage of scientific papers for future research, especially in cutting-edge domains like multidisciplinary sustainability studies and Nature-Based Solutions (NBS). In order to prevent missing significant studies, particularly those published in regional journals, newer journals, or fields that are expanding quickly, researchers who are seeking thorough literature reviews or meta-analyses may think about utilising Scopus in addition to WoS. In order to preserve accuracy and completeness, future bibliometric analyses, systematic reviews, and research evaluations will also need to recognise and incorporate data from Scopus due to its growing popularity. Table 5 presents data on the calculated exact values and the approximately calculated statistical significance of differences between the Scopus and Web of science data bases. In this research, the exact value was 0.535[b]. The amount of its probability that something happened by accident is not equal to or <0.05. The same was shown by the Mann-Whitney U value = 19, and 2-tailed statistical significance of differences ($P = 0.480$). The research results, therefore, showed no statistically significant differences in the number of published articles from Scopus and web of science data bases.

Table 4
No of published articles (Ranks).

	Data base sources	*N*	*Mean Rank*	*Sum of Ranks*
No of published articles	Scopus	7	8.29	58.00
	WoS	7	6.71	47.00
	Total	14		

Mean Rank = MR, Sum of Rank = SR.

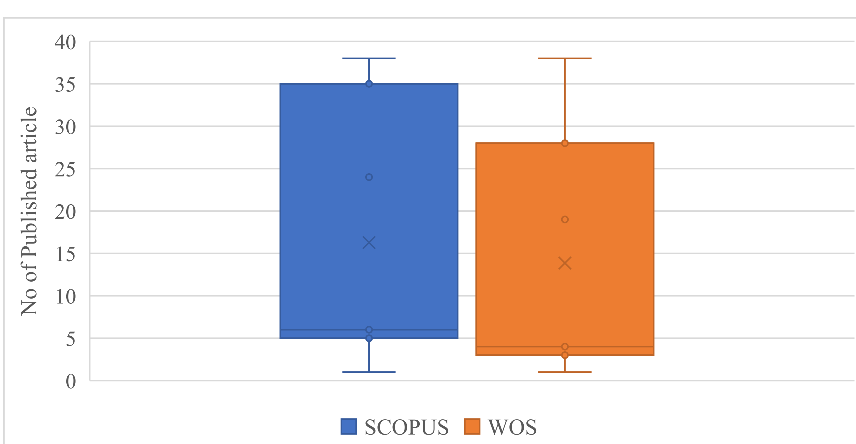

Fig. 7. Boxplot (means, medians, and standard deviations).

Table 5
Number of published articles (Test Statistics (a)).

	Number of published articles
Mann-Whitney U	19.000
Wilcoxon W	47.000
Z	−0.706
Asymp. Sig. (2-tailed)	0.480
Exact Sig. [2*(1-tailed Sig.)]	0.535[b]

a. Grouping Variable: Data base source: b. not corrected for ties.

Thus, the authors fail to reject the null hypothesis and conclude that there is insufficient evidence to claim a significant difference between the Number of published articles in Scopus and WoS data bases.

4. Conclusion and policy recommendations

The United Nations General Assembly established the SDGs in September 2015, which will run between 2016 – 2030. But as of the 2023 SDGs report, only 15 percent of the goals have been met. This is specially problematic given that the United Nations Environmental Programme 2023 has stated that NBS might influence over 90 percent of the SDGs. Interestingly, there has been some rising global interest in NBS ability to provide many co-benefits that can help with a variety of social concerns including many of the SDGs. The implementation of NBS offers a comprehensive and adaptable roadmap to achieving many SDGs. By using natural processes, NBS provide scalable and sustainable solutions to global concerns, building a resilient and inclusive future.

The articles found from these databases demonstrate an upward trend in publications over time (1–39), signifying the importance of NBS in achieving the SDGs. However, the study output fluctuated throughout time, climaxing in 2022 with 35.6 %. The European continent dominates the sunburst chart with about 55 percent of the total publications. Followed by the Asia continent, Southern America, Northern America, while Oceania and Africa contributed the least. Scientific output relating to SDGs & SDGs is heavily concentrated in Europe with about 55 percent, while Africa have significantly less contribution of about 3 percent. This implies that the knowledge and research necessary for effective implementation NBS to meet SDGs in the region most affected by environmental challenges are not evenly distributed.

India, Italy, United Kingdom, and Netherlands were ranked high in the decision column with respect to the most productive nations, followed by Brazil, Germany, USA, and Spain that where ranked to be medium while Korea and Portugal were ranked low according to the dataset. On the first ten affiliated universities, six came from Europe, two from North America, one each from South America and Asia, while none came from Oceania and Africa. NBS can indeed impact the majority of the SDGs, but practical implementation has lagged due to funding constraints, lack of policy integration, and technical barriers in some regions. Many developing nations, especially in Africa, lack the financial resources and institutional support needed to effectively implement NBS at scale. Nations with greater scientific output like India, Italy, and United Kingdom, have generated the most of NBS-SDGs related document. However, the collaboration network between nations remains limited, meaning that best practices and technological advancement are not being widely shared, particularly in underrepresented regions

More than two-thirds (2/3) of the SDGs can be achieved through NBS. Rainwater harvesting as a sustainable solution to water scarcity and pollution, addresses SDG6 by providing an additional domestic water source that meets basic human needs. Sustainable land use practices, biodiversity conservation, and ecosystem restoration all of which are key components of SDG 15 are addressed by NBS. NBS (agroforestry, reforestation, afforestation), addresses multiple challenges. These practices have been employed to enhance wood energy supply, combat food insecurity, restore degraded lands, and support climate change mitigation and adaptation. Sustainable management of forest ecosystem has led to improved soil health and increased tree biomass. These advancements have the potential to boost wood and fuelwood energy production, strengthen climate resilience, enhance biodiversity restore degraded lands, and improves food security. These outcomes align with SDGs (1,2,3,4,6,7,12,13,15). Adopting NBS (organic farming) practices can strengthen community ties, support local food system, and preserve traditional and cultural agricultural methods which aligns with SDG11. Furthermore, Agroforestry and reforestation project in Korea contribute to SDG (1, 2, 3, 8, 9, 11, 12, 13, 15).

This research used of the Mann-Whitney U test, as an alternative to the *t*-test. Unlike the *t*-test which compares the mean values of two groups, the Mann-Whitney U test compares their medians. This statistical technique examined the differences between two independent groups on a continuous scale. It is therefore considered a specific statistical technique that is significantly different from other nonparametric tests, primarily from the Friedman test and Wilcoxon rank test. According to the result from the Mann-Whitney U test, the authors uphold the null hypothesis that there is no significant difference between the Scopus and WoS databases with respect to the number of published articles.

This study critically highlights the notable geographic imbalance, especially the under-representation of African countries, in research linking Nature-Based Solutions (NBS) and the Sustainable Development Goals (SDGs), going beyond standard analyses of publication trends and citations. The study promotes improved inclusivity and worldwide research equality by drawing attention to these systemic problems with infrastructure, funding, and accessibility in research. Additionally, by showing that there is no discernible difference in the number of publications between Scopus and Web of Science, it provides methodological guidelines and encourages scholars to use both for better bibliometric practices and more thorough literature assessments. This analysis reinforces the case for mainstreaming NBS throughout sustainability planning and climate action as a multi-benefit solution rather than a limited sectoral tool, so establishing it as a central and transformative strategy that can contribute to most of the SDGs. Based on the conclusions, the authors make the following policy-based recommendations.

i. Given that most of the studies on SDGs and NBS are conducted by institutions in developed nations, there is a need to encourage collaboration and give research funding opportunities in emerging economies. This can contribute to a more diversified representation of research viewpoints and experiences.
ii. As a development priority, governments and international organisations ought to make investments in regional research capability. Diversifying research contributions and improving NBS's local effectiveness and global representation can be achieved through policies that promote South-South and North-South collaboration, facilitate open-access data sharing, and include indigenous and local knowledge into NBS planning.
iii. There is a need to facilitate information exchange and capacity-building programs to improve research capacities in emerging economies. This might include collaborations between institutions in industrialized and developing nations, as well as training seminars and mentorship programs, since NBS can influence over 90 percent of SDGs.
iv. Researchers should consider using both the Scopus and Web of Science databases to perform complete literature evaluations. While the number of published articles may be somewhat larger in Scopus, the absence of statistically significant variation shows that both databases provide equivalent coverage.
v. When doing research or systematic reviews, it is recommended that findings be validated across several databases to verify that the results are strong and reliable. This can assist in reducing any biases caused by depending entirely on one database. Depending

on the study subject and aims, specific databases may provide distinct benefits or restrictions that should be considered.

Finally, the results offered and interpretations provided in this research are based on the sample of literature obtained using Scopus and WoS databases. Future researchers may include thematic mapping in their research and other databases in their study like Dimensions, ScienceDirect, etc.

CRediT authorship contribution statement

Collins C. Okolie: Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **Gideon Danso-Abbeam:** Writing – review & editing, Writing – original draft. **Abiodun A. Ogundeji:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Formal analysis. **Solomon T. Owolabi:** Writing – review & editing, Methodology. **Olivia Kunguma:** Writing – review & editing, Visualization.

Declaration of competing interest

The authors write to declare their interests in relation to the submission of Achieving the Sustainable Development Goals through nature-based solutions amidst Climate change. Evidence from Scopus and Web of Science (WoS) databases to Sustainable Futures.

The authors hereby declare the following:

1. The authors declare no financial interests or affiliations relevant to the research presented in the manuscript and have not received any financial support or sponsorship from any organization.

2. The authors declare no personal interests that may influence the research presented in the manuscript and have no affiliations with any organizations or individuals with a stake in the findings.

3. The authors assure the objectivity, integrity, and impartiality of their research, stating they conducted it with honesty, integrity, and transparency, adhering to ethical standards.

4. The author pledges to promptly disclose any potential conflicts of interest during or after peer review or publication to the editorial board of the Journal of Cleaner Production.

We certify that the information provided in this Declaration of Interest Statement is true, accurate, and complete to the best of our knowledge and belief.

Thank you for considering our submission, and we appreciate your attention to this matter.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.sftr.2025.100855.

Data availability

Data will be made available on request.

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