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Research contribution of bibliometric studies related to sustainable development goals and sustainability

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Abstract
This bibliometric study analyzes 1433 former reviews on Sustainable Development Goals (SDGs) and Sustainability, providing a comprehensive overview of the evolving research landscape in this domain. Notably, we observe a substantial annual growth rate of 74% in publications and a remarkable 171% increase in total citations from 2016 to 2022, reflecting a growing interest in this area. We identify the leading countries and institutions contributing to quantitative reviews on SDGs and Sustainability. SDG 12 (Sustainable Consumption and Production) emerges as the most extensively studied and is highly represented in influential journals like *Sustainability* and the *Journal of Cleaner Production*. Across various research fields, SDGs 12 and 11 (Sustainable Cities and Communities) stand out, with SDGs 4 (Quality Education), 5 (Gender Equality), and 15 (Life on Land) showing significance in specific domains. Thematic analysis reveals key topics like environmental protection, circular economy, life cycle assessment, and supply chain management, with strong connections to SDG 12. Further clusters highlight environmental management, renewable energy, and energy policy linked to SDG 7 (Affordable and Clean Energy), along with a smaller cluster focusing on urbanization driven by SDG 11. Network analysis emphasizes the critical roles of SDGs 12 and 9 (Industry Innovation and Infrastructure) in achieving a sustainable future. However, alternative social network indicators highlight the potential influence of SDGs 8 (Decent Work and Economic Growth), 16 (Peace, Justice and Strong Institutions), and 17 (Partnerships for the Goals) on other goals. Intriguingly, mainstream SDG research predominantly focuses on SDGs 3 and 7, presenting challenges due to the volume and complexity of related publications. While SDG 7 could find suitable outlets in leading journals, addressing SDG 3's (Good Health and Well Being) complexity remains a formidable task. Nevertheless, conducting bibliometric studies on SDGs 3, 7, and 13 (Climate Action) offers promising opportunities in future if the associated challenges are addressed effectively.

Keywords Sustainable Development Goal · Sustainability · Bibliometrics · Bibliometric of bibliometrics · Social network analysis · Energy policy · Gender equality · Science mapping

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1 Introduction

The Sustainable Development Goals (SDGs), or the Global Goals, are a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity [1]. Adopted by the United Nations in 2015, the 17 SDGs aim to transform our world by 2030 through a comprehensive approach to sustainable development [2]. These goals address various social, economic, and environmental challenges, including poverty, inequality, climate change, and conflict [3]. The SDGs are crucial for countries, organizations, and individuals to align their efforts toward a common and ambitious vision for a better future [2, 4]. Given the significance of the SDGs and their potential to bring about positive change in our world, in this paper, we review the former reviews on SDGs to contribute to the ongoing conversation.

The SDGs have been the focus of extensive research and analysis since their adoption in 2015 [5, 6]. The current state of the art of research on SDGs reflects a multidisciplinary and interdisciplinary approach, with scholars and practitioners from various fields, such as economics, sociology, environmental science, and political science, among others, contributing to the understanding of the goals and their implementation [7–9].

A significant body of research has focused on the progress made toward achieving the SDGs, including assessments of the current state of play and trends in the implementation of the goals at the global, regional, and national levels [10–12]. Unfortunately, none curate a holistic picture of the state of research. Additionally, a growing body of research has explored the challenges and barriers to the implementation of the SDGs, including the lack of resources and funding, the lack of effective governance and institutions, and the challenges posed by conflicting interests and power dynamics [13–15]. These studies have highlighted the importance of innovative and inclusive approaches to implementing the SDGs and the need for strong partnerships between governments, the private sector, and civil society.

A review of the former literature reveals many SDG research areas, reflecting the goals' wide-ranging and complex nature. Some of the key research areas in the field of SDGs include:

Progress and implementation: Research in this area focuses on tracking and assessing the progress made through achieving the SDGs, including the identification of gaps and challenges in the implementation of the goals [16].

Economic and financial dimensions: Research in this area explores the economic and financial dimensions of the SDGs, including the identification of financing sources, the development of economic and financial policies, and the analysis of the economic and financial implications of the goals [17].

Environmental sustainability: Research in this area focuses on the environmental aspects of the SDGs, including the protection and restoration of ecosystems, the reduction of greenhouse gas emissions, and the development of sustainable and resilient communities [18].

Social inequality and poverty reduction: Research in this area focuses on the social dimensions of the SDGs, including the reduction of poverty, the promotion of gender equality, and the protection of human rights [19].

Political and institutional dimensions: Research in this area focuses on the political and institutional dimensions of the SDGs, including the role of governments, the private sector, and civil society in the implementation of the goals, as well as the development of governance structures and institutions to support sustainable development [20].

Data and measurement: Research in this area focuses on the development of data and measurement systems to track and assess progress towards the SDGs, including the development of indicators, methodologies, and data collection and analysis tools [21, 22].

Interdisciplinary and transdisciplinary approaches: Research in this area focuses on interdisciplinary and transdisciplinary approaches to sustainable development, including the integration of different perspectives and disciplines in the analysis and implementation of the SDGs [23].

Reviews: Precisely, research in this area attempts to classify and summarize former works depicting the progress made on specific SDGs. For example, SDG 3 [24], SDG 6 [25], SDGs 8 and 12 [26], etc. These comprehensive articles serve as critical bridges between the existing body of knowledge on SDGs and the current state of research, making them invaluable resources for scholars, students, and practitioners alike.

These are just a few examples of the many SDG research fronts. The field constantly evolves, and new research areas are emerging as the goals continue gaining attention and importance in the global development agenda. The current state of the art of SDG research reflects a growing recognition of the importance of the goals for sustainable development and the need for more action to achieve them. It also underscores the need for continued research and analysis to understand the challenges and opportunities associated with implementing the SDGs and the role different actors can play in promoting sustainable development [11, 27].

Given the dynamic, diverse, multidisciplinary, and interdisciplinary nature of research on SDGs, frequent, systematic, and timely assessment of the evolving body of knowledge is imperative to guide future research directions [28]. It has become increasingly challenging to gain meaningful insights from the vast literature using traditional means. Fortunately, several retrospectives have emerged to bridge the gap. For example, applying bibliometrics, Sweileh [24] attempts to review the literature focusing on SDG 3, i.e., good health and well-being. González García et al. [29] analyses the literature on SDG 4 i.e., quality education. Raman et al. [11] present a comprehensive analysis of SDGs 7 and 13, i.e., affordable and clean energy and climate action, respectively; Sharifi et al. [30] summarize the literature on SDGs 13 and 16, i.e., climate change and peace. In one of the recent works, Raman et al. [27] attempt to summarize the research advocating the fulfilment of SDGs 5, 8, and 10, i.e., gender equality, decent work and economic growth, and reduced inequalities. Notably, quantitative reviews of SDGs have proliferated significantly, prompting a need to review these prior retrospectives. This growing body of research underscores the importance of ongoing bibliometric and scientometric analysis in furthering our understanding of the multifaceted SDGs and providing insights for both researchers and policymakers.

Furthermore, the likelihood of certain SDGs being overrepresented in bibliometric assessment literature suggests that some SDGs remain insufficiently explored or unexplored in this context. Another intriguing aspect that could benefit bibliometricians, enthusiasts, and researchers in various SDGs is understanding the utilization patterns of different bibliometric methods and frameworks. This insight would reveal which methods, tools, and frameworks are frequently employed and which ones are underutilized. Analyzing the less commonly used methods opens a realm of untapped analysis opportunities. Additionally, identifying key bibliometric assessment efforts related to SDGs can shed light on emerging research themes within these goals and offer valuable insights to researchers and policymakers alike. Such information can assist policymakers in prioritizing emerging "thrust areas" that warrant research attention. In essence, we propose to offer a meta-analysis to empower researchers and institutions to make informed decisions. Precisely, we ask the following research questions (RQs):

- RQ1. What is the trend of bibliometric research in SDGs?
- RQ2. How do different bibliometric studies relate to various SDGs?
- RQ3. What are the top fields of research (FoR), and what topics are emergent in the research domain?

By addressing the RQs, we make several important contributions. We firmly believe our novel approach benefits both the de novo and seasoned scholars alike. Our extensive range of performance and network analyses is formidable to those fresh to the field of knowledge. They may specifically appreciate our exposition of the research trend, identification of the seminal works and notable scholars to follow, their affiliations denoting the research hotspots, and the range of thematic diversity evident in the research domain. At the same time, the seasoned academic may appreciate our introspection of the SDG maps and future research directions. Conversely, the policy makers gain insights for identifying areas where future sponsorship should concentrate.

The remaining part of the paper is structured as follows: Sect. 2 briefs the research methods, and Sect. 3 discusses the results. Section 4 deliberates on the emerging research topics, followed by our discussions and conclusions in Sect. 5.

2 Methodology

As we intend to analyze the bibliometric studies related to SDGs using bibliometric methods, a brief introduction to the field of bibliometrics and associated fields such as Scientometrics and Informetrics is attempted. Bibliometrics can be traced back at least to the late nineteenth century when explorations to study subject scattering in publications, the growth of literature and history of science, etc., using statistical methods began. The frequency distribution of scientific publications of Physicists and Chemists by Lotka [31] is treated as one of the first attempts to determine scientific productivity. While the key proposition of Lotka later gained popularity as Lotka's law of productivity, the seminal work by Bradford [32] was dubbed Bradford's law of scattering. Bernal [33] put forward the social function of Science and laid the foundation of Science of Science, and Zipf [34] came out with inverse relation law in many physical and social systems known as Zipf's law. The formalism of quantitative measures for measuring science was introduced by Price [35], whom Garfield and others acknowledged as the father of modern Scientometrics. Garfield introduced SCI or Science Citation Index, an indexing system for scientific literature, which can be regarded as a milestone development or bridge in the transition of pre-modern Scientometrics or science of science to 'Scientometrics'. While this transition happened, several important works were done on the underlying mechanism of scientific progress. Price [35] brought out the exponential

curve of science. Merton [36] extended the work of Bernal in a sociologistic perspective and strengthened science's 'social organization'. The introduction of bibliographic coupling [37], the introduction of historiographies by Garfield et al. [38], and the introduction of networks of scientific publications by Price [35] marked the take-off of modern Scientometrics. It allowed the possibility of systematic analysis of scientific literature via network science and other quantitative methods.

Small [39] and Marshakova [40] independently introduced the co-citation of documents as a method for measuring the relationship between documents. Perhaps all these achievements triggered the official coining of terms like 'bibliometrics' by Pritchard [41], 'Scientometrics' by Nalimov and Mulchenko [42], and 'informetrics' by Nacke [43]. These triumvirate fields evolved by introducing many indicators, methods for assessment and mapping of science, and several software packages such as VOSViewer [44] that incorporated these methods. An important development in the indicator domain was through Hirsch [45] in the form of the *h*-index, which was initially appreciated and soon criticized for its limitations in individual productivity assessment. Several indices, like the *g*-index [46], *t* and *f* indices [47], etc., were developed, and these are widely dubbed as *h*-type indicators, and one of the recent in this category is the Ψ-index [48]. Though these indices have some limitations, they are inspired by the h-index and some of its variants and are used for the development of diligently designed frameworks for institutional performance assessment [49] and for collaboration recommendation systems [50].

In this review, the Scientific Procedures and Rationales for Systematic Literature Reviews (SPAR-4-SLR) protocol developed by Paul et al. [51] and used extensively by other authors [27, 52] is adopted to guide the assembling, arranging, and assessing tasks (see Fig. 1). We disclose and explain the methodological choices at each stage of the protocol as follows:

2.1 Assembling

The initial step, known as assembling, involves gathering publications for examination. As this work deals with a bibliometric analysis of bibliometric studies related to SDG research, our data comprises works in the intersection of SDG, sustainability, and bibliometric research. The following search query is used to retrieve the bibliographic data from Scopus on February 28, 2023. Scopus is widely acknowledged and frequently utilized for quantitative analyses and it is the premier multi-disciplinary database containing peer-reviewed literature [53]. We selected the study period between 2016 and 2022 to focus on recent developments following the formal adoption of the UN SDG in September 2015. We applied the following search to retrieve a total of 1711 publications.

TITLE-ABS ((“SDG” OR “sustainable development” OR (sustainability)) AND (bibliometric OR scientometric OR “Science mapping” OR “citation analysis” OR bibliographic)) AND (LIMIT-TO (DOCTYPE, “ar”) OR LIMIT-TO (DOCTYPE, “re”) OR LIMIT-TO (DOCTYPE, “cp”) OR LIMIT-TO (DOCTYPE, “ch”) OR LIMIT-TO (DOCTYPE, “cr”)) AND (LIMIT-TO (PUBYEAR,2022) OR LIMIT-TO (PUBYEAR,2021) OR LIMIT-TO (PUBYEAR,2020) OR LIMIT-TO (PUBYEAR,2019) OR LIMIT-TO (PUBYEAR,2018) OR LIMIT-TO (PUBYEAR,2017) OR LIMIT-TO (PUBYEAR,2016) OR LIMIT-TO (PUBYEAR, English)) AND (LIMIT-TO (LANGUAGE, “English”)) AND (LIMIT-TO (SRCTYPE, “j”)).

2.2 Arranging

In the SPAR-4-SLR protocol, the arranging stage involves organizing codes and purifying articles by applying exclusion and inclusion criteria to the results obtained from the search. For organization, we downloaded the bibliometric data of articles from Scopus and sorted them by the article title, journal title, author name, institute affiliation, country of affiliation, author keyword, number of citations, and SDG linkage with articles. We utilized SciVal to identify the SDG linkage with articles. As for purification, we excluded 278 articles as they could not be associated with SDGs.

2.3 Assessing

In the last stage, assessment, evaluation, and reporting play a crucial role. The article's evaluation section highlights the analysis approach and research constraints. In this research, we utilized various software tools such as Scival [54], VOSviewer [44], Rawgraphs [55], SDG Toolkit [56], and MS Excel, depending on the specific requirements. MS Excel was employed for data filtering, sorting, listing, and graph creation. Scival played a key role in identifying the most and least researched SDGs, mapping SDGs to journals, countries, institutions, and authors, as well as identifying emerging research topics and their SDG focus. VOSViewer was primarily used for visualizing keyword co-occurrence mapping and co-citation mapping of SDGs. Rawgraphs aided in designing the Sankey diagram for mapping the top countries, institutions, and journals. SDG Mapper was used to determine the percentage of SDG mappings of keywords in different clusters, while

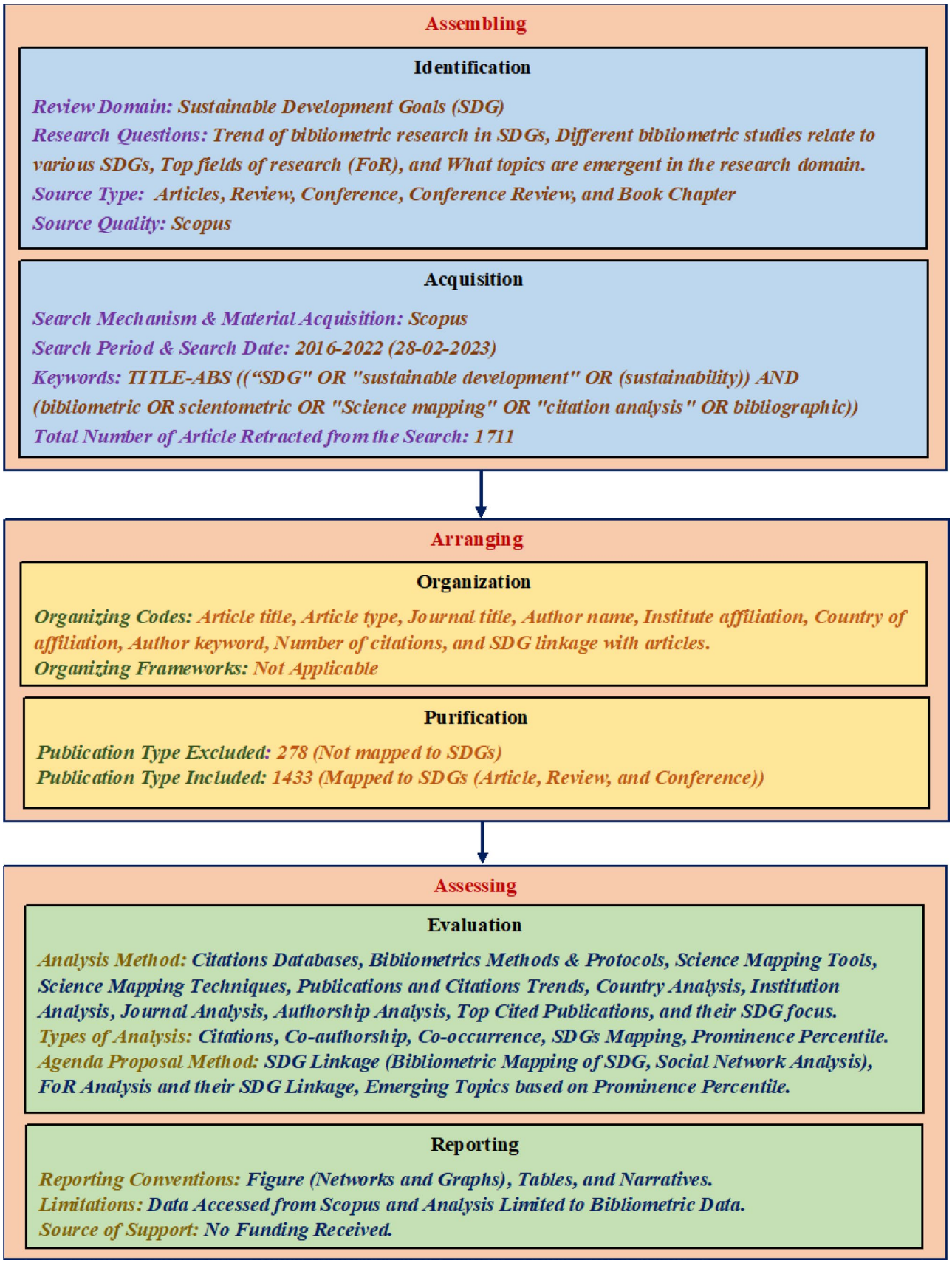


Fig. 1 The SPAR-4-SLR protocol

SDGToolkit was employed to construct an SDG network based on eigenvector and betweenness for analyzing the network of SDG goals.

3 Results and discussions

In accordance with the SPAR-4-SLR protocol, our analysis encompasses 1433 bibliometric studies on SDGs and sustainability. Initially, we categorize the study articles by their publication type, the search engines employed for collecting bibliographic data, the study methods they employ, and the science mapping tools and techniques they utilize. Subsequently, we delve into an examination of the trends in publications and citations, the authors' affiliations, including their countries and institutions, and the sources in which these studies are published. Furthermore, we present an in-depth analysis of the contributing authors. After the descriptive analysis, we proceed to provide a summary of the most highly cited publications and their corresponding SDG maps. Additionally, we compile a summary of keyword co-occurrence patterns, mapping them to their respective relevant SDG(s).

Table 1 summarizes bibliometric studies on various SDGs, revealing varying research focus. SDG12 (Responsible Consumption and Production) garnered the most studies at 699, followed by SDG9 (Industry, Innovation, and Infrastructure) with 535, and SDG8 (Decent Work and Economic Growth) with 586. In contrast, SDG5 (Gender Equality) saw only 26 bibliometric studies potentially suggesting scope for future research.

3.1 Citations databases (search engines)

Upon careful observation of the study articles, we find that scholars retrieve data from several search engines, such as Scopus, WoS, Google Scholar, and PubMed, both in isolation and in combination. However, most studies relied on Scopus or Web of Science (WoS). Table 2 presents the top three cited publications on SDGs, categorized by publication type and the search engines in which they appear.

Geissdoerfer et al. [57], a review of SDG12 is the top-cited article (TC: 2556) in WoS, followed by D'Amato et al. [58] and Olawumi & Chan [25], while Cheng [59] is the top-cited SDG article in Scopus (TC: 506) followed by Chen et al.[60] and Zyoud & Fuchs-Hanusch [61] cited 270 and 244 times, respectively. D'Amato et al. [58] cover multiple SDGs, such as SDG4, SDG8, and SDG12, while Olawumi and Chan[25] review articles on SDG6, SDG8, and SDG11. Among the top-cited reviews in Scopus, Cheng [59] reviews articles on SDG12, followed by Chen et al. [60] addressing

Table 1 Bibliometric studies on SDGs

TP	SDG
699	SDG12 (Responsible Consumption and Production)
586	SDG8 (Decent Work and Economic Growth)
535	SDG9 (Industry, Innovation and Infrastructure)
251	SDG4 (Quality Education)
246	SDG13 (Climate Action)
201	SDG7 (Affordable and Clean Energy)
200	SDG11 (Sustainable Cities and Communities)
120	SDG2 (Zero Hunger)
101	SDG6 (Clean Water and Sanitation)
100	SDG15 (Life on Land)
83	SDG3 (Good Health and Well-being)
68	SDG10 (Reduced Inequalities)
67	SDG16 (Peace, Justice and Strong Institutions)
50	SDG14 (Life Below Water)
49	SDG1 (No Poverty)
26	SDG5 (Gender Equality)
3	SDG17 (Partnerships for the Goals)

This table presents a summary of the SDG mapping of the study articles. SDG = sustainable development goals, and TP = total publications (includes SDG overlaps) on the search date

Table 2 Top cited articles based on the citation database and publication type

TC	Author(s)	Publication Type	SDG Focus	Search Engine
2556	Geissdoerfer et al. [57]	Review	12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Web of Science (TP: 852)
455	D'Amato et al. [58]	Article	4 QUALITY EDUCATION; 8 DECENT WORK AND ECONOMIC GROWTH; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	
348	Olawumi & Chan [25]	Review	6 CLEAN WATER AND SANITATION; 8 DECENT WORK AND ECONOMIC GROWTH; 11 SUSTAINABLE CITIES AND COMMUNITIES	
506	Cheng [59]	Article	12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Scopus (TP: 601)
270	Chen et al. [60]	Article	8 DECENT WORK AND ECONOMIC GROWTH; 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE; 16 PEACE, JUSTICE AND STRONG INSTITUTIONS	
244	Zyoud & Fuchs-Hanusch [61]	Review	4 QUALITY EDUCATION	

This table shows the top three cited review articles on SDGs indexed in Web of Science and Scopus. TP = total publications, and TC = total citations on the search date

SDG8, SDG9, and SDG16, and Zyoud & Fuchs-Hanusch's [61] focusing on SDG4. It is interesting to note that SDG12 (Responsible Consumption and Production) is the focus of two highly cited publications from both databases, while SDG8 (Decent Work and Economic Growth) is covered in three of the six listed publications. Additionally, the table demonstrates that influential reviews on SDGs are interdisciplinary, with multiple SDGs being addressed in various survey papers, possibly using various methods and review protocols.

3.2 Bibliometrics methods and review protocols

Many papers guide literature reviews, but few offer a definitive and transparent process for researchers to rely on. PRISMA and SPAR-4-SLR protocols aim to improve transparency and reliability in systematic reviews. The adoption of PRISMA has widely enhanced the quality and transparency of reporting in systematic reviews and meta-analyses. SPAR-4-SLR, introduced by Paul et al. [51], is an extension of the original SPAR framework, developed to guide researchers in conducting systematic mapping studies.

Our manual review of the study articles revealed that 156 articles followed the PRISMA protocol, while only 16 applied the SPAR-4-SLR protocol owing to its later inclusion, indicating the overwhelming popularity of PRISMA over SPAR-4-SLR for systematic reviews. As there is no explicit declaration about the usage of protocols in these articles, without in-depth assessment, it is not easy to understand whether such studies were conducted systematically or intended for literature reviews. Also, the usage of multiple protocols (exploring whether one can complement the other or not) for SLR, other quantitative methods, including sophisticated bibliometric methods and combinations of those, qualitative methods, and mixed-methods, etc., are not that evident from the body of literature we analyzed. Table 3 shows the top-cited reviews following the PRISMA and SPAR-4-SLR protocols and maps them to their respective SDG(s) focus.

Interestingly, our findings reveal a pattern among the top three reviews, i.e., while the top three using the PRISMA protocol are linked to SDG 3, SDG 4, SDG 10, SDG 11, and SDG 12, the top three for SPAR-4-SLR are associated with SDG 4, SDG 7, SDG 8, SDG 9, SDG 11, SDG 12, and SDG 13. As we delve into the exploration of science mapping tools in the next section, it's noteworthy that the utilization of both PRISMA and SPAR-4-SLR protocols appears to provide comprehensive coverage across a wide range of SDGs.

Table 3 Top cited PRISMA and SPAR-4-SLR protocol-based publications

TC	Author(s)	SDG focus	Protocol
103	Hallinger & Chatpinyakoop [62]	4 QUALITY EDUCATION; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	PRISMA (156)
68	Strifler et al. [63]	3 GOOD HEALTH AND WELL-BEING	
58	Kong et al. [64]	10 REDUCED INEQUALITIES; 11 SUSTAINABLE CITIES AND COMMUNITIES; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	
24	Kumar et al. [65]	4 QUALITY EDUCATION; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	SPAR-4-SLR (16)
4	Raman et al. [27]	7 AFFORDABLE AND CLEAN ENERGY; 8 DECENT WORK AND ECONOMIC GROWTH; 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION; 13 CLIMATE ACTION	
3	Secinaro et al. [66]	11 SUSTAINABLE CITIES AND COMMUNITIES	

This table presents the top-cited systematic review papers based on PRISMA and SPAR-4-SLR protocols. TC = total citations on the search date

3.3 Science mapping tools

Various science mapping tools, including Bibexcel, Gephi, VOSviewer, SciMAT, CiteSpace, and Bibliometrix, have been employed in bibliometric analyses. Moral-Muñoz et al. [67] compared these tools comprehensively, highlighting their strengths and weaknesses and providing guidance on which tool might be most appropriate for different research questions and objectives. Bibexcel analyzes scientific publications through co-authorship, citation, and co-citation analysis [68]. Gephi visualizes social and citation networks [69]. VOSviewer creates and visualizes bibliometric maps of relationships between papers, authors, and journals [44]. SciMAT analyzes co-citation patterns, text content, and network structures [70]. CiteSpace performs co-citation analysis to identify key concepts, authors, and research trends [71]. Bibliometrix is an R-package for comprehensive science mapping analysis, including bibliometric analysis, network analysis, and visualization [72].

Table 4 provides information on the top-cited articles that have used various science mapping tools in bibliometric studies on SDGs. Interestingly, the most widely used tool is VOSviewer, followed by CiteSpace and Bibliometrix. Our analysis reveals that the most common SDGs studied using these tools are SDG 4 (Quality Education), SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 12 (Responsible Consumption and Production). It is also interesting to note that some articles have used multiple tools, such as Rashidi et al. [73], who have used both Bibexcel and Bibliometrix.

In summary, Table 4 highlights the prevalence of science mapping tools in bibliometric studies on SDGs, with VOSviewer emerging as the most widely adopted tool, closely followed by CiteSpace and Bibliometrix. Our analysis highlights that researchers predominantly employ these tools to investigate SDG 4 (Quality Education), SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 12 (Responsible Consumption and Production). Additionally, it's worth noting that some studies utilize multiple tools, showcasing the versatility and adaptability required in this dynamic research domain. As we transition to the exploration of science mapping techniques in the next section, these findings underline the significance of science mapping tools in advancing our understanding of SDGs and the importance of selecting the right tools for the right research questions, ultimately contributing to the overarching goals of sustainability.

Table 4 Top cited SDG articles for science mapping tools

TC	Authors	SDG focus	Tool
511	Cheng [59]	12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Bibexcel (TP: 43) https://homepage.univie.ac.at/juan.gorraiz/bibexcel/
76	Mura et al. [74]	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	
72	Rashidi et al. [73]	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	
511	Cheng [59]	12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Gephi (TP: 49) https://gephi.org/
228	Feng et al. [75]	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	
76	Dhamija and Bag [76]	4 QUALITY EDUCATION; 8 DECENT WORK AND ECONOMIC GROWTH; 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	
251	Zyoud and Fuchs-Hanusch [61]	4 QUALITY EDUCATION	VOSviewer (TP: 536) https://www.vosviewer.com/
164	Duque-Acevedo et al. [77]	4 QUALITY EDUCATION; 8 DECENT WORK AND ECONOMIC GROWTH; 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	
126	Abad-Segura et al. [78]	4 QUALITY EDUCATION; 8 DECENT WORK AND ECONOMIC GROWTH; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	
75	Abduljabbar et al. [79]	11 SUSTAINABLE CITIES AND COMMUNITIES	SciMAT (TP: 49) https://sci2s.ugr.es/scimat/
72	Furstenau et al. [80]	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	
68	Agusdinata et al. [81]	7 AFFORDABLE AND CLEAN ENERGY	
354	Olawumi and Chan [25]	6 CLEAN WATER AND SANITATION; 8 DECENT WORK AND ECONOMIC GROWTH; 11 SUSTAINABLE CITIES AND COMMUNITIES	CiteSpace (TP: 218) https://citespace.podia.com/
181	Dos et al. [82]	8 DECENT WORK AND ECONOMIC GROWTH	
168	Li et al. [83]	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	
172	Di et al. [84]	4 QUALITY EDUCATION; 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Bibliometrix (TP: 171) https://www.bibliometrix.org/
111	Schöggl et al. [85]	8 DECENT WORK AND ECONOMIC GROWTH; 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	
84	Sharma et al. [86]	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	

Table 4 (continued)

This table shows the top-cited SDG article using various science mapping tools. TP = total publication, and TC = total citations on the search date

Table 5 Top cited SDG articles on various science mapping techniques

TC	Authors	SDG focus	Science mapping technique
124	Pizzi et al. [87]	4 QUALITY EDUCATION; 8 DECENT WORK AND ECONOMIC GROWTH; 10 REDUCED INEQUALITIES	Bibliographic coupling (TP: 125)
76	Bartolacci et al. [88]	12 RESPONSIBLE CONSUMPTION AND PRODUCTION; 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	
76	Mura et al. [74]	12 RESPONSIBLE CONSUMPTION AND PRODUCTION	
511	Cheng [59]	12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Co-citation analysis (TP: 347)
158	Zhang & Li [89]	11 SUSTAINABLE CITIES AND COMMUNITIES	
126	Abad-Segura et al. [78]	4 QUALITY EDUCATION; 8 DECENT WORK AND ECONOMIC GROWTH; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	
353	Olawumi & Chan [25]	6 CLEAN WATER AND SANITATION; 8 DECENT WORK AND ECONOMIC GROWTH; 11 SUSTAINABLE CITIES AND COMMUNITIES	Co-word analysis (TP: 185)
149	Si et al. [90]	11 SUSTAINABLE CITIES AND COMMUNITIES	
101	Zhu & Hua [91]	8 DECENT WORK AND ECONOMIC GROWTH	
164	Duque-Acevedo et al. [77]	4 QUALITY EDUCATION; 8 DECENT WORK AND ECONOMIC GROWTH; 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Co-authorship analysis (TP: 130)
76	Garrigos-Simon et al. [92]	8 DECENT WORK AND ECONOMIC GROWTH; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	
72	Rashidi et al. [73]	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	

This table shows the top-cited SDG article using various science mapping techniques. TP = total publications, and TC = total citations on the search date

3.4 Science mapping techniques

On manual review of publications, we discovered that 125, 347, 185, and 130 publications apply bibliographic coupling, co-citation, co-word, and co-authorship analyses, respectively. Table 5 shows the top three cited publications for the four science mapping techniques. Further investigation reveals that SDG 12 on responsible production and consumption is commonly featured across all techniques.

Thus, the consistent focus on SDG 12 across all four science mapping techniques underscores its significance in the literature. This implies a widespread recognition of SDG 12's importance in sustainability. Researchers employ various mapping methods to explore its different aspects, potentially influencing policy and practice. This finding encourages deeper exploration of SDG 12's implications and applications in academia and the real world, highlighting its relevance and providing direction for future research.

Along with the science mapping tools and techniques, understanding the publication and citation trends is vital in recognizing the evolving landscape of research in the field of SDGs and sustainability. As we delve into the specific trends, it's important to gain insights into the trajectories that this research area is taking and the SDGs that are at the forefront

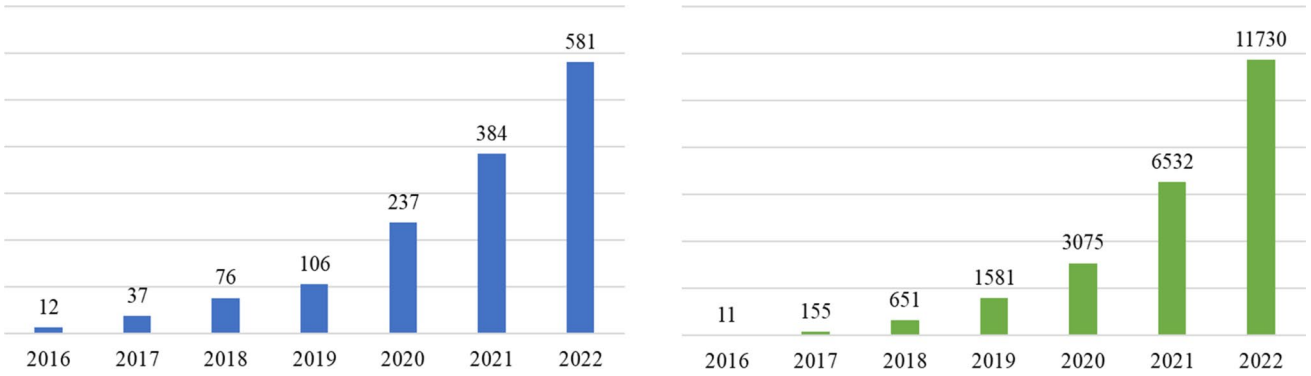


Fig. 2 Research performance (total publications and total citations)

of academic attention. Additionally, analyzing the publication and citation trends can provide valuable information for researchers, policymakers, and practitioners interested in the field of sustainability and SDGs.

3.5 Publications and citations trends

Figure 2 illustrates the substantial growth in total publications (TP) and total citations (TC) between 2016 and 2022, with both metrics experiencing remarkable expansion at an average compound annual growth rate (CAGR) of 71.5%. Notably, significant spikes in growth were observed between 2017 and 2020. An interesting trend emerges as TC outpaces TP in terms of growth rate, indicating that a select number of papers garner a disproportionate share of citations. This phenomenon suggests a growing specialization in the field, where a few highly influential papers dominate citation counts. An in-depth analysis reveals that 79% of publications receive at least one citation each, with 52% of them cited a minimum of 10 times. Impressively, 26 publications stand out by accumulating over 100 citations during the study period.

The significant growth in both total publications (TP) and total citations (TC), along with the evident concentration of citations on a relatively small number of papers, signifies several crucial points. Firstly, it suggests a burgeoning interest in the field of study, indicating the growing importance of research on the topic. Secondly, the concentration of citations reflects a deepening specialization within this field, where a handful of influential papers exert a substantial impact. This could be due to their groundbreaking nature or unique contributions. Furthermore, it highlights the need for researchers to recognize these influential papers, as they are likely to shape and guide future developments in the area. In summation, our exploration of the most cited bibliometric papers has illuminated the growing significance and evolving trends in this field. As literature continues to expand and diversify, it becomes increasingly vital to identify the research hotspots by recognizing the leading authors' affiliating countries and institutions.

3.6 Country analysis

Table 6 presents the countries accounting for 92% of the study articles. China tops the table both in TP and TC. Although Spain occupies the second slot on TP, it is replaced by the United Kingdom on TC. Interestingly, the count for TP and TC is comparatively low for India and Malaysia, suggesting future scope for more influential scientometric works on SDGs. The table further suggests a positive correlation between the number of publications and the number of citations among the nations. Countries like China, the United Kingdom, Spain, Italy, Brazil, and Australia have more publications and citations than India, the United States, Portugal, and Malaysia. This might indicate that these countries' research output on the scientometrics of SDGs is relatively higher. Interestingly, the countries with the most publications and citations belong to the Global North, while those with comparatively fewer publications and citations are part of the Global South, which essentially has lower levels of economic development.

A Sankey diagram (as presented in Fig. 3) is a flow diagram often used to visualize the flow of resources through a system. The width of the arrows (or "flows") represents the relative magnitude of the flow, while the height of the rectangles (or "nodes") represents the relative importance of the elements in the system. Based on the height of the rectangles, we observe that publications from countries such as China, Spain, Brazil, and the UK are closely aligned with several SDGs. Looking at the flows, SDG 12 (Responsible Consumption and Production), SDG 11 (Sustainable Cities and Communities), SDG 7 (Affordable and Clean Energy), SDG 13 (Climate Action), and SDG 9 (Industry, Innovation, and Infrastructure) have

Table 6 Top countries

Country	TP	TC
China	323	5733
Spain	202	3601
Brazil	147	2049
United Kingdom	139	5445
India	108	961
Italy	96	2061
Australia	83	1778
United States	79	1328
Malaysia	69	1090
Portugal	66	645

This table shows the top authors' affiliated countries publishing reviews on SDGs and sustainability. TP = total publications, and TC = total citations on the search date

the most number of publications mapped to them. SDG 16 (Peace, Justice, and Strong Institutions), SDG 17 (Partnerships for the Goals), SDG 10 (Reduced Inequalities), and SDG 5 (Gender Equality) have relatively fewer publications mapped.

The Sankey diagram visually highlights countries like China, Spain, Brazil, and the UK's significant contributions to specific SDGs. It also underscores the prominence of SDGs 12, 11, 7, 13, and 9 while indicating the need for increased research attention to SDGs 16, 17, 10, and 5.

3.7 Institution analysis

Table 7 shows the leading authors' affiliated institutions ranked on TP. Our analysis reveals that SDGs and Sustainability authors affiliated with the University of Almeria lead both in TP and TC, followed by the Chinese Academy of Sciences for TP and the Hong Kong Polytechnic University for TC. On closer investigation, we found that the average number of institutions per publication is 2.3, indicating good collaboration among researchers from different institutions. Additionally, authors affiliated with varsities of Global North countries like Spain, Germany, Japan, and Hong Kong exhibit superior performance compared to their counterparts from Global South countries like Brazil, South Africa, and Thailand in terms of both TP and TC.

Conversely, the Sankey diagram depicted in Fig. 4 links the authors' affiliated institutions and SDGs. It is worth mentioning that the University of Almeria in Spain and the Hong Kong Polytechnic University in Hong Kong are associated with all 15 SDGs. Upon closer examination, most publications from top institutions are mapped to SDG 12 (Responsible Consumption and Production), 11 (Sustainable Cities and Communities), and 4 (Quality Education). In contrast, SDG 16 (Peace, Justice, and Strong Institutions), SDG 3 (Good Health and Well-being), SDG 17 (Partnerships for the Goals), SDG 1 (No Poverty), SDG 14 (Life Below Water), SDG 6 (Clean Water and Sanitation), SDG 8 (Decent Work and Economic Growth), and SDG 15 (Life on Land) have fewer publications mapped suggesting scope for future publications.

Following our analysis of the research hotspots, we proceed to discuss the leading outlets publishing bibliometric and scientometric works on SDGs and sustainability.

3.8 Journal analysis

Table 8 provides insights into the leading sources publishing scientometric research on SDGs. Our findings suggest that *Sustainability* accounts for the highest number of publications related to SDG research, while the *Journal of Cleaner Production* leads the race with the most citations and average citations. It is also the journal with the highest impact factor, indicating its highly influential stance among peers.

Further, the Sankey diagram presented in Fig. 5 highlights the connection between journals and their respective SDG mappings. Notably, the *Journal of Cleaner Production* and *Sustainability* are mapped to 15 SDGs. Upon closer examination of highly cited journals, SDG 12 (Responsible Consumption and Production), 11 (Sustainable Cities and Communities), and 13 (Climate Action) have the most publications mapped, while SDG 5 (Gender Equality) and 10 (Reduced Inequalities) have relatively fewer publications mapped with the leading journals suggesting scope for future submissions.

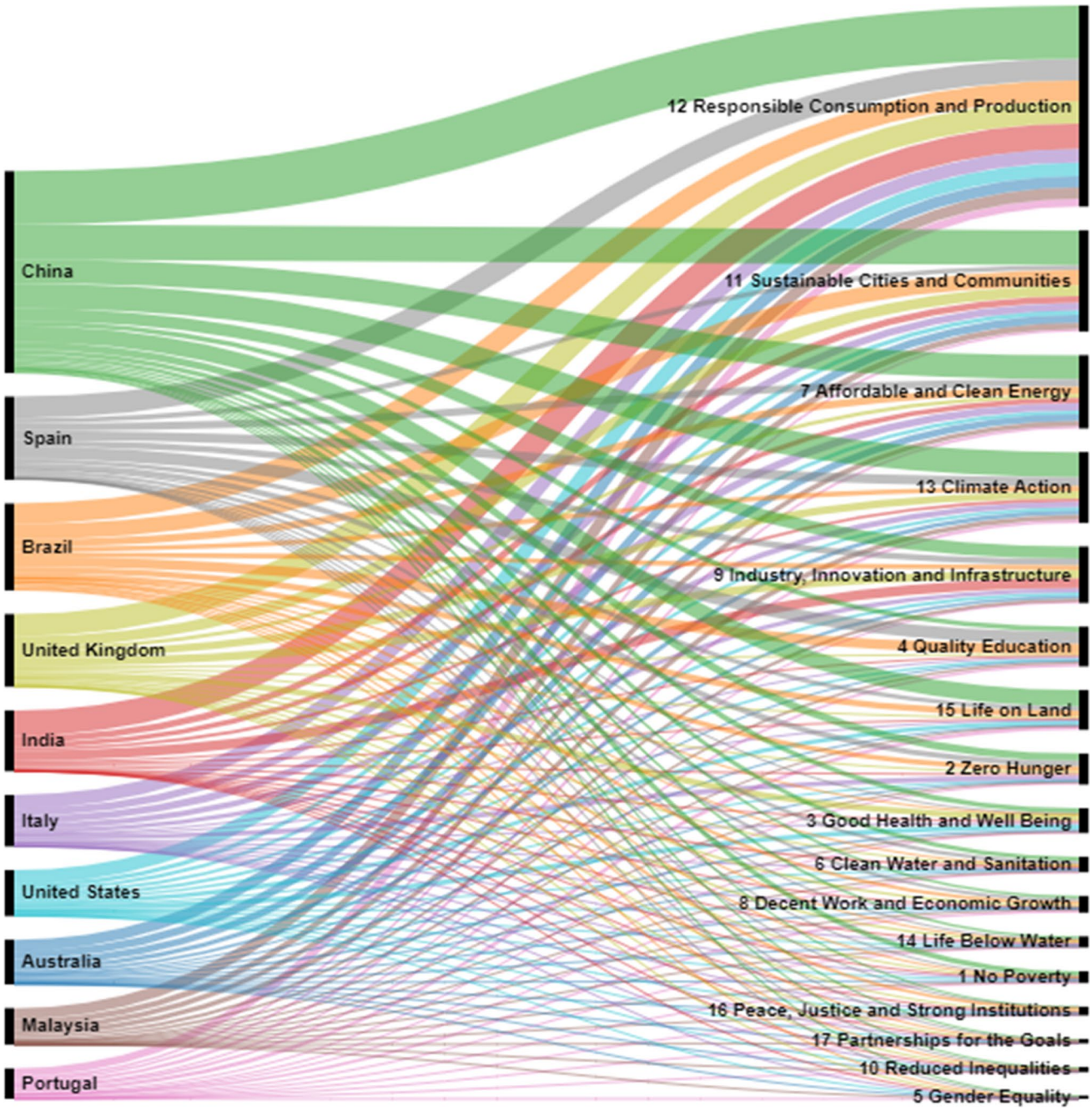


Fig. 3 Sankey diagram of country analysis

3.9 Authorship analysis

Table 9 presents the top authors publishing at least nine survey articles on SDGs, while Table 10 links their most cited publications with SDG(s). Ayyoob Sharifi tops the table with the most publications, while Luis J. Belmonte-Ureña is the most influential with the highest citations. Further analysis of the authorship pattern indicates that only 5% of the study articles are single-authored, while 95% have multiple authors, indicating high levels of collaboration. Among the multi-authored papers, those with three authors are the most common (about 25%), followed by those with two (about 22%). Interestingly, 33 papers (about 2%) have more than ten authors each.

Table 7 Top authors' affiliated institutions

Institution	Country	TP	TC
University of Almeria	Spain	56	1689
Chinese Academy of Sciences	China	39	554
University of Johannesburg	South Africa	28	479
Hong Kong Polytechnic University	Hong Kong	26	1147
Mahidol University	Thailand	21	449
Universidade Federal Fluminense	Brazil	19	307
University of Chinese Academy of Sciences	China	19	297
Hamburg University of Applied Sciences	Germany	18	57
Hiroshima University	Japan	17	118
Universidade Estadual de Campinas	Brazil	17	75

This table shows the top authors' affiliated institutions publishing reviews on SDGs and sustainability. TP = total publications and TC = total citations on the search date

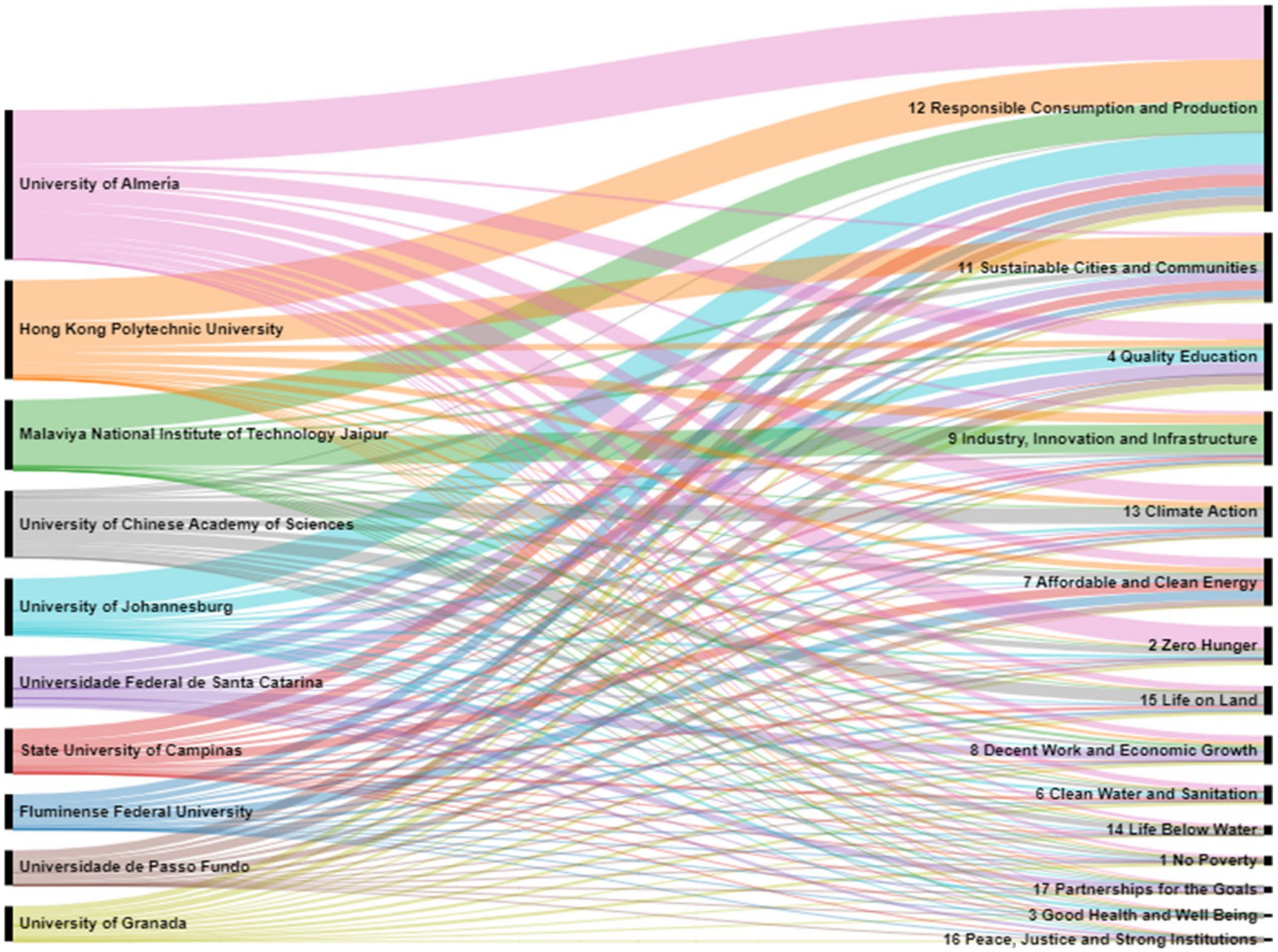


Fig. 4 Sankey diagram of institutions analysis

Table 8 Top sources

Journal Name	TP	TC	TC/TP	IF
Sustainability	303	3786	12.5	3.88
Journal of Cleaner Production	95	7165	75.4	11.07
Environmental Science and Pollution Research	41	368	9.0	5.19
International Journal of Environmental Research & Public Health	41	411	10.0	4.61
Energies	25	266	10.6	3.25
Environment, Development and Sustainability	17	99	5.8	4.08
Land	16	97	6.1	3.90
Water (Switzerland)	13	89	6.8	3.53
International Journal of Sustainability in Higher Education	11	109	9.9	2.85
Science of the Total Environment	11	180	16.4	10.75

This table shows the top sources publishing reviews on SDGs and sustainability. TP = total publications, TC = total citations, TC/TP = average citations, and IF = impact factor on the search date

We observe that highly impactful works from leading authors encompass a wide spectrum of topics such as the 'impact of Covid-19 on cities,''the significance of agricultural waste,''knowledge management in sustainability research and practice,''digital transformation in learning,''sustainable learning,''sustainable land use,''Industry 4.0 technologies for circular economic models,''cruise tourism research,' and more. Many of these authors have undertaken bibliometric analyses of related topics within one or a few preferred SDGs, while some, possibly bibliometric enthusiasts, have explored diverse topics across multiple SDGs. Although a comprehensive discussion of these contributions is beyond the scope of this analysis, the list of the most significant publications by top productive researchers reveals that SDGs 11, 12, and 4 are each associated with two publications. Given the impact generated by the analysis of these topics, we recommend that bibliometricians and enthusiasts should (i) delve deeper into these areas to uncover new aspects or overlooked dimensions and (ii) explore similar or related topics within SDGs 11, 12, 4, and others. While citations and impact can be strong motivators for research, especially for bibliometric enthusiasts, it is essential to consider the significance of SDGs to humanity. This entails assessing underexplored topics within the most studied SDGs, important aspects within less researched SDGs, and more. Such an approach can provide guidance to mainstream researchers, both academic and industrial, working on these SDGs. For instance, top contributing authors to bibliometric studies on SDGs have not typically focused on the most extensively researched SDGs like SDG 3 (Good health and well-being), 7 (Affordable and clean energy), and 13 (Climate Action), likely due to the sheer volume of associated literature. This represents a significant gap in bibliometric studies on SDGs, which offers substantial opportunities for bibliometric researchers. Therefore, we recommend that bibliometric analysts and enthusiasts embark on more challenging research endeavours, seeking out tools, methods, and approaches to analyze large bodies of literature.

We further analyzed the collaboration patterns among authors and their average impact. Table 11 shows that international collaborations lead the share of total publications (39.1%) and bear the highest average impact (TC/TP: 23.2). Only national collaboration had a share of 26.3% of total publications and a TC/TP ratio of 10.8. Only institutional collaboration had a share of 29.8% of total publications and a TC/TP ratio of 13.6. Single authorship (no collaboration) had the smallest percentage share of total publications at 4.8%, with a TC/TP ratio of 11.5.

3.10 Top cited publications and their SDG focus

Table 12 presents the top cited scientometric publications on SDGs and Sustainability. We find that the primary focus areas of the top-cited works are related to themes such as circular economy, green economy, and bio-economy. Interestingly, all of them are highly pertinent to sustainability. Further, the role of supply chain management in sustainability is also evident among the top-cited publications. The increasing application of multiple criteria decision analysis (MCDA) techniques for supply chain management and other similar findings prove to be essential for the growth of supply chain management in a direction aligned with sustainability. However, the under-exploration or neglect of risk factors associated with environmental and social aspects, which form the core sustainability values, is a concern that remains for further exploration.

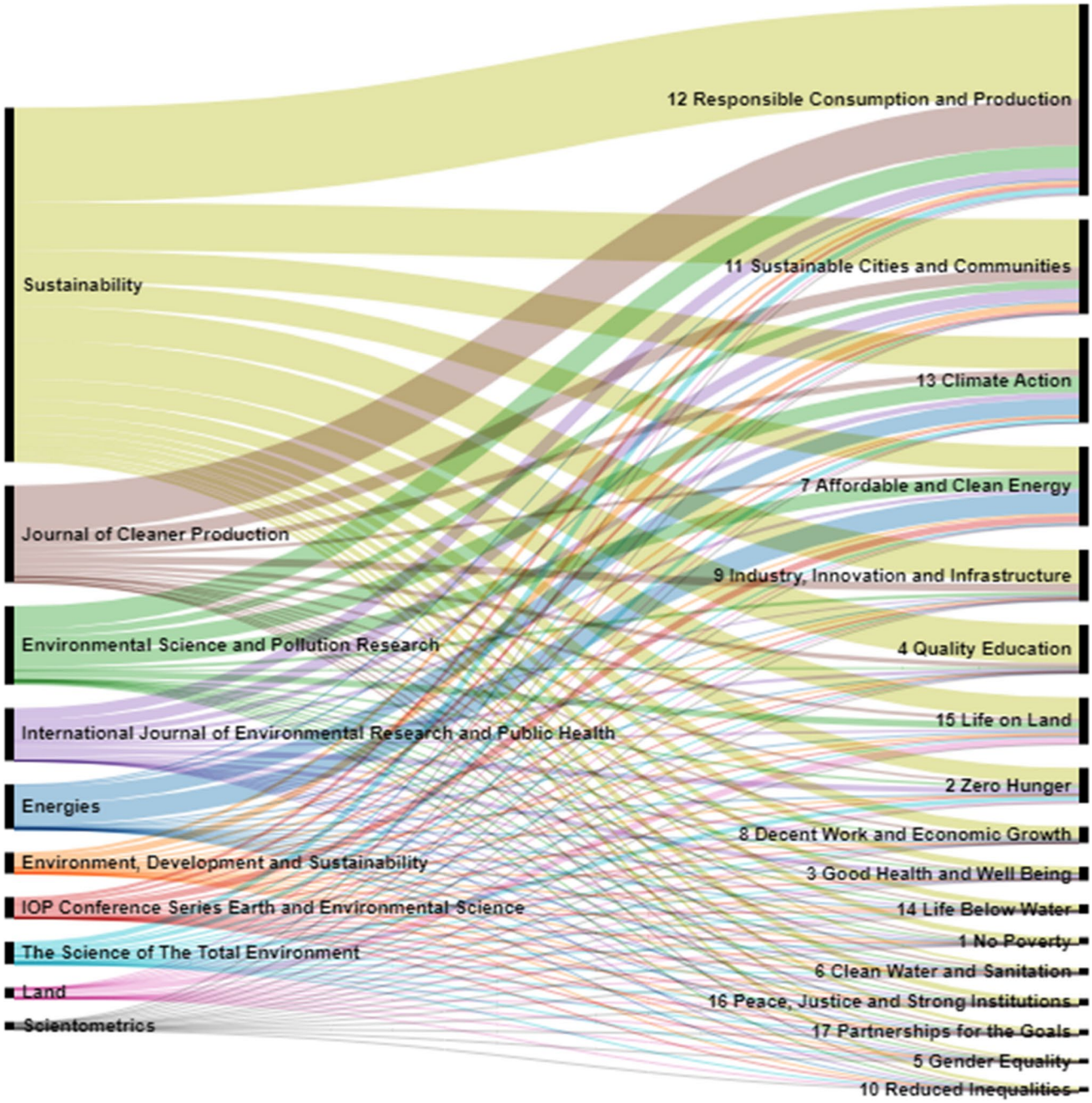


Fig. 5 Sankey diagram of journals analysis

The top-cited articles include Geissdoerfer et al. [57], who conducted a comprehensive review of the "circular economy," revealing its association with sustainability, emphasizing the circular economy as a prerequisite for sustainability. Cheng [59] presents a holistic literature review on the "sharing economy," focusing on business models, impacts, and sustainable development in tourism and hospitality management, urging a theory-informed research agenda on the sharing economy. D'Amato et al. [58] use machine learning to compare circular, green, and bio-economies, finding that the green economy addresses social and environmental issues more. Olawumi et al. [25] conducted a scientometric review of sustainability research trends, highlighting emerging themes in sustainable urban development, indicators, water management, and environmental assessment. Chen et al. [60] explore the impact of supply chain collaboration on sustainability, noting the need to address social issues in addition to economic and environmental concerns. Huang

Table 9 Most prolific authors

Author	Country	TP	TC	TC/TP	h-index
Ayyoob Sharifi	Japan	16	107	6.7	31
Luis J. Belmonte-Ureña	Spain	15	715	47.7	21
Walter Leal Filho	United Kingdom	13	231	17.8	35
Emilio Abad-Segura	Spain	11	499	45.4	17
Izabela Simon Rampasso	Chile	11	22	2.0	12
Rosley Anholon	Brazil	10	26	2.6	17
Philip Hallinger	Thailand	10	293	29.3	49
Aznar-Sánchez, José Ángel	Spain	9	369	41.0	19
Osvaldo Luiz Gonçalves Quelhas	Brazil	9	244	27.1	21
Alejandro Vega-Muñoz	Chile	9	44	4.9	13

This table shows the top authors publishing the highest number of reviews on SDGs and Sustainability. TP = total publications, TC = total citations, and TC/TP = average citations on the search date

et al. [101] investigate gender differences in productivity and impact in STEM fields, offering insights into t the sustainability of women's careers in academia. Zyoud et al. [61] analyze multiple criteria decision analysis techniques and their applications. Feng et al. [75] delve into corporate social responsibility in supply chain management, identifying research gaps and considering supplier perspectives. Li et al. [102] conducted a bibliometric analysis on coal gangue, highlighting its utilization but noting a lack of research on associated risks. Lastly, Martens et al. [103] study sustainability in project management, identifying key factors like sustainable innovation models, stakeholder management, and environmental policies.

In conclusion, Table 12, along with subsequent content analysis of top-cited works, highlights that six works, specifically those ranked 1, 2, 3, 8, 9, and 10, are closely associated with SDG 12. In contrast, four of the top-cited reviews are intertwined with SDGs 8 and 9, with works 3, 4, 5, and 9 relating to SDG 8 and works 5, 8, 9, and 10 having connections to SDG 9. It's noteworthy that SDGs 3 (Good Health and Well-being) and 7 (Affordable and Clean Energy), despite their prominence, have not been extensively examined using bibliometric methods, likely due to the extensive volume of available literature and potentially limited interest from core journals and research communities in these SDGs. Overcoming these challenges through well-designed bibliometric and scientometric studies in SDGs 3 and 7 holds significant promise, offering valuable insights for researchers and policymakers at various levels. As bibliometric and scientometric studies gain traction in SDGs 12, 8, 9, and related areas, encouraging bibliometricians to apply their innovative methods to these SDGs can greatly contribute to insightful research and informed policymaking processes within these domains. After gleaning insights from the top-cited reviews, we now delve into examining themes related to SDGs and sustainability by analyzing the co-occurrence of keywords.

3.11 Keyword co-occurrence analysis and SDG focus

To create the keyword co-occurrence map, we treated all keywords as the unit of analysis and applied the full counting method, setting a threshold of ten occurrences for each keyword. Out of the initial 7,859 keywords, only 192 keywords satisfied the threshold requirement. Figure 6 illustrates these 192 keywords forming four distinct clusters, each represented by a different color – cluster 1 (red), cluster 2 (green), cluster 3 (blue), and cluster 4 (yellow). The size of the circles and texts within each cluster indicates the strength of co-occurrence with other keywords, while the distance between the keywords and the thickness of the lines show the relatedness and linkages between them. Additionally, we analyzed the top 25 keywords in each cluster to determine their corresponding SDG mapping, calculating the percentage of keywords associated with each SDG Goal using SDG Mapper [104].

The keywords in Cluster 1 (see Table 13) exhibit significant links to several SDGs. We find that SDG 12 (Responsible Consumption and Production) has the most substantial relationship with these keywords, followed by SDG 4 (Quality Education), SDG 13 (Climate Action), and SDG 15 (Life on Land). The analysis of these keywords' co-occurrence in various publications indicates a growing concern for environmental sustainability and protection, especially in developing countries.

Table 10 Most cited publications of the most prolific authors

Author	Top Article	Bibliometric Technique(s)	SDG Focus
Ayyoob Sharifi	"The COVID-19 pandemic: Impacts on cities and major lessons for urban planning, design, and management"[93]	Keyword Co-occurrence analysis	11 SUSTAINABLE CITIES AND COMMUNITIES
Luis J. Belmonte-Ureña	"Agricultural waste: Review of the evolution, approaches, and perspectives on alternative uses"[77]	Co-citation, Co-authorship, Keyword Co-occurrence, Social network analysis	12 RESPONSIBLE CONSUMPTION AND PRODUCTION 2 ZERO HUNGER
Walter Leal Filho	"A literature-based review on potentials and constraints in the implementation of the sustainable development goals"[94]	Systematic selection and content analysis	11 SUSTAINABLE CITIES AND COMMUNITIES 17 PARTNERSHIPS FOR THE GOALS
Emilio Abad-Segura	"Sustainable management of digital transformation in higher education: Global research trends"[78]	Traditional bibliometrics, Co-citation, Co-authorship, Keyword Co-occurrence analysis	4 QUALITY EDUCATION
Izabela Simon Rampasso	"Knowledge management in the context of sustainability: Literature review and opportunities for future research"[95]	Bibliometrics & content analysis	4 QUALITY EDUCATION
Rosley Anholon	"The role of transformation in learning and education for sustainability"[96]	Qualitative case studies	4 QUALITY EDUCATION
Philip Hallinger	"Bringing context out of the shadows of leadership"[97]	Qualitative analysis	17 PARTNERSHIPS FOR THE GOALS
José Ángel Aznar-ánchez	"Worldwide research trends on sustainable land use in agriculture"[98]	Keyword Co-occurrence analysis	15 LIFE ON LAND
Osvaldo Luiz Gonçalves Quelhas	"Exploring industry 4.0 technologies to enable circular economy practices in a manufacturing context"[99]	Qualitative framework involving literature review	12 RESPONSIBLE CONSUMPTION AND PRODUCTION
Alejandro Vega-Muñoz	"In search of 'a research front' in cruise tourism studies"[100]	Scientific activity life-cycle, impact and relational indicators	17 PARTNERSHIPS FOR THE GOALS

This table associates the top-cited SDG(s) and Sustainability reviews of the top authors with the corresponding SDG(s) and indicates the bibliometric technique(s) applied

Table 11 Effect of collaboration

Collaboration Type	% Share	TC/TP
International	39.1%	23.2
Only national	26.3%	10.8
Only institutional	29.8%	13.6
Single authorship (no collaboration)	4.8%	11.5

The keywords in Cluster 2 (see Table 14) exhibit close associations with SDG 9 (Industry, Innovation, and Infrastructure) and SDG 12 (Responsible Consumption and Production). Research within this cluster has emphasized the adoption of circular economy models, which encompasses life cycle assessment, waste management, and recycling, to minimize the environmental impact of industries. Furthermore, efficient supply chain management, facilitated by digital technologies and Industry 4.0, has been studied to reduce carbon footprint and promote environmental sustainability, particularly in the construction industry. Findings from this cluster of studies indicate that decision-making processes based on life cycle assessment can effectively promote responsible consumption and production in the context of buildings and construction, contributing to the realization of SDG 9 and SDG 12.

The keywords in Cluster 3, as detailed in Table 15, primarily exhibit connections to SDG 6 (Clean Water and Sanitation) and SDG 7 (Affordable and Clean Energy). Research within this cluster is centered on the development of policies that advance sustainable environmental management and the conservation of water and energy resources. Key focal points include renewable energy, energy efficiency, and the reduction of carbon emissions, all of which play crucial roles in mitigating environmental impacts and fostering sustainable economic development. While these keywords are less strongly associated with SDG 2 (Zero Hunger) and SDG 3 (Good Health and Well-being), they are nonetheless vital in comprehending the environmental determinants influencing food production and human health.

The keywords in Cluster 4 (see Table 16) predominantly align with SDG 11 (Sustainable Cities and Communities). Research in this cluster has concentrated on formulating a conceptual framework for urban development that harmonizes environmental sustainability, social inclusivity, and economic growth. Smart cities have emerged as a viable solution for addressing challenges resulting from urbanization, encompassing issues like traffic congestion, air pollution, and waste management. Urbanization and land use changes have also impacted biodiversity, leading to reduced ecosystem services such as clean air and water, pollination, and nutrient cycling. Consequently, prioritizing urban sustainability and biodiversity conservation in developing cities and urban areas is vital to fulfilling the objectives of SDG 11. While these keywords exhibit a weaker connection to SDG 15 (Life on Land), it remains essential to acknowledge the interplay between urban development and biodiversity preservation.

3.12 Co-citation map of SDGs

The SDG goals are interdependent, meaning that one goal's achievement depends on the success of the other goals [105]. Using network analysis techniques, Le Blanc [106] demonstrated that SDG connections are somewhat unequal. Some goals have multiple targets connecting them to many other goals, while others have weak connections to the rest of the SDG system. We created a co-citation map (see Fig. 7) to visualize the relationships between different SDGs. The proximity of the SDGs on the map reflects their semantic association, indicating that publications related to those SDGs are often cited together in the same set of publications. The nodes' size represents the SDG frequency in terms of overall publications, while the thickness of the edges shows how often these SDGs are co-cited. Figure 7 displays the SDG map suggesting three clusters.

Cluster 1 (green) has a thematic focus on social development and equality, as it comprises SDG related to education (SDG 4), healthcare (SDG 3), gender equality (SDG 5), poverty reduction (SDG 1), and building peaceful and just societies (SDG 16). The keywords within this cluster may pertain to social inclusion, human rights, access to education and healthcare, and reducing inequalities (SDG 10).

Cluster 2 (red) emphasizes SDG 8 (Decent Work and Economic Growth), SDG 13 (Climate Action), SDG 2 (Zero Hunger), SDG 15 (Life on Land), SDG 6 (Clean Water and Sanitation), and SDG 14 (Life Below Water). This cluster's thematic focus appears to be on environmental sustainability, comprising SDGs related to climate change, land, ocean conservation, and water and food security. The co-occurrence of keywords within this cluster may pertain to sustainable agriculture, responsible consumption and production, water and waste management, and renewable energy.

Table 12 Top cited review articles

TC	TC/Year	Author(s)	Title	Search Engine	TAS	Time Period	SDG Focus
2526	421.0	Geissdoerfer et al. [57]	"The circular economy—A new sustainability paradigm?"	Web of Science	295	2006–2016	12 RESPONSIBLE CONSUMPTION AND PRODUCTION
506	72.3	Cheng [59]	"Sharing economy: A review and agenda for future research"	Scopus, EBSCO Google Scholar	162	2010–2015	12 RESPONSIBLE CONSUMPTION AND PRODUCTION
455	75.8	D'Amato et al. [58]	"Green, circular, bio economy: A comparative analysis of sustainability avenues"	Web of Science	1943	1990–2017	4 QUALITY EDUCATION 8 DECENT WORK AND ECONOMIC GROWTH 12 RESPONSIBLE CONSUMPTION AND PRODUCTION
348	69.6	Olawumi et al. [25]	"A scientometric review of global research on sustainability and sustainable development"	Web of Science	2094	1991–2016	6 CLEAN WATER AND SANITATION 8 DECENT WORK AND ECONOMIC GROWTH 11 SUSTAINABLE CITIES AND COMMUNITIES
270	45.0	Chen et al. [60]	"Supply chain collaboration for sustainability: A literature review and future research agenda"	Scopus, Web of Science, and Business Source Premier	1778	1987–2015	8 DECENT WORK AND ECONOMIC GROWTH 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE 16 PEACE, JUSTICE AND STRONG INSTITUTIONS
255	85.0	Huang et al. [101]	"Historical comparison of gender inequality in scientific careers across countries and disciplines"	Web of Science	865	1955–2010	5 GENDER EQUALITY 10 REDUCED INEQUALITIES

Table 12 (continued)

TC	TC/Year	Author(s)	Title	Search Engine	TAS	Time Period	SDG Focus
244	40.7	Zyoud et al. [61]	"A bibliometric-based survey on AHP and TOPSIS techniques"	Scopus, Web of Science, Google Scholar, PubMed	10,188	One time interval (20th April 2016)	4 QUALITY EDUCATION
225	37.5	Feng et al. [75]	"Corporate social responsibility for supply chain management: A literature review and bibliometric analysis"	Scopus, Google Scholar	628	1997–2017	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION
223	55.8	Li et al. [102]	"Comprehensive utilization and environmental risks of coal gangue: A review"	WoS, China National Knowledge Internet (CNKI)	237	1992–2018	8 DECENT WORK AND ECONOMIC GROWTH; 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION
193	32.2	Martens et al. [103]	"Key factors of sustainability in project management context: A survey exploring the project managers' perspective"	–	199	1994–2014	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION

This table displays the top-cited quantitative review articles on SDGs and Sustainability, aligning them with their respective focused SDG(s). It also provides essential citation metrics, including TC (total citations), TC/Year (average annual citations), and TAS (total articles used for the study)

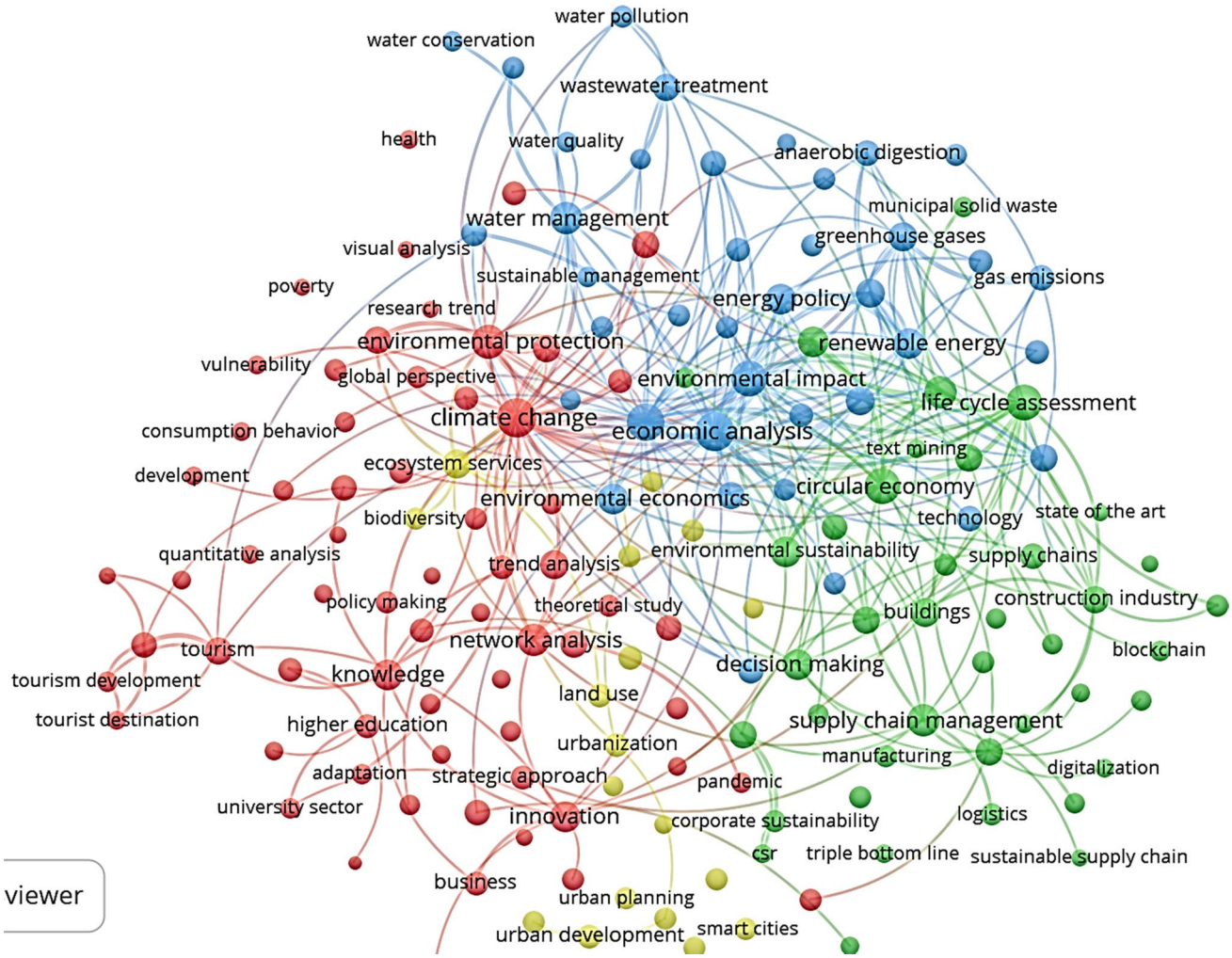
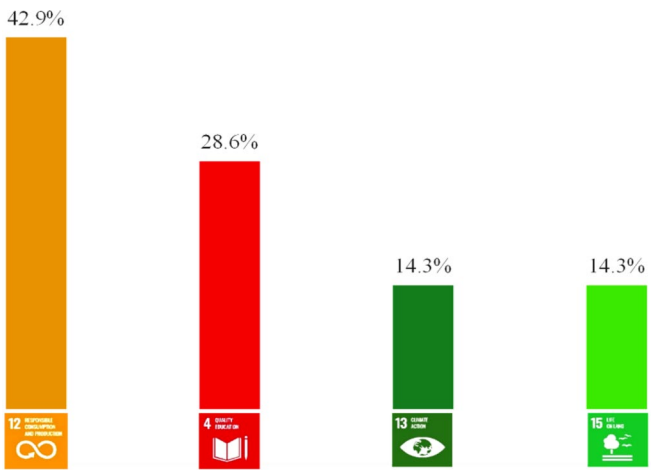


Fig. 6 Keyword co-occurrence

Table 13 Cluster 1 keywords' SDG mapping

Cluster 1 (red)	SDG Mapping
Climate change environmental protection network analysis innovation knowledge trend analysis developing countries tourism social networks conservation	

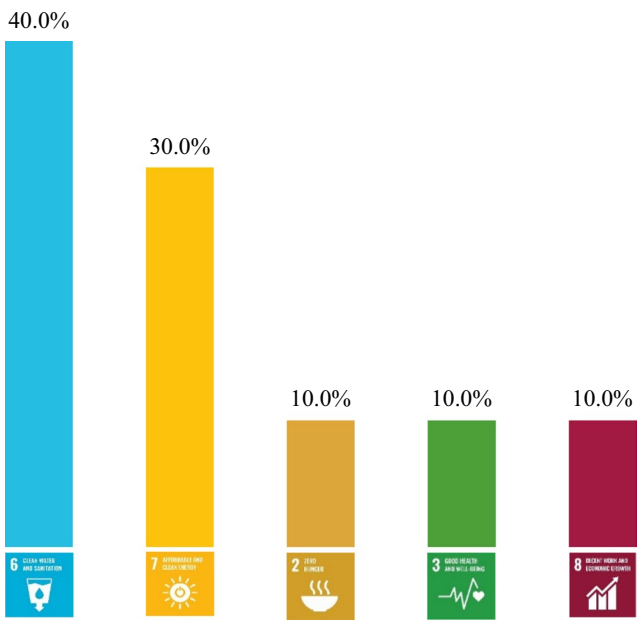
This table correlates the cluster 1 keywords with their corresponding SDGs

Table 14 Cluster 2 keywords' SDG mapping

Cluster 2 (green)	SDG Mapping
Life cycle assessment circular economy supply chain management waste management decision making recycling environmental sustainability buildings construction industry industry 4.0	

This table correlates the cluster 2 keywords with their corresponding SDGs

Table 15 Cluster 3 keywords' SDG mapping

Cluster 3 (blue)	SDG Mapping
Economic analysis environmental management environmental impact water management energy policy renewable energy environmental economics greenhouse gases energy efficiency carbon emission	

This table correlates the cluster 3 keywords with their corresponding SDGs

Cluster 3 (blue) focuses on SDGs 12 (Responsible Consumption and Production), SDG9 (Industry, Innovation, and Infrastructure), SDG7 (Affordable and Clean Energy), and SDG11 (Sustainable Cities and Communities). This cluster's thematic focus appears to be sustainable urbanization, infrastructure development, and energy consumption. The co-occurrence of keywords within this cluster may pertain to the circular economy, green technology, energy efficiency, and sustainable transportation.

Table 16 Cluster 4 keywords' SDG mapping

Cluster 4 (yellow)	SDG Mapping
Ecosystem services urbanization urban development land use conceptual framework smart cities biodiversity cities urban area urban sustainability	85.7%  14.3% 

This table correlates the cluster 5 keywords with their corresponding SDGs

The co-citation map of SDGs has provided us with valuable insights into the semantic associations and connections between these goals. As we delve into the realm of social network analysis (SNA) to investigate the linkages among these SDGs, we will uncover a deeper layer of their interdependence and the roles they play in shaping sustainable development. This analysis will offer a more comprehensive view of how these goals interact and influence one another, contributing to our understanding of the dynamic nature of SDGs and their significance in driving global sustainability.

3.13 Social network analysis (SNA) of SDG linkages

Our study uniquely incorporates Social Network Analysis (SNA) to understand the interconnected nature of SDGs [106]. For analyzing the network of SDGs, we used "SDGToolkit" to construct an SDG network focusing on metrics such as eigenvector and betweenness centrality parameters. We utilized output files generated by VOSviewer, including the map file delineating item weights and the network file indicating link strengths between the items, as the input for SDGToolkit's subsequent analyses [107–109] The betweenness centrality of an SDG node measures its significance as a connecting point in the flow of information within the network. This is calculated by counting how often the node lies on the shortest path between two other SDG nodes. An SDG node with high betweenness centrality serves as a bridge between different sections of the network. Eigenvector centrality is another social network analysis metric that measures a node's influence within a network [110]. It considers the number of connections a node has and the centrality of its connected nodes. In other words, the importance of a node is determined by the number of important nodes it is connected to SDG nodes with high eigenvector centrality in SDG networks will be regarded as key centers of attention.

Figure 8a illustrates that SDG 8 (decent work and economic growth), SDG 7 (affordable and clean energy), and SDG 12 (responsible consumption and production) have the highest eigenvector centrality values, indicating that they are the network leaders. Figure 8b, on the other hand, presents an SDG network based on betweenness centrality. The thickness of the links between the two goals on the map represents the strength of the connection between SDGs. The strongest links are observed between SDG 9 and SDG12 (industry and consumption), SDG 8 and SDG12 (work and consumption), and SDG 8 and SDG13 (work and climate). The network emphasizes the central role of SDGs 8, 9, 12, and 13 in the network.

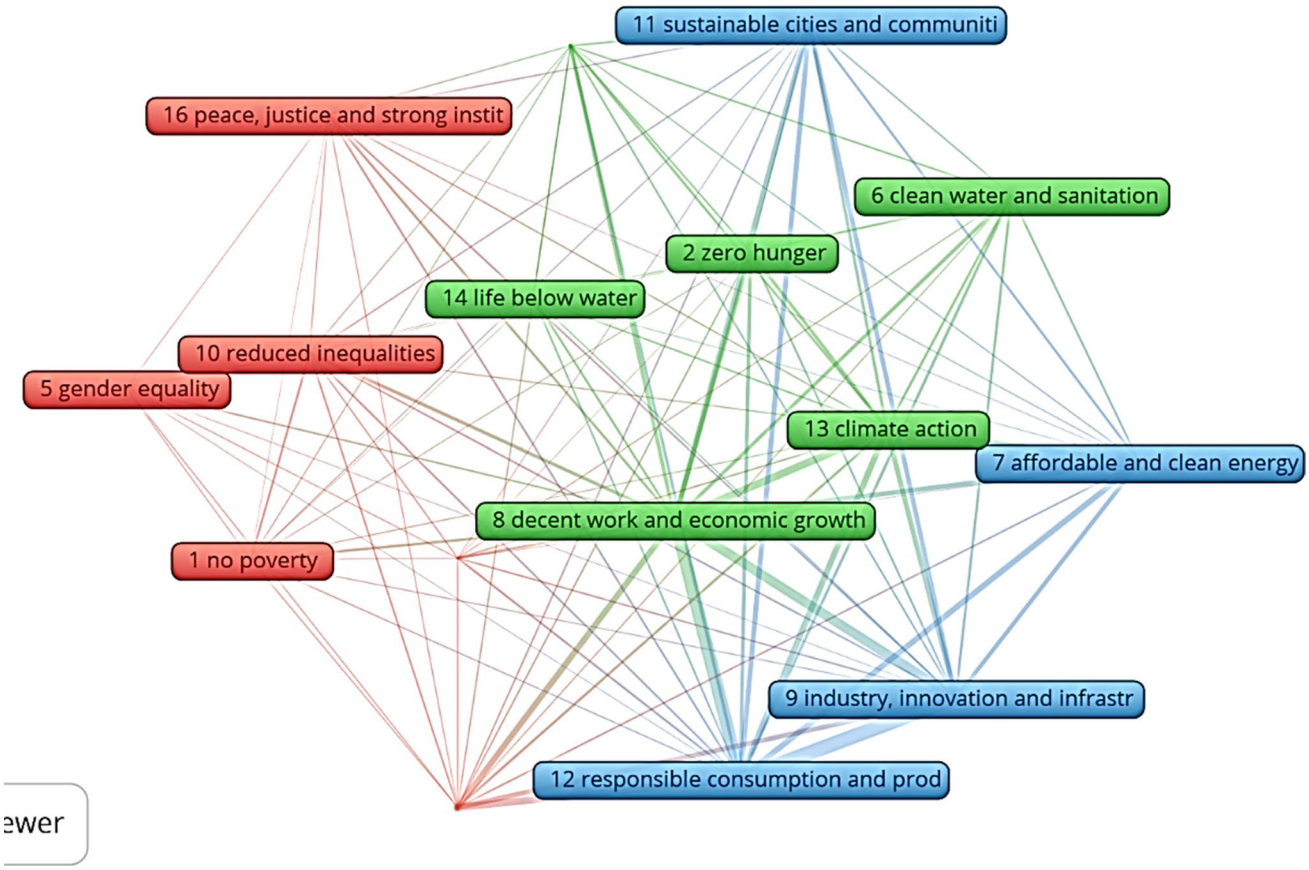


Fig. 7 Co-citation map of SDGs

Fig. 8 **a** SNA of SDGs based on eigenvector centrality. **b** SNA of SDGs based on betweenness centrality

As we gain a deeper understanding of the SNA of SDG linkages, we move forward to examine how different Fields of Research (FoRs) connect with these SDGs. This exploration will provide valuable insights into the multidisciplinary and interdisciplinary nature of SDGs, shedding light on the various research domains contributing to the achievement of these global objectives.

Table 17 Top field of research (FoR)

Field of Research	TP	TC	TC/TP
Library and Information Studies	145	1374	9.48
Strategy, Management and Organisational Behaviour	84	767	9.13
Environmental Management	74	659	8.91
Building	39	458	11.74
Marketing	34	230	6.76

This table compares the top fields of research based on total publications (TP), total citations (TC), and average citations (TC/TP)

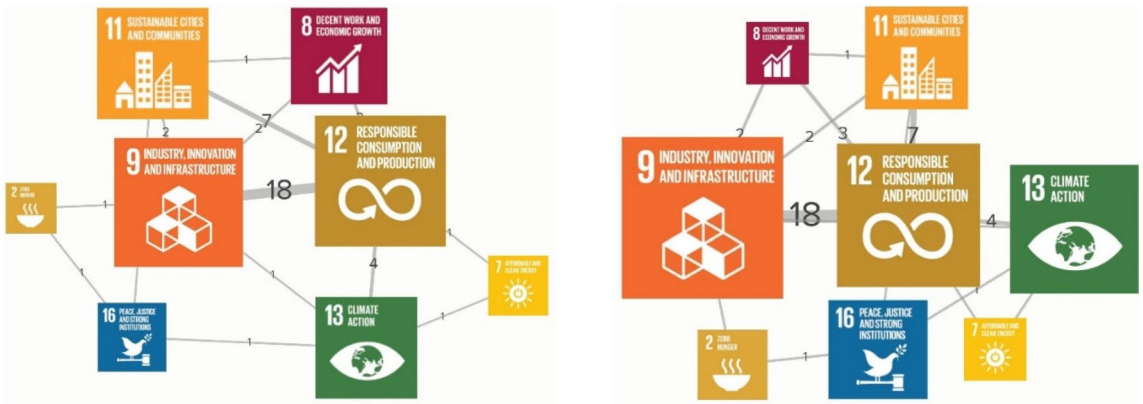


Fig. 9 **a** SNA of Library and Information Studies based on eigenvector centrality. **b** SNA of Strategy, Management, and Organizational Behaviour based on eigenvector centrality

3.14 Fields of research (FoRs) and their SDG linkages

Table 17 compares the top five FoR categories based on their total publications (TP), total citations (TC), and average citations (TC/TP). Library and Information Studies leads with the highest number of total publications (145) and total citations (1374). Its substantial average citations of 9.48 underscore the significant influence and impact of research in this field on the academic community. The field of Building boasts the highest average citations at 11.74 and the second-highest total citations (458), indicating a substantial level of impact and relevance in its research. Marketing, with a slightly lower average citation rate of 6.76 and the lowest total citations (230), still maintains a noteworthy level of influence. Strategy, Management and Organizational Behaviour, along with Environmental Management fields, display similar average citation rates, suggesting that research in these fields also renders substantial impact.

We employed SNA to delve further into the top two FoRs, namely Library and Information Studies and Strategy, Management, and Organizational Behaviour, based on TP and TC. In the case of Library and Information Studies, Fig. 9a depicts SDG 11 as the leader within the network, boasting the highest eigenvector centrality value. It's followed by SDG 13, SDG 12, and SDG 15, which also wield significant influence. Figure 9b displays the SDGs exhibiting the highest betweenness centrality, with thicker links indicating stronger connections between these SDGs. The most robust links are observed between SDG 4 and 14 (Energy and Climate), SDG 9 and 12 (Industry and Consumption), and SDG 11 and 12 (Cities and Consumption).

As for the Field of Research, Strategy, Management, and Organisational Behaviour, Fig. 10a underscores the centrality of SDG 12. Figure 10b provides a network map of SDGs based on SNA centrality measures. Analyzed in terms of eigenvector centrality, SDG 9 (Industry) and SDG 12 (Consumption) exhibit high centrality. This suggests that these SDGs are not only pivotal to the research within this field but are closely connected to other highly relevant SDGs, forming a cohesive group in the network of relationships between different SDGs and research topics. Additionally, SDG 9 (Industry), SDG 12

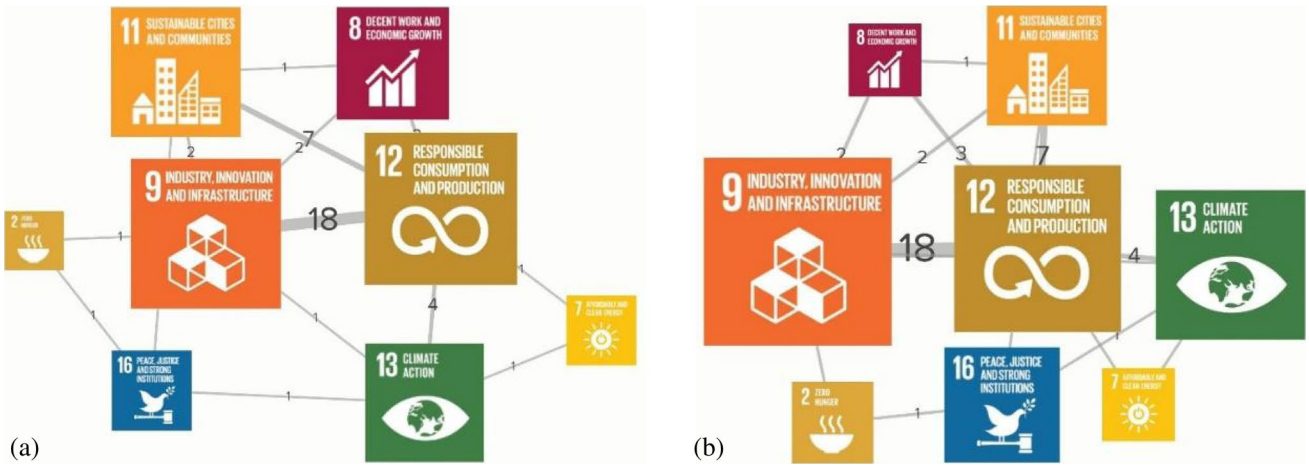


Fig. 10 **a** SNA of Library and Information Studies based on betweenness centrality. **b** SNA of Strategy, Management, and Organizational Behaviour based on betweenness centrality

Table 18 Top prominence topics

Prominence percentile	Topic
99.979	Sustainability reporting and global reporting initiative
99.942	Cause-related marketing and corporate social responsibility
99.933	Green supply chain, environmentally preferable purchasing, and green practices
99.657	Education for sustainability and higher education institutions

This table exhibits the top emerging research topics based on their prominence percentile score in Scopus

(Consumption), and SDG 13 (Climate) show high betweenness centrality, indicating their substantial influence in shaping the research agenda within this field. These SDGs occupy central positions in the network of relationships between various SDGs. The most substantial link is between SDG 9 and 12, signifying the interconnection between industry and consumption.

4 Emerging research topics and their SDG focus

This study's findings propose various areas for additional investigation. We identified future research topics by utilizing the prominence percentile obtained from SciVal, a database mining tool in Scopus (see Table 18). The momentum of a field, represented by prominence, serves as the basis for ranking these topics.

4.1 Sustainability reporting and global reporting initiative

Sustainability reporting [111] and the Global Reporting Initiative (GRI) framework can play a critical role in achieving the United Nations' Sustainable Development Goals (SDG) by allowing companies to measure, disclose and be accountable for their economic, social, and environmental performance. Highly cited articles on this topic are shown in Table 19. The GRI framework, a widely used standard for sustainability reporting, aligns the company's sustainability reporting with the SDG and provides transparent and comparable information about their performance on issues related to the SDG such as SDG 4 (Quality Education), SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action). Sustainability reporting and the GRI framework also support companies in identifying and managing risks and opportunities related to the SDG, setting targets, and measuring progress toward achieving the SDG. In addition to GRI, other reporting frameworks such as the Sustainability Accounting Standards Board (SASB), Integrated Reporting (IR), and the Carbon Disclosure Project (CDP) also contribute to harmonizing corporate sustainability reporting with SDGs, thereby broadening the scope and impact of these initiatives.

Table 19 Topic: sustainability reporting, global reporting initiative

TC	Author(s)	Title	Journal	SDG
119	Pizzi et al. [87]	"Management research and the UN sustainable development goals (SDGs): A bibliometric investigation and systematic review"	Journal of Cleaner Production	
76	Mura et al. [74]	"The evolution of sustainability measurement research"	International Journal of Management Reviews	
64	Rodrigues et al. [112]	"Mapping of the literature on social responsibility in the mining industry: A systematic literature review"	Journal of Cleaner Production	

This table discloses the top three reviews and their SDG mapping concerning Sustainability Reporting and Global Reporting Initiatives

Within the realm of sustainability reporting and the Global Reporting Initiative (GRI), Pizzi et al. [87] review investigates the impact of the Sustainable Development Goals (SDGs) on business organizations. Through bibliometric and systematic literature review methods, this study examines 266 publications from leading journals published between 2012 and 2019, revealing four primary research themes related to SDGs: technological innovation, firms' contributions in developing countries, non-financial reporting, and education for SDGs, mapping primarily to SDGs 4, 8, and 12. Similarly, Mura et al. [74] study focuses on sustainability measurement, categorizing it into eight main areas and 12 sub-fields through bibliometric analysis, aligning with SDGs 9 and 12, and emphasizing the importance of common metrics and stakeholder perspectives. In the mining industry, Rodrigue et al. [112] systematic literature review and bibliometric analysis highlight the growing interest in social responsibility, specifically in terms of relationships with local communities and CSR reporting. This research contributes to the understanding of the mining sector's commitment to social responsibility and its alignment with SDGs 4, 8, and 12.

4.2 Cause-related marketing and corporate social responsibility

Cause-related marketing and corporate social responsibility (CSR) contribute to achieving the United Nations' Sustainable Development Goals (SDG) by raising awareness and funds for causes, improving social and environmental impact, and integrating social, environmental, and economic considerations into the company's operations. Highly cited articles on this topic are shown in Table 20. By implementing cause-related marketing, companies can contribute to SDG 1 (No Poverty) and SDG 3 (Good Health and Well-being). By implementing CSR, companies can contribute to SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production), and SDG 16 (Peace, Justice, and Strong Institutions). Additionally, by supporting sustainable development through their supply chain and procurement practices, companies can contribute to achieving SDG 12 (Responsible Consumption and Production) and SDG 15 (Life on Land).

In the context of corporate social responsibility (CSR) and its connection to sustainable development (SD), Ye et al. [113] conducted a comprehensive bibliometric analysis. This study, in alignment with SDGs 8, 9, and 12, revealed that CSR's relationship with SD is a burgeoning topic, evidenced by a growing body of literature within leading journals and contributions from key authors. The co-author networks appeared fragmented, and the study identified 11 clusters of concern, with "stakeholder" and "NGO" being consistent themes. Additionally, the research frontier was marked by "climate change" as a new but particularly prominent focus, showcasing the evolving dynamics in this field. Simultaneously, Sarkar et al. [114] explored the evolving landscape of corporate social responsibility (CSR) by analyzing 110 definitions spanning the years from 1953 to 2014. Their approach involved co-word analysis to map key terms, their centrality, and interrelationships. This study, in alignment with SDG 12, discerned six recurring dimensions underlying the CSR concept: economic, social, ethical, stakeholders, sustainability, and voluntary. The analysis offered a new, comprehensive definition of CSR, capturing all these dimensions and providing an objective perspective that complements previous qualitative bibliometric analyses of CSR. Furthermore, Abad-Segura et al. [115] conducted a bibliometric analysis spanning 2001–2018, focusing on the relationship between corporate social responsibility (CSR) and sustainability, which strongly aligns with SDGs 4, 9, and 12. The study revealed a growing interest in this field, mainly within the category of Business, Management, and Accounting, with prominent contributions from journals like the Journal of Business Ethics and Sustainability. The most productive authors, institutions, and countries were identified, with the United States leading in publications and citations. This analysis also indicated a rising trend in global research in recent years.

4.3 Green supply chain, environmentally preferable purchasing, and green practices

Table 21 unveils the top-cited reviews related to green supply chains, environmentally preferable purchasing (EPP), and green practices. When organizations adopt green supply chain management, they can lower the environmental impact of their operations, enhance energy efficiency, and encourage sustainable consumption and production. These efforts directly support SDG 7 (Affordable and Clean Energy), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). Similarly, implementing EPP as a strategy for procuring environmentally friendly products allows organizations to shrink their carbon footprint, conserve vital natural resources, and endorse eco-friendly alternatives, thereby advancing SDG 12. Green practices, on the other hand, encompass a range of actions such as, reduction in water consumption, recycling, and adoption of energy-efficient technologies. These measures significantly contribute to the realization of SDG 12 and SDG 13.

Table 20 Topic: cause-related marketing and corporate social responsibility

TC	Author(s)	Title	Journal	SDG
92	Ye et al. [113]	"A bibliometric analysis of corporate social responsibility sustainable development in sustainable development"	Journal of Cleaner Production	
88	Sarkar et al. [114]	"Zeitgeist or chameleon? A quantitative analysis of CSR definitions"	Journal of Cleaner Production	
75	Abad-Segura et al. [115]	"The sustainable approach to corporate social responsibility: A global analysis and future trends"	Sustainability (Switzerland)	

This table discloses the top three reviews and their SDG mapping concerning Cause-Related Marketing and Corporate Social Responsibility

Table 21 Topic: green supply chain, environmentally preferable purchasing, and green practices

TC	Author(s)	Title	Journal	SDG
270	Chen et al. [60]	"Supply chain collaboration for sustainability: A literature review and future research agenda"	International Journal of Production Economics	
224	Feng et al. [75]	"Corporate social responsibility for supply chain management: A literature review and bibliometric analysis"	Journal of Cleaner Production	
174	Dos et al. [82]	"The analytic hierarchy process supporting decision making for sustainable development: An overview of applications"	Journal of Cleaner Production	

This table discloses the top three reviews and their SDG mapping concerning Green Supply Chain, Environmentally Preferable Purchasing, and Green Practices

New technology is driving change in business strategies and increasing production and process innovation possibilities, particularly in supply chain collaboration for sustainability. Research explores the links between sustainability collaboration and company performance on economic, environmental, and social metrics. A thorough examination of Table 21 reveals that Chen et al. [60], a systematic literature review and bibliometric analysis mapped to SDG 8, 9, and 16, found that research on supply chain collaboration for sustainability is increasing but lacks attention to social considerations and horizontal collaboration partners. Further, research on corporate social responsibility (CSR) in supply chain management (SCM) has also increased recently. Mapped to SDG 9 and SDG 12, the study by Feng et al. [75] aims to systematically evaluate CSR knowledge structure and progress for SCM through bibliometric analysis and network analysis of 628 peer-reviewed publications. Results show that theoretical and conceptual research dominates the field, focusing on sustainable development and economic and social effects. Research gaps include a lack of practical and normative modelling and a lack of consideration for suppliers in emerging economies. Appearing third in the table, Dos et al. [82], mapped to SDG 8, conducted a systematic literature review on using the analytic hierarchy process in decision-making for sustainable development. It analyzes 173 manuscripts published between 2014 and 2018 from Web of Science, Scopus, and Science Direct databases. The study aims to identify gaps and future research pathways in using the analytic hierarchy process for sustainable development.

4.4 Education for sustainability and higher education institutions

Education for sustainability in higher education institutions can play a crucial role in achieving the SDG by providing students with knowledge, skills, and values, incorporating sustainable practices into their operations, and carrying out research and innovation in sustainable development. Table 22 shows the highly cited reviews on this topic. By providing education for sustainability, higher education institutions empower students to become responsible citizens and active agents of change in their communities and thus contribute to SDG 4 (Quality Education), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action). By incorporating sustainable practices, research and innovation, they can help reduce environmental impact, address some pressing environmental and social challenges, and lead by example to achieve SDG 12 (Responsible Consumption and Production).

The comprehensive analysis in Table 22 reveals significant developments in both Higher Education for Sustainable Development (HESD) and Education for Sustainable Development (ESD) research. In the case of HESD, Hallinger et al. [62] conducted a highly cited bibliometric review, analyzing 1,459 Scopus-indexed documents. This study highlighted a rapidly growing knowledge base, primarily originating from developed societies, identifying key authors, core journals, and three research clusters. It serves as a benchmark for future HESD research, offering guidance to scholars and aligning with SDGs 4 and 12. Concurrently, Grosseck et al. [116] conducted a bibliometric analysis of 1,813 papers on ESD between 1992 and 2018, illustrating the field's growth, international collaboration, and core research directions in alignment with SDGs 4 and 12. Furthermore, Avelar et al. [117] systematically reviewed the literature on education for advancing the implementation of SDGs, examining 193 publications in the Web of Science. This research identified networks of co-authorship, themes, institutions, and countries and highlighted four dominant thematic lenses supporting the integration of sustainability, ethics, and responsible management education in higher education to promote sustainable development through SDGs 4, 8, and 12.

5 Conclusions

The declaration of SDGs represents one of the most visionary actions in the history of the United Nations. Although awareness about SDGs existed before this declaration, it instilled a renewed sense of direction and course of action for national policymakers and other critical stakeholders, including research communities in academia and industry. In response, various scholarly databases mapped scientific publications before and after this declaration to the 17 SDGs as they found relevant. Consequently, the literature related to SDGs has amassed to an enormous volume, and the difficulty in analyzing it using traditional and systematic methods is increasing daily. Fortunately, numerous literature analyses of SDGs have been conducted using bibliometric and scientometric methods. As bibliometrics matures as a field, boasting many useful methods and tools, and continues to evolve, these studies are anticipated to provide vital insights for policymakers and other stakeholders. However, it is crucial to determine the extent to which each SDG has been studied and analyzed through the lens of bibliometric and scientometric research. Such exploration will reveal gaps

Table 22 Topic: education for sustainability and higher education institutions

TC	Authors	Title	Journal	SDG
101	Hallinger et al. [62]	"A bibliometric review of research on higher education for sustainable development, 1998–2018"	Sustainability (Switzerland)	
56	Grosseck et al. [116]	"Education for sustainable development: Evolution and perspectives: A bibliometric review of research, 1992–2018"	Sustainability (Switzerland)	
54	Avelar et al. [117]	"Education for advancing the implementation of the Sustainable Development Goals: A systematic approach"	International Journal of Management Education	

This table discloses the top three reviews and their SDG mapping concerning Education for Sustainability and Higher Education Institutions

in the existing bibliometric and scientometric literature analyses on SDGs. To address this, we attempted a bibliometric and scientometric analysis of existing bibliometric and scientometric analyses of SDGs.

Our first research question delves into the research trends discerned through bibliometric and scientometric studies concerning SDGs. It's apparent that the total publications in this domain have experienced substantial growth, with a compound annual growth rate (CAGR) of 74% between 2016 and 2022. Even more striking is the increase in total citations, which have surged at a CAGR of 171% during the same period. These statistics underscore the rapid expansion and growing attention garnered by bibliometric studies on SDGs within the research community. Notably, our analysis identifies the leading contributing countries in quantitative reviews on SDGs, with China, Spain, Brazil, the United Kingdom, and India standing out. In terms of institutions, universities based in Spain, China, South Africa, Hong Kong, and Thailand claim top positions in our study.

In addressing our second research question, we've uncovered significant findings regarding the relationship between various bibliometric studies and different SDGs. Firstly, we have determined that SDG 12 emerges as the most extensively researched SDG across both Web of Science and Scopus. Notably, it ranks highest among article types, encompassing research and review articles. Moreover, SDG 12 is also the most prevalent in bibliometric studies at both the country and institutional levels. Our analysis further reveals that the journals most prolific in publishing bibliometric studies on SDGs are Sustainability and the Journal of Cleaner Production. These journals exhibit a strong predilection for publications related to SDGs 12, 11, 13, and 7. Lastly, our examination highlights the top 10 authors who exhibit a strong publishing presence related to SDG 12.

Pursuant to our third research question, we scrutinized the premier fields of research and assessed the burgeoning topics in this research domain. Our examination of the SDG connections within crucial FoRs highlights SDGs 12 and 11 as the most prominently researched SDGs across various fields. Within the top two most-researched FoRs, SDG 4 claims the top spot in terms of betweenness and eigenvector scores. Notably, SDG 5 and SDG 15 also exhibit significance in the fields of 'Library and Information Studies' and 'Strategy, Management, and Organizational Behavior,' respectively. Furthermore, our analysis delves into the most significant themes emerging in bibliometric examinations of the SDGs. We employ keyword co-occurrence and content analysis of top-cited publications within this timeframe.

Notably, themes related to environmental protection, industries such as tourism, circular economy, life cycle assessment, supply chain management, and waste management feature prominently. These thematic clusters are largely dominated by studies associated with SDG 12. A substantial cluster also encompasses themes like environmental management, renewable energy, and energy policy, with SDG 6 at the forefront. A smaller cluster, conversely, centers around urbanization and its aspects, predominantly under SDG 11. Content analysis offers deeper insights into the role of the circular economy, waste management, and the challenges entailed in operationalizing the SDGs. Some bibliometric studies spotlight the significance of knowledge management practices at the governance and management level for SDG accomplishment. These trending subjects provide ripe opportunities for researchers both in academia and industry, including those specialized in scientometrics and bibliometrics.

Moreover, our network analysis aimed at identifying SDG linkages formed through bibliometric studies underscores that SDGs 12 and 9 exhibit robust connections with most other SDGs, underscoring their pivotal roles in achieving a sustainable future. However, alternative social network analysis (SNA) indicators such as eigenvector and betweenness metrics reveal that SDGs 8, 16, and 17 possess higher scores than SDG 12. This indicates their substantial potential to influence the realization of other SDGs.

A salient observation emerges when we contrast mainstream SDG research, which predominantly focuses on SDGs 3 and 7, with bibliometric analyses. In this context, bibliometric research doesn't emphasize these SDGs to the same extent. Challenges include the sheer volume of publications linked to these SDGs and the complexity of comprehending medical and health-related publications (SDG 3) and technical literature (SDG 7). Specifically, concerning SDG 7, journals like Sustainability and the Journal of Cleaner Production can be targeted since they frequently accommodate bibliometric studies. Nevertheless, addressing the case of SDG 3 poses more complex challenges in terms of identifying suitable outlets. Despite these obstacles, conducting bibliometric studies on SDGs 3, 7, and 13 can be highly rewarding if the unique challenges they pose are effectively addressed.

Further, we recommend that bibliometric researchers explicitly declare the use of Systematic Literature Review (SLR) protocols when assessing SDG literature through bibliometric means. This transparent declaration enhances the rigour and reproducibility of research. Moreover, considering the feasibility, exploring the use of multiple protocols can provide a more comprehensive view of the field. Additionally, we encourage scholars to expand their methodological horizons. Instead of relying solely on 'easy-to-use' or 'convenient' tools and approaches, the field would greatly benefit from the exploration of sophisticated bibliometric tools, methods, and approaches. This broader toolkit can

yield deeper insights and enhance the quality of bibliometric studies. Lastly, beyond quantitative methods and tools, we urge researchers to consider the utilization of qualitative and mixed methods. These approaches can offer valuable context and nuance, contributing to a more comprehensive understanding of the SDG literature.

This study's findings significantly contribute to the academic understanding of Sustainable Development Goals (SDGs) research, particularly in bibliometric studies. The observed compound annual growth rate (CAGR) of 74% in publications highlights an escalating academic interest in SDGs. Notably, the predominance of SDG 12 in research outputs and its extensive coverage across diverse article types and journals showcases an academic inclination towards environmental sustainability topics. The findings also reveal significant intersections between different SDGs and fields of research. Furthermore, the study's methodological advancements, such as social network analysis, set new standards for future research. The study's findings also have significant practical implications for policymakers, industry leaders, and practitioners involved in the implementation of SDGs. Industries such as tourism, circular economy, life cycle assessment, supply chain management, and waste management are identified as key areas where SDG research can be translated into practical solutions. The study also highlights the pivotal role of knowledge management in achieving SDGs, suggesting that effective governance and management practices are crucial for SDG accomplishment.

Finally, no matter how rigorous a study is, it inevitably carries some limitations. The primary constraint of this research pertains to its use of Scopus as the primary source for bibliographic data and SciVal for SDG mapping. Expanding the scope to encompass additional data sources could potentially yield different results, thus warranting further reviews with similar objectives in the future.

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Code availability Not Applicable.

Declarations

Ethics approval and consent to participate This article does not contain any studies with human participants performed by any of the authors.

Informed consent This article does not contain any studies with human participants performed by any of the authors.

Competing interests The author(s) declare no competing interests.

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