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Review

Bibliometric Analysis of Research Hotspots and Frontiers in Progress towards the Sustainable Development Goals

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Abstract: The United Nations Sustainable Development Goals (SDGs), established in 2015, are binding targets for monitoring the sustainable status of all countries in the world. Developing localized SDGs indicator systems, assessing SDGs progress comprehensively, and creating policy tools have gradually become the hotspots of scientific research and practical application of the SDGs. To systematically sort out the research status of the SDGs progress and identify problematic gaps, this paper uses bibliometric methods to analyse the scientific knowledge mapping of SDGs research, sort out the general characteristics, scientific cooperation, cutting-edge hotspots and future research trends of SDGs research. Besides, this paper promotes the integration of academic research into concrete practice by linking it to mainstream SDGs progress reports. The results show that: ① The amount of SDGs research literature in 2015–2022 is on a growing trend, and the existing research is characterised by multidisciplinary crossover. Research institutions such as Utrecht University, the Chinese Academy of Sciences, and the University of the Chinese Academy of Sciences have contributed the most to SDGs research. ② The research hotspots include the SDGs practice of different responsible subjects, the comprehensive assessment of the progress of SDGs, the scientific research of SDGs indicators, and the research on the interaction between the goals of SDGs. ③ Environmental issues, indicators, energy transition, education and agriculture are the hot directions of SDGs research. Energy saving and carbon reduction, sustainable practices of supply chain management, and promoting the progress of environmental dimension goals are the focus of subsequent research. According to the results of the bibliometric analysis, future SDGs research should pay attention to strengthening multi-party cooperation, using innovative technologies to support the assessment of SDGs progress, and formulating sustainable development strategies.

Keywords: Sustainable Development Goals (SDGs); SDGs evaluation; CiteSpace; bibliometrics

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1. Introduction

In September 2015, the 193 Member States of the United Nations unanimously adopted Transforming Our World: the 2030 Agenda for Sustainable Development (2030 Agenda) at the United Nations Summit on Sustainable Development [1]. The 2030 Agenda builds on the Millennium Development Goals (MDGs) to form the Sustainable Development Goals (SDGs), which comprise 17 goals and 169 targets. The SDGs cover poverty reduction, hunger eradication, health and well-being, quality education, gender equality, clean water, clean energy, decent work and economic growth, industrial innovation, reducing inequalities, sustainable cities, responsible consumption and production, climate action, oceans and terrestrial organisms, peace and justice, and partnerships, essentially articulating a global vision for development up to 2030 [2]. In contrast to the MDGs, the SDGs are a universal agenda for global sustainable development, calling on all countries to adopt holistic development strategies that balance "economic development, social inclusion and environmental sustainability", with the aim of better reconciling the provision of ecosystem services with the ecological demands of human socio-economic development, and

maintaining the sustainability of ecosystems [3]. Under the planetary boundaries frame, sustainability is conceived as the ability to stay within 9 ecological carrying-capacity thresholds [4,5]. To ensure that SDGs are always moving in the right direction and the sum of environmental pressures does not exceed planetary boundaries, the latest progress of the SDGs should be monitored over time to assess implementation progress, identify priority targets and detect implementation issues [6,7].

Following the introduction of SDGs, countries have integrated these goals into their national strategies, highlighting the importance of assessing SDGs progress. The United Nations Inter-Agency Expert Group on SDG Indicators (IAEG-SDGs) was established to develop a global indicator framework for objective, annual assessments of SDGs progress. The United Nations Department of Economic and Social Affairs publishes the Sustainable Development Goals Report, Progress towards the Sustainable Development Goals: report of the Secretary-General and the Global Sustainable Development Report, and the Global Sustainable Development Report. These reports detail the global implementation of the SDGs, and analyse specific targets and indicators. Given the diversity of national contexts, the applicability of the global indicator system varies. The UN encourages country-specific studies, based on the IAEG-SDGs framework, to accurately assess SDGs progress. This strategy promotes integrated global, regional, and national assessments. International organisations, including the UN Sustainable Development Solutions Network (SDSN), coordinate these assessments. Key regions such as the European Union, Asia-Pacific, the United Kingdom, Germany, Japan, South Korea, and the United States are conducting tailored assessments, which are critical for translating the global SDGs into national and local action plans.

To dynamically track the progress of research on SDG target indicators and evaluation methods, Elsevier used a bottom-up approach to build datasets for each SDG, based on the Scopus database [8]. Fudan University published the Action Report of Higher Education in China about SDGs, reviewing the contribution of Chinese higher education to the implementation of the SDGs with quantitative data on research outputs [9]. Such reports describe the number of publications, the number of international articles, the weighted impact and other indicators to provide a comprehensive picture of the scientific research process on SDGs. There is also a review literature on SDGs research, which summarises and synthesises the existing literature [10–12]. While bibliometrics is conducive to systematically sorting out the lineage and distribution patterns of research, there are still few studies that use bibliometrics to clarify the existing progress in the field of SDGs research. Despite the abundance of studies claiming to be based on systematic analyses of SDGs literature, there remains a notable absence of comprehensive macro-level understanding and diagnostic assessment of problematic gaps. In particular, the analysis of core issues and cutting-edge hotspots remains insufficient to effectively support the global assessment of SDGs progress and implementation strategies. The study embarks on a comprehensive analysis of core issues and cutting-edge hotspots within the SDGs framework. With a commitment to advancing global SDGs practices, this research leverages the bibliometric software CiteSpace 6.2.R6 to meticulously examine pertinent literature, identify research hotspots, and research frontiers. By aligning these findings with mainstream SDGs progress reports, the study bridges academic inquiry with practical applications, seeking to uncover the disparities between current developmental trajectories and the goals. The overarching objective is to illuminate the current status of SDGs progress and explore research trends, thereby furnishing valuable insights for further research endeavours and informed decision-making in SDGs implementation.

2. Materials and Methods

The Web of Science (WoS) database hosts tens of thousands of high-impact, multidisciplinary academic journals, serving as a reputable source of citation information worldwide. Its core collection encompasses internationally renowned research publications across various fields, including agronomy, management, engineering, and economics. Therefore,

it is reasonable and effective to use WoS as the data source in this study. Specifically, the data used in the literature analysis for this study were derived from the SCI-E database. We took the release of SDGs by the United Nations in 2015 as the time starting point, and the search period is from 2015 to 2022. The search date was 4 November 2023, the WOS search topic was "Sustainable Development Goals" or "SDGs", the document type was selected as "Article", "Proceeding Paper" or "Review Article", and the research direction was geography, environment, ecology, resources, economy, society, etc. After a manual screening of the literature not related to the topic, a total of 6011 English documents were obtained and exported in plain text file format. After pre-processing and de-weighting, 6007 documents were obtained. The main parameters of the visualisation process were selected as follows: the time slice was 1 year, the threshold was selected as the 50 data with the highest frequency of occurrence in each time slice, the association strength was selected as the cosine algorithm, and the cropping technique was adopted as the pathfinding technique. Cluster analysis was performed using the LLR log-likelihood ratio algorithm [13].

In addition to the literature analysis, this paper also summarises and analyses selected SDGs progress reports published by international bodies for the period 2015–2022, with the aim of capturing the latest progress on the SDGs. The reports include the Sustainable Development Goals Report and Progress towards the Sustainable Development Goals: report of the Secretary-General, published annually by the UN Department of Economic and Social Affairs; the Global Sustainable Development Report (GSDR), published every four years; and Sustainable Development Report, published by the SDSN (formerly known as SDG Index and Dashboards Report, which has been renamed the Sustainable Development Report since 2019). In addition, the article further uses Python text mining to obtain a list of high-frequency words in the SDGs report to understand the main concerns and trends of SDGs progress at the global level.

3. Results and Discussion

3.1. Analysis of Research Status

3.1.1. Literature Volume and Distribution of Disciplines

Since the UN proposed the SDGs in 2015, there has been a rapid increase in the number of related research publications (Figure 1). The volume of SDGs research literature has increased rapidly, from 50 publications in 2015 to 1823 publications in 2022. The number of publications can indicate the level of academic interest in an area. Figure 2 shows that, in the context of approaching the endpoints of Agenda 2030, research in the field of the SDGs is increasingly valued by national and international scholars.

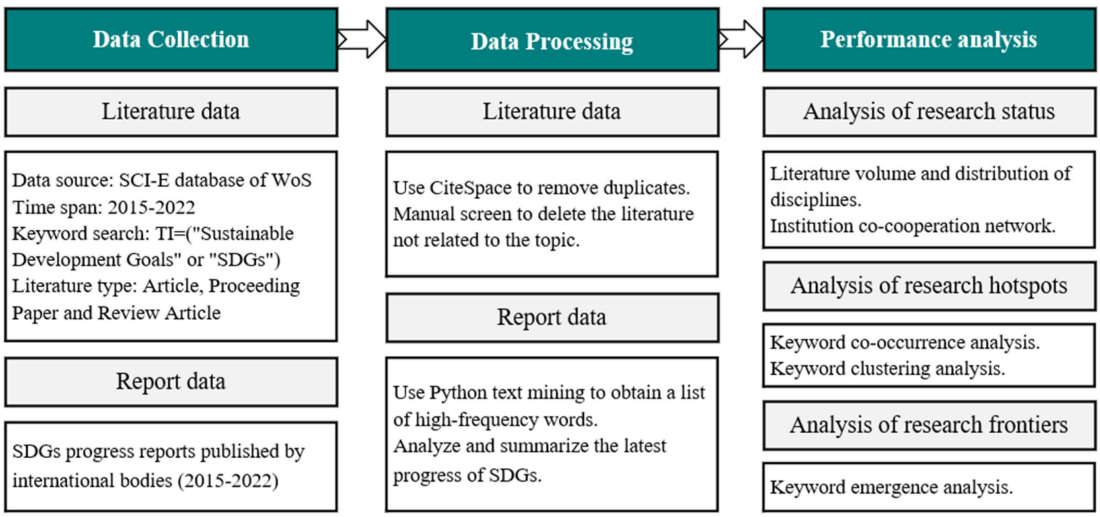

Figure 1. Research design and methodology.

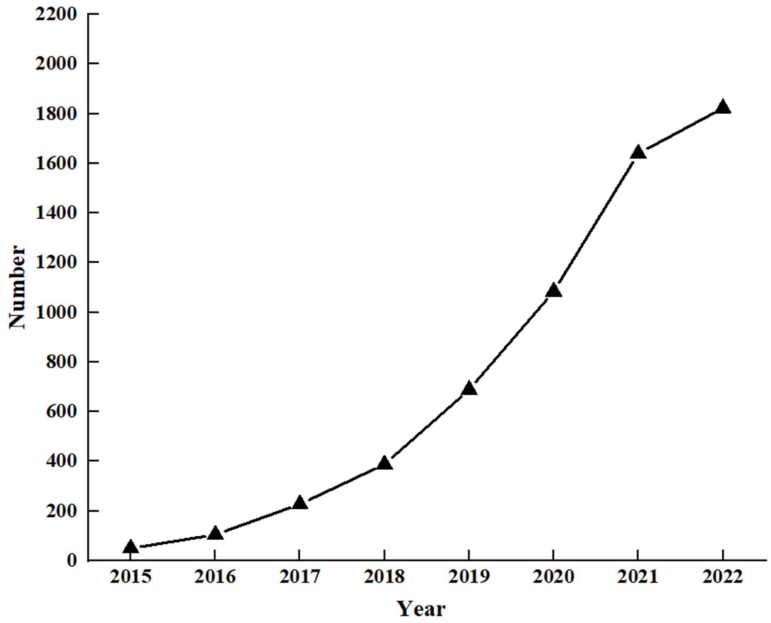

Figure 2. Annual number of published papers on SDGs research from 2015 to 2022.

The SDGs include specific targets across a range of economic, social and environmental domains. Assessing progress towards the SDGs requires multidisciplinary and multi-institutional participation to fully support the need for global SDGs progress assessment and SDG implementation tools. In terms of the distribution of SDGs research disciplines (Figure 3), the published papers mainly focus on environmental sciences and ecology and economics, in addition to social sciences, resource sciences, energy sciences, agricultural sciences, geographical sciences, computational sciences and technology, etc., and the interdisciplinary character is more evident. At present, except economics, environmental science and ecology, where there are more studies, there are relatively few studies in other fields, demonstrating the need for synergistic development in multiple fields.

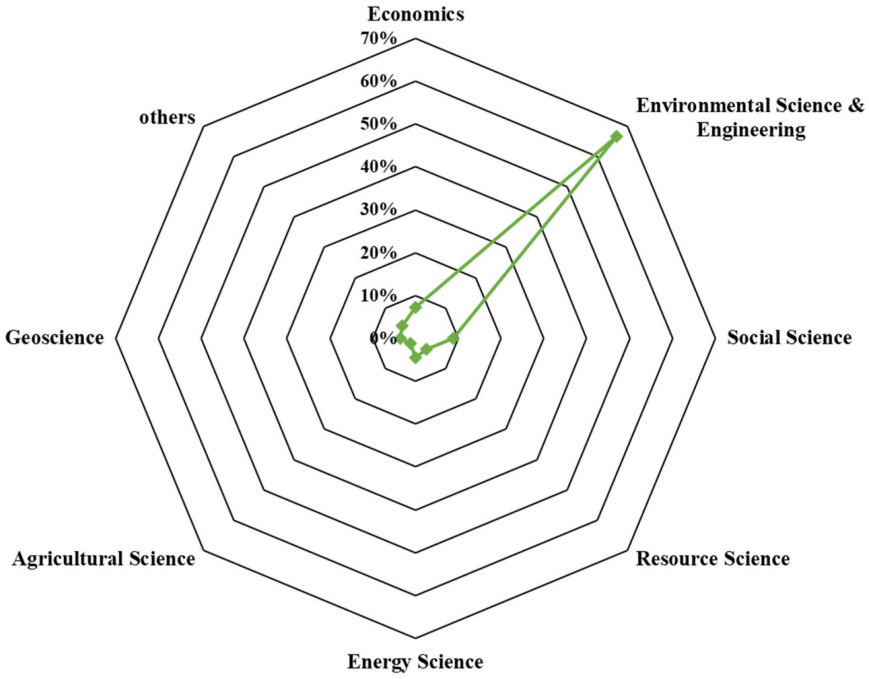

Figure 3. Distribution of SDGs research disciplines.

3.1.2. Research Institutions

CiteSpace was used to analyse the co-occurrence of research institutions to obtain a map of institution collaboration networks (Figure 4). In terms of institutional collaboration, the Chinese Academy of Sciences (CAS), University of Chinese Academy of Sciences (UCAS), Beijing Normal University (BNU), Stockholm University (SU) and Utrecht University (UU) were in the top five in terms of the number of publications. Utrecht University in the Netherlands has the highest intermediary centrality (0.34) and has extensive collaborations with universities such as the University of Michigan, the University of Oxford and the University of Florida. It is followed by the Free University of Amsterdam, which has a mediated centrality of 0.31 and has close collaborations with the University of Hong Kong, the University of Toronto and the University of Washington. Although Chinese research institutions such as CAS and UCAS are at the top of the list in terms of the number of publications, their mediational centrality is low in both cases (0.01 for CAS and 0.02 for UCAS). To a certain extent, this reflects that Chinese research institutes have less cooperation with research institutes in other countries when conducting SDGs research, and fail to gain academic influence that is coordinated with the amount of literature published.

Figure 4. Map of the cooperation networks among institutions of SDGs research.

3.2. Analysis of Research Hotspots

3.2.1. Keyword Co-Occurrence

Through the keyword co-occurrence analysis, it is possible to capture the focus themes of SDGs progress research. As shown in Figure 5, the keyword co-occurrence network is more closely connected and the co-occurrence relationship between keywords is clearer, indicating a wide range of research themes and diversified research hotspots. We selected the top 15 high-frequency keywords on the co-occurrence map, excluding "SDGs" and "sustainable development", and also selected the top 15 high-frequency keywords from the text analysis of the reports using Python (Table 1). The high-frequency keywords in the literature reflect the hotspots of academic research and the interests of researchers, while the keywords in the report directly reflect the focus and key issues of actual SDGs progress.

A comparison of the keywords in the literature and the report shows that the hotspots of academic research and practice are generally consistent, with both focusing on SDGs implementation tools such as "indicators" and "evaluation", as well as "biodiversity", "climate change" and "biodiversity". Climate change", "water resources", "energy", "food" and "carbon emissions" can be found. "Carbon emissions" and other key SDG themes are also present. Note that "data" is the most frequent keyword in the report, but not in the literature, reflecting the fact that data is a key issue for real progress on the SDGs, but has not received the attention it deserves in academic research.

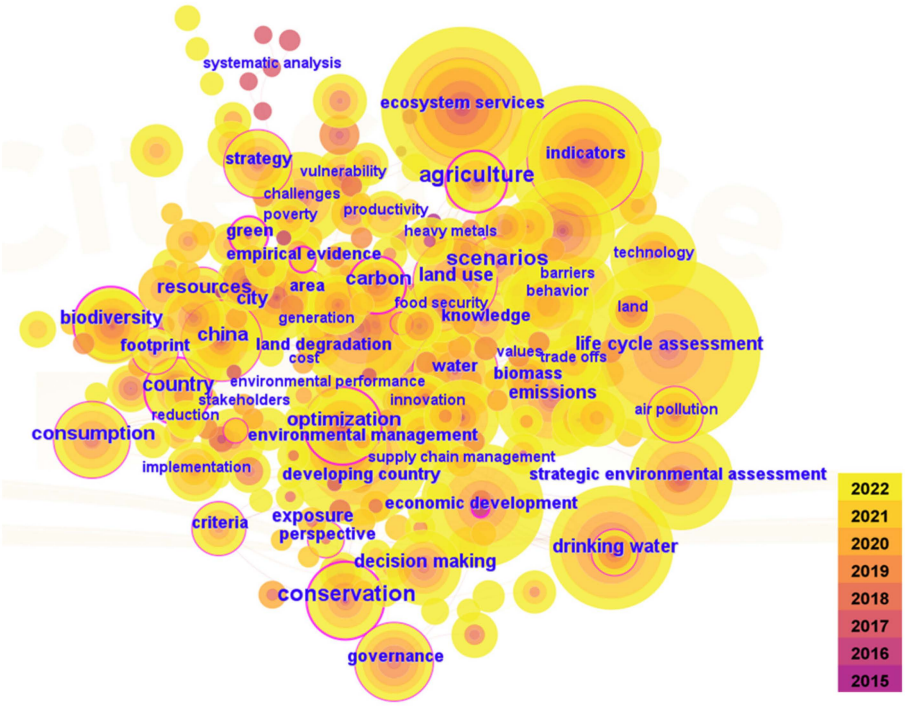

Figure 5. Map of co-occurring keywords of SDGs research.

Table 1. High-frequency keywords of SDGs research and reports.

Articles		Reports	
Keywords	**Frequency**	**Keywords**	**Frequency**
life cycle assessment	302	data	2006
climate change	231	indicators	1365
energy	206	biodiversity	362
impact assessment	185	climate change	337
framework	143	assessment	225
model	141	infrastructure	224
performance	138	renewable energy	224
indicators	124	water resource	140
emissions	123	gender equality	132
ecosystem services	97	economic growth	126
biodiversity	96	sustainability	81
circular economy	91	carbon emission	74
city	82	food security	68
food	73	quality education	59
water	72	climate action	42

3.2.2. Keyword Clustering

To explore the research hotspots of SDGs progress, this article used the keywords as a measure to draw the SDGs keyword clustering network map (Figure 6). After clustering the keyword co-occurrence network using the LLR algorithm, the Q value is 0.4835 and

the S value is 0.7405, so the clustering results are significant and reasonable. By analysing the clustering network and summarising the highly cited literature, the following research hotspots were obtained.

(1) Different responsible entities to advance the implementation of the SDGs

Progress towards the Sustainable Development Goals: report of the Secretary-General published in 2022 states that the combined efforts of governments, the private sector and civil society are key to getting progress on the SDGs back on track against the backdrop of a climate crisis, a new coronary pandemic and an increase in conflicts around the world [14]. Governments are key to driving progress on the SDGs, and primarily responsible for advancing it. Since the introduction of the SDGs by the UN in 2015, many governments have submitted voluntary reviews of their progress on the SDGs at the national, regional and city levels [15]. For example, China and the Netherlands have submitted voluntary reviews of SDGs progress at the national level, and as of November 2023, 192 countries have made 375 country-specific voluntary presentations (including letters of intent for 2024 and 2025), and 159 voluntary local review reports have been prepared. To identify local sustainable development priorities, national/regional governments have actively established localised SDGs assessment indicator systems, such as Agenda 2063 of the African Union member states, which puts forward 20 targets and 174 sub-targets, and Germany's National Sustainable Development Strategy Report 2021, which constructs an indicator system of 17 goals and 75 indicators. However, the Sustainable Development Report 2022 published by SDSN states that spillovers between countries are pervasive and often overlooked, severely hampering the realisation of the global SDGs [16]. Developing a systematic assessment methodology that takes into account spillovers and trade-offs to guide policymaking and promote international cooperation is an important factor in overcoming obstacles and accelerating progress.

Business plays a decisive role in the implementation and financing of the 2030 Agenda, and businesses are working on the advancement of the SDGs. De Villiers et al. used IoT and blockchain technology to measure the efforts and progress of businesses in achieving the SDGs [17]. Song et al. benchmarked the engagement of Global 500 companies with SDGs, measuring corporate contributions to SDGs [18]. However, some researchers found that firms did not sufficiently align materiality with the SDGs, and that firms' efforts to advance individual goals have been far greater than meeting the other targets [18,19]. In addition, it is undeniable that some companies use SDGs as a marketing tool to "bleach green" and lead investors or consumers to make incorrect judgements, which not only does not contribute to the achievement of SDGs, but also undermines the credibility of SDGs. Therefore, effectively embedding SDGs into companies' business development strategies and corporate governance models is important for companies to advance SDGs [20–22], yet there are few relevant studies and further interdisciplinary research is needed.

In addition to governments and businesses, academic institutions and the public are widely recognised as contributors to SDGs [11]. Academic institutions are crucial for theoretical research such as a deep understanding of the interactions of SDGs and the systematic construction of SDGs assessment methodologies, but lack the capacity for sustainable practice, and should aim to bridge the gap between theory and practice in the future [23]. The public has a huge potential contribution to the realisation of SDGs [24], but there are few relevant studies, and further research is needed to guide policy development to better leverage the public's role in advancing SDGs.

(2) SDGs Progress Evaluation Methodology

Scientific monitoring and evaluation of SDGs progress is key to ensuring the realisation of the SDGs, and a major difficulty and challenge in accurately planning sustainable development actions. Since the UN launched Agenda 2030 in 2015, the evaluation of SDGs progress has gradually shifted from qualitative to quantitative research, with early government-led qualitative reports mainly focusing on describing the SDGs process and future challenges. In recent years, researchers have started to conduct quantitative anal-

yses of SDGs progress at different scales, such as national, regional and urban, building on the series of SDSN studies. Quantitative methods, such as calculating SDGs indicators and constructing SDGs indicator boards, have formed a relatively stable theoretical framework [25,26]. Zhou et al. conducted an in-depth analysis of the progress of SDGs implementation at the country and regional levels based on the 2019 SDGs Index and Indicator Board Global Report released by SDSN, and found that there are large differences in the progress of SDGs across regions, including OECD member countries, East Asia, Latin America and Africa [27]. Zhu et al. conducted an indicator board analysis of the SDGs progress in 31 provinces in China from 2015 to 2016, and found that there is an imbalance in the progress of SDGs across Chinese provinces [28]. Current efforts to monitor the SDGs focus on indicators of progress, which cannot explain the complex dynamics of sustainable development [11]. The SDGs have been a major source of inspiration for the development of the SDGs. To ensure fairness and sustainability in assessing progress towards the SDGs, monitoring and evaluation should integrate local realities rather than focusing solely on indicator metrics. The localisation of the SDGs is essential to overcome the mismatch between theory-driven indicators and local conditions. Allen et al. created a localised indicator system applicable to the Arab context for evaluating the progress of Arab SDGs [29]. Jones and Comfort discussed the challenges of localisation in the UK, arguing that a lack of coherent policy, limited awareness and funding gaps remain [30].

Due to the complexity of assessing SDGs progress at different scales, it should be streamlined by harmonising all characteristics from global to local domains. Data gaps and lags remain the biggest obstacle to effective assessment [31,32]. Remote sensing data are important for improving the availability of data on ecological and environmental indicators due to their global coverage, complete time series, and high spatial resolution [33]. They can support the quantitative assessment of the progress of SDGs. Wang et al. assessed the progress of SDG1 at the district and county level in China based on multi-source remote sensing data such as night light imagery and land cover data [34]. Liang et al. constructed a comprehensive assessment framework for the sustainable development of urbanisation in Hainan Island, China, and used remote sensing to analyse the progress of the relevant targets in time and space from 2011 to 2020 [35]. Therefore, localised assessment methods based on local conditions, data availability and granularity, and statistical capacity building are key factors in assessing the progress of SDGs.

(3) Scientific Study of SDGs Indicators

While the SDG indicators were adopted and widely supported in 2017, the lack of science in their development and the challenges of local implementation still need to be further addressed and refined [11]. On the one hand, some researchers have emphasised the importance of existing indicators. On the other hand, some researchers highlight the scientific shortcomings and limitations of existing indicators. In 2017, the SDSN published SDG Index and Dashboards Report, which noted that trade-offs and spillover effects are ignored by most indicators [36]. Hall et al. highlighted the uncertainties and data limitations of the SDG3 indicators, which may lead to inaccurate aggregation and assessment of public health and affect the measurement of SDG3 progress [37]. Giles-Corti et al. pointed out the inconsistencies between SDG11 and the urban indicator framework developed by UN-HABITAT, emphasising that many SDGs indicators assess outcomes and do not include fully integrated “upstream” policies and interventions [38]. On the other hand, some researchers have focused on the scientific aspects of indicator selection and calculation methodology in the localisation process of SDGs. Wang et al. introduced the detailed rules of the SDG12.7.1 methodology to guide the implementation of government green procurement in China and to form a performance evaluation tool that fits the national context [39]. McCracken and Meyer analyse the methodology used to assess SDG6.5.2, noting that the normative and binary nature of the indicator obscures the political complexity of the process of establishing cooperation [40]. In addition, missing and delayed data continue to affect the monitoring of indicators. The Inclusive Wealth Report 2018, published by

UNEP [41], stated that data gaps for indicators affected 77 per cent of environment-related targets (SDG13, SDG14 and SDG15).

The purpose of establishing indicators is to quantitatively measure the progress of the SDGs. This allows for an objective assessment of each indicator's current state, the degree of improvement needed, and the gap between the current status and the goals of the agenda. These reference benchmarks are essential in assessing sustainable development on a global scale, both regionally and nationally. They also facilitate the conduct of global sustainable development studies under the same or similar discourse systems, and enable horizontal comparisons between regions or countries. Therefore, research on the scientificity, adaptability, reliability and accessibility of indicators is indispensable. There is an urgent need to develop scientific metrics, seek data innovation and cooperation, and improve data coverage to ensure that all goals are measurable and that all countries can monitor progress.

(4) Interaction studies between SDGs objectives

The greatest transformative potential of the 2030 Agenda lies in its emphasis on the interconnectedness and interplay of the 17 SDGs, and the importance of implementing the SDGs as an "indivisible" whole [42]. This indivisible whole requires policymakers to carefully consider the many potential interactions between the 169 goals and to ensure that progress on one goal does not jeopardise progress on others. However, little is known about the synergies and trade-offs between targets and how they are reflected in policy, and further research is needed to systematically identify interactions between targets. Current research has used literature, expert judgement, quantitative and modelling approaches [43].

Some researchers have worked on creating reliable models to frame the interactions between the 17 goals. Nilsson et al. proposed a seven-point scoring framework for goal interactions to highlight integrated policy priorities [44]. Collste et al. developed a system dynamics-based iSDG model to support synergistic and trade-off analyses of 17 goal-related policies [45]. Van Soest et al. combined expert interviews, integrated assessment models from different disciplines and text mining to develop integrated assessment models to explore interactions between resource use objectives and the Earth system. Other researchers have worked on the linkages between specific targets [46]. Fuso Nerini et al. and McCollum et al. analysed the synergies and trade-offs between SDG7 and other targets [42,47]. Von Stechow et al. analysed the trade-offs between SDG13 climate action and the other SDGs, highlighting that curbing energy demand is crucial across the goals [48]. Mantlana and Maoela argued that there are both synergies and trade-offs among SDG6, SDG13 and SDG15 [49]. Due to the different focus and context of the studies, the lack of completeness of the data, and the subjective and one-sided nature of the studies, the results of these SDGs interaction studies have rarely been adopted by national SDGs implementation programmes, and the synergies and trade-offs between the goals have not been taken into account when assessing SDGs progress [10]. To ensure consistency between scientific results and policy practice in the future, it is imperative to enhance the monitoring system for indicators, address data gaps, and develop models for analysing scenarios at different scales.

The water–energy–food nexus underpins SDG6, SDG7 and SDG2, and their interactions also have direct or indirect impacts on the other SDGs. Zhang et al. constructed China's water–energy–food nexus based on the SDGs nexus framework and quantified the interactions between the six targets (SDG2, SDG6, SDG7, SDG8, SDG12, and SDG15) through a panel vector autoregressive model, and found that the impact of SDG8 on changes in the water–energy–food nexus was generally higher than that of SDG12 [50]. Cheng et al. used the coupled coordination model to quantitatively assess the coordinated development levels of SDG2, SDG6 and SDG7 in China, and the results show that the coupled coordination degree maintains a good trend and moves from primary coordination to good coordination, but the development levels of SDG6 and SDG7 still lag behind those of SDG2 [51]. Molefe and Inglesi-Lotz examined the dynamics between water, energy, food and economic conditions in the African countries of Angola, Ethiopia, Kenya, Nigeria and South Africa and found that there are synergies between the three goals, with impor-

tant policy implications for the continent's current and future development status [52]. Although a large number of studies have explored the water–energy–food nexus, the following problems remain: a lack of spatial and temporal evolution data to reflect the linking processes in the coupled system and a lack of data at the subnational scale, which affects the formulation of sustainable development management policies [53]. Future research should pay more attention to how the water–energy–food nexus can provide a mechanistic tool for achieving the SDGs.

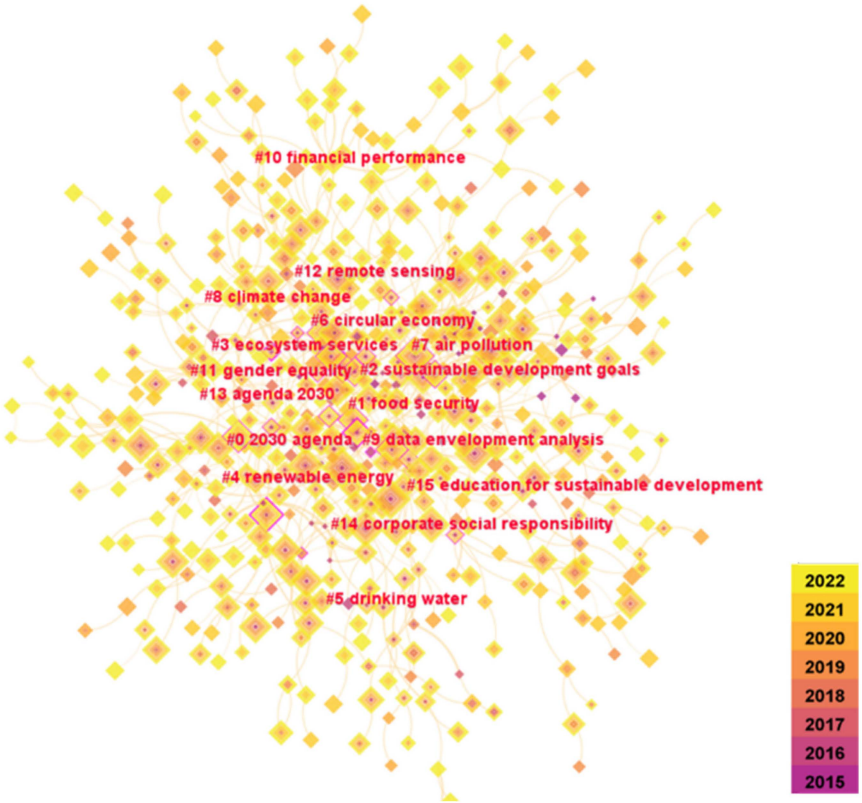

Figure 6. Map of keyword clustering of SDGs research.

3.3. Evolution of Research Hotspots and Analysis of Research Frontiers

Keyword emergence refers to the rapid increase in the number of occurrences of a keyword in the literature over a given period, causing changes in the hotspots of the research field. Therefore, the keywords that have emerged in recent years can, to some extent, reflect the research frontiers. Figure 7 shows the top 25 most cited emergent keywords in SDGs research and the start and end years of their emergence, reflecting the influence of certain keywords in different periods of SDGs research. This shows that the research field of SDGs has diversified characteristics, and different research hotspots are presented in different periods. The keyword with the longest period of emergence is "environment", with research related to the goals of the environmental dimension of the SDGs appearing in large numbers from 2015 onwards and remaining hot until 2019. The emergence intensity of "energy consumption" and "carbon emissions" is the highest, indicating that these are the most popular research topics in recent years. In addition, the dynamic analysis of keywords can reveal the evolutionary trend of research hotspots in a subject area. Combining the keywords and their emergence start times, SDGs research is divided into three stages: (1) From 2015 to 2017, "country" and "environment" appear at the earliest, indicating that SDG research has become the most popular in recent years. "Network" and "index" then start to appear, indicating that the design of evaluation indicators at the national level and networks of target relationships are key elements in this period. In addition, the appearance of "poverty" and "developing country" indicates that poverty eradication and the develop-

ment of sustainable modern energy in developing countries are also important research contents in this period. (2) From 2018 to 2020, "corporate social responsibility", "university" and "community" become the most important research topics. "Community" becomes a new emergent word, indicating increased attention to assessing progress on the SDGs and analysing problems at the micro level. The emergence of "corporate social responsibility" indicates that, during this period, there has been an increased focus on the role of business in advancing the SDGs. The emergence of "university" and "education" indicates that the contribution of education, especially higher education, to the SDGs and the development of education for sustainable development is an important research content in this period. The emergence of "agriculture" indicates that assessing progress, identifying problems and planning pathways for sustainable agricultural development are also hot research topics in this period. (3) From 2021 to 2022, "energy consumption" and "carbon emission" become the key words in this period. This indicates that sustainable energy use and development is one of the current research frontiers, and energy conservation and carbon reduction are the current research priorities. The emergence of "supply chain" indicates that the sustainable practice of supply chain management and promotion of circular economy development are also current research hotspots. The emergence of "environmental sustainability" highlights that driving progress in the implementation of environmental dimensions remains a current research priority.

Keywords	Year	Strength	Begin	End	2015 - 2022
country	2015	10.69	**2015**	2018	
environment	2015	9.94	**2015**	2019	
resilience	2016	10.06	**2016**	2018	
developing country	2016	9.17	**2016**	2017	
network	2016	9.17	**2016**	2017	
index	2017	16.08	**2017**	2020	
poverty	2017	11.8	**2017**	2018	
land use change	2018	9.79	**2018**	2018	
corporate social responsibility	2019	15.89	**2019**	2022	
university	2015	10.66	**2019**	2019	
barrier	2015	9.84	**2019**	2019	
education	2015	9.72	**2019**	2022	
community	2016	9.71	**2019**	2019	
development goal	2020	17.35	**2020**	2020	
2030 agenda	2020	15.82	**2020**	2020	
opportunity	2020	15.31	**2020**	2020	
agriculture	2015	14.71	**2020**	2022	
risk	2018	10.87	**2020**	2020	
energy consumption	2017	17.72	**2021**	2022	
carbon emission	2021	17.43	**2021**	2022	
supply chain	2021	15.82	**2021**	2022	
efficiency	2021	15.43	**2021**	2022	
environmental sustainability	2021	15.43	**2021**	2022	
behavior	2019	12.57	**2021**	2022	
implementation	2019	11.42	**2021**	2022	

Figure 7. Map of keyword emergence of SDGs research.

4. Conclusions

With the aid of CiteSpace, this paper employs the bibliometric method to analyse the literature related to SDGs research. It examines the annual number of publications, the trend of changes, the disciplinary fields involved, the research topics and their collaboration, the research hotspots, and the frontiers of SDGs research from 2015 to 2022. This analysis aims to deepen the SDGs follow-up and provide a reference for further research. The main conclusions are as follows:

(1) From the perspective of the current research situation, the number of research literature has shown a growing trend, and the existing research has been characterised by the intersection of multiple fields and disciplines, with economics, environmental science and ecology accounting for the majority of the research results, while other disciplines need to be further developed. Research institutions such as Utrecht University in the Netherlands, the Chinese Academy of Sciences, and the University of the Chinese Academy of Sciences have contributed the most to SDGs research;

(2) From the perspective of research hotspots, research in the field of SDGs is centred on social, economic and ecological themes, with climate change, energy transition, food security, and biodiversity being key directions in the study of the progress of SDGs. The hotspots include the practice of SDGs by different responsible subjects, the comprehensive assessment of the progress of SDGs, the study of the scientific validity of the indicators of SDGs, and the interaction of the objectives of SDGs;

(3) From the perspective of research frontiers, environmental issues, indicators, energy transition, carbon emissions and climate change, evaluation of SDGs at macro and micro scales, education for sustainable development, and agriculture for sustainable development are the hot directions of SDGs research. The keyword emergence results show that sustainable use of energy and energy saving and carbon reduction, sustainable practices of supply chain management, and promoting progress in the implementation of environmental dimension goals are the hotspots in the frontier of SDGs research and the focus of subsequent research.

In summary, SDGs research has a broad field and diversified research content, and a large number of research results have been accumulated so far, laying the foundation for subsequent SDGs research. According to the research hotspots and the needs for the implementation of the 2030 Agenda, future SDGs research should focus on the following aspects:

(1) Strengthening multi-stakeholder cooperation for sustainable development. Achieving the SDGs requires close collaboration, cooperation and coordination among all stakeholders to share responsibility and turn intentions into actions. On the one hand, it is necessary to actively promote cooperation and exchanges among stakeholders such as governments, enterprises, research institutions and the public, and to create an atmosphere in which society as a whole participates in sustainable development and jointly implements sustainable development concepts and actions by strengthening development-oriented cooperation and enhancing two-way knowledge exchange. On the other hand, it is necessary to establish and enhance global partnerships, deepen international data cooperation within the framework of global development initiatives, and expand opportunities for cooperation and knowledge sharing through the establishment of highly interconnected digital ecosystems and data partnership. This will imbue sustainable development with renewed vigour and vitality;

(2) Innovative technologies to support the assessment of SDGs progress. At the data level, the Sustainable Development Goals Report 2022 makes it clear that data is the resource to reshape and accelerate the realisation of the SDGs, and that access to, and mastery of, timely, high-quality data is more important than ever [54]. At present, SDGs research does not pay much attention to the expansion of data sources, regular monitoring, rapid reporting and intelligent assessment. Subsequent research should actively apply remote sensing data, big data, cloud computing, artificial intelligence, and other technological means to expand the data sources of sustainable development indicators, improve the database of SDGs indicators, and optimise the SDGs monitoring and evaluation process. At the

same time, it will improve the completeness of data, deepen research on the interactions of the SDGs, and promote coherence between scientific results and policy practice. At the methodological level, spillover effects and trade-offs are currently seriously hindering the realisation of the SDGs, while technologies such as big data and artificial intelligence bring descriptive, predictive, prescriptive and discursive capabilities that can help strengthen sustainable governance and add value to traditional methods. Systematic evaluation methods and assessment models, built using digital technologies, will help to scientifically reflect the actual progress of the SDGs and provide lessons for the formulation of local sustainable development policies;

(3) Finding strategic solutions to promote sustainable development. The results of the literature measurement show that the sustainable development of the water–energy–food system, carbon emissions and climate change, as well as progress in the implementation of the goals of the environmental dimension, are important elements of the SDGs follow-up research. One of the challenges in achieving the SDGs is to reconcile the contradiction between the scarcity of resources such as water, energy and food and the ecological needs of human socio-economic development. Future research should continue to focus on how to ensure water, energy and food security and how the water–energy–food nexus can provide a mechanistic tool for achieving the SDGs. Climate change is one of the greatest challenges facing humanity today. Climate change and the SDGs should be better linked to maximise the effectiveness of action in both areas. How to reconcile carbon emission reduction and economic growth in the context of climate change mitigation, and how to integrate climate change mitigation strategies into sustainable development planning, are important elements to focus on in subsequent studies. Finally, the poor performance of ecosystem-related SDGs is one of the common problems facing the implementation of the SDGs in countries around the world, with unavailability of environmental data and poor implementation of environmental policies as possible causes. There is an urgent need to place "planetary health" at the centre of the planning and formulation of sustainable development policies, and to build institutional mechanisms that are compatible with socio-economic development and resource endowments.

It is important to note that the results of the study may be biased due to the incompleteness of the selected databases, the insufficient amount of data and the subjectivity of the literature review, and it is expected that these will be improved in subsequent studies.

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