



# A bibliometric analysis of sustainable development goals (SDGs): a review of progress, challenges, and opportunities

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## Abstract

The Sustainable Development Goals (SDGs) are a global appeal to protect the environment, combat climate change, eradicate poverty, and ensure access to a high quality of life and prosperity for all. The next decade is crucial for determining the planet's direction in ensuring that populations can adapt to climate change. This study aims to investigate the progress, challenges, opportunities, trends, and prospects of the SDGs through a bibliometric analysis from 2015 to 2022, providing insight into the evolution and maturity of scientific research in the field. The Web of Science core collection citation database was used for the bibliometric analysis, which was conducted using VOSviewer and RStudio. We analyzed 12,176 articles written in English to evaluate the present state of progress, as well as the challenges and opportunities surrounding the SDGs. This study utilized a variety of methods to identify research hotspots, including analysis of keywords, productive researchers, and journals. In addition, we conducted a comprehensive literature review by utilizing the Web of Science database. The results show that 31% of SDG-related research productivity originates from the USA, China, and the UK, with an average citation per article of 15.06. A total of 45,345 authors around the world have contributed to the field of SDGs, and collaboration among authors is also quite high. The core research topics include SDGs, climate change, Agenda 2030, the circular economy, poverty, global health, governance, food security, sub-Saharan Africa, the Millennium Development Goals, universal health coverage, indicators, gender, and inequality. The insights gained from this analysis will be valuable for young researchers, practitioners, policymakers, and public officials as they seek to identify patterns and high-quality articles related to SDGs. By advancing our understanding of the subject, this research has the potential to inform and guide future efforts to promote sustainable development. The findings indicate a concentration of research and development on SDGs in developed countries rather than in developing and underdeveloped countries.

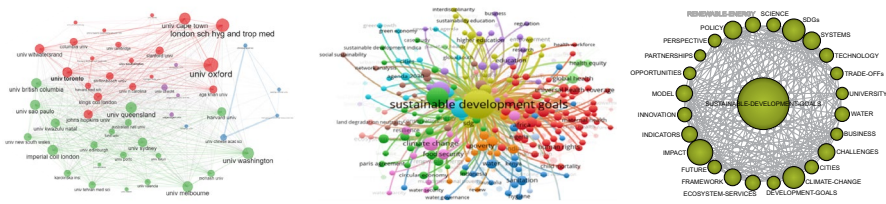
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## Graphical abstract

### A bibliometric analysis of sustainable development goals (SDGs): a review of progress, challenges, and opportunities



**Keywords** Systematic literature review · Bibliometric analysis · Sustainability · Sustainable development · Environment · Web of science

## 1 Introduction

The Anthropocene era is marked by a range of significant global challenges, including climate change, environmental degradation, public health issues such as global pandemics, rising social inequality, and food and water scarcity in several countries (Huang & Chang, 2022; Khojasteh et al., 2022). The growing human population demands the speedy development of modern infrastructure, including housing, health care, quality roads, education, communication, and related services (Aravindaraj & Rajan Chinna, 2022). Traditional lifestyles and values are eroding fast and being replaced by technology-driven living standards (Chen & Wang, 2022; Wahab et al., 2012).

The rapid development of the global economy driven by excessive consumption of natural resources and unsustainable development policies has led to serious socioeconomic and environmental challenges in recent decades (Guo et al., 2022). Achieving benchmarks of economic growth at any cost has become a top priority for governments to withstand international competition and fulfill local aspirations. In this process, narratives on development often ignore and overlook the irreversible harm caused by developmental hazards to natural entities and the amount of entropy raised in the earth's system (Alcántara-Ayala, 2002; Hemingway & Gunawan, 2018).

Sustainability has an important role in the world agenda, mainly after the advances of the Rio Declaration on Environment and Development in 1992 (Rio 92), the Declaration of Principles for the Sustainable Management of Forests, and the Agenda 21 of the United Nations Conference on Environment and Development (Guo et al., 2022). These advances discussed how to make sustainable development a reality in the world. Furthermore, in September 2001, the United Nations presented the Millennium Development Goals (MDGs) as a list of common goals for the world community to achieve by 2015. Since then, remarkable progress has been made toward achieving the MDGs (Fehling et al., 2013). The objectives of MDGs were to minimize deepening global mistrust toward international economic institutions and provide a unique platform for the member states to act collectively with individual accountability (McArthur, 2014). Thus, implementing the MDGs would improve health standards, reduce maternal and child mortality, minimize social disparities, promote gender justice and eradicate poverty among populations to make the earth system a better place to live (Chasse, 2016; Doyle & Stiglitz, 2014). Long-time concerted and consistent efforts of the UN ultimately

succeeded in convincing member states to envisage the tenets of MGDs in their development policies and follow the proposed timelines (Lomazzi et al., 2014).

In 2015, the United Nations General Assembly adopted the Sustainable Development Goals (SDGs) in the 2030 Agenda for sustainable development, which included 17 goals and 169 targets. Since then, greater attention has been paid to sustainability at different levels of governance structures in financial institutions, companies in the public and private sectors, and in governments across the planet (Death and Gabay, 2015). Nevertheless, the ongoing deforestation of the Amazon (Silva et al., 2023) and rising levels of greenhouse gas emissions are posing severe threats to the health of our planet. This, in turn, is leading to a chain of climate phenomena that have an impact on the economies of nations and the quality of life of their populations (Espinoza et al., 2023), as well as an increase in the frequency of severe natural disasters (Mishra et al., 2022). Thus, what are the current progress, challenges, and opportunities for the SDGs? Understanding the level of discussion on the SDGs theme is crucial for us to know the available proposals and solutions and see the path forward. In this sense, SDGs have sparked significant interest among a wide range of stakeholders, including those involved in environmental decision-making, business, finance (Di Vaio et al., 2022), and water services, particularly governance, management, and technical solutions (Di Vaio et al., 2021). Currently, there is global consensus on the importance of implementing the SDGs, which can lead to development while preserving the environment and the population's quality of life (Bebbington & Unerman, 2018). Water sustainability issues were included in the UN's Agenda 2030 and 17 SDGs, providing a common framework for measuring sustainable development from a social, economic, and environmental perspective (Glass & Newig, 2019).

Before sustainable development, the major pitfall of approaches includes the absence of sectoral integration in making strategies and their implementation on the ground level (Garcia-Feijoo et al., 2020). The negative consequences of development policies included focusing on a specific sector over other development sectors, which resulted in diverging outputs and followed by trend-setting of broad objectives (Morley et al., 2017). The SDGs were considered to determine the international development agenda and the countries' development policies and programs. Although the SDGs are universal, member states are free to adopt the goals of their choice based on available resources, socioeconomic priorities, and their decided pace of transformation (Eisenmenger et al., 2020). The inception of SDGs has triggered many systematic studies to understand, prioritize, and evaluate the progress of goals adopted by countries. The findings of these studies are expected to promote rigorous, evidence-based, reliable, and timely evaluation of achievements toward fulfilling the purposes of countries in their diverse socioeconomic settings (Kroll et al., 2019; Mensah, 2019; Weitz et al., 2018). Currently, decisions made regarding the SDGs are critical for the social, political, environmental, and economic sustainability of the planet. Understanding the global context based on a review of progress, challenges, and opportunities regarding the SDGs is crucial and must be studied.

Research, innovation, and sustainable education are essential mechanisms to achieve the SDGs. Over the years, the study of SDGs has experienced a consistent increase in research activity since its approval in 2015. The existing body of knowledge on SDGs provides researchers with the opportunity to explore the SDGs research domain from a variety of perspectives based on previous publications, which is essential for revealing the structure of the domain and helping researchers better understand the status quo and future trends of SDGs-related topics and to focus their studies more effectively. Some studies have attempted to assess the literature on SDGs by examining prior works. These studies can be classified into two types: qualitative and quantitative review studies. Among the qualitative SDGs review studies, Allen et al. (2018) conducted an assessment of national progress and approaches to implementing the SDGs in different countries based on existing literature. Caiado et al. (2018)

discussed the roles and opportunities provided by ICTs and AI for achieving the SDGs. Lund et al. (2018) systematically reviewed how the SDGs can be used to address the social causes of mental disorders and how they could be improved to help prevent mental disorders. Leal Filho et al. (2020) explored the potential effects of the coronavirus pandemic on the SDGs. To analyze the inclusion, progress, and challenges of the implementation of SDGs, Persson et al. (2016) revised the SDGs based on alignment and internalization and concluded that increased attention and visibility of nationally defined and internalized targets are likely to enhance implementation effectiveness and should therefore be accommodated in the follow-up and review systems. Allen et al. (2016) revised and assessed 80 quantitative models that have the potential to support national development planning for the SDGs. Hak et al. (2016) highlighted the importance of indicators in analyzing the SDGs. Guo et al. (2022) measured and evaluated SDG indicators with big earth data for a more comprehensive analysis of SDGs.

In recent years, to supplement the existing qualitative reviews of SDGs research, scholars have also explored the SDGs domain through quantitative support such as meta-analysis and bibliometric analysis. Among these quantitative studies, Yamaguchi et al. (2023) performed a bibliometric analysis of the literature on SDGs to assess the evolution and consolidation of scientific research from 2015 to 2022 retrieved from the Web of Science core collection and descriptive bibliometric analysis. The results showed that the field of SDGs is fast-growing, with a trend toward diversification of research areas. Similarly, many bibliometric studies are being published on SDGs, mainly related to the business sector, education, and poverty (Pizzi et al., 2020; Prieto-Jiménez et al., 2021; Yu and Huang, 2021). However, there is little bibliometric research that covers the general aspects of the SDGs and their evolution. We believe that multi-disciplinary bibliometric research on the SDGs literature is still needed to enable researchers to capture more comprehensive, diverse, and detailed information in this area. To serve as a complement to previous bibliometric studies, this paper attempts to continue the bibliometric journey by exploring the SDGs research domain from a more holistic perspective. In simple words, this study investigates the bibliometric analysis of progress, challenges, opportunities, trends, and prospects of SDGs by the global community from 2015 to 2022, providing insight into the evolution and maturity of scientific research in this field.

The major factors that distinguish this study from previous bibliometric studies on SDGs are the use of a new bibliometric technique, the SciMat, which examines the intellectual structure of SDGs research from both static and dynamic perspectives. Additionally, we analyzed the contents of the most cited articles on each cluster generated by the SciMat tool. Diverse maps of science, including a word cloud of keywords, the most cited keywords, a conceptual structure map, a keyword co-occurrence network, and strategic diagrams, were constructed to depict the intellectual structure of the SDGs domain from different angles.

A bibliometric analysis of the SDGs can have a significant impact on understanding the evolution and consolidation of scientific research on the subject. It can provide an overview of scientific production, identify trends, gaps, and strengths in research, and establish relationships between different authors, institutions, and countries. In this way, bibliometric analysis can contribute to the planning of future research and improve the efficiency of efforts to achieve the SDGs. Furthermore, it can help assess the progress and impact of efforts already made to achieve the SDGs' goals and targets, as well as identify areas where more effort and investment are needed. In short, a bibliometric analysis of the SDGs can provide a solid foundation for evidence-based decision-making and contribute to the success of global sustainable development efforts.

In order to analyze the published research on SDGs, we divided this work into several sections, such as this Introduction to the topic, containing a brief theoretical review and the objective of this study. Section two contains a literature review highlighting a brief evolutionary

history of the development of MDGs and SDGs, the similarities/differences between MDGs and SDGs, and comparisons with other policies around the world. Section three describes the methodology used, database selection and search strategy, and bibliometric analysis. Section four presents the results and analysis, section five highlights the major discussions about SDGs, and section six shows the conclusions of this study. The study of SDGs has seen a steady rise in research since its approval in 2015. The exponential growth of publications has shown a slowing in recent years, suggesting a consolidation phase where literature reviews play a crucial role as high-evidence documents.

## 2 A brief history of the development of MDGs and SDGs

### 2.1 Evolutionary history of MDGs and SDGs

Toward the end of the twentieth century, defining development has increasingly become associated with 'wellbeing,' which is generally perceived as more than mere economic growth. There has been increasing consensus on rejecting the hegemony of Gross Domestic Product (GDP), a monetary measure to establish the market value of the finished or final goods and services produced or availed during a specified time period by any country, as an indicator of development. By 1980, emphasis is given to devising alternative indicators to measure and assess development (Allen et al., 2018). Some alternatives are the Genuine Progress Indicator, World Value Survey, Gross National Happiness Index, Happy Planet Index, Better Life Index, and many others (Costanza et al., 2009; Rajkarnikar, 2022). This is in the context of the broader realization that overemphasis on economic growth-centric development has led to massive environmental degradation, economic inequality, conflict, and socio-cultural unrest. The challenges are how to define development. Which indicators are to be monitored to assess development?

Most importantly, ensure that these indicators emphasize improving environmental conditions, quality of social life, reducing economic inequality, and establishing peace and harmony; however, it does not compromise economic development. None of these alternative indicators of development are entirely adequate. However, they become a building block for the foundation of alternative thinking that emphasizes inclusiveness, sustainability, eco-friendly, trans-disciplinary-and-cooperative effort, and global consensus.

The UN's MDGs were one of the outcomes of these discourses adopted by the UN in 2000. The MDGs comprised eight primary targets, with the first objective being to eradicate extreme poverty and hunger (Chen et al., 2023). This objective had a fixed target to reduce the number of people living on less than a dollar per day by half. The second objective was to achieve universal primary education, while the third was to promote gender equity and empower women. The fourth was to reduce child mortality rates below the age of five by two-thirds, and the fifth target was to improve maternal health. The sixth was to combat diseases such as AIDS and Malaria, and the seventh objective was to ensure environmental sustainability by enhancing access to drinking water and other environmental amenities, especially for underprivileged populations. The eighth SDG aimed to promote global partnerships for development. While the MDGs focused on individual development rather than national development, all SDGs promote the idea of equitable development. National and international cooperation is focused on making development accessible to all, especially those who are underprivileged and underdeveloped (Kherbache & Oukaci, 2020). By 2020, progress toward achieving the MDGs had been mixed. However, the MDGs framework was widely recognized as a successful program by the end of

its term in 2015. For example, the number of people living in extreme poverty declined from 1.9 billion in 1990 to 836 million in 2015, and the average primary education enrolments across the developing world increased from 83% in 2000 to 91% in 2015. However, the positive trend in reducing poverty was interrupted in 2020 due to the COVID-19 crisis, leading to a significant increase in poverty, with the number of people living in extreme poverty rising by 70 million to surpass 700 million. The global extreme poverty rate rose to 9.3%, up from 8.4% in 2020 (World Bank, 2023). Similarly, substantial improvements were made in gender equality. Klasen (2018) found a persistent gender gap in areas of opportunities, wage rate, political and economic empowerment, and other well-being parameters. Some goals were achieved at the global level, while many countries failed to meet the target. For example, child and maternal mortalities were reduced by approximately half by 2015, but children from poor households were still more likely to be affected by malnutrition, and infant mortality rates were twice as high in the poorest households compared to those in richer households (Awaworyi Churchill, 2020).

Similarly, the goal of access to safe drinking water was not successfully achieved in rural areas (United Nations, 2015). In a nutshell, the progress was uneven. Further, in other goals, though a significant level of success was achieved, the target was not met. MDG assessments suggest adding new goals and changes to existing goals. For example, Swain and Yang-Walentin (2020) indicate that adding a ninth goal to the eight MDGs eliminates extreme inequality at the national level in every country. The MDGs were criticized for their lack of adequate focus on people with disabilities (Wolbring, 2011), conflict and peace (Hill et al., 2010), and human rights (Fehling et al., 2013). To summarize, as MDG Gap Task Force, founded by the UN, gives a comprehensive view of the status of the implementation of the MDGs (United Nations, 2015). No development program or initiative is ever cent percent successful. The impact assessment of a program is always along with a continuous range in which the present status stands somewhere. From several impact reports, one thing is evident MDGs certainly made visible impacts on the targeted aspects. For example, one of the noteworthy achievements is a decline in extreme poverty from 47 to 14% from 1990 to 2015 (United Nations, 2015b). Similarly, the share of undernourished people was also reduced to half.

Further, the child mortality rate declined by 45% during this period (United Nations, 2015b). However, infectious diseases, gender, and income inequality continued to prevail, and millions of people were still in extreme poverty. Around the globe, more than 60 million people were affected by the conflict from 1990 to 2015 (United Nations, 2015b). While MDGs had considerable achievements, there were some lacunas as well. The distribution pattern of MDGs implementation varies from region to region and goal to goal. Many developing nations were seriously off-target in cases of undernourishment, infant mortality, maternal mortality, and sanitation. For infant and maternal mortality, around 53% and 61% of the developing nations were reported to be seriously off-target. Again, 40% of the nations were seriously off-target for sanitation. On the other hand, many countries had remarkable progress in eradicating extreme poverty, achieving education and gender parity, and providing clean drinking water. The implementation of MDGs had a differential impact on different sections of people. For example, the poorer sections of the developing nations were often left out of the benefits reaped by MDGs (World Bank, 2016). Thus, the accomplishments of the MDGs have neither been uniform across all the goals nor across different parts of the globe. Regional variation in the level of achievement in the case of goals like infant mortality rate, maternal mortality rate, and eradication of malnutrition were low, indicating the poor status of these goals across the world.

On the other hand, high regional variations were noticed in the achievements of the goals, such as eradication of poverty, sanitation, maternal mortality rate, and infant mortality rate. There are also differences in the degree of consistency in implementing MDGs. For example,



a very low level of consistency in the status of goals is noticed in countries of the Middle East, North Africa, and South Africa. The MDGs were targeted to be achieved by 2015, but the target status at the end of 2015 sowed the seed of thought among the policymakers to chalk out another set of goals to substantiate the earlier existing MDGs. Therefore, the 17 SDGs were reinvented out of the earlier eight MDGs.

The first framework of SDGs was chalked out at the Rio+20 conferences (the United Nations Conference on Sustainable Development) in Rio de Janeiro in June 2012 to carry forward the impetus sowed by the MDGs in the pursuit of holistic global development. In July 2014, a document containing 17 goals was proposed by the UN General Assembly Open Working Group (OWG) for the General Assembly's approval in September 2015. This document served as the first official draft of the SDGs. The global community adopted the 2030 agenda for sustainable development goals, including 17 SDGs and 169 targets, and 232 indicators, in September 2015. Subsequently, global SDGs commenced in 2016 and offer an evidence-based policy framework for sustainable development and planning till 2030. SDGs represent the commitment of member countries to achieve sustainability in various sectors (Allen et al., 2018). SDGs became an important component of the international development agenda for all countries and significantly influenced national planning post-2015. While the SDGs are universal, the countries have the liberty to determine their priorities and target and scale, and pace of transformation.

Assessing the process of SDGs interventions and their progress over different goals by member countries continues to be challenging. As discussed by Allen et al. (2018), one of the overarching challenges is dealing with each goal in isolation. That means the integration of sustainable economic, social, and environmental development objectives is yet to be achieved. The interactive relationship between seventeen SDGs and 169 targets compels the planning practices to see it holistically. In 2016, in the first voluntary national review of SDGs was fairly presented, the implication of the knowledge gap of a detailed view of interactive relations among targets and goals and the ability to maintain a holistic perspective has an impairing impact on the planning and implementation of SDGs (Weitz et al., 2018).

## 2.2 Similarity and difference between MDGs and SDGs

Since there was a disparity in the achievement status of the MDGs, efforts were taken to build the SDGs in a way so that a sustainable world could be made with equal value for environmental sustainability, social inclusion, and economic development. It is essential to understand that SDGs are not formulated to replace MDGs; instead, they are intended to substantiate them. Some of the goals under SDGs are improvisations over the previous MDGs, while some new goals have been incorporated into this new framework. Compared to MDGs, SDGs are considered a broader and more complex, integrated, and stimulating agenda for all countries to implement.

Relative to the formulation of MDGs, the process of devising the SDGs was more participatory, involving consultation with civil societies, the private sectors, and the governments of a fair number of countries. The result is a far more comprehensive list of goals, far greater targets (169), and several indicators (232), including many of those goals left out by MDGs. For example, it emphasizes climate change, the environment, peace and conflict, work, and the ocean. However, like MDGs, SDGs are criticized for not emphasizing human rights (Sengupta, 2018).

Given the comprehensiveness of SDGs, their assessment requires immense human and financial capital that seems too enthusiastic for developing countries with limited

resources (Fenny, 2018). The MDGs requirements were more modest (21 targets and 60 indicators) in nature and also complex. While 93 SDGs indicators out of 232 are classified as Tier 1. Again, these indicators are more conceptual clarity, and more than 50% of the countries regularly comply with these data. The left-out indicators are defined as Tier 2 (72 indicators) with conceptual clarity, but data are unavailable. However, the data related to Tier 3 (62 indicators) are not regularly collected by countries because of the non-availability of a well-established methodology or available format of data collection.

The challenge of ensuring environmental sustainability is more marked since the new SDGs try to integrate sustainability issues with multidimensional poverty and inequality. While MDGs considered four different types of environmental targets, the number has expressively increased in the SDGs, containing seven environmental goals (i.e., goals No. 7, 9, 11, 12, 13, 14, and 15), monitored through 77 indicators. The goals are as follows: Goal 7: ensure access to affordable, reliable, sustainable, and modern energy for all, Goal 9: build resilient infrastructure, promote sustainable industrialization, and foster innovation, Goal 11: make cities inclusive, safe, resilient, and sustainable, Goal 12: ensure sustainable consumption and production patterns, Goal 13: take urgent action to combat climate change and its impacts, Goal 14: conserve and sustainably use the oceans, seas, and marine resources, and Goal 15: sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss.

### 2.3 Comparing with other policies around the world

The MDGs of the United Nations have been one of the most talked-about policy interventions globally in the last couple of decades. These policy targets have been formulated, critically reviewed, implemented, and analyzed for the achievements and impacts they have made on the globe. As global needs have changed with changing socio-political equations and dynamics, a strong need has been felt to shift the MDGs framework paradigm. Therefore, the MDGs have been revisited and reinvented to give rise to a set of SDGs. MDGs went on to a certain extent to achieve these goals. They paved the way for higher-order growth needs as SDGs, which aim to address more profound and complex health issues, including mental well-being, nutritional security, quality education, innovation, peace and justice, cultural vitality, equality, and environmental and social resilience, etc.

## 3 Methodology

The study's methodology is based on a qualitative method focused on the content of papers related to SDGs, as proposed by Di Vaio et al. (2020). The methodology applied in this study has two stages. In the first stage, the data extraction method, which includes database selection, and the search strategy, were illustrated, and then the bibliometric analysis was done using bibliometric techniques with the help of appropriate software. These databases have been chosen because they notoriously publish theoretical or empirical studies on topics related to SDGs (Alvino et al., 2021). The details of the workflow are presented in Figure 1.



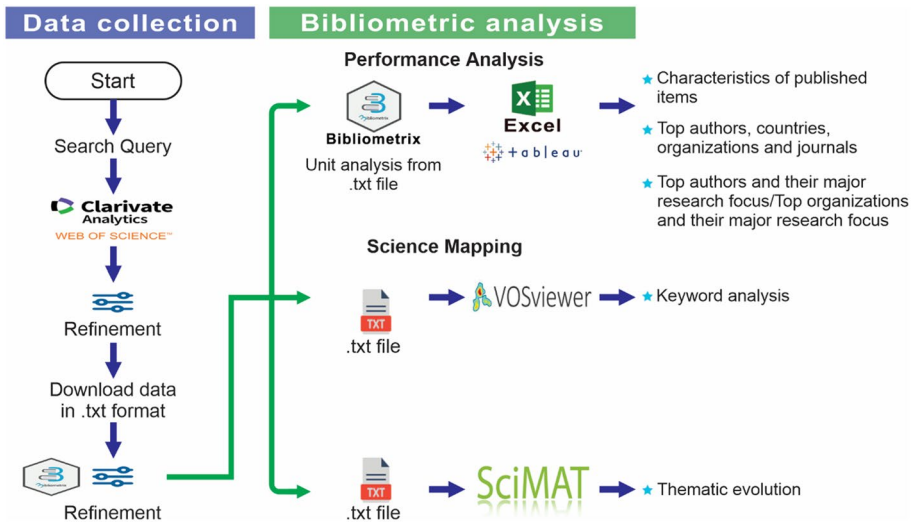


Fig. 1 Research flow, methodology, and tools

### 3.1 Database selection and search strategy

To collect data for this review, we must select one of the citation databases that index all literature related to SDGs. The Scopus and Web of Science are commonly used databases by the research community for literature searches and bibliometric analyses (Mishra et al., 2020, 2021; Sudarsana & Baba, 2019). In this study, the Web of Science (WoS) core collection citation database was used as the primary source of data collection for processing and analysis. This study used the year 2015 because SDGs were adopted on September 2015, and further, we have extended it till October 2022, which is the most recent data available. This database is considered the most well-known citation database, and bibliographical data are stored in a well-structured manner (D'Amore et al., 2022; Harzing & Alakangas, 2016; Vaio et al., 2021), which sufficiently validates the use of the WoS database in the existing study. The effectiveness of the analysis results mainly depends on the search strategy technique. Thus, an effective search strategy was constructed according to the database characteristics after selecting the database to be used.

The following advance query was used: TS=(“sustainable development goals” OR “SDGs” OR “millennium development goals”), [refined by]: DOCUMENT TYPES: (ARTICLE OR REVIEWS) AND [excluding] PUBLICATION YEARS: (2023), Timespan: 2015–2022. Indexes: SCI-EXPANDED, SSCI, CPCI-S, A&HCI, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, IC, CCR-EXPANDED. This query retrieved 12,176 publications (articles and reviews) from 2015 to 2022 on October 2 (2022). The above time period was fixed because SDGs were adopted on September 2015. The identified 12,176 literature records, the citation information, bibliographic information, abstract and keywords, and other information were exported to.txt format files. Then, the dataset in a Bibliometrix package file was transferred from Rstudio software for performing bibliometric analysis and thematic trend analysis (Aria & Cuccurullo, 2017). Next, it was transferred to SciMat software for extracting strategic diagrams and thematic evolution maps, after which a specific analysis was performed (Cobo et al., 2012).

### 3.2 Bibliometric analysis

Bibliometrics uses mathematical and statistical methods to analyze literature quantitatively regarding scientific publications' production, growth, maturation, and consumption. As a result, it has been widely used as an essential tool for assessing and analyzing development status in the research field in terms of the researcher's production (Ellegaard & Wallin, 2015), the collaboration between institutions (Skute et al., 2019), the impact of state scientific investment in national R&D productivity (Fabregat-Aibar et al., 2019), and the academic quality (van Raan, 1999), among other possibilities (Glänzel, 2012). The bibliometrics analysis consists of performance analysis and science mapping analysis. Performance analysis is based on bibliometric indicators that measure the production of individual actors (author, institution, country, and journal) and the impact achieved through publications and citation data. Science mapping analysis provides the topological and temporal representation of a particular research field's cognitive and social structure (Cobo et al., 2012).

A wide variety of bibliometrics tools are available for bibliometric analysis; the mainstream bibliometrics analysis tools include Biblioshiny (R Package), VOSviewer, BibExcel, SciMAT, and CiteSpace (Aria & Cuccurullo, 2017; Cobo et al., 2011, 2012; Moral-Muñoz et al., 2020). Each tool has different mapping principles, algorithms, visual outputs, and strengths and weaknesses. However, a single tool is not suitable for all types of analysis (Cobo et al., 2011). Following Cobo's review, CiteSpace, Biblioshiny (R Package), and SciMAT were finally selected for this study. The details of each tool as given below.

#### 3.2.1 Biblioshiny (R-tool software)

Biblioshiny is an open-source application that has the potential to import data from different sources (Scopus, Web of Science, among others) and provides various types of bibliometrics analysis (Aria & Cuccurullo, 2017). In this study, we have utilized several modules offered by the Bibliometrix application. These modules are primary information, annual scientific production, citation, more relevant sources, more relevant author and affiliation, country, and word cloud.

#### 3.2.2 VOSviewer

VOSviewer is another bibliometric tool widely used for creating bibliometric networks of different actors (e.g., authors and organizations) using various network analysis methods such as co-author, co-citation, term co-occurrence, and bibliographic coupling (Van Eck & Waltman, 2009). In this study, we used the term co-occurrence analysis to identify major themes of a research domain. The maps obtained from this software include nodes and edges, indicating the keywords (nodes) and their relationship (edges). Interested readers are referred to the VOSviewer manual for more details about these different analyses (<https://www.vosviewer.com/publications>).

#### 3.2.3 CiteSpace

CiteSpace is also an open-source package based on the Java platform developed by Drexel University (Chen, 2006). Indeed, its prime aim is to facilitate the dynamic tracking of

emerging trends in the knowledge domain, focusing on identifying key points and turning points in developing knowledge in a field. In the present study, this is mainly applied to the burst detection of analysis function to find hotspots in the research field.

### 3.2.4 SciMAT

SciMAT is an open-source software tool developed to perform a bibliometrics analysis under a longitudinal framework and provides support to different types of analysis. In this study, we utilized the term co-occurrence module to identify closely linked concepts and explore the thematic evolution of the nexus during the last six years. The information related to the procedure and implementation of this software is presented in (Cobo et al., 2012). This software offers two types of maps: strategic diagrams and thematic evolution maps.

### 3.3 Strategic diagrams

Strategic diagrams (Figure 2) reflect the research themes and research keywords based on two indicators of cluster centrality (indicating the strength of interdisciplinary links and the centrality of the theme in research development) and density (indicating the degree of strength)) (Cobo et al., 2012). The first diagram (a) is a two-dimensions map divided into four quadrants based on their relevance. The themes are represented as a circle, and their

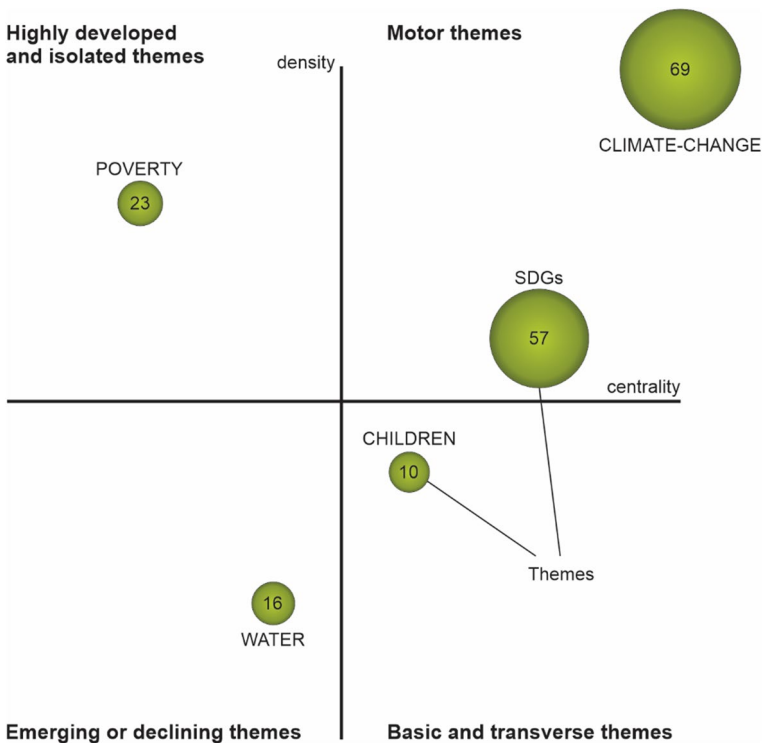


Fig. 2 Structure of the strategic diagram

size is proportional to publications associated with the theme. The second is a diagram where the components and their relationship are represented. The four areas, according to their relevance, are Motor themes (Q1: Upper-right quadrant), Highly developed and isolated themes (Q2: Upper-left quadrant), Emerging or declining themes (Q3: Lower-left quadrant), and Basic and transversal themes (Q4: Lower-right quadrant). Motor themes are well-developed topics and the main field of research. Highly developed and isolated themes are topics at a reasonable level in terms of density but are not very central and considered marginal. Emerging or declining is an undeveloped and marginal issue. At the same time, basic and transverse are central issues with a lack of proper density.

## 4 Result and analysis

To conduct a bibliometric analysis of SDGs related to data retrieved from the WoS in terms of publication, citations, and impact, the following analysis types were considered: Information about data, trends, and characteristics of research publication, most preferred and productive journals, productive author, journal and country, most cited documents, keyword analysis, and thematic evaluation. The detailed results are as follows.

### 4.1 Information about data

Table 1 provides information on articles retrieved from the Web of Science published from 2015 to 2022. It was found that 12,176 publications published in 1956 journals use 14,120 keywords plus and 26,262 author's keywords. The number of authors contributing to this domain is 45345, a very high number. There is a high collaboration in SDGs literature, as shown by the collaboration index. The average citation per article is 15.06, and the articles

**Table 1** Descriptive statistical information about the collection

Description	Results
Articles	12,176
Timespan	2015–2022
Authors	45,345
Sources (journals, books)	1956
Average years from publication	1.94
Average citations per article	15.06
Average citations per year per doc	4.38
Keywords plus (ID)	14,120
Author's keywords (DE)	26,262
Author appearances	66,353
Authors of single-authored articles	1132
Authors of multi-authored articles	44,213
Single-authored articles	1254
Articles per author	0.252
Authors per article	3.72
Co-Authors per articles	5.45
Collaboration index	4.05

per author ratio are 0.269, which means, on average, almost four authors have written one document.

## 4.2 Literature trend analysis and characteristics of research publication

In 2015, the SDGs were set up by the United Nations General Assembly (UN-GA) to work toward a sustainable society in which economic prosperity is achieved, and social and environmental concerns are met. Those goals are intended to be completed by 2030 and are included in an UN-GA Resolution called the 2030 Agenda or Agenda 2030. Since then, the interest of the academic community and specialists in the issue of sustainable development, implementations of SDGs at national, regional, and global levels, and informality have materialized in papers, reports, and various other publications.

Table 2 provides the year-wise growth rate of publications and their citations concerning SDGs. A total of 12176 research articles related to SDGs were published from 2015 to 2022, cited 189960 times in total, with an average citation rate per article of 15.06 during the period. In 2015, only 298 articles were published, and these articles received 8725 citations. Since then, it can be seen from Table 2 that the number of published journal articles about SDGs has an obviously and continuously increased trend. This trend shows that progressively more attention has been paid to this domain in recent years. Among the 12176 articles, about 51% were published in the last two years, while nearly 26% were published in 2022. The annual distribution of citation count has shown a slight fluctuation trend. The year 2022 had the highest number of articles, at 3249, and these articles have received 6487 citations. The highest number of citations (34736) was acquired in 2018.

## 4.3 Most preferred and productive journals for publications

Academic journals are considered the prime medium for disseminating scientific output and are worth researching in any scientific domain (Wuni et al., 2019). The most preferred and prominent journals that publish articles in the SDGs domain have been explored. A total number of 3732 articles regarding SDGs were published in these top 15 journals between 2015 and 2022. Table 3 gives the leading journals, each with the number of publications, citations, and the Impact Factor (IF). The leading journals preferred by the researcher are sustainability, Switzerland, with 1730 (12%) publications, 13545 citations, and 3.88 impact factor, followed by Journal of Cleaner Production, UK, with 371 (2.9%) publications, 8574 citations, and 11.07 IF, and Science of the Total Environment,

**Table 2** Number of articles and their citations each year in SDGs research in the WoS database

Year	Articles	Citations
2015	298	8725
2016	449	20,234
2017	680	28,153
2018	1007	36,349
2019	1401	32,938
2020	2101	34,736
2021	2991	22,338
2022	3249	6487

**Table 3** Top 15 journals, the number of documents regarding SDGs research yearly, published articles, citations, and impact factor (IF)

Name	NP	h-index	TC	IF	Country
Sustainability	1730	43	13,545	3.88	Switzerland
Journal of Cleaner Production	371	51	8574	11.07	UK
Science of the Total Environment	191	34	5655	10.75	Netherlands
International Journal of Environmental Research and Public Health	170	19	1295	4.61	Switzerland
Plos One	168	25	2128	3.75	USA
Environmental Science and Pollution Research	153	23	1681	5.05	Germany
Energies	133	13	667	3.25	Switzerland
Sustainable Development	127	25	2781	8.56	Canada
Sustainability Science	112	24	2695	7.93	Japan
International Journal of Sustainability in Higher Education	106	13	684	4.6	UK
Journal of Environmental Management	98	22	1816	3.92	USA
World Development	97	23	45	6.67	UK
Water	95	17	921	3.53	Switzerland
Environment Development and Sustainability	94	13	671	3.97	Netherlands
Remote sensing	87	17	991	5.45	Switzerland

*NP* = Total of publications, *TC* = total of citations, and *IF* = impact factor

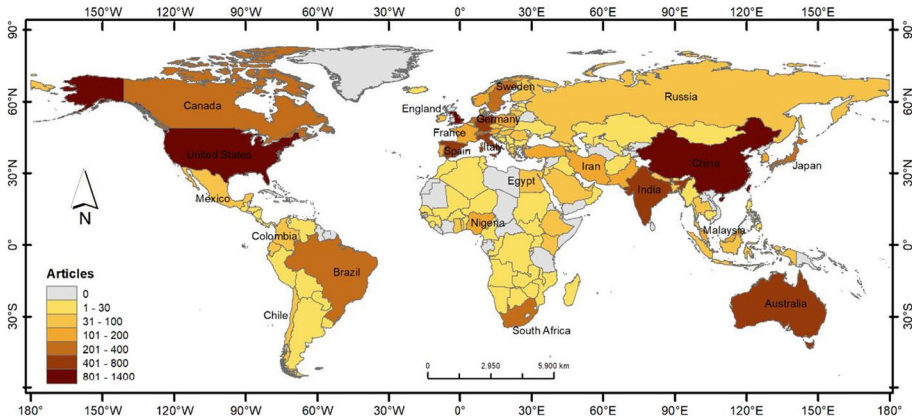
Netherlands with 191 (1.5%) publications, 5655 citations, and 10.75 IF. The table shows that the Journal of Cleaner Production has the highest h-index of 51, the Sustainability has an h-index of 43, and the journal Science of the Total Environment has an h-index of 34. The table also shows that although sustainability has 1359 more publications (total of 1730) than the Journal of Cleaner Production (total of 371 publications), the Journal of Cleaner Production's impact factor is almost three times higher than Sustainability. A very interesting feature is that in SDGs, the International Journal of Environmental Research and Public Health is the 6<sup>th</sup> most productive journal having a total number of productions of 153, but its h-index is too low. It is also observed that Switzerland produces a greater number of journals in this field than other countries.

#### 4.4 Highly productive countries and their collaborations

All corresponding authors and their affiliations in each article were considered in the analysis of the most predominant ones. The articles originate from 137 countries/regions. Figure 3 shows the geographical distribution of production for the countries/regions. Table 4 presents the statistics of the top 10 countries/regions based on the total publications in this field. The USA is the most prolific country with 1313 publications (10.7%), followed by China and the UK with 1310 (10.7%) and 1171 (9.6%) publications each. The three countries account for 31% of the total publications, indicating their prominent position in the research field. Furthermore, the USA's publications have received the highest number of citations (34013) compared to others, showing that it dominates the publication count and has a solid academic influence in the research field.

Concerning collaboration, the UK and the USA again topped for both Single Country Publications (SCP) and Multiple Country Publication (MCP) (Table 4). The ratio of MCP





**Fig. 3** Geographical distribution of production in the WoS

**Table 4** Top 10 countries of publication based on corresponding author and their citations, collaborations trend, and SDGs Index Rank

Rank	Country	Articles	Citations	SCP	MCP	2022 SDGs index rank
1	USA	1313	34,013	676	637	41
2	China	1310	13,808	708	602	56
3	United Kingdom	1171	25,988	479	692	11
4	Australia	673	15,512	312	361	38
5	Spain	653	6332	498	155	16
6	India	504	4591	333	171	121
7	Germany	471	8998	249	222	6
8	Italy	446	6188	267	179	25
9	Canada	370	5463	162	208	29
10	Brazil	303	3552	160	143	53

*SCP*: Single country publications, and *MCP*: Multiple country publications

to total publications for most of the Top 10 countries was 22–62%. Still, it was about 50% for the UK, reflecting that each country exhibited a strong preference for international cooperation regarding the SDGs study. Table 4 also includes the 2022 SDGs Index Rank of each country.

### 4.5 Highly productive institutions/organizations

Table 5 provides the top 10 most productive institutions/organizations in SDGs research in terms of publications. The first-ranked institution is the University of Oxford in the UK, which has published 307 articles in this research field, and most of the articles related to maternal mortality (Kassebaum et al., 2016; GBD 2017 DALYs and HALE Collaborators, 2018) and maternal health (Patel et al., 2018) (see Table 6). The second and third were the London

**Table 5** Top 10 productive institutions/organizations in SDGs research

Organization/Institution	Articles	Country
University of Oxford	307	UK
London School of Hygiene & Tropical Medicine	259	UK
Tehran University of Medical Sciences	244	Iran
The University of Queensland	223	Australia
University of Washington	221	USA
University of Melbourne	188	Australia
University of Cape Town	181	South Africa
Imperial College London	166	UK
University of São Paulo	164	Brazil
Chinese Academy of Sciences	155	China

**Table 6** Top 10 organizations' research focus

Organization/Institution	Major Research Areas
University of Oxford	Maternal mortality, maternal health, and Paris Agreement
London School of Hygiene & Tropical Medicine	Health systems, child health, global health, systematic review, and child mortality
Tehran University of Medical Sciences	Risk factors, health systems, health services, SDGs indicators, universal health coverage, drinking water, and water and sanitation
The University of Queensland	Mineral Security, Gender Inclusion, and greenhouse gas emissions
University of Washington	Risk factors, maternal mortality, child health, mental health, and antenatal care
University of Melbourne	Maternal mortality
University of Cape Town	Mental health and maternal health
Imperial College London	Waste management
University of São Paulo	Sustainable development and air pollution

School of Hygiene & Tropical Medicine and the Tehran University of Medical Sciences, which published 259 and 244 articles, respectively. The majority of these ten institutions are from the UK (30%) and Australia (20%), and the rest are from Iran (10%), South Africa (10%), the USA (10%), China (10%) and Brazil (10%). It is important to note that there is no single institution from India, even though it was placed in the top ten countries list.

Regarding collaborations, the University of Oxford has strong collaborations with other institutions, especially the University of Cape Town, the London School of Hygiene & Tropical Medicine, King's College London, Johns Hopkins University, and Stanford University, as depicted in Fig. 4.



Lotka's law. As shown in Figure 3, 35605 researchers published an article, accounting for 78.5% of the total. The number of scholars who published more than six papers was 921, accounting for 0.2% of the total. It can be seen that the researchers in the SDGs research area and the number of documents are similar to the dotted line in the figure, which basically obeys the general law of Lotka's law. This reflects that the number of authors who have written only one or two articles in the field of SDGs is relatively large. Most scholars in this field have just started in this area, and perhaps this is why research has not yet been in-depth.

Table 7 provides the top 10 most prolific authors by the number of articles from 2015 to 2022, which account for 2.3% of overall articles published from 2015 to 2022. The author with the largest number of papers published and the highest h-index is Zulfiqar Ahmad Bhutta. He has published papers in the field of SDGs since 2015. His main research direction is to evaluate health-related SDGs, as presented in Table 8. One of Zulfiqar Ahmad Bhutta's papers is 'Global, regional, and national disability-adjusted life-years (DALYs) for 315 diseases and injuries and healthy life expectancy, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015', published in *Lancet* in 2016, has the highest number of citations ( $TC = 1196$ ). Regarding citations, Christopher J. L. Murray has achieved the highest citations compared with other authors. Andrew Adewale Alola, Avik Sinha, and Festus Victor Bekun are published on the same topic, i.e., renewable energy. From the geographical perspective, the core authors from the USA account for 30% of the top 10 core authors, which means that the USA currently has stronger research strength in the SDGs research field than other countries.

#### 4.7 Keyword analysis

Researchers are using keywords to provide a concise description of the research content. As a result, it is one way to identify hot topics and themes of a research domain based on keyword analysis (Zhang et al., 2016). The selected documents in the field of SDGs were further examined based on highly occurred keywords via bibliometric software. The Web of Science database offers two types of keywords- author's keywords and keywords plus. Keywords plus are words or phrases that frequently appear in the titles of an article's references but do not appear in the title of the article itself (Garfield, 1990). The results of this analysis are presented in the form of word clouds. Word cloud analyses of the 30 most frequent keywords in the publication collection are shown in Figure 6, where a higher

**Table 7** Top 10 most prolific authors

Rank	Authors	Articles	TC	h-index	Country
1	Zulfiqar Ahmad Bhutta	39	5169	23	Canada
2	Yang Liu	34	2666	12	China
3	Jianguo Liu	31	1405	16	USA
4	Walter Leal Filho	30	1006	12	Germany
5	Andrew Adewale Alola	29	1798	17	Turkey
6	Avik Sinha	26	1430	18	India
7	Festus Victor Bekun	25	1414	14	Turkey
8	Christopher J. L. Murray	25	5199	17	USA
9	Aluisio J. D. Barros	21	755	11	Brazil
10	Jamie Bartram	21	591	13	USA









**Table 9** Thirty-four keywords with a burst of at least two years

SI No	Keyword	Frequency	Burst	BurstBegin	BurstEnd
1	Millennium development goal	191	53.01	2015	2018
2	Care	244	24.26	2015	2018
3	Mortality	213	23.75	2015	2018
4	Health	478	18.33	2015	2018
5	Developing country	188	17.92	2015	2018
6	Intervention	122	16.23	2015	2017
7	Child mortality	53	15.27	2015	2019
8	Middle income country	61	15.06	2015	2018
9	Maternal health	72	14.41	2015	2018
10	Newborn	27	13.72	2015	2018
11	Disease	114	13.56	2015	2019
12	Survival	33	12.96	2015	2019
13	Country	220	12.64	2015	2017
14	Death	54	12.19	2015	2018
15	Global burden	55	12.02	2015	2020
16	Systematic analysis	47	11.52	2015	2019
17	Global health	110	11.52	2015	2018
18	Risk factor	81	10.65	2015	2018
19	Aid	25	9.81	2015	2019
20	Maternal mortality	53	9.71	2015	2019
21	Human right	41	9.71	2016	2020
22	Conservation	171	9.21	2017	2018
23	Children	96	9.09	2015	2017
24	Countdown	30	9	2015	2018
25	Hygiene	21	8.63	2016	2019
26	Citizen science	17	4.66	2020	2022
27	Self-efficacy	16	4.39	2020	2022
28	Firm	15	4.12	2020	2022
29	Local government	14	3.84	2020	2022
30	Ghana	25	3.39	2020	2022
31	Benefit	50	3.32	2020	2022
32	Crop	12	3.29	2020	2022
33	Nanoparticle	12	3.29	2020	2022
34	Impact assessment	20	3.18	2019	2022
35	International trade	20	3.18	2019	2022
36	Empowerment	19	3.02	2019	2022
37	Intensification	11	3.02	2020	2022
38	Law	11	3.02	2020	2022
39	Cultural heritage	11	3.02	2020	2022

the circle size is proportional to the number of documents associated with each research theme. An analysis of the results obtained for each period is shown below.

### 4.9.1 First period (2015–2018)

According to the strategic diagram (Figure 9), four research themes can be observed in the 2434 papers selected in this period contributed by 11974 authors: Climate-Change, Millennium-Development-Goals, Middle-Income-Country, Model and Determinants. Of these, two were considered motor themes (Climate-Change and Millennium-Development-Goals), one a highly developed and isolated theme (Middle-Income-Country), one emerging or declining (Model), and finally, one other was considered basic (Determinants). The performance measures for each theme, as shown in Table 10, complement the information provided by the diagram. According to Table 10, the following two relevant themes are highlighted: Climate-Change and Millennium-Development-Goals. These themes attain a high impact rate in comparison with the remaining themes.

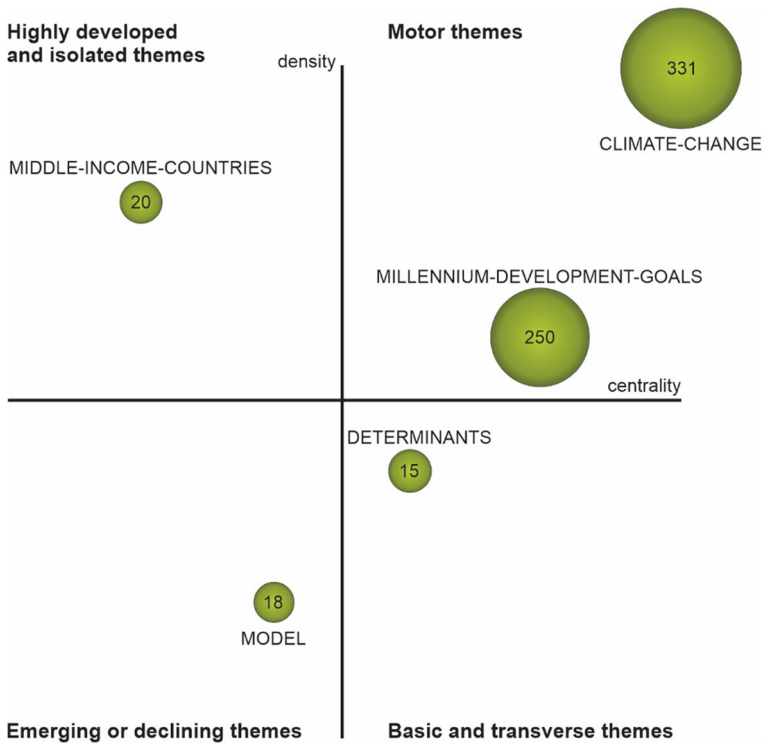
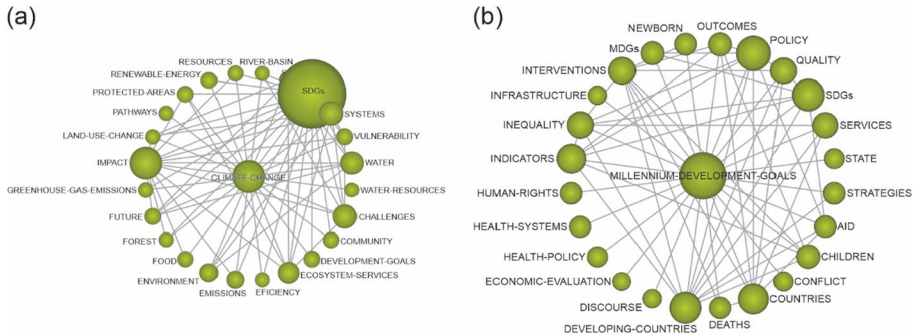


Fig. 9 Strategic diagram for the 2015–2018 period

Table 10 Performance measures for themes (2015–2018)

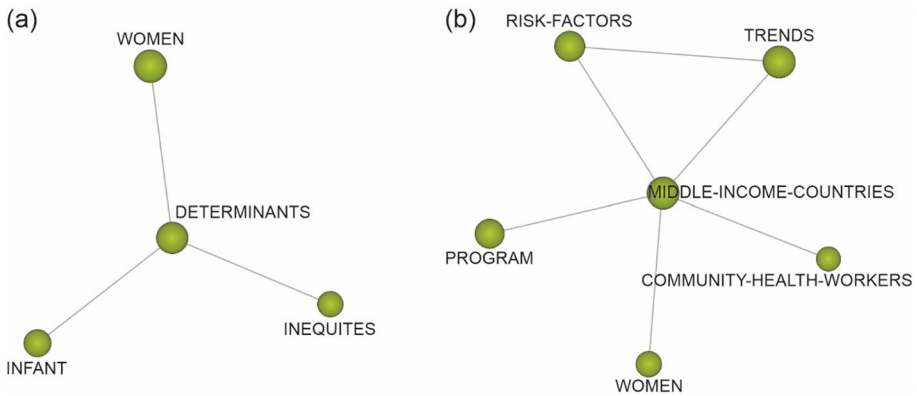
Name	TP	h-index	TC
Climate-Change	331	60	13,775
Millennium-Development-Goals	250	32	4,881
Middle-Income-Countries	20	14	1,654
Model	18	10	445
Determinants	15	8	175



**Fig. 10** Thematic network of (a) climate-change and (b) millennium-development-goals

The motor theme Climate-Change obtained the highest citation count in this period and recorded the highest h-index score. It is related to general topics of SDGs (Climate Action). Mainly, it is focused on how it affects every country on every count due to the rise in average surface temperatures on Earth. It has become a hot research field today since it disrupts national economies and affects lives, costing people, communities, and countries dearly today and even more tomorrow. Figure 10a depicts a cluster network of Climate-Change. Topics Such as progress on health and climate change (Watts et al., 2017), approaches to managing social and environmental issues in the tropics (Reed, 2016), soil health and carbon management (Lal, 2016), importance of soil and its awareness (Keesstra et al., 2016), land degradation Neutrality (Cowie et al., 2018), nature-based solutions in land management for enhancing ecosystem services (Keesstra et al., 2018), national land system sustainability emergency via sustainability programs (Bryan et al., 2018), Strengthening protected areas for biodiversity and ecosystem services (Xu et al., 2017), Smart Sustainable Cities (Bibri & Krogstie, 2017), future economic consequences of diabetes and Kidney Disease (Luyckx et al., 2018), maternal mortality (GBD 2017 DALYs and HALE Collaborators, 2018; Kassebaum et al., 2016), Sustainable Wellbeing (Costanza et al., 2016), social inclusiveness (Gupta & Vegelin, 2016), policy for managing the food, water, and energy (Rasul, 2016), approaches for Global Sustainable Development (Liu et al., 2018), implementation of SDGs (Stafford-Smith et al., 2017), sustainable development indicators (Hak et al., 2016), transformative innovation policy (Schot & Steinmueller, 2018), off-grid solar energy (Nerini et al., 2018), electricity access (Alstone et al., 2015) are disused in this cluster.

Millennium-Development-Goals is one of the motor themes and is the second most crucial theme of this period. This theme comprises research conducted on different aspects of Nations Millennium Development Goals (Figure 10b), especially health-care access and quality (Abbott et al., 2017; Fullman et al., 2018; Milat et al., 2015), health policy (Buse & Hawkes, 2015), Children mortality (Ebener et al., 2015; Wolf et al., 2018), global rules for the private sector (Scheyvens et al., 2016), drinking water (Adams, 2018; Martinez-Santos, 2017), poverty (Asadullah & Savoia, 2018), MDGs progress (Gaffey et al., 2015; Mohammadi et al., 2017; Moucheraud et al., 2016). It mainly focuses on the global development agenda transitions from the MDGs to the SDGs.



**Fig. 11** Thematic networks of (a) determinants and (b) middle-income-countries

The basic and transversal theme determinants are composed of a few publications, but they received the best impact (h-index) in this period. It represents the research conducted (Figure 11a) on different aspects of Determinants, such as women, infants, and inequality. It mainly focuses on delivery care services (Pulok et al., 2016), Intimate partner violence (Mohammed et al., 2017), maternal health care services (Ganle, 2016; Mehata et al., 2017), and mortality (Ahmed et al., 2016; Dendup et al., 2018). Middle-Income-Countries is a highly developed and isolated theme that represents research conducted on Middle-Income-Countries (Figure 11b) with living conditions of poor rural households, Early Childhood Development (Black et al., 2015, 2017; Richter et al., 2017), Equity in vaccination coverage nutrition (Arsenault et al., 2017), and child marriage (Kalamar et al., 2016).

#### 4.9.2 Second period (2019–2022)

In this period, a total of 9742 publications were contributed by 36816 authors, distributed in eight SDGs themes (Figure 12), with five major research themes (Motor themes plus basic theme): Sustainable-Development-Goals, CO<sub>2</sub>-Emissions, Areas, Emissions, and Strategies. Regarding the performance measures shown in Table 11, five themes stand out due to the citations achieved and scored h-index over 8: Sustainable-Development-Goals, CO<sub>2</sub>-Emissions, Strategies, Children, and Areas. However, the motor themes Sustainable-Development-Goals and CO<sub>2</sub>-Emissions are the most inflectional for structuring the SDGs research field.

Sustainable-Development was consolidated as a motor theme in this period (Figure 12). Moreover, it is the theme with the highest number of documents and achieves the highest number of citations count and h-index score. It obtains the highest density score, which means that its research has great internal cohesion. SDGs rise from the evolution of the themes of Climate change, Model, and Millennium-Development-Goal of the previous period. The research (Figure 13a) on this theme relates to 17 goals.

To further show more information from this cluster, some most cited papers of this cluster are also investigated. To name a few, Salvia et al. (2019) examined the difficulties and potentials in pursuing and implementing the SDGs, especially among developing

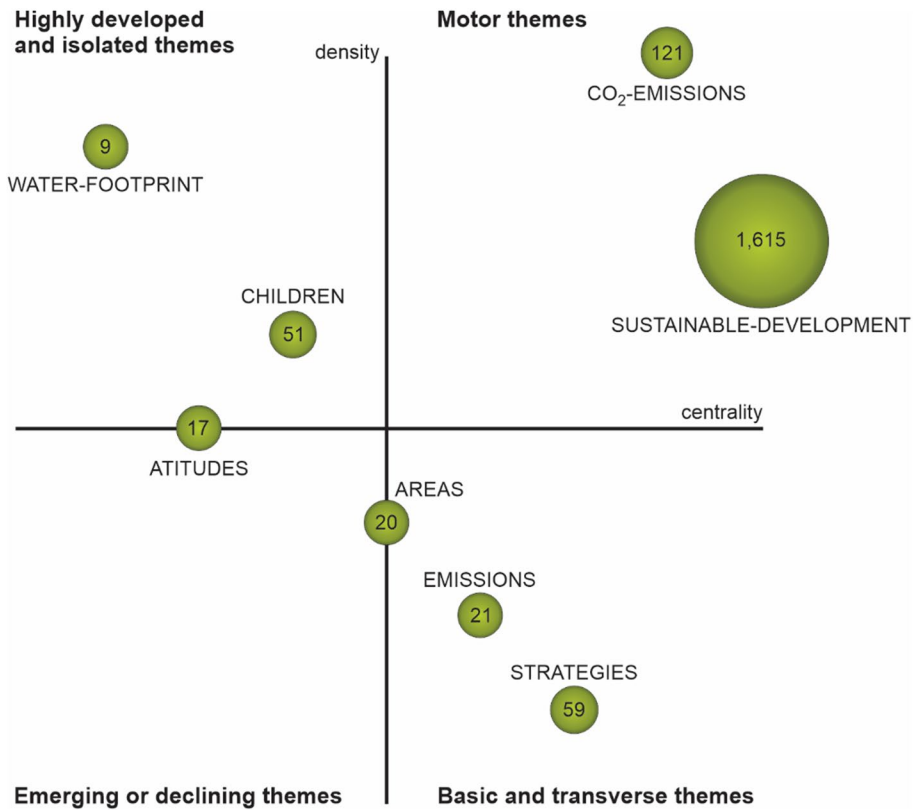


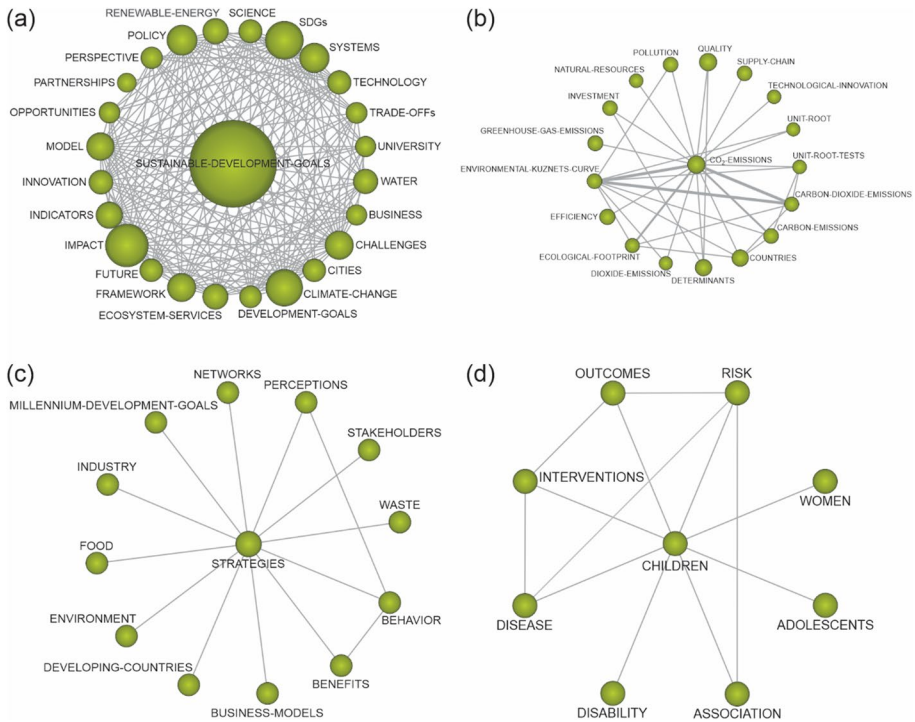
Fig. 12 Strategic diagram for the 2019–2021 period

Table 11 Performance measures for themes (2019–2022)

Name	TP	h-index	TC
Sustainable-Development-Goals	1615	44	13,567
CO <sub>2</sub> -Emissions	121	25	2,323
Strategies	59	12	451
Children	51	8	283
Areas	20	8	273
Emissions	21	7	231
Attitudes	17	5	68
Water-Footprint	9	6	155

nations. Schroeder et al. (2019) studied the contribution of circular economy practices such as repair, remanufacturing, and recycling to SDGs. More efforts in skill training, technology development, and multistakeholder partnerships are required to make advanced Circular Economy practices. Hughes et al. (2019) discussed Blockchain research, practice, and





**Fig. 13** Thematic network of (a) SDGs, (b) CO<sub>2</sub>-Emissions, (c) strategies, and (d) children

its potential in the future in various fields and factors. Leal et al. (2019) noted that the implementation of the SDGs at universities is still in the initial stage. They provided an overview of the level of emphasis placed on the SDGs by Higher Education Institutions. Nerini et al. (2019) explored the connection of climate change action with other SDGs. They suggested that climate change action can strengthen all 17 SDGs while undermining efforts to achieve 12. Governance processes and structures must be better connected to maximize the legitimacy and effectiveness of action in both domains. Huovila et al. (2019) reported the standardized indicators for smart, sustainable cities that balance sustainability and smartness. Fonseca et al. (2020) mapped the relationship between SDGs. They found no significant correlation with other SDGs, especially Climate action and partnerships for the goals, which provides scope for future research.

The theme of CO<sub>2</sub> emissions emerged during this period and can be considered one of the main topics of SDGs, as evidenced by its high h-index score and the considerable number of citations. CO<sub>2</sub> emissions have evolved from the themes of Determinants and Millennium Development Goals in the previous period. Across the globe, countries are consistently facing one of the greatest challenges of the 21st century: saving and sustaining the environment. The most developed countries are often the largest emitters of carbon dioxide (CO<sub>2</sub>), resulting in an urgent policy drive toward environmental sustainability.

The research on this theme relates to ecological footprint, greenhouse gas emissions, natural resources, pollution, technological innovation, and supply chain (Figure 13b). To further show more information from this cluster, some most cited papers of this

cluster are also investigated. To name a few, following the SDG 17 of improving global partnerships for sustainable development, Shahbaz et al. (2019) explored the association between foreign direct investment and carbon emissions in the Middle East and North African region in the 1990–2015 period. They found that there is a need to develop comprehensive trade and energy policies by targeting cleaner production practices for a sustainable environment and fulfilling the objectives of SDGs. Sarkodie and Strezov (2019) examined the effect of foreign direct investment inflows, economic development, and energy consumption on disaggregate greenhouse gas emissions. Alola et al. (2019) discussed the role of trade policy, energy consumption, economic growth, and fertility rate on environmental pollution in 16 European member countries. Saint Akadiri et al. (2019) reported that by using renewable energy, carbon emission mitigation is very much achievable in the EU-28 countries and should also be adopted by all countries as an effective global policy to achieve SDGs by the year 2030.

The basic theme of strategies appears in this period as one of the emerging research themes. It mainly focuses (Figure 13c) on 17 SDGs strategies for promoting sustainable practices and solutions that address our society's main issues. To further show more information from this cluster, some most cited papers of this cluster are also investigated. To name a few, Chen et al. (2020) proposed strategies for green chemistry principles implementation from the aspects of governance, industry, and education. Dantas et al. (2021) reviewed the contribution of the circular economy and industry 4.0 toward achieving SDGs.

The highly developed and isolated motor theme of children appears in this period as a bifurcation of the MDGs theme from the previous period. The research (Figure 13d) is related to disease, risk, interventions, childhood development, and disability. To further present information from this cluster, we investigated some of the most cited papers. The bold new target of safely managed water, sanitation, and hygiene for all by 2030 warrants the attention of researchers, policymakers, and practitioners. Cumming et al. (2019) reported that major water, sanitation, and hygiene interventions did not affect childhood stunting, and mixed effects on childhood diarrhea resulted from five consensus points. Chen et al. (2019) studied how dietary changes can significantly contribute to achieving the 2030 national SDGs. Early childhood development is key to achieving SDGs and can be negatively influenced by many adversities, including home violence, neglect, abuse, and parallel health. There were consistent and strongly negative relationships between all measures of childhood adversity and all five childhood growth and development outcome measures at the age of 18 months (Bhopal et al., 2019). Bhutta et al. (2020) reported how countries could reduce child stunting, with or without closing geographical, economic, and other population inequalities. Josenhans et al. (2020) studied the sexual exploitation of boys. Hall et al. (2019) suggested that research should focus on interventions to alleviate poverty-related stress to achieve the United Nations SDGs. Toska et al. (2020) reported that children of an adolescent mother with AIDS show more health problems than others. This should be controlled in a country with a high number of adolescents.

#### 4.9.3 The most cited publications

The contents of the most cited papers are considered to be of great importance in the academic world, as they reflect the impact of research in a particular field. By analyzing the most cited papers, it is possible to understand the current state of knowledge in a certain area and identify gaps that need to be filled in future research. In this context, it is also

possible to understand the implications for future research based on the contents of the most cited papers (Gaffey et al., 2015). When it comes to the SDGs, the most cited papers are a reflection of the current state of research in the field and provide important insights into the areas that need further investigation. Table 12 displays the most frequently cited papers according to the total number of citations received. It is noteworthy that the papers authored by Liu et al. (2016), Pecl et al. (2017), Zhang et al. (2015), Black et al. (2017) Kruk et al. (2018), Patel et al. (2018), Black (2015), and GBD 2017 DALYs and HALE Collaborators (2018), Kassebaum et al. (2016) occupy the top 10 spots in the ranking. The majority of these papers focus on health, climate change, nitrogen, and agriculture.

The selected articles address various topics related to the SDGs established by the United Nations. The most cited papers on the SDGs reflect this need, as they often involve the analysis of inequalities and the identification of ways to ensure that everyone has access to the resources and opportunities they need to thrive (Zhu et al., 2021). Among the top 10 most cited articles, we have selected the six most highly cited ones for special attention. Liu et al. (2016) study investigated the causes of infant mortality at the global, regional, and national levels, offering important implications for achieving SDGs related to health. Meanwhile, Pecl et al. (2017) discussed the effects of climate change on biodiversity, highlighting the importance of preserving ecosystems for human well-being. Zhang et al. (2015) analyzed nitrogen management as a form of sustainable development, given its importance for agriculture and pollution reduction. On the other hand, Black et al. (2017) conducted a study on early childhood development, emphasizing the importance of this period for the formation of healthy and productive adults. Kruk et al. (2018) addressed the need for high-quality health systems to achieve SDGs related to health, highlighting the importance of innovation and political commitment. Finally, Patel et al. (2018) work explored the relationship between mental health and sustainable development, emphasizing the need for public policies that address this issue in an integrated manner. Together, these articles highlight the complexity and interdependence of the SDGs, as well as the need for an integrated approach to sustainable development. In addition, the studies emphasize the importance of research and innovation in addressing global challenges and achieving the goals established by the United Nations (Table 12).

In conclusion, the contents of the most cited papers on the SDGs provide important insights into the current state of research in the field and the implications for future research. The need for interdisciplinary approaches, practical solutions, a focus on equity and social justice, and innovation and technological solutions are some of the key implications that can be derived from the analysis of the most cited papers. By considering these implications, future research can contribute to the achievement of the SDGs and ensure that everyone has access to a high quality of life and prosperity.

## 5 Discussion

To assess the distribution of SDGs in literature review publications over the years, the articles were individually analyzed and classified. It should be noted that the publications could be included in multiple categories. As a result, the majority of documents were categorized under general aspects of sustainability, including environmental sciences, environmental studies, and green science and sustainable technology.

**Table 12** The top 10 most-cited documents in the dataset

Authors	Journal	Citations	Title
Liu et al. (2016)	Lancet	1549	Global, regional, and national causes of under-5 mortality in 2000–15: an updated systematic analysis with implications for the sustainable development goals
Pecl et al. (2017)	Science	1317	Biodiversity redistribution under climate change: impacts on ecosystems and human well-being
Zhang et al. (2015)	Nature	1026	Managing nitrogen for sustainable development
Black et al. (2017)	Lancet	970	Early childhood development coming of age: science through the life course
Kruk et al. (2018)	Lancet Global Health	906	High-quality health systems in the sustainable development goals era: time for a revolution
Patel et al. (2018)	Lancet	763	The lancet commission on global mental health and sustainable development
Keesstra et al. (2016)	Soil	734	The significance of soils and soil science toward realization of the united nations sustainable development goals
Britto et al. (2017)	Lancet	586	Nurturing care: promoting early childhood development
Le Blanc (2015)	Sustainable Development	535	Toward integration at last? The sustainable development goals as a network of targets
GBD 2017 DALYs and HALE Collaborators (2018), Kassebaum et al. (2016)	Lancet	500	Global, regional, and national levels of maternal mortality, 1990–2015: a systematic analysis for the global burden of disease study 2015

The results of the bibliometric analysis indicate that research and development on the SDGs are more concentrated in developed countries than in developing and underdeveloped nations. This trend highlights the need for greater investment and engagement from developing countries in addressing the global sustainability challenges posed by the SDGs. This study is the first to conduct a bibliometric analysis of the SDGs and examine the progress, challenges, and opportunities during the period from 2015 to 2022. The results of this study reveal differences in the utilization of the SDGs theme.

Based on the analysis and results obtained from this paper, we have observed a huge disparity in participation in the development process through scientific contributions. The current development trajectories also follow the same path, with countries and regions with more resources contributing more than those with fewer resources. According to Sweileh (2020), the highest volumes of research are found in SDGs 1, 3, 11, 12, and 15. Similar results were obtained by Sianes et al. (2022), who used bibliometric methodologies to evaluate the impacts of SDGs on the academic agenda, while Salvia et al. (2019) highlighted that SDGs 11, 12, 13, and 15 were high research themes, and SDGs 8 and 14 were least researched.

According to the results obtained, articles related to SDGs on hunger, energy, and peace were only published starting in 2017, while articles related to more applied and diverse SDGs research were found starting in 2018, as also reported by Yamaguchi et al. (2023). Regarding the studies published starting in 2018, those of an environmental nature, i.e., related to nature and technology areas such as water and sanitation, industry, innovation and infrastructure, food and agriculture, business and management, development studies, and urban studies, climate change, and ecosystems, can be highlighted. These results show progress and a trend in SDGs studies, pointing to a growth in environmental research. Similar findings have been reported in previous studies by Sweileh (2020), Londono-Pineda and Cano (2022), and Yamaguchi et al. (2023). However, Yamaguchi et al. (2023) focused on the most cited articles, and Sweileh (2020) only analyzed articles with the phrase “sustainable development goal”, while this study has a broader scope. In addition, Londono-Pineda and Cano (2022) analyzed the main methodologies used for evaluating SDGs through bibliometric analysis. Scopus and Web of Science were identified by El Mohadab et al. (2020) as the primary databases for bibliometric analysis.

This study demonstrates that countries with the most institutional affiliations from authors also have corresponding funding to support research in diverse universities and institutions. Most of the publications found were articles published in highly indexed journals. However, the concentration of cutting-edge knowledge in specific countries, institutions, and authors is a concern. According to Londono-Pineda and Cano (2022), co-authorship can be an efficient strategy for institutions in developing countries to generate high-impact publications on issues related to SDG assessments. Sweileh (2020) notes that collaboration related to SDGs in America and Europe is strong, but collaboration in African and Asian countries is poor. To promote a more comprehensive assessment of the SDGs, it is necessary to transcend independent SDG assessments and recognize the thresholds of each dimension, allowing for the consideration of trade-offs among the SDGs. Didegah and Thelwall (2013) suggest that inviting and collaborating with researchers from third-world countries would help publish high-impact factor journals and attract funds for research proposals related to SDGs.

It can be inferred that there is a regionalization of research interest related to various goals and targets of SDGs. The developed world (USA, Canada, Australia, and Europe) is more interested in SDG 4 (Quality Education), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action) but the African

world more interested in SDG 13 (Climate Action), SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 5 (Gender Equality), SDG 6 (Clean Water and Sanitation), SDG 15 (Life on Land) (Körfggen et al., 2018; Salvia et al., 2019). Thus, it is observed that most of the research on SDGs is related to social problems like poverty, hunger, education, conflict, gender, and peace. However, global warming and climate change are also global environmental threats to the life-supporting system on earth (Zhenmin & Espinosa, 2019). These results were expected, as environmental sciences are an interdisciplinary academic field that integrates physics, biology, and geography and studies the environment and the solution to environmental problems, covering a wide range of topics (Yamaguchi et al., 2023).

The top 10 countries, institutions, and authors publishing on SDGs represent the world's developed economies. However, most research carried out was related to social problems (poverty, hunger, education, gender, and peace) in the underdeveloped world (Yamaguchi et al., 2023). The lack of participation or opportunity to contribute to the global goals research would make countries remain unaware of the happenings around the world, thus making SDGs 2030 unattainable. One of the primary goals of the SDGs is to demonstrate the world as a whole rather than just a few countries. However, the patterns of research and development highlight that research interest is regionalized according to the scale of the problem in their area (Sweileh, 2020).

Climate, ecosystems, health systems, and inequality have been major research areas in the past, contributing to SDGs 13, 14, 15, 3, and 10 (Yamaguchi et al., 2023). The highly productive countries contributing to SDGs research themes include the USA, UK, Australia, Germany, China, Switzerland, Spain, India, and South Africa. European countries, including Sweden, Austria, France, Finland, and Denmark, are top of the list of high research citations. The top 10 productive institutions/organizations in SDGs research are based on the UK, USA, Australia, Switzerland, and South Africa. The top 10 prolific authors in SDGs come from the USA, Switzerland, the UK, Canada, and Iran. The gap is evident in the goals covered, countries' participation, institutions, and the share of authors from particular regions. Developed countries research more on SDGs than developing and underdeveloped countries, where most of the world population lives (Salvia et al., 2019; Sweileh, 2020). The voices of these people are silent in research publications. Their narratives fail to find a place in our research documents.

The study makes a valuable contribution to the literature as the first review to focus on the most frequently evaluated SDGs, and one of the few studies, along with Sweileh (2020), Londono-Pineda and Cano (2022), and Yamaguchi et al. (2023), to identify the recurrent types of assessments related to the 2030 Agenda for SDGs. The findings are in line with the need for research that promotes more comprehensive assessments of the agenda, as highlighted by Ahner-Mchaffie et al. (2018), El Mohadab et al. (2020), Meschede (2020) and Zhu et al. (2021). To achieve a more comprehensive assessment of the SDGs, it is essential to move beyond individual evaluations and instead recognize the interdependence and trade-offs among the various dimensions, which can be achieved by acknowledging the thresholds of each SDG.

## 6 Concluding remarks: the way forward

This study investigated the bibliometric analysis of trends, trajectories, and prospects of SDGs by the global community based on the Web of Science core database from 2015 to 2022. Even after seven years of implementation of SDGs, the agenda of 2030 are



having still complex interlink age between goals and also overambitious targets. The result of the study revealed an increasing trend of publication during the studied period, but goals are not highlighted in a consolidated manner.

The top five countries with the highest number of publications and citations are from the developed world (USA, China, UK, Australia, and Spain), whereas the least contributing countries are from the developing world. Again, the top 5 productive authors are also from the developed world. It has been highlighted that good health and well-being are the thematic areas of research for the underdeveloped world, and climate action is a focus area of research for high-income countries. Thus, it shows that the goals of SDGs are not consolidated but divisive in nature, and the reason may be practical challenges surrounding implementing SDGs. Again, keyword analysis emphasized about core research areas: ‘sustainable development goals, climate change, agenda 2030, circular economy, Africa, poverty, global health, governance, food security, sub-Saharan Africa, millennium development goals, universal health coverage, indicators, gender, and inequality’; and these words are primary needs of human life.

The goals related to the basic needs of human being to just have human life should not treat as unrealistic aspirations and call for prioritizing SDGs. Therefore, education, funding, and innovation of green technology are critical elements to achieve the target of SDGs in 2030. Again, there is a need for a periodical investigation of SDGs-related published documents to get an insight into the gap in achieving the global 2030 agenda.

There is no specific theory regarding the SDGs. Instead, they represent a holistic approach to global development with 17 interconnected and interdependent goals. Achieving them requires collaboration from all sectors of society, emphasizing an integrated approach, technology, financial inclusion, and continuous monitoring. The importance of collaboration, an integrated approach, technology, financial inclusion, and continuous monitoring has been identified as the main theoretical findings of the SDGs. There are no specific practical discoveries related to the SDGs, as they represent a holistic approach to global development, with goals such as eradicating poverty, ensuring gender equality, protecting the environment, and promoting economic growth. Practical advancements related to the SDGs have been made in areas such as policy and decision-making, partnerships and collaboration, data and measurement, and financing. The implementation of SDGs has also demonstrated the importance of a multi-stakeholder approach, innovative financing mechanisms, and technology to achieve sustainable development.

Studies on the SDGs are highly complex due to the interdisciplinary nature and scope of the objectives and targets involved in this theme. Therefore, more research should be carried out to fill this gap by developing more effective and reliable methods to verify progress toward the SDGs. To achieve this, it is recommended to incorporate other bibliographic databases to further increase the reach of the bibliometric review of this topic, including non-Web of Science databases and the inclusion of grey literature such as reports from government and non-governmental agencies.

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**Data availability** The data that support the findings of this study are available upon reasonable request.

## Declarations

**Conflict of interest** The authors declare that they have no conflict of interest.

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