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Review

The Trends and Content of Research Related to the Sustainable Development Goals: A Systemic Review

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Featured Application: Bibliometric analysis of SDG-related papers with CATAR can help academic scholars, public sectors, and practitioners utilize the growing volume of literature.

Abstract: This study employed a comprehensive systematic review of the literature (SRL) process with the Content Analysis Toolkits for Academic Research (CATAR) for conducting a bibliometric analysis of the 2814 general SDG-related papers and 92 review papers selected from the Web of Science database from 2013 to 2022. The overview analysis found that the US and UK took the lead in publication and citation. The WHO and several universities were identified as the most prominent institutes around the globe. The field distribution of the most cited papers revealed the existence of a "strong sustainability" paradigm and the importance of science and technology. A landscape of 1123 papers was included in eight clusters according to the bibliographic coupling algorithms in the Multi-stage Document Clustering (MSDC) process. These clusters were then categorized into three groups, "synergies and trade-offs", "networking", and "systems analysis", demonstrated in the theme maps. As for the 92 SDG-related review papers, most were shaped based on literature analysis without specified countries. Moreover, SDG 3 was identified as that exclusively studied in most papers. The information presented is expected to help research scholars, public sectors, and practitioners monitor, gather, check, analyze, and use the growing volume of SDG-related academic articles.

Keywords: bibliometric analysis; CATAR; SDGs; synergies and trade-offs; review papers

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1. Introduction

As first addressed in the historical document *Our Common Future*, "sustainable development" for ensuring intergenerational justice for human beings has been advocated and studied for decades since the late 1980s [1]. In the Millennium Summit of the United Nations in 2000, the Millennium Development Goals (MDGs) were agreed upon for shaping the 21st century. Eight goals and a corresponding twenty-one targets were announced and to be achieved by the end of 2015. The need for a new framework of goals to succeed in the MDGs was discussed in the World Sustainable Development Summit, also known as Rio+20, held in 2012. Thus, the construction of Sustainable Development Goals (SDGs) was noted in the concluding document *The Future We Want* as a mission to be completed before 2016 [2].

The SDGs were then accepted as a resolution titled *Transforming our world: the 2030 Agenda for Sustainable Development*, adopted by the UN General Assembly in September 2015 [3]. People, planet, prosperity, peace, and partnership were the five Ps emphasized as the cores. As before, the UN made a strong statement on eradicating poverty in all

forms as the most crucial challenge. Moreover, integration and indivisibility of the 17 SDGs and relevant 169 targets for supporting balanced economic, social, and environmental sustainability. Since then, more and more actions have been stimulated following the framework and values of the SDGs.

A large number of academic studies have also offered strong support for the SDGs' progress, ranging from strategic plans, policy adaptation, implementation tools, and SDG-specified actions. More studies concerning the commitments and alignment of countries' SDGs and their stage achievements can be found in the literature in relatively earlier years. For example, Persson et al. [4] found that increased attention and visibility of the SDGs in a country, together with specified customized targets, may improve application effectiveness and the projects and reviews that followed. A systemic review of many reports and articles identified significant signs of progress in implementing SDGs for the first two years. However, a lack of system thinking and integrated analytical methodologies and tools was identified [5–7]. Caiado et al. conducted a literature-based review to detect the problems and opportunities of employing the SDGs. They concluded that more resources on education and information, promising political leadership and governance, international partnership, innovation, and aggregated and reliable indicators are necessary to fill the gaps [8]. More studies focusing on implementing the SDGs' challenges and opportunities were published with varied scopes [9,10].

Sustainable development should be framed and interpreted as a comprehensive connotation that can balance the triple bottom lines (TBLs), i.e., economy, society, and environment, and cannot be overemphasized. Thus, any issue in the real world can be linked to some SDGs with different contents of connectivity. These can be reflected in the SDG-related literature, with some studies concentrating on a specific SDG or even some targets, while many are associated with several SDGs. Bibliometric approaches and other "systematic review of the literature" (SRL) methods were employed to find out essential information implicitly existing in the studies. For example, Yeh et al. analyzed more than 1000 SDG-related articles in the Scopus database from 2015 to 2018. They found SDG 3 (good health and well-being) had the highest preference among the papers [11], consistent with the results from other studies [12]. The SDG 3-10 pair took the lead in the tied frequencies. When looking at the topics, Díaz-López et al. recognized the top five paper themes with the content of the SDGs from both Web of Science and Scopus were human, SDG, health policy, greenhouse gases, and maternal health services through extensively examining more than 10,000 articles from 2016 to 2020 [13]. Health, climate change, and related water and energy issues, which correspond to SDGs 3, 13, 6, and 7, respectively, were among the focuses of academia. The term "SDG 3" has been explicitly included in the title of many articles, showing the authors' intention to focus on health and well-being-related issues in the framework of the SDGs [14–19]. As climate change is becoming one of the most overwhelming challenges nowadays, numerous studies are directly connected to SDG 13 [20–23] and interrelated to SDG 6, SDG 7, and others [24–28] found in the literature.

We can also find review studies for some specified issues or fields while considering the SDGs' properties of integration and indivisibility. Bennich et al. selected 70 peer-reviewed articles and explored several themes relevant to SDG interactions instead of respective SDGs, including policy changes, conceptualizing inter-SDG interaction, data sources, and methodology [29]. These review studies also accentuated the core concepts of sustainable development and possible research paths. Leal Filho et al. went through an in-depth content analysis of SDG-related documents, claiming that researchers should consider people, planet, prosperity, partnership, dignity, and justice as the crucial elements in relevant studies to fit them into the interrelationships of the SDGs as discussed and designed [30], which were endorsed by other studies for human rights and SDGs [31,32]. The roles of central and local governments and NGOs in promoting and implementing SDGs were also explored via SRL and content analysis [33–36]. Subjects in the broadened fields of business, health, and education were also on the spotlights of SDG-related review papers [37–43]. Moreover, research methodologies, approaches, and tools for examining the SDGs and the

associated research were also reviewed. Techniques such as geospatial information systems (GIS), remote sensing and multiple criteria decision making (MCDM) [44–46], conceptual issues such as carrying capacity, social innovation, and corporate social responsibility (CSR) [47–49], and other comprehensive themes can be found in the literature.

As more and more research articles accumulate, bibliometrics or scientometrics can help understand the trends and content of SDG-related research papers and identify the gaps. Some studies were carried out with a general scope of the SDGs without focusing on specific themes [12,50–52], while more were conducted with respect to a variety of topics, e.g., general management [53], supply chain [54], entrepreneurship [55], health and well-being [56,57], suicide mortality rate [58], SARS and COVID-19 [59], biofuel [60], agri-food [61], education [62–64], and peace–sustainability nexus [65], to name a few. As some systemic studies aiming at examining the progress and applicability of the SDGs were carried out in relatively early years, an updated analysis offering the trends and context of SDG-related articles with more accumulated information would be valuable. Moreover, previous bibliometric studies on SDGs as a general issue focused more on meta-level data analysis instead of the more holistic or integrated research topics. In this study, we planned to employ a comprehensive SRL process with a bibliometric tool, CATAR, to depict a whole picture of how SDGs were studied and incorporated into the research articles in an efficient and inclusive way. Overview and clustering analysis will be carried out with some essential information for mapping and demonstration. Networking is the central idea of our bibliographic analysis, as every peer-reviewed article cites previously published articles. The information presented by this study is expected to help research scholars and practitioners interested in or devoted to sustainable development and the SDGs monitor, gather, check, analyze, and use the growing volume of related articles in the literature. Moreover, it would be one of the few studies elaborating on the papers reviewing SDG-related articles and offering deeper observations on the trends of applying SDGs in academia.

2. Materials and Methods

2.1. Research Article Selection

As mentioned in the previous section, we are interested in understanding the overview of the academic articles published after the ideas of Sustainable Development Goals were released. We conducted a systematic literature review as the guiding principle of this bibliometric study. The first step would be determining the research questions, which can then decide the databases and searching strategies. Primary research questions include:

RQ1: What countries published the most SDG-related papers and were cited most?
RQ2: What academic institutes published most SDG-related papers and were cited most?
RQ3: What is the distribution of academic fields of these papers?
RQ4: What are the characteristics and themes of the leading paper clusters?
RQ5: What are the critical papers in each of the leading clusters?
RQ6: What are the major patterns of the SDG-related review papers?
RQ7: What SDGs were examined in the SDG-related review papers?

Web of Science (WOS) was selected as the target journal database. It employed many high-quality, interdisciplinary, and international journals with representative indexes as follows [12]:

- SCI-EXPANDED: Science Citation Index Expanded (since 1945)
- SSCI: Social Sciences Citation Index (since 1956)
- A&HCI: Arts and Humanities Citation Index (since 1975)
- ESCI: Emerging Sources Citation Index (since 2015)

The algorithm with the Boolean operators was hired to discover the precise and accurate set of papers that we needed. As the target papers were those with Sustainable

Development Goals, which could be shown in the title, abstract, or keywords, the first trial was:

TI = (SDG* OR sustainable development goal*)

A total of 4208 papers were selected from 2013 till early June 2022 through conducting this algorithm. However, we found that a few articles had "SDG" in the titles, but those were the abbreviations of other scientific terms instead of the Sustainable Development Goals. Thus, we added one extra rule to make sure all SDGs in the papers were Sustainable Development Goals, making the new algorithm as

TI = (SDG* OR sustainable development goal*) AND AB = sustainable development goal

This excluded 1394 papers, and the resulting set of papers included only those associated with Sustainable Development Goals, being a total of 2814 papers.

The other set of papers to be examined were those review papers with SDGs explicitly in the title. The following algorithm was used to generate the dataset:

TI = (SDG* OR sustainable development goal*) AND TI = review AND AB = sustainable development goal

There were 92 papers identified and collected from 2013 till now in the dataset for further analysis.

2.2. Tools Used for Bibliometric Examinations

We selected the Content Analysis Toolkits for Academic Research (CATAR) as the tool to conduct relevant bibliometric analysis. CATAR was developed in 2007 with Hierarchical Agglomerative Clustering (HAC) as its core algorithm. Since then, it has been used to analyze academic papers in various fields [66–70].

The two major modules of CATAR are overview and clustering. The overview module can capture information in all fields, e.g., author, affiliation, country, publication year, and citation. It is also applicable in conducting statistical analysis and data mapping. Thus, the researchers can easily understand the papers in the datasets. The publication trends in time (year) and space (country and institute) will be demonstrated for further examination.

The clustering module of CATAR has two functions: bibliographic coupling and co-word analysis. Any paper cited by two or more papers would play a pivotal role in connecting these papers. The primary calculating mechanism of the bibliographic coupling function is that two papers were linked through their common references. This has been employed in many bibliometric studies incorporating SDGs [12,53,55,59,65] and mostly with network analysis. In CATAR, bibliographic coupling analysis was conducted through paired matrix operations. The Hierarchical Agglomerative Clustering (HAC) and the Multidimensional Scaling (MDS) techniques [70] made the whole process efficient and powerful. HAC can be classified as a document clustering tool, capable of consistently capturing documents and clusters with more remarkable similarities without assigning the number of clusters [71]. Two papers with more common references encompass a higher similarity and tend to be captured in the same cluster. With repeated iterations and comparisons, the Multi-stage Document Clustering (MSDC) process would result in a hierarchy of topics, concepts, and documents, as shown in Figure 1 [67]. Those dotted linkages and nodes shown would not be classified in the higher level as their similarity scores were lower than a pre-defined threshold number. The papers in clusters could then be exhibited on a map according to their similarities following the MDS rules.

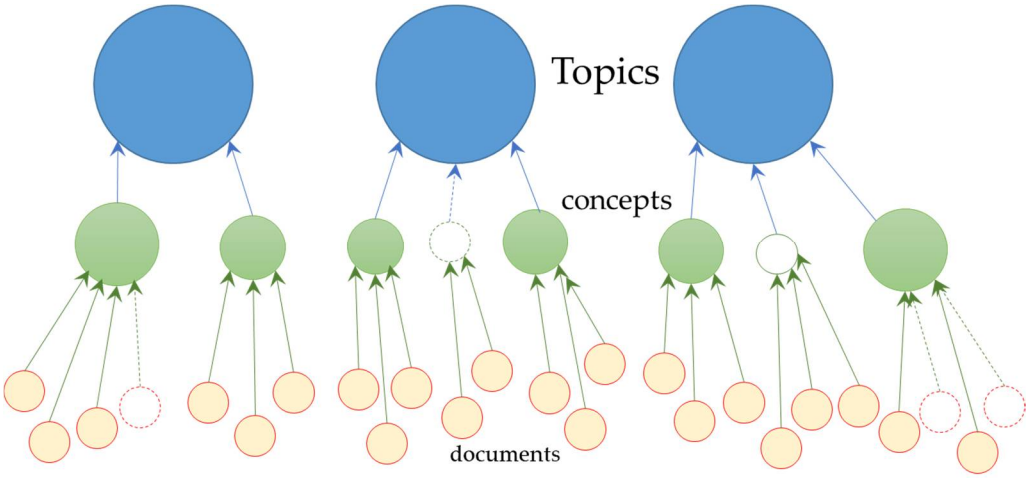


Figure 1. Schematic diagram of the Multi-stage Document Clustering (MSDC) process with HAC techniques.

2.3. Content Analysis of the Review Papers

For the 92 papers in the dataset of review papers with SDGs in their titles, given the number of papers was relatively small, it was not practical to employ CATAR to carry out the bibliometric analysis. Instead, we used traditional content analysis by categorizing the papers according to a pre-defined table. Important aspects included the corresponding SDGs, scope (comprehensive review of all SDGs, focusing on one or several specified SDG(s), review of review), research methodology (literature analysis, others), and geographic range (the globe, a specified continent, a specified country/region). As the SDGs could not be identified straightforwardly just by the term, e.g., SDG 5, but through understanding the meanings or corresponding keywords, we made use of the SDG-related references in some studies such as Yeh et al. and McCollum et al. [11,49] with some modifications, as listed in Table 1. A group of eight graduate students were trained and then filled out the category table. The results were then checked, modified, and confirmed by the authors. Common-used spreadsheet software such as Excel would be appropriate to answer the RQ6 and RQ7 proposed in the preceding.

Table 1. Guidelines for categorizing the selected SDG-related review papers.

	SDG	Relevant Keywords
1.	No poverty	poverty; *poor
2.	Zero hunger	hung*; food; agricult*; *nutriti*; ”food energy”
3.	Good health and well-being	health*; mortality; death*; disease*; illness* medicine*; vaccine*; “world health organization”; WHO
4.	Quality education	educat*; learn*; school*; train*; knowledge; skill*; teach*
5.	Gender equality	”gender equality”; wom?n; girl*; femal*; feminis*; marriage; unpaid
6.	Clean water and sanitation	*water*; hydro*; aqua*; sanitation*; hygien*
7.	Affordable and clean energy	*energy; *fuel; electri*; biomass; *power
8.	Decent work and economic growth	”decent work”; ”decent job”; *employ*; worker*; labour; labor; *econom*; ”economic growth”; ”financial institution*”; ”financial perform*”; ”corporate social responsibility”; CSR; business
9.	Industry, innovation, and infrastructure	Infrastructure; industr*; innovation; research*; internet; technology ”Information and communications technology”; ICT
10.	Reduced inequalities	*equal*; inclus*; ”protect* polic*”; ”developing countr*”; ”least developed countr*”; ”low?income countr*”; mobility; migra*; ”world trade organization”; WTO

Table 1. *Cont.*

SDG		Relevant Keywords
11.	ustainable cities and communities	city; cities; urban*; settlement*; housing; slum*; transport*; heritage; "public space*"; building*; "disaster risk management"; "air quality"
12.	Responsible consumption and production	consumption; consumer; production; product*; waste*; chemi*; reuse; recycle*; "corporate social responsibility"; CSR; subsid*; "green economy"; "circular economy"; "low-carbon economy"; "green product"; "green growth"; "clean growth"; "environmental tax*"
13.	Climate action	climat*; weather*
14.	Life below water	ocean*; mari*; sea*; coast*; *fish*; "life ? water"
15.	Life on land	*land*; ecosystem*; *forest*; terrestrial; biodiversity; "biological diversity"; desertification
16.	Peace, justice and strong institutions	peace*; violen*; war; just*; institution*; law*; crim*; *legal*; legislat*; act*
17.	Partnerships for the goals	global*; world; internation*; cooperat*; partnership*; trade; export

Note: The Boolean search was used to expand the number of publications in the resulting pool of the WOS database. Quotation marks means the corresponding keywords as one unit and to be searched together; an asterisk means the front or back of the keyword might insert letter(s); a question mark means the middle of a word or a phrase inserts a letter or a word.

3. Results and Discussions

3.1. The Overview Analysis of SDG-Related Academic Papers since 2013

As a paper could be published by several authors, we employed the "Fractional Count" (FC) function in CATAR to calculate the weighted counts of the nationality of the papers. The guiding rule of FC is that "all the co-authors are counted as a single author" [67]. Thus, for example, each of the two authors of a paper would share 0.5 points, counted and accumulated for the whole dataset. Table 2 lists the accumulated FCs for the eight countries that the authors were from, i.e., the United States, the United Kingdom, Spain, Australia, China, Germany, India, and the Netherlands, from rank 1 to 8 in order. Although using different calculation mechanisms, these results were similar to those of several bibliometric studies regarding SDGs based on the publication countries. The USA, UK, Australia, China, Canada, Germany, Switzerland, and the Netherlands were among the top countries. The USA was top, covering approximately half of all publications, and was followed by the UK [12,52] or China [72–77]. The trends indicating that each country's FCs increased year by year can also be observed. The FCs in 2022 were relatively lower because we retrieved papers in early June 2022 and, consequently, these numbers do not represent the whole year.

Table 2. The top eight countries with the most FCs of publications from 2013 to 2022.

Year	US	UK	Spain	Australia	China	Germany	India	Netherlands
2013	1	1.2	0	0.7	0.2	1	0	0.3
2014	0.4	1	0	0.7	0	2	0	1
2015	4.1	5	0	0.5	0	1.1	1	0.4
2016	18.5	6.2	0.2	2.2	2.6	4	1.6	5.4
2017	28.9	19.7	2.5	13	1.5	7.2	2.9	6.2
2018	41.5	39.1	8	17.7	5.7	10.7	6.6	11.1
2019	47.7	49.8	19.7	22.2	20	24.7	12.8	14.3
2020	55.3	51.1	67	29.1	30.8	20.8	22.1	23.6
2021	53.9	62.5	73	38.3	52.6	23.6	29.9	16.8
2022 [1]	20.1	20.4	27.8	24.1	26.8	10.4	12.2	5
Total FC	271.4	256.1	198.2	148.4	140.1	105.6	89	84.1

[1] The numbers for 2022 covered from January to early June.

Different papers could be cited a variety of times, depending on innovation, usefulness, understandability, and many other factors. The FCs of the papers cited by other papers could also be obtained with the same counting rules. Table 3 shows the top eight countries

in terms of the total FCs of the accumulated citations of the papers. The US and the UK still had the highest total FCs, whereas the ranks for other countries changed moderately. Switzerland entered the list, replacing India. These results also echoed those rankings in terms of citations of SDG-related publications, with the work of the US and UK dominating the front areas, regardless of research topics [12,56,59,78,79]. These numbers and ranks showed how those researchers interested in SDG-related themes thought of valuable references to the studies conducted and published by authors from these countries.

Table 3. The top eight countries with the most FCs of citations from 2013 to 2022.

Year	US	UK	Australia	Germany	Netherlands	Switzerland	Spain	China
Total FC	5683.1	5349	2602.4	2590	2427.1	1689.5	1682.6	1526.8

Among the countries listed in Tables 2 and 3, most are western countries, except for China and India in Asia. This showed SDGs had been promoted, implemented, and studied much more in these North American and European countries. In terms of linguistic use, China is the only Asian country not using English in academic institutes and universities. This result indicated China's interest and involvement in SDGs during both the development and the implementation stages.

In addition to those countries with more related publications, the institutes making significant contributions were also determined. These indicated the leading universities, research institutes, or organizations globally. Using the same algorithms, the top eight institutes with the most FCs of their publications and citations are listed in Tables 4 and 5, respectively. The institute with the most FC of publications was the Chinese Academy of Sciences, demonstrating a status of prominence. This also showed its dominating situation in China, as the publication FC of China was just around half of that for the US. University Utrecht held a similar position as it was the only institute from the Netherlands on the list. The WHO was listed in both lists of most publications and citations, reflecting the attention paid to the health-related SDG 3 [11]. WHO's critical role in promoting and achieving SDGs, especially SDG 3, was emphasized in other bibliometric studies [56,58,80]. The leading institutes with the most citations differed from those with most publications. This meant that the institutes listed in Table 5 were relatively authoritative, as their publications were cited most. Some distinguished institutes included the United Nations, Charles University in Prague (Czech), the London School of Hygiene and Tropical Medicine (UK), Columbia University (US), and Johns Hopkins Bloomberg School of Public Health (US). Information in this regard has rarely been explored in the literature. We believe that these institutes' critical roles in realizing the SDGs' vision cannot be exaggerated.

Table 4. The top eight institutes with the most FCs of publications from 2013 to 2022.

Year	CAS [1]	UUt	UCL	UQd	WHO	UMb	UOx	UVa
2013	0	0	0	0.5	0.5	0	0	0
2014	0	0	0	0.3	0	0	0	0
2015	0	0	0.5	0	0.3	0.2	0.2	0
2016	0.3	0.6	0.8	0.1	1.3	0.1	0.4	0.1
2017	0	1.8	0	2.8	2.1	0.9	1.4	0
2018	0.5	0.6	3.6	1.3	5.4	0.6	2.1	0
2019	2.8	3.3	1.9	3.9	1.2	0.6	3.4	0.8
2020	3.7	6	3.4	2.7	1.7	0.2	3.4	4.7
2021	6.5	2.3	3.3	1.4	0.4	5.6	1.6	4.7
2022	4.2	0.2	0.7	0.6	0.6	4.4	0.2	1.3
Total FC	18.1	14.8	14	13.6	13.6	12.6	12.6	11.6

[1] The abbreviations represent the following institutes: CAS: Chinese Academy of Sciences; UUt: University Utrecht; UCL: University College London; UQd: University of Queensland; WHO: World Health Organization; UMb: University of Melbourne; UOx: University of Oxford; UVa: University of Valencia.

Table 5. The top eight institutes with the most FCs of citations from 2013 to 2022.

Year	WHO [1]	UN	CUP	UCL	LSHTM	CU	JHUPH	UUt
Total FC	719.7	537.2	515.4	426.8	406.6	392.5	346.9	339.7

[1] The abbreviations represent the following institutes: WHO: World Health Organization; UN: United Nations; CUP: Charles University in Prague; UCL: University College London; LSHTM: The London School of Hygiene and Tropical Medicine; CU: Columbia University; JHUPH: Johns Hopkins Bloomberg School of Public Health; UUt: University Utrecht.

We were also interested in understanding the academic fields to which the SDG-related papers belonged, as these studies were supposed to be cross-disciplinary, comprehensive, and integrated. We checked this by examining the total citations of the papers regardless of the number of authors for one single paper. Articles in the field of "Environmental Sciences and Ecology" have been cited most, reaching a total citation number of 20,088, followed by 14,826 in "Science and Technology". "Business and Economics" was ranked third place, followed by "Engineering", "General and Internal Medicine", "Public Environmental and Occupational Health", "Development Studies", and "Energy and Fuels", as listed in Table 6. This distribution in the fields of paper citations revealed several phenomena that could be discussed. At first, the domains connected to environmental science, ecology, science and technology, and engineering occupied three of the four leading fields. The top two had citation numbers several times in the following fields. Although the balance between the economic, social, and environmental aspects of sustainable development and the SDGs has been stressed repeatedly, the environmental aspect was still of significant concern when different stakeholders mentioned, discussed, and implemented relevant projects. For example, Bonnedahl et al. argued that a strong sustainability perspective was the premise of shortening the distances between people and their actions in space, time, function, and relations. The classical IPAT equation was quoted as an example of why environmental concerns should be prioritized [81]. Zhongming et al. stressed that strengthening the environmental dimensions was crucial for the accomplishments of SDGs in Asia and the Pacific [82].

Table 6. The top eight fields with the most citations from 2013 to 2022.

Year	ES&EC [1]	S&T	B&E	ENG	G&IM	PEOH	DS	E&F
2013	150	150	0	0	0	22	0	0
2014	375	115	1	0	0	10	0	0
2015	403	749	120	11	328	172	623	65
2016	1880	697	487	86	1688	589	357	0
2017	2232	1724	582	60	406	543	159	347
2018	3992	2429	606	539	772	812	254	1143
2019	5291	4133	724	1407	41	309	532	102
2020	3932	3441	963	1168	103	218	440	292
2021	1723	1302	723	510	73	144	133	254
2022	110	86	93	24	0	0	6	38
Total FC	20,088	14,826	4299	3805	3411	2819	2504	2241

[1] The abbreviations represent the following institutes: ES&EC: Environmental Sciences and Ecology; S&T: Science and Technology; B&E: Business and Ecology; ENG: Engineering; G&IM: General and Internal Medicine; PEOH: Public, Environmental, and Occupational Health; DS: Development Studies; E&F: Energy and Fuels.

Moreover, natural sciences and engineering/technology still dominated the SDG-related research databases compared with social sciences. In fact, this has been underlined in many SDG-related studies, in which some stated how vital science and technology were for SDGs [83,84], while some other papers focused on the roles of science and technology in itemized issues such as food security and safety [85,86], risk reduction [87], and industrial innovation and upgrade [88]. A relatively high number of citations of business and economics papers could reflect the real motivations of the commercial and financial sectors to adopt SDGs, as explained by the UN and many firms and consulting compa-

nies [57–59]. Those medicine and public health-related fields demonstrated how SDG 3 was of significant concern again. Besides, development studies could be linked to the general sustainable development studies, and energy echoed the emerging importance of climate change issues [26,89,90]. Figure 2 illustrates the number and trends of citations in the top eight fields. The numbers in the top year for each field were also presented. The citations of most fields dropped significantly after 2020, with "Business and Economics" the exception. The fields "General and Internal Medicine" and "Development Studies" reached their peaks in earlier years, showing change trends. The number of SDG-related papers has continued to grow since 2013, as demonstrated in Figure 3. The fact that the most popular fields in the SDG-related literature have reached their peaks reveals that more papers in other fields could be found.

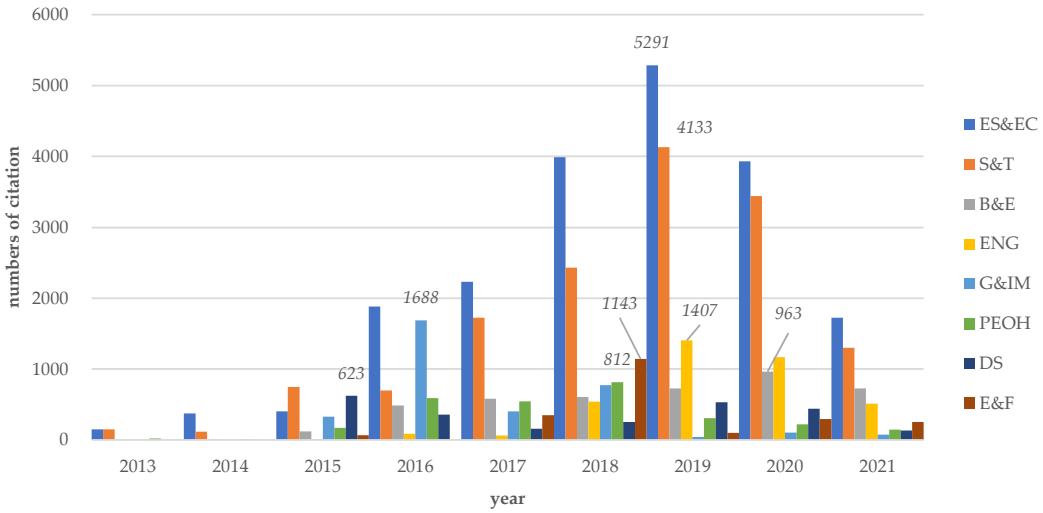


Figure 2. The number and trends of citations in the top eight fields and the number in the top year for each field.

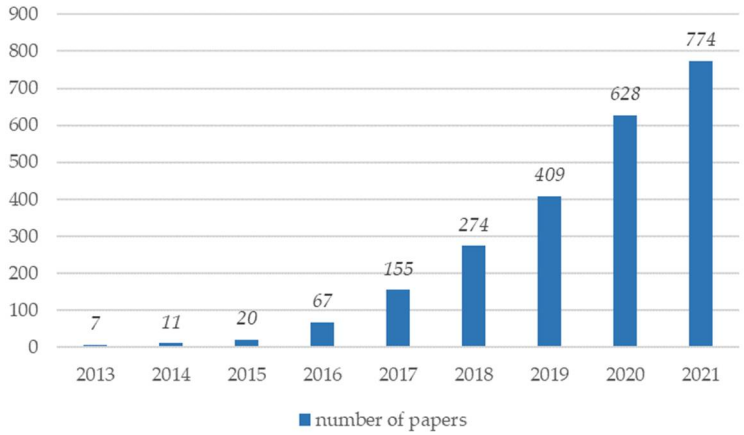


Figure 3. The number of SDG-related papers in the database from 2013 to 2021.

3.2. Work of the Hierarchical Agglomerative Clustering Technique

We employed CATAR to carry out multi-stage document clustering (MSDC) with bibliographic coupling (BC) as the core algorithm. A landscape of 11 clusters was derived, with a total of 1170 papers participating in the process. The numbers and percentages of papers and the characteristic terms of the 11 clusters were demonstrated in Table 7. Together with the characteristic terms, these papers can be referred to for defining each cluster. The most cited articles in each cluster can also be obtained by running CATAR.

Table 7. The 11 clusters derived by CATAR and the corresponding numbers and percentages of papers, and the characteristic terms.

Cluster No.	Number of Papers	Percentage of Papers	Characteristic Terms
1	504	43.10%	synergy, trade-offs, successful, turn, spain
2	144	12.30%	education, critical, education for sustainable development, esdg, netherlands
3	134	11.50%	program, multi-objective, optimization, goal program, multi-objective optimization
4	92	7.90%	interaction, sdg interaction, comparison, literature, fic
5	73	6.20%	institutional, investor, compa, pension, business
6	67	5.70%	network, interlinkage, quantitative, decouple, income-based
7	58	5.00%	company, logic, sustainability, decade of action
8	51	4.40%	citizen, monitor, citizen science, water, quality
9	26	2.20%	promote, unify, database, bundle
10	17	1.50%	prioritization, machine, natural, language, boost
11	4	0.30%	partial, order, partial order, european, union

We found relatively few papers included in the last three clusters. It means that information shown by these clusters would not be essential, but adopting them in the whole HAC framework could make interpretations and applications complicated. Thus, these three clusters were removed. Further analysis of the remaining eight clusters was then conducted.

Table 8 demonstrates the two most cited papers in each cluster [28,91–105]. The resulting names of the clusters were also determined and included in this table. The biggest cluster related to synergies and trade-offs of SDGs, including almost half of the papers. The second-largest cluster captured papers with a rather critical point of view toward SDGs, emphasizing education and inequity. The third cluster covered a similar number of papers to the second one, basically relating to systems analysis techniques such as optimization, multi-objective programming, and multi-criteria decision making (MCDM). The fourth cluster was also about interactions between SDGs but more on the knowledge structure analysis, comparison, and classification. The remaining clusters were also named according to the most cited papers and keywords extracted by CATAR. They are "business and institution", "income and networking", "cooperation and resilient transformation", and "water and citizen science".

Table 8. The 11 clusters derived by CATAR and the corresponding numbers and percentages of papers and the characteristic terms.

Cluster No.	Number of Citations	Most Cited Papers	Name of the Cluster
1	389	Pradhan, P., Costa, L., Rybski, D., Lucht, W., and Kropp, J. P. A systematic study of sustainable development goal (SDG) interactions. *Earth's Future* 2017, *5*, 1169–1179. [91]	Synergies and trade-offs
	108	Kroll, C., Warchold, A., and Pradhan, P. Sustainable Development Goals (SDGs): Are we successful in turning trade-offs into synergies? *Palgrave Commun.* 2019, *5*, 1–11. [92]	
2	63	Kopnina, H. The victims of unsustainability: A challenge to sustainable development goals. *Int. J. Sustain. Dev. World Ecol.* 2016, *23*, 113–121. [93]	Critical issues, inequality, and education
	46	Kopnina, H. Education for the future? Critical evaluation of education for sustainable development goals. *J. Environ. Educ.* 2020, *51*, 280–291. [94]	
3	65	Jayaraman, R., Colapinto, C., La Torre, D., and Malik, T. Multi-criteria model for sustainable development using goal programming applied to the United Arab Emirates. *Energy Policy* 2015, *87*, 447–454. [95]	Systems analysis
	34	Jayaraman, R., Colapinto, C., La Torre, D., and Malik, T. A Weighted Goal Programming model for planning sustainable development applied to Gulf Cooperation Council Countries. *Appl. Energy* 2017, *185*, 1931–1939. [96]	
4	33	Pham-Truffert, M., Metz, F., Fischer, M., Rueff, H., and Messerli, P. Interactions among Sustainable Development Goals: Knowledge for identifying multipliers and virtuous cycles. *Sustain. Dev.* 2020, *28*, 1236–1250. [97]	Interaction, comparison, and classification
	30	Bennich, T., Weitz, N., and Carlsen, H. Deciphering the scientific literature on SDG interactions: A review and reading guide. *Sci. Total Environ.* 2020, *728*, 138405. [28]	

Table 8. *Cont.*

Cluster No.	Number of Citations	Most Cited Papers	Name of the Cluster
5	40	García-Sánchez, I. M., Rodríguez-Ariza, L., Aibar-Guzmán, B., and Aibar-Guzmán, C. Do institutional investors drive corporate transparency regarding business contribution to the sustainable development goals? *Bus. Strategy Environ.* 2020, *29*, 2019–2036. [98]	Business and institution
	30	Garcia-Sanchez, I. M., Aibar-Guzman, B., Aibar-Guzman, C., and Rodriguez-Ariza, L. "Sell" recommendations by analysts in response to business communication strategies concerning the Sustainable Development Goals and the SDG compass. *J. Clean. Prod.* 2020, *255*, 120194. [99]	
6	62	Lusseau, D. and Mancini, F. Income-based variation in Sustainable Development Goal interaction networks. *Nat. Sustain.* 2019, *2*, 242–247. [100]	Income and networking
	3	Dawes, J. H. P. SDG interlinkage networks: Analysis, robustness, sensitivities, and hierarchies. *World Dev.* 2022, *149*, 105693. [101]	
7	21	Van Tulder, R., Rodrigues, S. B., Mirza, H., and Sexsmith, K. The UN's sustainable development goals: can multinational enterprises lead the decade of action? *J. Int. Bus. Policy* 2021, *4*, 1–21. [102]	Cooperation and resilient transformation
	15	Van Zanten, J. A. and Van Tulder, R. Beyond COVID-19: Applying "SDG logics" for resilient transformations. *J. Int. Bus. Policy* 2020, *3*, 451–464. [103]	
8	26	Quinlivan, L., Chapman, D. V., and Sullivan, T. Validating citizen science monitoring of ambient water quality for the United Nations sustainable development goals. *Sci. Total Environ.* 2020, *699*, 134255. [104]	Water and citizen science
	12	Quinlivan, L., Chapman, D. V., and Sullivan, T. Applying citizen science to monitor for the Sustainable Development Goal Indicator 6.3. 2: a review. *Environ. Monit. Assess.* 2020, *192*, 1–11. [105]	

The information obtained so far can be demonstrated using the Multidimensional Scaling (MDS) technique of CATAR. The relative positions between any two clusters were calculated for depicting the theme map. A circle represents a cluster of articles, and the area reflects the number of papers included. The distances between two circles signify their strength of connectivity. A shorter length means they are closely interrelated.

The theme map derived by CATAR is shown in Figure 4. We invited several experts in the areas of sustainability science, environmental education, and CSR to read the exporting documents of CATAR and attempt to derive concise and integrated group names that can embrace most of the central ideas and methodologies of the closely related clusters. It was evident that the eight clusters could be merged into three more prominent clusters. Cluster 1 was unique as one conceptual category with much more papers than others. Clusters 2, 6, and 8 were closely interrelated to each other. Clusters 3, 4, 5, and 7 formed another group. The groups were named "synergies and trade-offs", "networking", and "systems analysis", as described below.

Group 1: synergies and trade-offs
Group 2: networking (to combat critical inequity in basic needs such as water and education)
Group 3: systems analysis (of interactions between stakeholders for resilient transformation)

The information shown in Figure 4 indicates that synergies and trade-offs between various issues and SDGs have been the focus during these years. As this group contained only one big cluster, we expect more relevant studies to be published shortly. Group 2 (networking) consists of three clusters related to critical reflection regarding how SDGs may exert negative impacts on people's basic needs in low-income societies. The three clusters overlapped each other, especially cluster 2 and cluster 8, showing water issues highly connected to inequality. This echoed the statement that "water is a basic human right", argued by the UN and in many reports and studies [84,106]. Group 3 also contains four closely covered clusters, in which cluster 3 and cluster 4 share the most common areas. The studies included were traditional sustainability-oriented studies on interaction, comparison, and classification of complicated systems using mathematical and economic tools. These categories of research have been conducted for decades before SDGs were introduced. Thus, Group 3 seems to be more distant from Group 1 when compared with Group 2. Figure 5 is another demonstration of the clusters and groups showing their

names, relative sizes (number of papers), and distances between them. This theme map may present a whole picture regarding the in excess of 1000 papers captured through HAC in CATAR, plus be potentially helpful for an experienced researcher to understand their position and a newcomer to grasp possible research strategies.

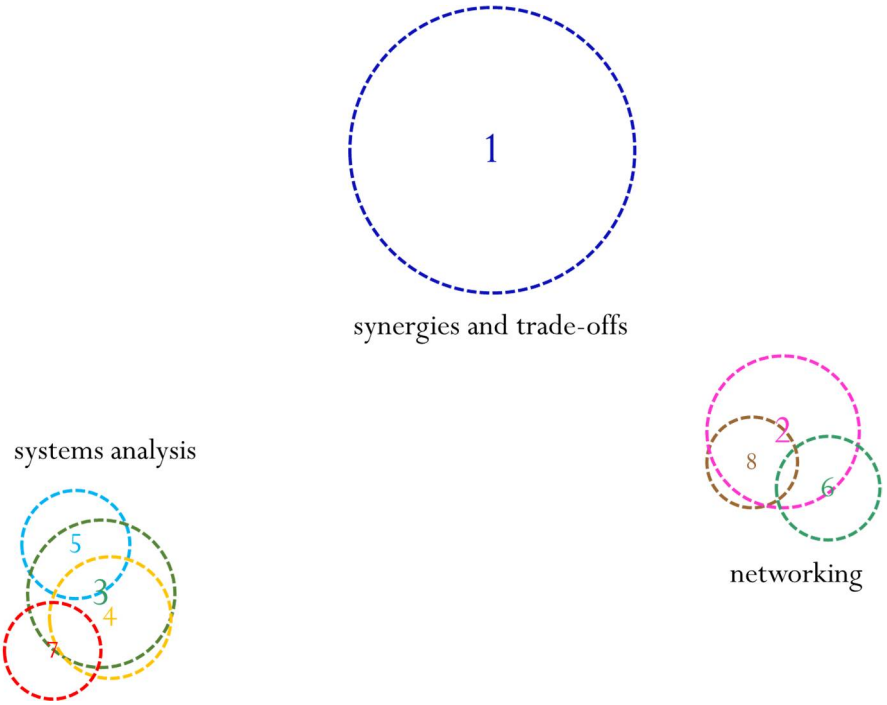


Figure 4. Theme map derived by the Multidimensional Scaling (MDS) technique.

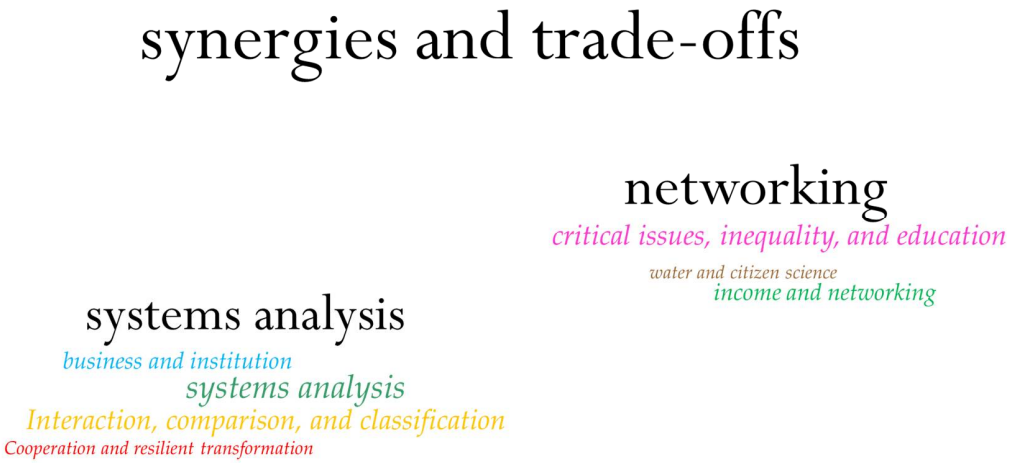


Figure 5. Theme map demonstrating the names and relative sizes of the clusters and groups, as well as the distances between them.

3.3. Content Analysis of the SDG-Related Review Articles

Each of the 92 review papers searched from WOS was read and marked by a group of graduate students and then confirmed by the authors. The first question of interest was what the corresponding SDGs in the SDG-related review papers were. A special point would be marked if only one SDG was studied in the paper. Otherwise, a general point would be marked for each of the SDGs examined. The results, as shown in Figure 6, demonstrated that SDG 3 (good health and well-being) was the SDG studied alone in most papers, followed by SDG 6 (clean water and sanitation), SDG 7 (affordable and clean energy), and SDG 12 (responsible consumption and production). There was no single review paper

just for SDG 5 (gender equality) or SDG 10 (reduced inequalities). This indicated that those social issues directly connected to people's daily lives, such as health, water, energy, consumption, and production, caught more researchers' attention and were thus explored as an SDG-related review paper. The frequencies of all SDGs studied in the SDG-related review papers were not very different, ranging from 33 to 42 if neglecting the frequencies of the exclusive study.

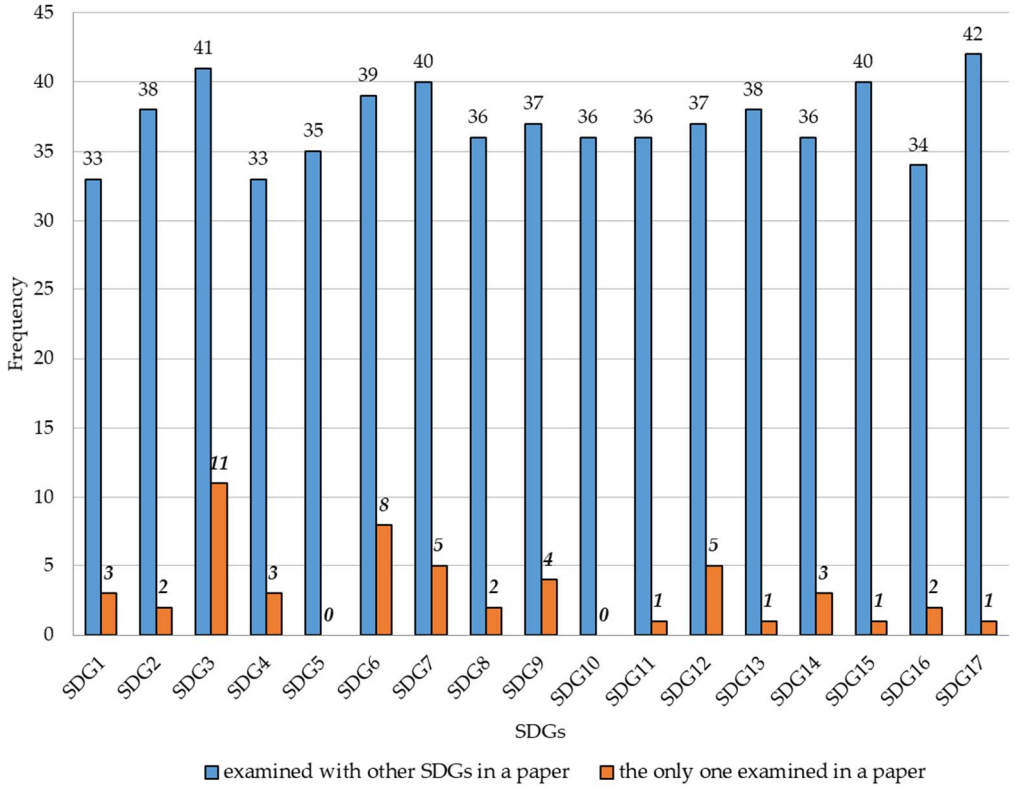


Figure 6. Frequencies of the SDGs examined with or without other SDGs in the SDG-related review paper.

The major patterns of these SDG-related review papers were also examined and marked in the category table. In terms of scope, 26 papers were comprehensive reviews of SDGs and 58 papers focused on one or several specified SDGs, while there was 8 "review of review" papers. Literature analysis was the core research methodology for most papers (79 out of 92). We also found 3 case studies and 10 papers studied via other methods, e.g., GIS, Life Cycle Analysis, and discourse analysis. Of the 92 SDG-related review papers, 73 had a global scope instead of specified continents or countries. We also found a paper on fetal growth restrictions in Africa and 18 studies on various SDG-related issues in one or several countries such as India, Bangladesh, Nepal, Honduras, Uganda, Madagascar, China, Australia, UK, Sweden, Israel, New Zealand, Italy, Singapore, Denmark, Norway, and Romania. Information regarding the patterns of these review papers is illustrated in Figure 7.

A review study will be conducted based on many published papers in associated fields. The 92 papers themselves showed the widespread attention and growing number of SDG-related research in academia. They could also signify the general picture of more than 2000 papers. Based on the analysis, we could understand that most SDG-related studies examined one or several SDGs by employing literature analysis without assigned continents or countries. This also showed the space to conduct research with different scopes or using different methodologies.

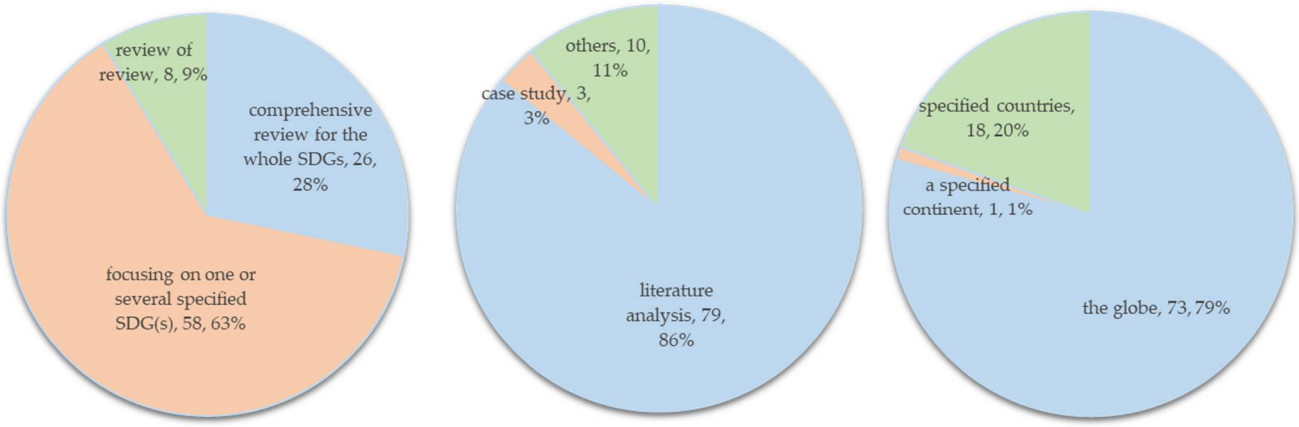


Figure 7. The major patterns of the SDG-related review papers in terms of scope, methodology, and geographic range, from left to right.

4. Conclusions

In this study, we searched those papers incorporating SDGs and SDG-related review papers published from 2013 to 2022 in the Web of Science (WOS) database. We found that western countries dominated the SDG-related research, while China was one of the few exceptions on the list regarding geographic or linguistic characteristics. The substantial role of the WHO in promoting and achieving SDGs, especially SDG 3, was also revealed. The UN and several distinguished institutes from China, the Czech Republic, the UK, and the US were also identified based on the citations. Information in this regard has been explored very little in the literature. These institutes in the list have played a vital role in achieving global SDGs.

The distribution of SDG-related papers' fields symbolized the dominant position of the environmental aspects among the triple bottom lines to achieve SDGs. We found that the natural sciences and engineering/technology dominated the space of SDG-related research. With this as the background, we need to redouble our efforts to promote interdisciplinary, cross-disciplinary, or trans-disciplinary research projects to facilitate the integration of the TBLs and balance natural and social sciences as the SDGs need to be achieved as an indivisible framework.

Eight clusters were derived by employing CATAR according to the rules in the bibliographic coupling (BC) algorithms in the Multi-Stage Document Clustering (MSDC) process of the HAC framework. They were merged into three groups "synergies and trade-offs", "networking", and "systems analysis", shown with relative sizes and distances. The clusters "critical issues, inequality, and education", "income and networking", and "water and citizen science" were included in the second-largest group, "networking", showing that water and education were highly correlated to inequality. This message is consistent with statements made by the UN, such as the concept that water is a fundamental human right of UN Resolution A/RES/64/292 [106] and the need to eliminate educational inequality in the Education for Sustainable Development (ESD) programs of UNESCO [107]. The whole picture and interactions between the clusters and groups may help the experienced researcher understand their position in the global perspective and a newcomer to determine their research roadmaps.

This study was among the few exploring SDG-related review papers. We found that the social SDGs directly connected to people's daily lives, such as health, water, energy, consumption, and production, caught more researchers' attention. In another sense, the frequencies of all SDGs studied in these review papers were within a narrow range. More SDG-related studies generally concentrated on specified SDGs instead of SDGs as an indivisible and integrated framework as stated in the UN resolution. System thinking is crucial in the studies associated with sustainable development (SD) and SDGs. With the aid of the bibliometric analysis tools and practical interpretations of the results,

people can understand the key information hidden in the big picture and clusters. In brief, we suggest critical thinking is also necessary to look at the core issues to avoid "unsustainable development".

The information presented in this study is expected to help research scholars, public sectors, and practitioners in the broad area of sustainable development, especially those interested in SDGs, to monitor, gather, check, analyze, and use the growing volume of academic articles in the literature more systematically and efficiently. Further research could include in-depth bibliometric studies of the roles of SDGs in some specified academic areas, for some emerging issues, and in some geographic regions. More customized literature research combining the computerized or "smart" bibliometric analytical tools and traditional, more human-based content analysis is also recommended.

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Informed Consent Statement: Informed consent was shown in the first paragraph of the survey questionnaire such that the respondent understood data would be used for academic publications.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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