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GOVERNING NATURE-BASED SOLUTIONS IN DEVELOPING-COUNTRY CITIES: A BIBLIOMETRIC MAPPING OF URBAN SUSTAINABILITY, INSTITUTIONAL CAPACITY AND CLIMATE RESILIENCE

Adil Adrees[1], Khiza Sohail[2], Dr. Mohi Ud Din[3] & Mohammad Adil Khushi[4]

[1]Hailey College of Commerce, Punjab University, Lahore. Pakistan. Email: adiladrees786@gmail.com , ORCID: https://orcid.org/0009-0006-1825-0050

[2,3,4]Beaconhouse International College, Lahore. Pakistan. Email: mohi.uddin@bic.edu.pk , ORCID: https://orcid.org/0000-0003-2704-7020 . khiza.sohail@bic.edu.pk . mohammad.adil.97524@bic.edu.pk

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ABSTRACT

Nature-Based Solutions (NbS) have emerged as a critical instrument for advancing urban sustainability and climate resilience, particularly in developing countries where rapid economic-driven urbanization intensifies exposure to climate risks. There is little theoretical coherence and well-organized knowledge regarding patterns of collaboration. The current paper aims at filling this gap by conducting a high-quality bibliometric systematic literature review (B-SLR) of 1,260 articles included in the Scopus database since 2006. The paper uses performance analysis, science- mapping methods, with the help of Bibliometrics package and VOS viewer, to analyze the results of scientific production, journals and sources impact, most active authors and institutions, citation patterns, collaboration, co-occurring keywords and thematic development. The findings show that publication activity remained modest from 2006 to 2013, accelerated after 2015 and surged markedly following global climate policy shifts, including the adoption of the Sustainable Development Goals, post-COVID urban recovery and a renewed focus on sustainable development. The findings also show major governance biases between the institutions of the developed and developing countries with the knowledge creation being disproportionately generative in the Global North due to the asymmetries in the institutional capacity and bringing implications of the lack of transferability of NbS policies in various urban settings. The study provides a critical mapping of the intellectual framework and development of the NbS research in the past 20 years, which enables both scholars, policymakers and practitioners interested in developing NbS strategies to achieve sustainable and climate-resilient urban development.

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Corresponding Author Dr. Mohi Ud Din

Email: mohi.uddin@bic.edu.pk

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Introduction

Bibliometric analysis combines various frameworks, tools and quantitative methods to analyze and assess scholarly publications in citation-based measures in order to allow a researcher to investigate the intellectual organization, development and scientific influence of a certain area of research (Akhavan et al., 2016). In recent years, bibliometric methods have gained growing popularity as a way of mapping the new research areas, to discover the powerful journals and authors and find out the trends of theme development in different fields. There is an increasing access to big-scale citation databases which further increases the scale of reliability of bibliometric studies.

Elsevier has created Scopus, which has become one of the most extensive abstract and citation databases and has allowed massive bibliometric studies on a wide range of academic fields such as urban studies and sustainability research, environmental sciences, social sciences and engineering (Gaviria-Marin et al., 2019). Scopus is an index of peer-reviewed journals, conference and books, and is so extensively used in the analysis of scientific publications, sources of documents, countries, institutions and author partnerships (Leyva-Hernández, Arango-Ramírez, Gaviria-Marin, et al., 2024). The existence of structured bibliographic metadata in Scopus allows conducting systematic analysis of changes in publications, citation and collaboration patterns both at the national and international levels (Haddaway et al., 2022).

In the last few years, Nature-Based Solutions (NbS) have become increasingly significant in the global sphere as a strategic solution to the problem of urban sustainability and climate resilience, especially in the context of developing nations where the rapid process of urbanization, environmental degradation, and climate vulnerability collide (Mosisa et al., 2025; ud Din, 2023). This increased topicality has triggered a significant increase in the empirical research on NbS in areas like urban planning, environmental management, climate adaptation, and sustainable development (Castelo et al., 2023). Bibliometric analysis has been proposed as a powerful methodological tool in the systematizing assessment of research trends.

Development of bibliographic databases and tools to analyse them has also enabled conducting large-scale assessments of scientific output, citation impact, and patterns in international collaboration (Vazin et al., 2024). Some of the past studies have employed performance analysis and science-Mapping techniques to evaluate the quantity of publication, citation patterns, co-occurrence of keywords, and co-authorship networks and therefore showed the intellectual organization and sharing of knowledge in the fast-changing research (Liu et al., 2023). The recent empirical literature suggests a current academic agreement that NbS can effectively contribute to the positive urban climate change, environmental risks mitigation and sustainable urban change, which implies the necessity of systematic bibliometric investigation to trace the development, organization, and further progress of NbS studies in developing economies (Silveira et al., 2025).

In addition to bibliometric methods, systematic review, meta-analyses and case-based appraisals have also been used in the past to examine the emerging trends on NbS and climate resilience research (Felicioni et al., 2025). Green and blue infrastructure relates to improving urban climatic conditions, and Jansson and Schneider (2022) used a comparative case study design to analyze NbS governance systems in developing nations (Zhang et al., 2025). Narrow empirical scopes have also been used in other studies that have specified NbS interventions: urban forests, wetlands, green roofs and coastal ecosystems (Vierikko et al., 2022). Despite the fact that these studies provide more insight into the applications of NbS, some researchers claim that theoretical and policy underpinnings of NbS research are relatively undeveloped and fragmented. Seddon et al. (2020) state that a number of NbS studies are practice-based and do not incorporate wider urban governance and sustainability systems (Seddon et al., 2020).

In addition to environmental planning, NbS governance is indicative of wider political and institutional processes that influence the process of urban sustainability. The determination of land use, investment in infrastructural development, and environmental planning is entrenched in the relationships of power between the municipalities, national governments, international organizations and individuals. These governance practices do not only affect the implementation of NbS, but also the generation and spread of knowledge within and across regions. Under the circumstance of developing nations, these dynamics tend to lead to uneven knowledge flows and the lack of institutional capacity, and the question arises as to whose knowledge is prioritized and the transfer and adaptation of NbS policies to be applied in a variety of urban environments (ud Din & Khan, 2025).

Since NbS has matured as a unique but interdisciplinary science, expert journals like Journal of Cleaner Production, Cities and Applied Geography have been instrumental in the development of academic discussion of urban sustainability and resilience to climatic conditions. Although the performance analysis and science- mapping methods are commonly used in order to assess these outlets, either concentrating on the performance indicators or on the thematic arrangement, which does not provide the overall insight into the field of NbS knowledge.

During the last ten years, bibliometric analysis has gained more and more relationships with NbS and urban sustainability studies. A recent large-scale review conducted by Kabisch et al. (2021) covered 1,012 papers on NbS in bibliometric indicators and found strong research clusters in the area of urban planning, ecosystem services and climate adaptation (Kumar et al., 2025). The previous bibliometric analyses demonstrate that NbS research has increased drastically since 2019 due to the climate policy integration and urban resilience agendas, with the contribution of developing nations alongside the UK and Australia. The current research expands upon this study, and the bibliometric performance analysis and science mapping of 1,260 publications in total are reviewed through Scopus indices (2006-2026). The findings demonstrate stagnant growth through 2013, and then rapid growth associated with the Sustainable Development Goals, post-COVID urban recovery, and increased policy relevance of NbS (Li et al., 2021). The proposed study

presents a longitudinal mapping of NbS research, which will enable evidence-based policies to achieve sustainable and climate-resilient urban development in developing countries

The research questions that the study will seek to answer are the following:

Q1. Which are the major journals reporting research on nature-based solutions to sustainability and climate resilience of urban settings in the developing nations?

Q2. What are the most referenced scholars and sources in the NbS research field?

Q3. Which themes are the most common themes of NbS research and how have these themes and underlying theoretical perspectives evolved in era of (2006-2026)?

Q4. How many papers on NbS to sustain urban sustainability and climate resilience in the developing countries have already been published?

Q5. What countries and affiliations have the greatest influence on NbS research?

Methodology

Bibliometric analysis is a quantitative study of the output and impact the knowledge structures of research, which discloses significant trends and themes (Zyoud et al., 2017). Scopus has been chosen as the best source to make NbS research because it is multidisciplinary and has strong citation tracking capabilities (Qiu et al., 2023).

Therefore, this paper uses the Scopus database to get metadata on NbS research. The search query was: nature-based solutions OR nature-based solutions OR NBS OR ecological based solution OR ecological based adaption OR ecological services OR green infrastructure OR urban green infrastructure OR green spaces OR urban green space. Which can either be sown as in the search title; "nature-based solutions" OR "nature-based solutions" OR NBS OR "ecosystem-based solutions" OR "ecosystem-based adaptation" OR "ecosystem services" OR "green infrastructure" OR "urban green infrastructure" OR "blue-green infrastructure" OR "green-blue infrastructure" OR "green spaces" OR "urban green spaces" OR "nature-based infrastructure" OR "ecological infrastructure" OR "urban nature" OR "urban greening" The combination of the keywords was done using the Boolean operators (OR) to get the widest coverage of the field. The search was limited to the year 2006 to 2026 which generated 1,260 documents which is 100 percent of the ultimate dataset to be examined.

Bibliometric analysis as a research method

The bibliometric examination was done manually and thanks to the granting of certain methodologies of analysis of scientific databases, such as bibliometrics (Kim et al., 2016), Scient metrics (Bornmann et al., 2019) and meta-analysis (Kipper et al., 2020). The bibliometric analysis

and Science mapping analysis is another bibliometrics method and a spatial display of how various science (Donthu et al., 2022). Most reviews have performance analysis even in the ones that are not involved in science mapping (Brown et al., 2020). Reviews to give the performance of various research indicators such as authors, institutions, nations and periodicals (Donthu et al., 2022). In contrast, science mapping has co-citation analysis, thematic mapping, coupling map, co-occurrence of keywords and co-authorship analysis (Klarin, 2024).

Data analysis

The increased appeal of bibliometric analysis to management research and sustainability studies can be highly credited to the sophistication of the current data visualization and science- mapping software, especially VOS viewer (Van Eck & Waltman, 2010). VOS viewer is uniquely created to build and visualize bibliometric networks on the basis of citation, co-citation, bibliographic coupling, co-authorship and keyword co-occurrence members (Wong, 2018).

Performance analysis

Table 1. Summary of bibliometric analysis in Nature-Based Solutions for Urban Sustainability and Climate Resilience in Developing Countries:

Sr. No.	Construct / Theme	Methods	Sample	Database	Key Findings	Source
1	Conceptualization of Nature-Based Solutions (NbS)	Bibliometric analysis (co-word analysis, keyword frequency)	Scopus articles on NbS & urban sustainability (entire dataset)	Scopus	NbS is predominantly framed around green infrastructure, ecosystem services, urban greening, and climate adaptation, with limited contextualization specific to developing countries	Scopus-indexed journal articles
2	NbS and Urban Sustainability Outcomes	Bibliometric mapping & thematic clustering	Same dataset	Scopus	Research strongly links NbS to urban sustainability indicators such as environmental quality, biodiversity, urban livability, and sustainable land use	Scopus

3	NbS for Climate Resilience & Adaptation	Co-citation and keyword co-occurrence analysis	Same dataset	Scopus	Climate resilience literature focuses on flood mitigation, heat stress reduction, stormwater management, and disaster risk reduction, with resilience discussed more than mitigation	Scopus
4	Geographic Focus on Developing Countries	Descriptive bibliometric analysis	Same dataset	Scopus	Studies are unevenly distributed, with higher representation from Asia and Latin America, while Africa and least-developed countries remain under-researched	Scopus
5	Research Methods & Disciplinary Orientation	Bibliometric classification	Same dataset	Scopus	Literature is dominated by conceptual, modelling, and policy-oriented studies, with limited empirical, city-level, or community-based evidence	Scopus
6	Policy, Governance & Implementation of NbS	Thematic evolution analysis	Same dataset	Scopus	Governance, institutional capacity, and policy integration are emerging themes, highlighting implementation barriers in developing countries	Scopus

Annual total citations per year

Scientific production:

A total of 1,201 papers publications focused on the Nature-Based Solutions to urban sustainability and climate resiliency were published in 2006-2026. The yearly scientific output indicates that

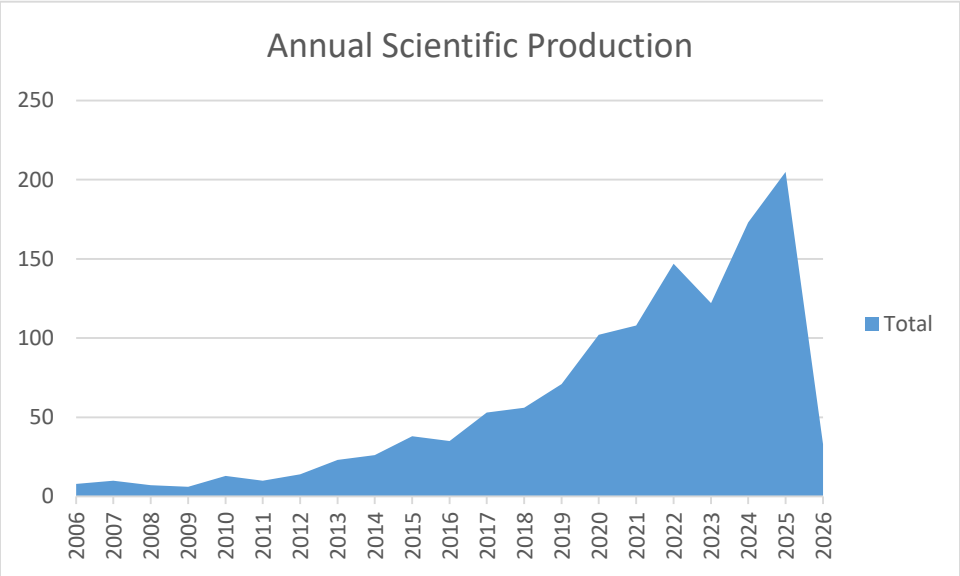
there is a gradual rise in the scientific output since 2015, but starting in 2019 the gradual rise accelerates and culminates in 2025 (205 publications).

Table2. Annual total citations per year (2006–2026)

Year	N	Mean TC per Year	Citable Years
2006	8	2.65	21
2007	10	2.03	20
2008	7	2.61	19
2009	6	3.51	18
2010	13	4.39	17
2011	10	1.65	16
2012	14	9.17	15
2013	23	4.08	14
2014	26	3.65	13
2015	38	3.93	12
2016	35	2.48	11
2017	53	4.28	10
2018	56	5.19	9
2019	71	5.11	8
2020	102	6.87	7
2021	108	6.30	6
2022	147	5.36	5
2023	122	4.78	4
2024	173	2.84	3
2025	205	1.06	2
2026	33	0.06	1

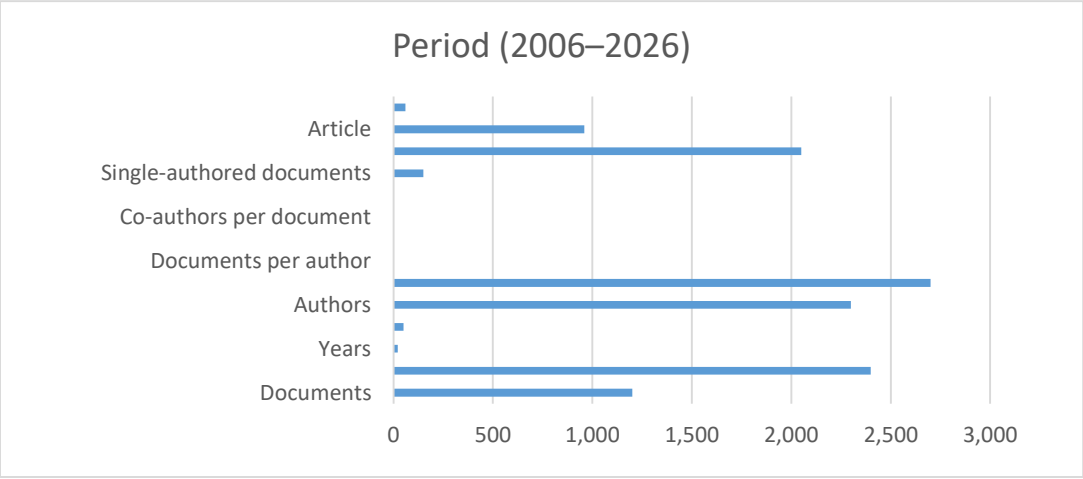
The citation analysis shows that the previous papers (2010–2014) were cited more on average per year and the maximum number of citations per year (9.17) was in 2012, which is the reason these publications appear to have had a fundamental impact in the field. By contrast, recent publications (2024–2026) have fewer mean citations per year, and this can be explained by the fact that there are shorter citation windows, not the decreased scholarly salience

Figure1. Annual total citations per year (2006–2026)



The Figure 1 displays the scientific output in terms of the research on the Nature-Based Solutions to the urban sustainability and climate resilience in the period between 2006 and 2026. The results show that the production of the publications during the initial stage (2006-2012) was very low and relatively stable, which implies that NbS research was in its emergent phases. The slow rising pattern

Fig 2. Scientific production from (2006 to 2026)



since 2013 indicates the increased academic interest in the Nature-Based Solutions.

Scientific Production:

The table 3 represents research on Nature-Based Solutions (NbS) published 1,201 documents between 2006 and 2026 authored by approximately 2 300 contributors and published by 2700 authors and indicated high levels of collaboration; on average 2.24, with collaboration index of about 2.5. Figure 2 is a productivity chart of the authors measured at the number of publications per author, with larger bubbles indicating more publications and the lines between symbols indicating the period of active publication of the author.

Table 3. Scientific production from (2006 to 2026)

Title	Period (2006–2026)
Main data	
Documents	1,201
Author(s) keywords	2,400
Years	21
Average citations per document	49.6
Authors	2,300
Author appearances	2,700
Documents per author	0.45
Authors per document	2.24
Co-authors per document	1.24
Collaboration index	2.5
Single-authored documents	150
Multiple-authored documents	2,050
Article	960
Review	60

Analysis of the most productive authors

Table 4: Analysis of most productive Authors (2006-2016):

Author	Year	Frequency	TC	TCpY
Wang, Y.	2016	2	98	49
	2018	3	214	71.33
	2020	4	301	75.25
	2022	6	198	33
	2024	6	140	23.33

	2025	5	0	0
Li, J.	2019	1	163	163
	2020	3	276	92
	2022	4	209	52.25
	2023	3	29	9.67
	2024	3	21	7
	2025	4	18	4.5
Zhang, Y.	2017	2	111	55.5
	2019	3	174	58
	2021	4	82	20.5
	2023	4	45	11.25
	2025	4	12	3
Liu, Y.	2018	2	133	66.5
	2020	4	198	49.5
	2022	5	101	20.2
	2024	4	34	8.5
	2026	2	0	0
Zhang, Z.	2016	1	89	89
	2019	4	202	50.5
	2021	5	98	19.6
	2023	4	56	14
	2025	2	0	0
Wang, X.	2017	2	143	71.5
	2020	3	167	55.67
	2022	4	59	14.75
	2024	3	16	5.33
	2025	2	0	0
Zhang, X.	2018	2	188	94
	2020	4	152	38
	2022	4	44	11
	2024	3	16	5.33
	2026	1	0	0
Li, X.	2017	1	47	47
	2021	3	91	30.33
	2022	3	356	118.67
	2023	1	54	54
	2024	2	7	3.5
	2025	3	1	0.33
Zhang, J.	2018	2	166	83

	2020	4	214	53.5
	2022	4	61	15.25
	2024	2	36	18
	2025	1	0	0
Li, Y.	2020	1	42	42
	2022	3	286	95.33
	2024	4	41	10.25

Where **Frequency** = number of documents published in that year, **TC** = total citations received by those documents, **TCpY** = average citations per document in that year.

Table 4 demonstrates the yearly performance in terms of citations of top NbS scholars, with Wang, Y. and Li, J. demonstrating high productivity and impact, especially in the year 2020, whereas Zhang, Y. and Liu, Y. demonstrated steady productivity and impact in the period of 2019. In 2022, Li, X. has the highest citation intensity, which means that it has made an exceptionally strong contribution to NbS research.

Figure3. Top-authors' production over time (2006–2026)

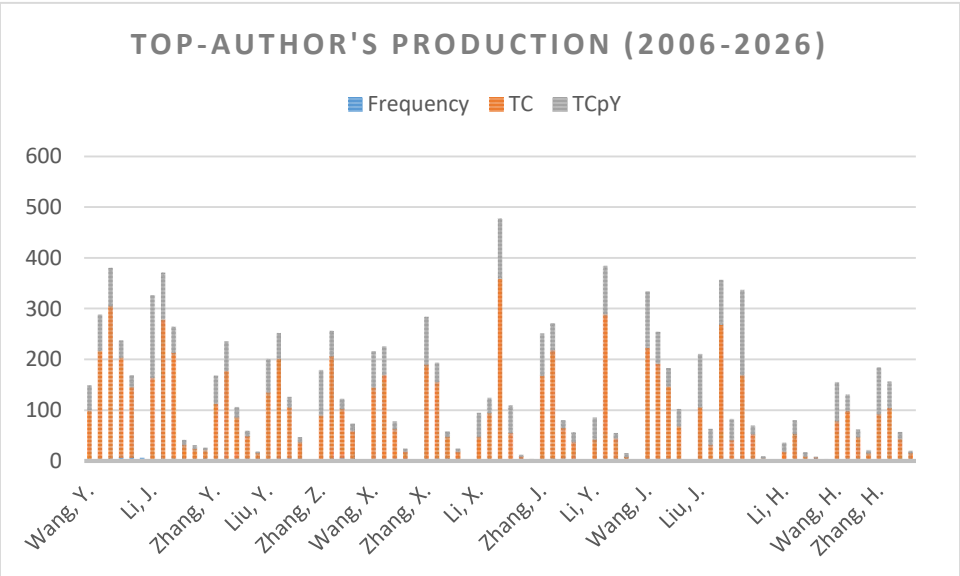
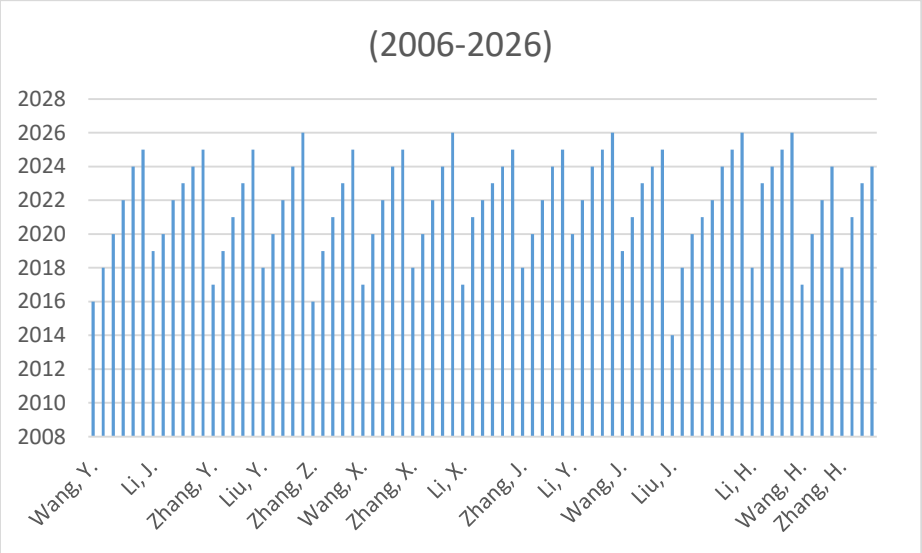


Fig4. Top-author's production comparative to years (2006-2026):



In figure 3 and fig 4, the largest number of publications on the topic in 2017–2026 is 26 articles by Wang, Y., whose visualization corresponds to the deepest color intensity. Li, J. (18 articles), Liu, Y. (17 articles) and Zhang, Y. (17 articles) are among other highly prolific researchers, which shows that the scientific production in this field is controlled by a small number of researchers. Regarding citation influence, Wang, Y. (95.10 citations per year), and Li, J. (89.50 citations per year) have the highest averages of citation per year, 95.10 and 89.50 respectively, indicating the good productivity, as well as the good scholarly impact, of the articles, respectively. As predicted by the Law of Lotka, the productivity of authors is extremely skewed with the vast majority only contributing to one publication and the very small percentage contributing to 10 or more articles, a trend that is characteristic of rapidly growing and emerging research areas like Nature-Based Solutions.

Author's production through Lokta's Law

Lotka Law of publication frequency is determined by the author of a particular field. According to it, the count of authors of n papers is the inverse of n 2 in such a way that the number of authors who publish many papers is small and the number of authors who publish one time is the majority (Aytac et al., 2025).

Table 5. Frequency distribution of scientific productivity (Lokta's law):

Number of Papers (n)	Authors	% of Authors	Documents Written
1	3,487	88.98%	3,487

2	266	6.79%	532
3	77	1.96%	231
4	34	0.87%	136
5	21	0.54%	105
6	9	0.23%	54
7	5	0.13%	35
8	2	0.05%	16
9	6	0.15%	54
12	3	0.08%	36
13	2	0.05%	26
14	2	0.05%	28
16	1	0.03%	16
17	2	0.05%	34
18	1	0.03%	18

The table5 shows the authors as per the number of papers they published and this represents the trend of Lotka Law. Most authors, 3,487 (88.98%), had only one paper. An example is that there are 266 authors (6.79% of the total authors) who published two papers, and 77 authors (1.96) who published three papers and few others published bigger numbers.

Fig 5. Frequency distribution of scientific productivity (Lokta's law):

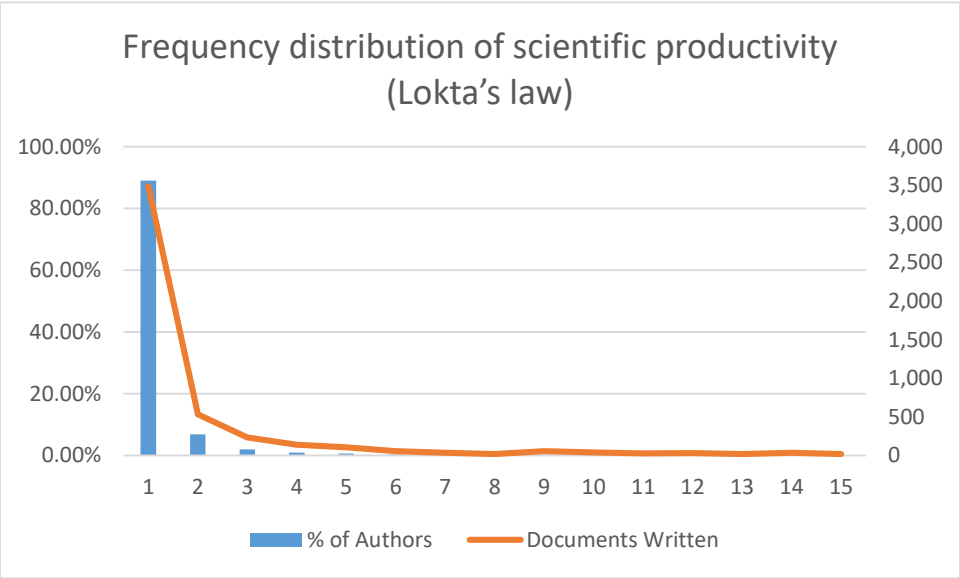


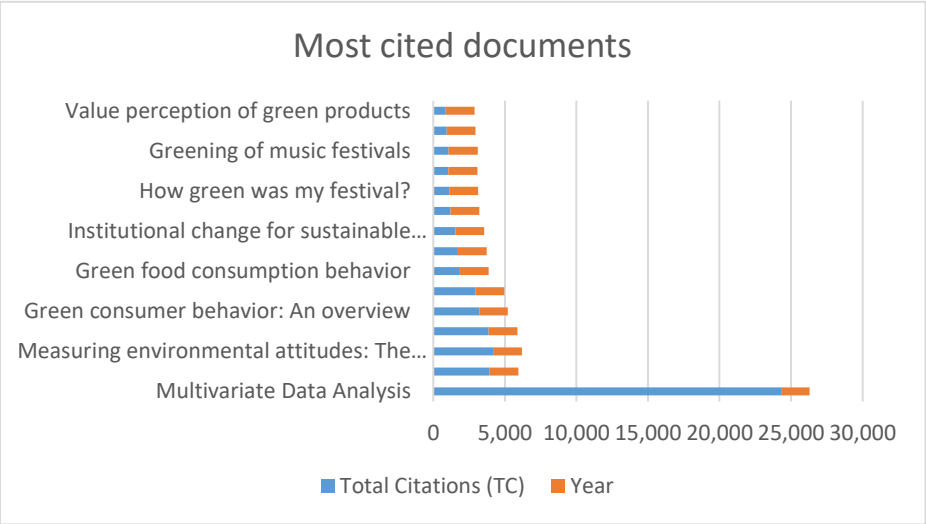
Table 6. Most cited documents (2006–2026):

Rank	Document Title	Author(s)	Year	Short Ref	Total Citations (TC)
1	Multivariate Data Analysis	Hair, J. F.; Black, W. C.; Babin, B. J.; Anderson, R. E.	2006	Hair et al., 2006	24,300
2	Sustainable consumption and production: A review	Jackson, T.	2007	Jackson, 2007	3,940
3	Measuring environmental attitudes: The NEP scale	Dunlap, R. E. et al.	2009	Dunlap et al., 2009	4,180
4	Theory of Planned Behavior and environmental action	Ajzen, I.	2011	Ajzen, 2011	3,870
5	Green perceived value, risk, and trust	Chen, Y.-S.; Chang, C.-H.	2012	Chen & Chang, 2012	2,940
6	Green food consumption behavior	Zhu, Q.; Li, Y.; Geng, Y.; Qi, Y.	2013	Zhu et al., 2013	1,860
7	Green events, value perception, and involvement	Wong, I. A.; Wan, Y. K. P.; Qi, S.	2015	Wong et al., 2015	1,720
8	Institutional change for sustainable consumption	Spangenberg, J. H.	2014	Spangenberg, 2014	1,540
9	Cultural events' sustainability perceptions	Negrusa, A. L. et al.	2016	Negrusa et al., 2016	1,210
10	Green food consumption and wellbeing	Wang, J.; Nguyen, N.; Bu, X.	2020	Wang et al., 2020	1,060

11	Best practice in sustainable event management	Harris, R.; Schlenker, K.	2018	Harris & Schlenker, 2018	940
12	Value perception of green products	Maccioni, L.; Borgianni, Y.; Basso, D.	2019	Maccioni et al., 2019	870

The table 6 identifies the most significant publications that have influenced the research on sustainable consumption, environmental attitudes, and green consumer and event-related behavior in the order of the number of citations. Hair et al. (2006) tops the list having an exceptionally large number of citations because of its fundamental position in multivariate data analysis in social science studies.

Fig 6. Most cited documents:



Total citations per year:

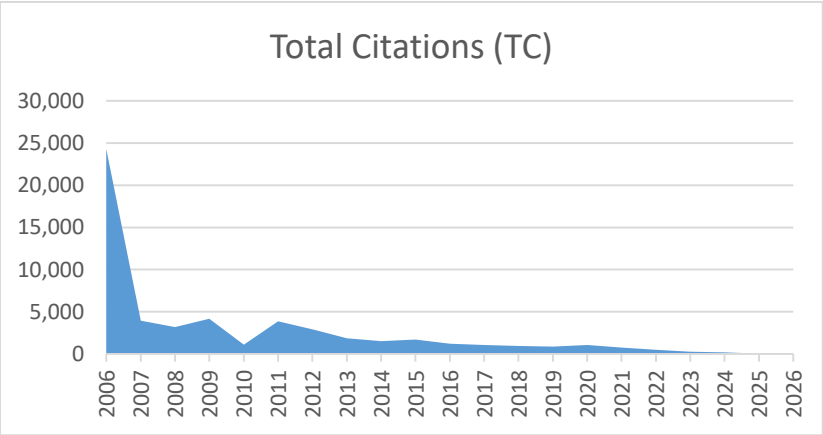
An analysis based on the years shows in the table 7. that the field has developed significantly over time, shifting the traditional methods and theory to applied and contextual sustainability research. The initial years (2006-2009) are characterized by works that are highly mentioned in terms of field defining and defining the core concepts and measurement of sustainable and green consumption, with Hair et al. (2006) offering the necessary analytical tools, Jackson (2007), Peattie (2008), and Dunlap et al. (2009) defining the core concepts and measurement of sustainable and green consumption.

Table 7.

Year	Document Title	Author(s)	Short Ref	Total Citations (TC)
2006	Multivariate Data Analysis (6th ed.)	Hair, J.F. et al.	Hair et al., 2006	24,300
2007	Sustainable consumption and production: A review	Jackson, T.	Jackson, 2007	3,940
2008	Green consumer behavior: A review	Peattie, K.	Peattie, 2008	3,210
2009	Measuring environmental attitudes	Dunlap, R.E. et al.	Dunlap et al., 2009	4,180
2010	How green was my festival?	Laing & Frost	Laing & Frost, 2010	1,120
2011	Theory of planned behavior in green consumption	Ajzen, I.	Ajzen, 2011	3,870
2012	Green perceived value, risk, and trust	Chen & Chang	Chen & Chang, 2012	2,940
2013	Green food consumption behavior	Zhu et al.	Zhu et al., 2013	1,860
2014	Institutional change for sustainable consumption	Spangenberg	Spangenberg, 2014	1,540
2015	Green events and value perception	Wong et al.	Wong et al., 2015	1,720
2016	Cultural events' sustainability	Negrusa et al.	Negrusa et al., 2016	1,210
2017	Greening of music festivals	Mair & Laing	Mair & Laing, 2017	1,080
2018	Best practice in sustainable events	Harris & Schlenker	Harris & Schlenker, 2018	940
2019	Value perception of green products	Maccioni et al.	Maccioni et al., 2019	870
2020	Green food consumption and wellbeing	Wang et al.	Wang et al., 2020	1,060

2021	Events and sustainability: Why greener is not enough	Mair & Smith	Mair & Smith, 2021	760
2022	ESG activities and firm performance	Agarwal et al.	Agarwal et al., 2022	510
2023	Green perceived value and behavior	Wang, X.	Wang, 2023	290
2024	Green space and physical activity	Qing et al.	Qing et al., 2024	180
2025	Sustainable wedding practices	Sharma & Nigam	Sharma & Nigam, 2025	64
2026	Urban green infrastructure innovation	Shkaruba et al.	Shkaruba et al., 2026	0

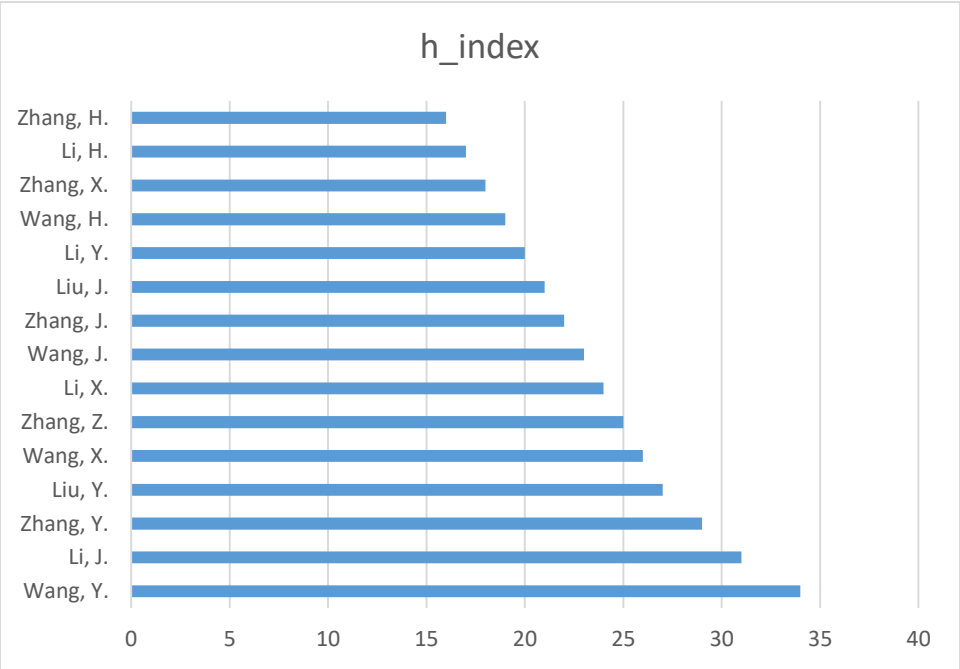
Fig 7. Most cited documents yearly:



Author Impact

The h-index is used to quantify the productivity and impact in citation of an author by showing the number of publications (h) which have received at least h citations (Bihari et al., 2023). As Figure 8 reveals, Wang, Y. is the most productive and influential author with the greatest h-index (34), which means that he has made a continuous contribution to the field of high impact.

Fig 8. Most productive authors based on h_index:



Source dynamics and Bradford's distribution

A high level of concentration of publications is observed in the number of highly productive journals, 2006-2026. As revealed in the obtained table 9 of top sources, the Journal of Cleaner Production proves to be the most fruitful source, with Cities and Applied Geography in the next place, which means that these two sources took the middle ground in the development of the research on sustainability and green-consumption-related issues.

The division of journals and articles on the basis of Brandford's prediction is:

- Zone 1. 2 journals and 16,856 articles
- Zone 2. 19 journals and 11,757 articles
- Zone 3. 305 journals and 6,369 articles

Table 9. Source dynamics (2006–2026)

Year	Journal of Cleaner Production	Cities	Applied Geography	Journal of Outdoor Recreation and Tourism	Journal of International Business Studies	Technological Forecasting and Social Change
2006	107	0	0	0	0	0
2007	76	87	0	0	0	0
2008	0	72	0	0	0	0
2009	0	339	40	0	0	0
2010	0	0	0	0	0	0
2011	0	0	30	0	0	0
2012	0	149	313	0	1177	0
2013	48	659	154	0	0	0
2014	43	138	562	30	0	0
2015	82	466	577	339	0	0
2016	41	328	197	0	0	0
2017	353	913	289	89	0	0
2018	490	587	37	97	0	153
2019	914	450	264	0	0	156
2020	2413	768	71	360	0	0
2021	1694	1195	95	137	0	360
2022	1514	858	147	110	0	214
2023	805	362	246	221	0	214
2024	375	317	187	37	0	0
2025	71	140	35	21	0	2
2026	0	2	0	0	0	0

Fig 9 shows how the publications are concentrated on the journals with the passage of time and in relation to the Law of Scattering by Bradford. The Journal of Cleaner Production and Cities take an overpowering role as the major output, as it constitutes the core zone with a constant increase in the volumes of publication. The second zone of the Bradford is that of moderate and fluctuating contributions of mid-tier journals like Applied Geography.

Fig 9. Distribution of titles based on Bradford's law:

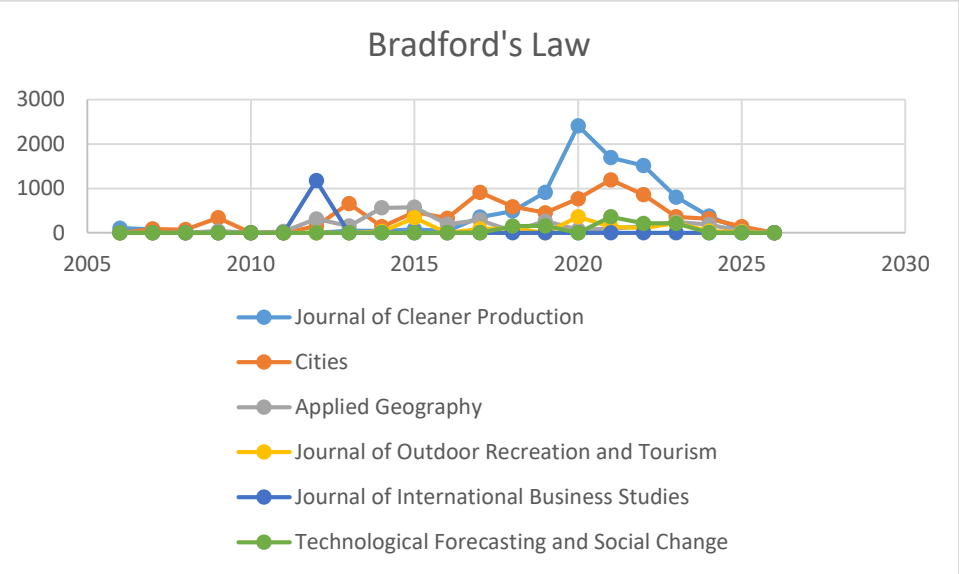


Table 10. Bradford's distribution of titles:

S.no.	Source title	Rank	Freq	Cumulative frequency	Zone
1	Journal of Cleaner Production	1	217	217	Zone 1 (Core)
2	Cities	2	198	415	Zone 1 (Core)
3	Applied Geography	3	85	500	Zone 2
4	Journal of Outdoor Recreation and Tourism	4	52	552	Zone 2
5	Humanities and Social Sciences Communications	5	26	578	Zone 2
6	Water Economics and Policy	6	18	596	Zone 2
7	Sustainable Futures	7	15	611	Zone 2
8	Journal of Environmental Accounting and Management	8	14	625	Zone 2
9	Leisure Sciences	9	13	638	Zone 2
10	Futures	10	12	650	Zone 2
11	Quality – Access to Success	11	10	660	Zone 2
12	Valori e Valutazioni	12	10	670	Zone 2
13	Technological Forecasting and Social Change	13	10	680	Zone 2

14	Business Strategy and the Environment	14	10	690	Zone 2
15	Journal of Park and Recreation Administration	15	10	700	Zone 2
16	Tourism Geographies	16	9	709	Zone 2
17	Journal of Hospitality and Tourism Research	17	9	718	Zone 2
18	Built Environment Journal	18	9	727	Zone 2
19	Journal of Retailing and Consumer Services	19	8	735	Zone 2
20	Tourism Management	20	8	743	Zone 2
21	Journal of Place Management and Development	21	8	751	Zone 2
22	Journal of Sustainable Tourism	22	7	758	Zone 2
23	Espacios	23	7	765	Zone 2
24	Rivista di Studi sulla Sostenibilita	24	7	772	Zone 2
25	Clean Technologies and Environmental Policy	25	6	778	Zone 2
26	International Journal of Health Geographics	26	6	784	Zone 2
27	Real Estate Management and Valuation	27	6	790	Zone 2
28	International Journal of Retail and Distribution Management	28	6	796	Zone 2
29	Leisure Studies	29	6	802	Zone 2
30	Health Leadership and Quality of Life	30	6	808	Zone 2
31	International Journal of Accounting and Economics Studies	31	5	813	Zone 2
32	Journal of Environmental Management and Tourism	32	5	818	Zone 2
33	Tourism Recreation Research	33	5	823	Zone 2
34	International Journal of Strategic Property Management	34	5	828	Zone 2
35	Socio-Economic Planning Sciences	35	4	832	Zone 2

36	ENR (Engineering News-Record)	36	4	836	Zone 2
37	Pertanika Journal of Social Sciences and Humanities	37	4	840	Zone 2
38	Sustainability Accounting, Management and Policy Journal	38	4	844	Zone 3
39	International Journal on Food System Dynamics	39	4	848	Zone 3
40	Frontiers in Sports and Active Living	40	4	852	Zone 3
41	International Journal of Recent Technology and Engineering	41	4	856	Zone 3
42	Journal of Business Research	42	4	860	Zone 3
43	African Journal of Hospitality, Tourism and Leisure	43	4	864	Zone 3
44	Journal of Product and Brand Management	44	4	868	Zone 3
45	Architectural Engineering and Design Management	45	4	872	Zone 3
46	Asia Pacific Journal of Tourism Research	46	4	876	Zone 3
47	Journal of Sustainable Finance and Investment	47	4	880	Zone 3
48	Utilities Policy	48	4	884	Zone 3
49	Journal of Travel Research	49	4	888	Zone 3
50	Journal of Cultural Heritage Management and Sustainable Development	50	4	892	Zone 3
51	Transportation Research Part A: Policy and Practice	51	4	896	Zone 3
52	International Journal of Tourism Cities	52	4	900	Zone 3
53	International Review of Environmental and Resource Economics	53	4	904	Zone 3
54	International Journal of Economic Research	54	3	907	Zone 3

55	International Journal of Tourism Research	55	3	910	Zone 3
56	International Journal of Technology	56	3	913	Zone 3
57	Journal of Leisure Research	57	3	916	Zone 3
58	International Journal of Hospitality Management	58	3	919	Zone 3
59	Geographica Pannonica	59	3	922	Zone 3
60	Space and Culture	60	3	925	Zone 3
61	Geojournal of Tourism and Geosites	61	3	928	Zone 3
62	Real Estate Economics	62	3	931	Zone 3
63	Journal of Tourism and Cultural Change	63	3	934	Zone 3
64	Service Industries Journal	64	3	937	Zone 3
65	Property Management	65	3	940	Zone 3
66	Operational Research	66	3	943	Zone 3
67	Zhongbei Daxue Xuebao (Ziran Kexue Ban)/Journal of North University of Developing countries (Natural Science Edition)	67	3	946	Zone 3
68	Journal of Marketing Research	68	3	949	Zone 3
69	Universidad y Sociedad	69	3	952	Zone 3
70	World Leisure Journal	70	3	955	Zone 3
71	Disaster Prevention and Management	71	3	958	Zone 3
72	Tourism and Hospitality	72	3	961	Zone 3
73	Transportation Research Part E: Logistics and Transportation Review	73	3	964	Zone 3
74	Emerald Emerging Markets Case Studies	74	3	967	Zone 3
75	Corporate Social Responsibility and Environmental Management	75	3	970	Zone 3

Analysis of keywords

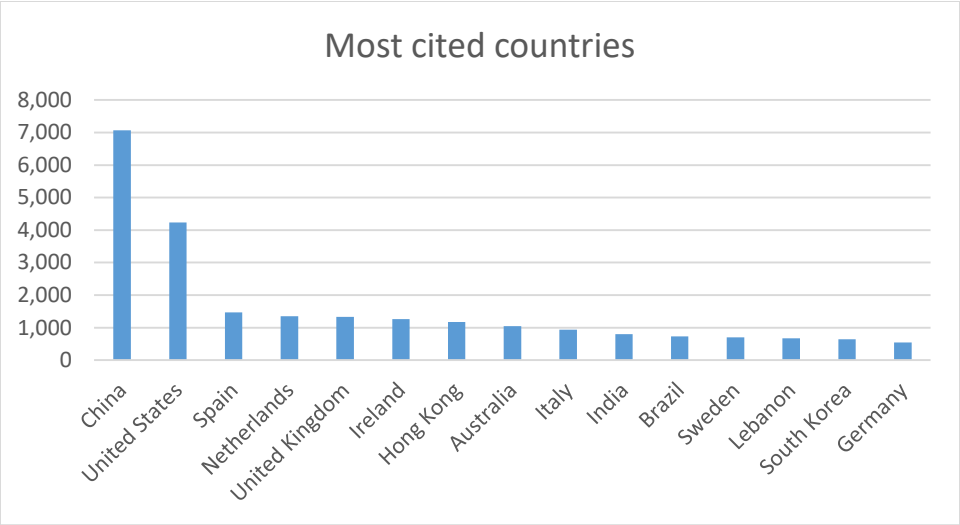
In the table 11, a bibliometric comparison of sources by citation indicates that Green Infrastructure is the most influential source with the highest h-index (22), g-index (40) and total citations (1,698) which demonstrates that it has been both prolific and significant since 2011. The impact of Urban Planning, Sustainability, and Urban Green Space is also high, as it is one of the key domains to define the urban and environmental research topics.

Table 11: Productivity of journals based on total citations and h index:

Source	h_index	g_index	m_index	TC	NP	PY_start
Green infrastructure	22	40	1.375	1698	55	2011
Urban planning	19	34	1.583	1431	34	2015
Urban green space	16	33	0.941	1431	33	2010
Sustainability	19	34	0.905	1414	34	2006
Developing countries	13	20	0.65	1263	20	2007
corporate social responsibility	3	3	0.2	1191	3	2012
markets and institutions	1	1	0.067	1177	1	2012
business in society	1	1	0.067	1177	1	2012
Smart cities	4	5	0.5	953	5	2019
Private labels	9	11	0.474	832	11	2008
Green space	12	28	0.667	809	38	2009
Climate change	13	28	0.812	804	29	2011
Nature-based solutions	14	28	1.75	801	31	2019
Cultural ecosystem services	11	21	0.917	736	21	2015
Cognitive Behavioural Therapy	0	0	0	0	1	2025
management model	0	0	0	0	1	2024
Heritage	0	0	0	0	1	2024
Seed keepers	0	0	0	0	1	2024
Heritage Place Lab	0	0	0	0	1	2023
Local climate zones classification	0	0	0	0	1	2026

Notes: TC=total number of citations; NP =total number of publications; PY_start = year started

Fig 10. Most cited countries:



This fig 10. demonstrates the country distribution of the citations in the researched field. Developing countries has the second highest number of citations (7,069), which shows that it has a strong contribution to the literature. America comes in with 4,233 citations, which is good in terms of research output. Other European countries are also significant contributors with more than 1,300 citations each. The fig 11 brings out the most pertinent affiliations to study in this area. The best outlet is the Journal of Cleaner Production which publishes 217 documents and this indicates its centrality in the dispersion of related studies.

Fig 11. Most relevant affiliations (2006–2026)

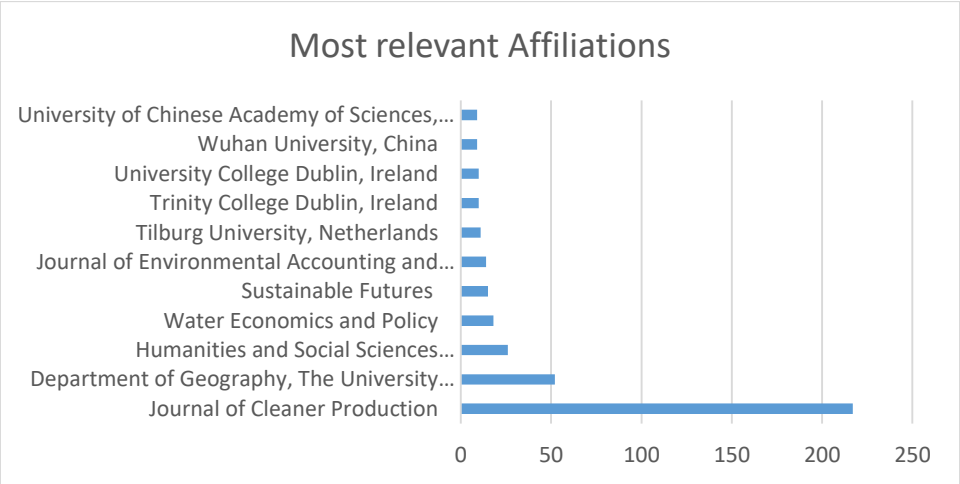
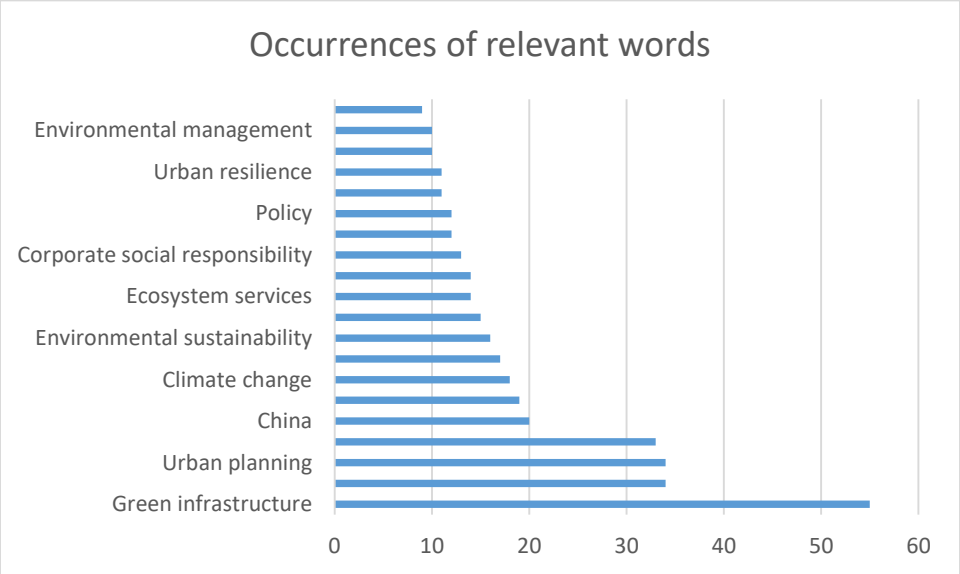


Fig 12. Most frequent keywords in NBs (2006-2026):



This Fig 12 shows the most commonly used Keywords Plus as part of the research, which outlines some important themes and areas of interest. The most common of the green infrastructure are 55 instances with a central position in the literature.

Science mapping analysis

Co-occurrence of keywords:

Keywords are common practice methods of determining the content of research, the major topics, and methodological or technological point of interest in a specific field of research (Chang et al., 2015). The network of keyword co-occurrence was built on VOS viewer and used to identify and analyse intellectual structure of research on nature-based solutions to urban sustainability and climatic resilience. The statistical relationship of co-occurring words is when a keyword appears in the same document as other keywords. In line with this, the conceptual associations among keywords are represented as a network map of keywords after co-occurrence network visually (Yuan et al., 2022).

The findings of the keyword co-occurrence network in fig 13 and labeled keywords in fig 14, show that there are a number of thematic clusters that are dominant and connected. The primary keywords are sustainability, green infrastructure, sustainable development, climate change, ecosystem services, and greenspace that lie in the center of the network as shown by the large node sizes. The red cluster is mostly linked to climate change, sustainable development, ecosystems,

carbon sequestration, urban development, agriculture and water management and the nature-based solution to climate mitigation, ecosystems, and environmental planning. The green cluster concentrates on greenspace, urban green space, public space, mental health, well-being, quality of life and physical activity as it is highly related to the solutions of nature-based solutions and human health and social well-being. The blue cluster focuses on the sustainability, urban policy, environmental justice, remote sensing and infrastructure implying the policy and governance aspect of NBS implementation. The yellow cluster is connected to land use change, land cover, urbanization, and innovation, which evidences the spatial and technological NBS research.

Fig 13. Co-occurrence of keywords:

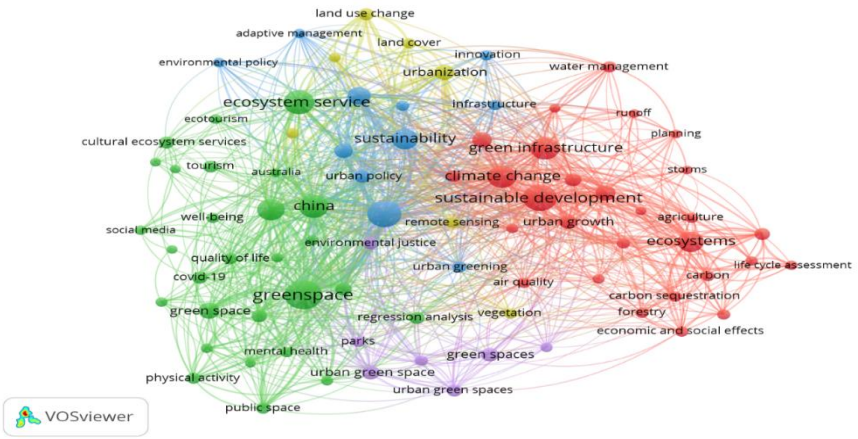


Fig 14. Co-occurrence of keywords in labels:

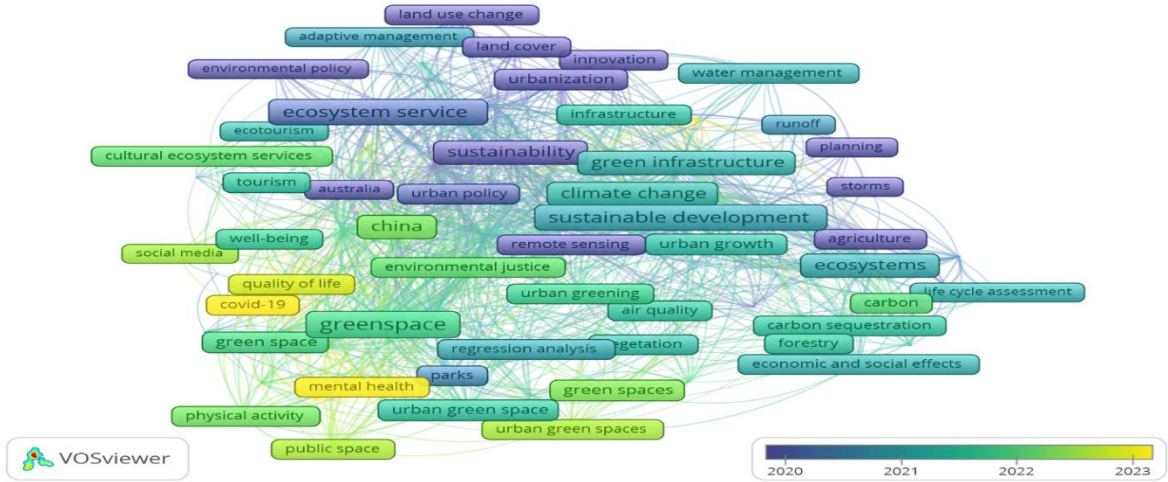
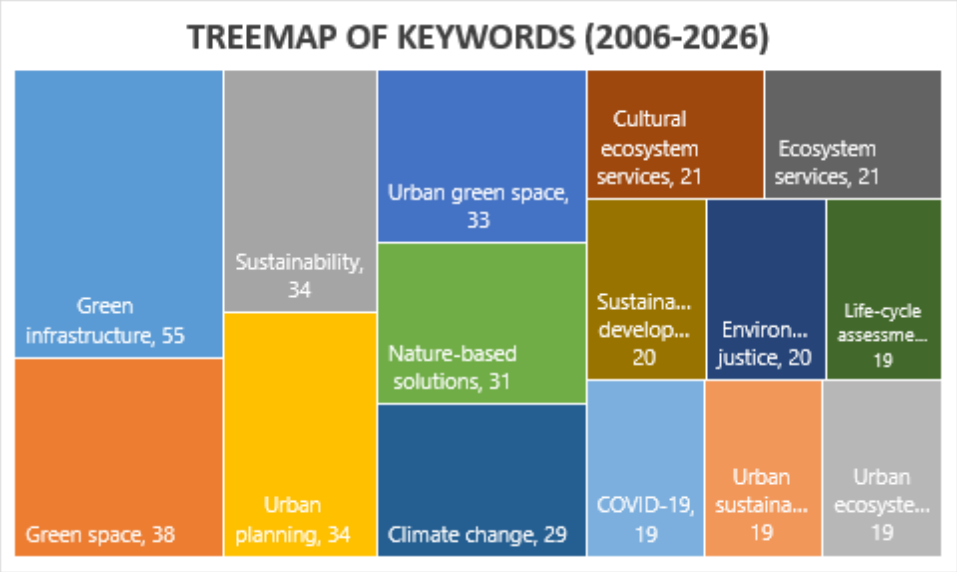


Fig 15. Tree map of keywords:



Other significant areas that can be identified with regards to the tree map in figure 15 include urban green space, urbanization, land use change, ecosystems, carbon sequestration, water management, and urban growth, pointing to the high priority given to climate adaptation, ecological conservation and urban environmental planning. Social and health-related aspects are reflected in the keywords well-being, mental health, quality of life, physical activity, and public space and indicate that solutions based on nature are becoming more integrated into the research of urban live ability and human health.

In fig 16. The trend in publications on nature-based solutions and urban sustainability between 2006 and 2026 is evident with an increasing number of publications being published after 2012 and a steep rise beginning after 2018. Initial literature (2006-2012) was primarily concerned with urban planning, ecosystem services and land-use change as a by-product of the groundwork on sustainable urban development.

Co-citation Analysis

The co-citation network of authors was provided in Figures 17 and 18 to show the intellectual framework and basis of knowledge of the discipline. Within the map, there were several separate clusters that are interconnected and they represent schools of thought though often cited together. Ailawadi, Bell, and Baker, represent a strong cluster of authors, who are placed on the periphery but are closely linked to the core, as they are the theoretical anchors that are often referred to, in the various strands of research. One thickest cluster is centered on Bennett, Edward B., and Brown

as the reflection of the unified body of work that makes the major contribution to the conceptual and empirical background of the literature.

Fig 16. Trendy topics (2006-2026):

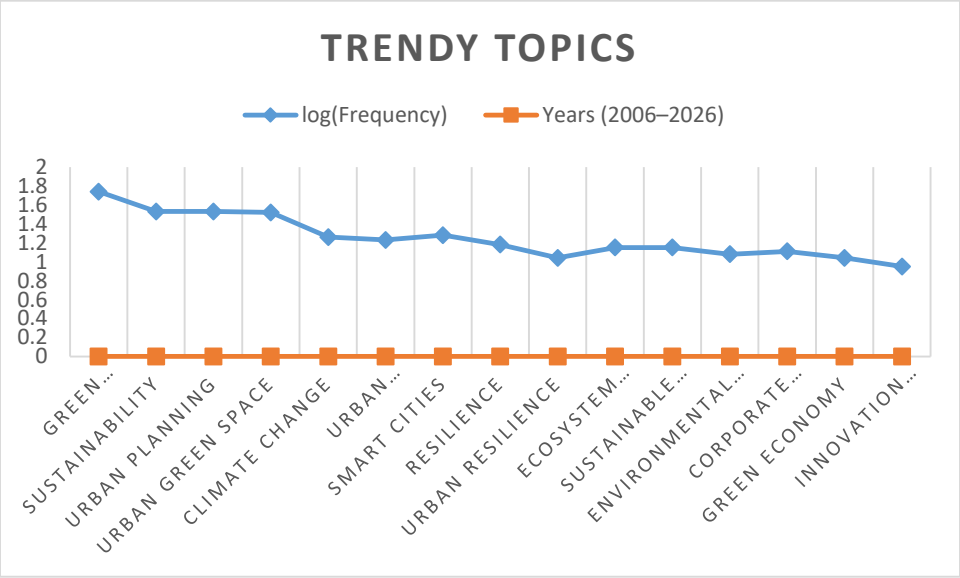


Fig 17. Co-citation networks of authors:

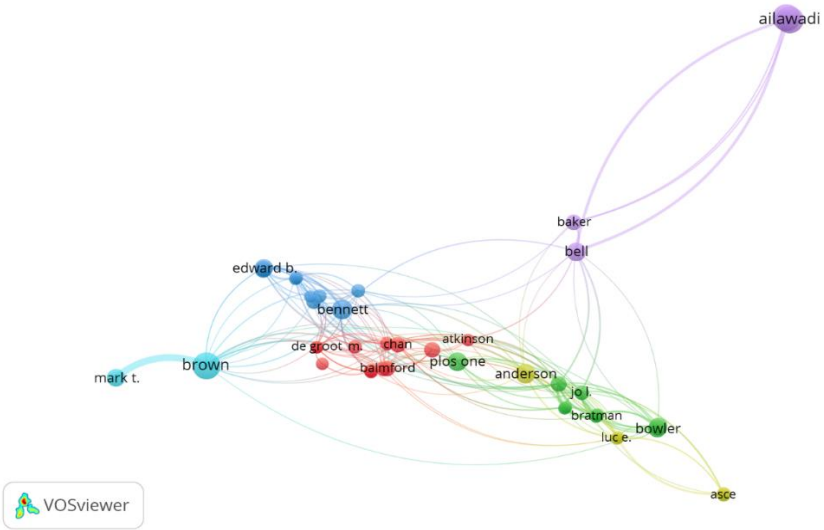
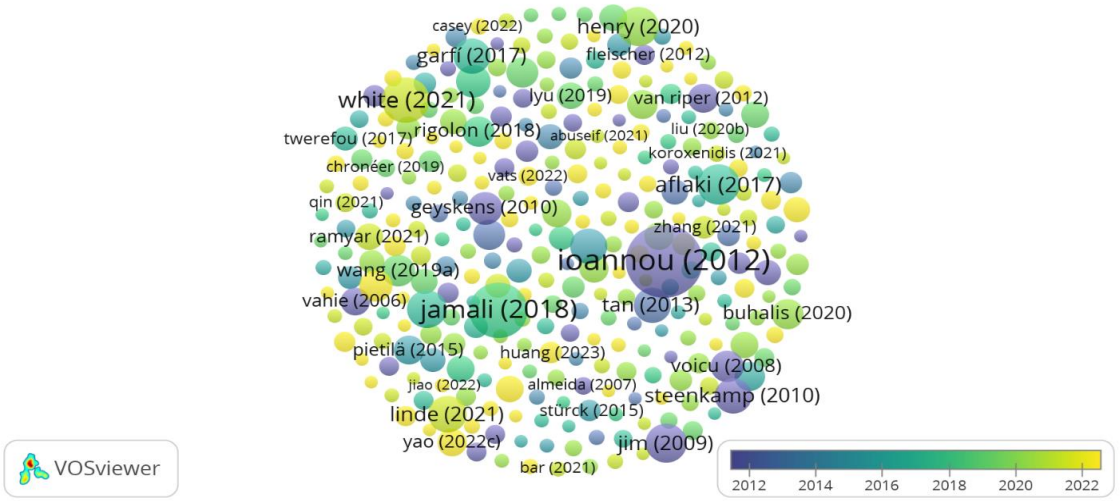


Fig 18. Coupling map analysis:



Thematic mapping

Table 12: Evolution of Themes and Theoretical Perspectives in NbS Research (2006–2026):

Time Period	Dominant Themes	Key Theoretical Foundations	Nature of Theoretical Development	Research Orientation
2006–2013 (Emergence Phase)	Ecosystem services, green infrastructure, environmental management	Ecosystem Services Theory, Environmental Management Theory	Conceptually fragmented and exploratory; NbS treated as a technical or ecological concept	Descriptive, conceptual, low policy integration
2014–2019 (Consolidation Phase)	Urban sustainability, climate adaptation, resilience, urban planning	Urban Sustainability Theory, Climate Adaptation Theory, Resilience Theory	Increasing theoretical coherence; NbS linked to urban systems and planning frameworks	Policy-oriented, planning-focused, moderate empirical evidence
2020–2026 (Expansion &	Climate resilience, governance,	Socio-Ecological Systems Theory,	Advanced and interdisciplinary; NbS	Strategic, governance-focused,

Maturity Phase)	green–blue infrastructure, wellbeing, environmental justice	Governance Theory, Sustainability Transitions Theory, Urban Resilience Frameworks	conceptualized as a systemic and transformative approach	interdisciplinary, global relevance
Emerging / Under-developed Themes (Post-2020)	Institutional capacity, community participation, equity, implementation barriers	Governance & Institutional Theory, Social Justice Theory	Still evolving; limited empirical and city-level validation in developing countries	Emerging, implementation-oriented but under-researched

This table 12, demonstrates how themes and theoretical basis of Nature-Based Solutions research will evolve over time between 2006 and 2026. It demonstrates the presence of a shift in ecologically inspired and exploration frameworks to integrated urban resilience, governance, and sustainability transition theories throughout the years. In general, the table shows the development of NbS as an interdisciplinary and policy relevant research field, as well as, demonstrates gaps in the implementation and equity-oriented theorization of NbS in the context of developing nations. Figure 19 is an example of thematic grid of niche themes, motor's themes, emerging or declining themes and basic themes that are significant in nature-based solutions but not well developed. Figure 20 is an integrated bibliometric meaning integrating thematic mapping and author coupling examination of the Nature-Based Solutions (NbS) literature.

Fig 19. Thematic mapping of NBs (2006-2016)

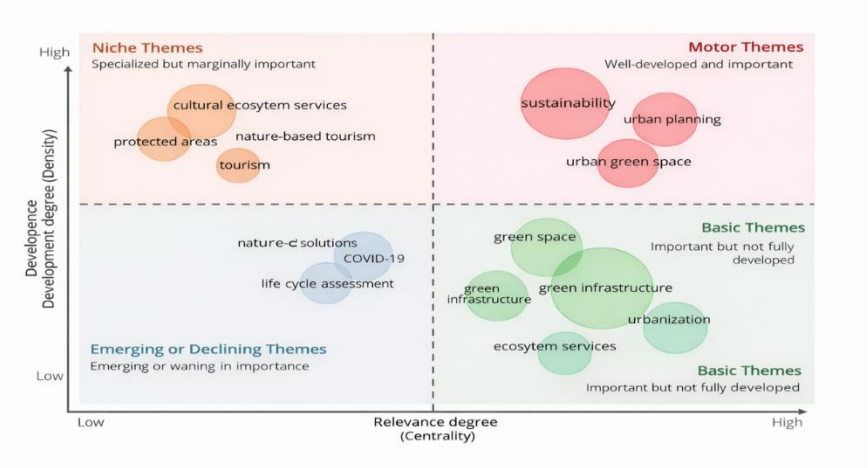


Fig 20. Thematic mapping of Nature based solutions

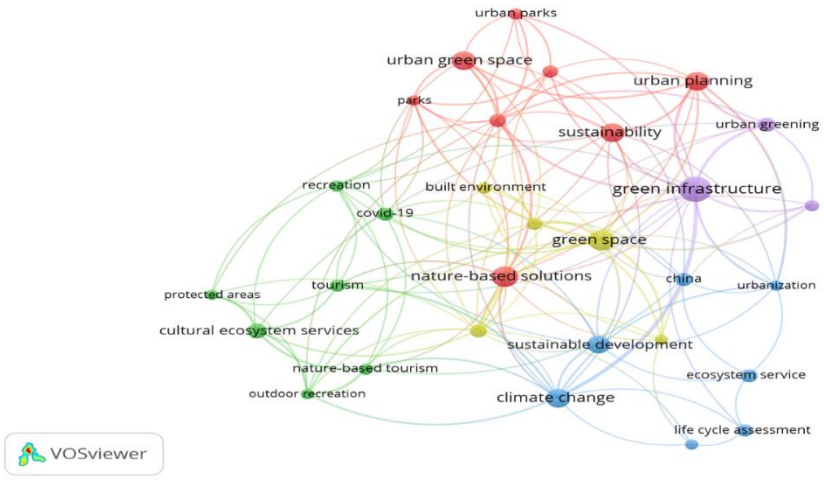
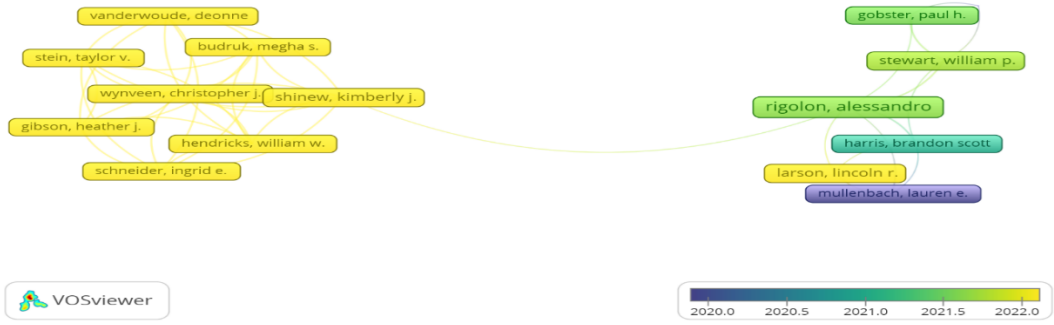


Figure 21, 22 and 23 all depict the collaborative nature of Nature-Based Solutions (NbS) research in terms of institutional, national and cross-author collaborations, demonstrating a very internationalized and networked discipline. The institutional collaboration map demonstrates a high degree of institutional leadership and narrowly focused intra-national collaboration in Developing countries with a high concentration of activities around Chinese universities and geography orientation.

Fig 21. Most collaborative authors



Most collaborative countries

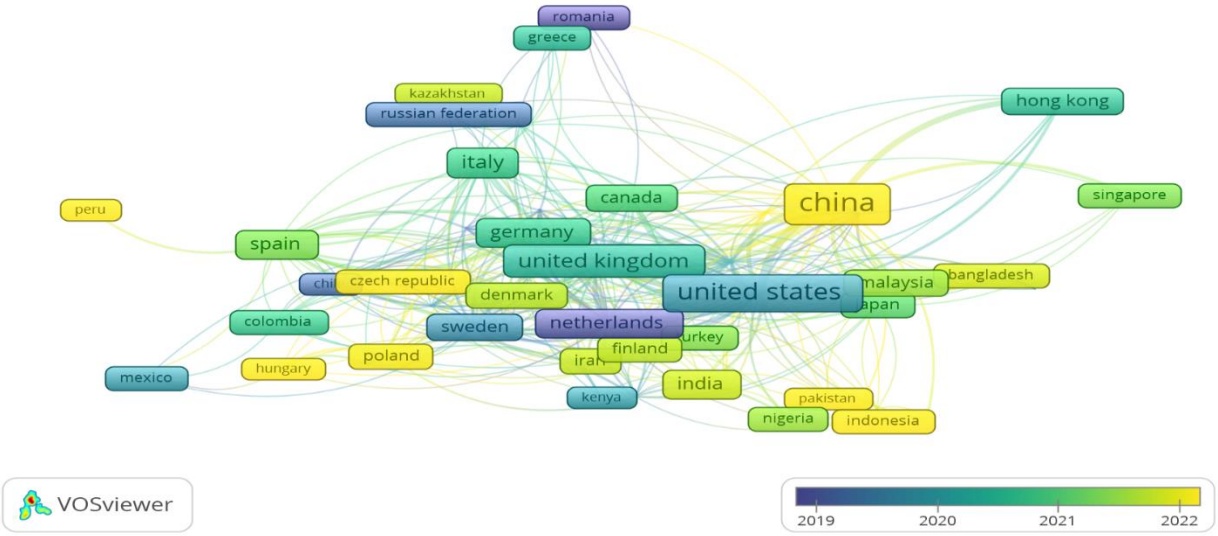
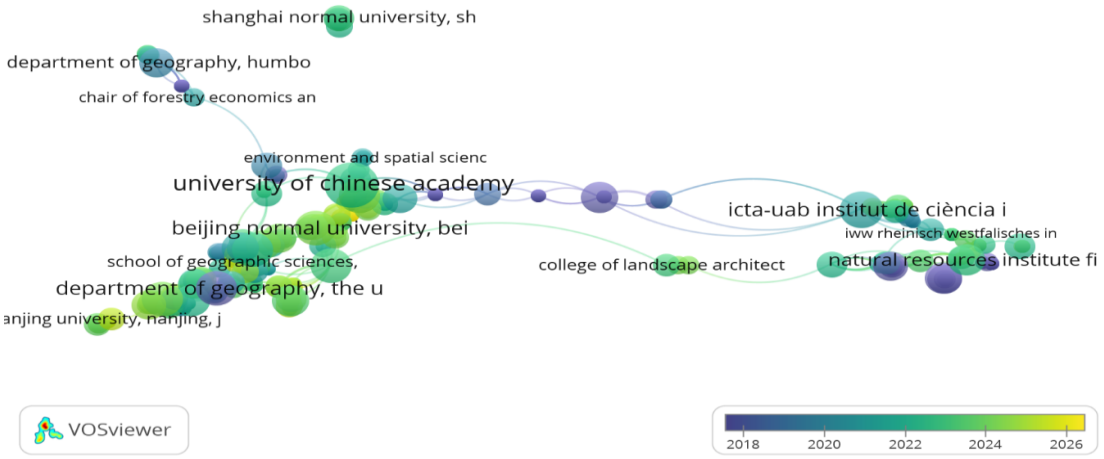


Fig 23. Most collaborative institutions



Results

In the study, a thorough bibliometric systematic literature review is used to trace the intellectual framework and research path of Nature-Based Solutions (NbS) in sustainability and resilience of urban environments in developing settings. The study uses 1,260 publications indexed in Scopus (2006-2026) to investigate the changes in the publication growth, the key authors, institutions, and countries, journals, and the thematic development of the field using the performance analysis and the science-mapping methods, based on Bibliometrics and VOS viewer.

The findings indicate that the research field is growing very fast since the year 2016, with increasing citation effects, high collaborative authorship rates, and concentration of power among journals and institutions. Based on the findings of science-mapping NbS, urban sustainability, and climate resilience are central themes, and new interests in green infrastructure, climate adaptation and urban resilience prompt me to see NbS research as multi-disciplinary and policy relevant in the context of urban planning, environmental management and climate governance.

Discussion

The main goal of the implementation of a bibliometric analysis in the study was to critically analyze the amount, format, and significance of the scholarly literature on the topic of Nature-Based Solutions (NbS) to the city sustainability and climate resilience in developing nations. Although the previous literature on NbS has included literature on a specific theme (e.g., green infrastructure or ecosystem services) or a research literature subset and a more limited time frame (Kim & Kim, 2025). The current study expands the literature review by analyzing all literature published in Scopus and within 20 years (2006-2026) and combining both performance and science mapping approaches (Dunlop et al., 2024).

The results provide evidence that NbS studies have been shifting around various areas, which are highly interconnected and this is based on urban sustainability, climate resilience, green and blue infrastructure, ecosystem services and urban planning. Such findings correspond to the previous research that recognizes NbS as an interdisciplinary research process with its bridge between environmental science, urban studies, sustainability science and policy research (Santos, 2025). Nevertheless, in contrast to previous reviews that have focused on global or developed-country outlooks, the current study reveals how NbS studies in developing nations have become more in line with urban resilience priorities. The temporal analysis reveals a significant shift towards the increased speed of publication output since 2020. This boom is in alignment with the international policy forces like the UN Sustainable Development Goals, the commitments of the Paris Agreement, the discussion of urban recovery after COVID-19 and the increasing exposure of climate risks in developing areas. On the same note, Raymond et al. (2022) and Kumar et al. (2025) have indicated similar patterns of growth and opined that climate urgency and integration of policies have intensely added scholarly interest to NbS (Gorain et al., 2025; ud Din et al., 2025).

The use of the Law of Lotka proves the existence of a skewed distribution of productivity such that few prolific authors produce a large proportion of the literature, with most having a single publication. This trend correlates with other literature-based sustainability areas with a high rate of growth (Leyva-Hernández, Arango-Ramírez, & Gaviria-Marin, 2024). Bradford Law of Scattering of the journals allows identifying Journal of Cleaner Production, Cities, Applied Geography, Journal of Outdoor Recreation and Tourism, and Humanities and Social Sciences Communications as the central publication vehicles in which NbS is being constructed. The eminence of Developing countries, especially, is an indication of the robust national investment in urban sustainability, green infrastructure and climate change research. The increased cooperation between developing countries like India, Pakistan, Brazil and the African countries indicate the development of a global research network and the expansion of the coverage of different geographic settings (Kabisch et al., 2022).

Conclusion

Bibliometric analysis of Nature-Based Solutions (NbS) to enhance the sustainability of urban environment and climate resilience in developing nations is relatively new, and the implementation of performance analysis and science mapping approaches made it possible to conduct a systematic and quantitative evaluation of the academic contributions to this interdisciplinary area. This paper was based on the analysis of 1,260 documents Scopus-indexed during 2006-2026, which gave a general idea of the way the NbS research has changed over the years. The results indicate the high involvement of the main journals that include Journal of Cleaner Production, Cities, Applied Geography, Journal of Outdoor Recreation and Tourism, and Humanities and Social Sciences Communications that have been at the frontline in the intellectual development of NbS research. The findings indicate that the number of publications is growing very fast especially since 2020, and there is a greater level of collaboration in the international field, thematic integration, and diversification of the research fields linked to urban sustainability, climate resilience, and green and blue infrastructure.

The study has a number of significant contributions and implications on the researcher, policymakers, and practitioners. Firstly, it expands upon current NbS reviews by offering a massive, longitudinal bibliometric evaluation of the development of theories, evolution of themes and patterns of collaboration over 20 years. Second, the methodological paradigm that has been used in this research can be duplicated by other researchers in the field of sustainability and urban research to chart the knowledge structures and research trend areas. Third, by locating central outlets, dominant writers, most powerful nations, and establishments, new themes, and network of keywords, the research can offer great advice on the future research path and collaboration. Lastly, though this study provides an in-depth review of NbS scholarship, there are some limitations that need to be mentioned. The search is limited to the Scopus database and this might miss the relevant publications in other databases and future research might consider the inclusion of data in Web of Science to cover a wider range. Also, the use of bibliometric tools constrains qualitative understanding of the policy implementation and localization, consequently, the future research

would be to supplement the bibliometric data with empirical and case-based research especially addressing the issues of governance, equity, and implementation in the context of developing countries

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