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Sustainable Development and Climate Change in India: Understanding the Key themes and Emerging Areas

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Abstract

In the present research, a bibliometric analysis of research trend on sustainable development and climate change in India for the period between 2015 and 2024 is performed. We analyzed 8,882 Web of Science research papers extracted for data, using bibliometric tools (Biblioshiny and VOSviewer) to understand key themes, emerging areas and collaboration networks. We find that sustainable development, climate change, renewable energy, and sustainable development goals rank the highest, with a sharp increase in publications on circular economy and machine learning. Several subfields are uncovered through the thematic analysis, with sustainable development and environmental sustainability being the core areas of research and niche themes of the research emerging, such as photocatalysis or wastewater treatment. The research network of international collaboration indicates the significance of international alliances, especially with nations like China, the USA, the United Kingdom, and Saudi Arabia, for growth in research on these topics. Further, factorial analysis reveals the conceptual structure of the field and the interconnection of key terms, and shows the evolution of focus on renewable energy, circular economy and Geographic Information Systems (GIS). In general, this study provides a comprehensive approach to studying the trends and dynamics of research on sustainable development and climate change in India and serves as a valuable reference for future studies and policy-making.

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Keywords
Bibliometric Analysis; Circular Economy; Climate Change; India; Renewable Energy; Sustainable Development.

Introduction

Climate change presents a major obstacle to achieving sustainable development worldwide since sustainability and climate change form an inseparable relationship.[1] The United Nations SDGs acknowledge SDG 13 as crucial because it unites both climate adaptation and mitigation strategies to secure sustainability and maintain social and economic

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systems with environmental resilience.[2] The rise of global greenhouse gas emissions has caused both temperature rise effects and strong weather patterns which damage ecosystems, endanger food security and drinking water resources and local economies.[3,4] India experiences high vulnerability to climate change because of its fast economic development combined with heavy population density, rapid urban growth and its dependence on rain-fed agriculture production systems.[5] Current environmental sustainability challenges in India require managing economic growth since temperature rises and irregular rainfalls with extreme weather events affect millions of citizens.[6] Industrial development and urbanization at high speeds have exacerbated all existing problems regarding environmental destruction along with natural resource consumption and economic inequalities.[7] India is the most susceptible to Climate Change given rising temperatures, erratic monsoons and ever frequent and intense extreme weather events.[8] It has been enthusiastic in appropriating the principles of sustainable development and its policies are counterbalanced to the UN's Sustainable Development Goals (SDG). Development of renewable energy deployment has also occurred in the country and by 2030, it hopes to have 50% of its energy generated from a non-fossil fuel source.[9] However, these efforts are continually working to find a fine balance between economic growth, environmental protection and social equity. For such complex problems to be dealt with benefits of evidence-based policymaking, technological innovation, and capacity-building studies on sustainable development and climate change are essential.[10]

Moreover, bibliometric study is a powerful means for inspecting the evolution, frequency and patterns of the research of a specific research domain, discovering key players performing that research, and detecting research trends along with gaps.[11] Such analyses will help in illuminating the way we are progressing and the obstacles we are facing in meeting these universal global issues with regard to sustainable development and climate change (SDSC) in India.[12] India is on a journey of its own to achieve a harmony between its economic aspirations and environmental responsibilities and understanding these research trends is essential based on the need and the urgency for eco-informed investments and innovations for innovative solutions. Still, the Indian research landscape has been so far neglected, although there is a wide-spread academic interest in SDSC around the world. Because most of the current research is already there, the majority of the studies are related to distinct aspects, such as renewable energy and environmental policies, without describing the whole picture of the research ecosystem.[13,14] Moreover, from the considerations of quick strides in a circular economy, GIS applications, and machine learning, a systematic analysis to figure out the contribution of these areas in sustainability research in India is being called for. Such an understanding, however, is absent, which limits policymakers and researchers from exploiting emerging opportunities and filling in key gaps. A gap exists between India's sustainable development and climate change research and scholarly work in the field conducted internationally as represented by the present study: the bibliometric study on India's sustainable development and climate change research.

Therefore, this study seeks to address this gap through a bibliometric assessment on sustainable development and climate change in India. The specific objectives are: (a) to identify and analyse key research trends, themes and publication patterns, (b) to map emerging areas (renewable energy, circular economy, and GIS applications) used to provide inputs to sustainable development and climate change research, and (c) to expose the most important contributors (authors, institutions, keyword occurrences and journals) for this research field. Research gaps will be uncovered, and suggestions for further studies will be provided. Through this analysis, it proposes to construct an integrated perspective of the research ecosystem to guide researchers, practitioners and policy-makers working toward promoting sustainability and climate resilience in India.

Literature Review

Sustainable development and climate change are two focus areas implementing two global challenges which are inter connected as well as crucial for sustainable development (SD). SD was introduced by the Brundtland Commission Report (1987), which highlights the necessity of current generations not

compromising the ability of future generations to satisfy their own need. Since the adoption of the SDGs in 2015, these goals offer a holistic framework to achieve global sustainability by 2030, targeting a number of issues, including poverty eradication, clean energy, and climate action.[15,16] India is one of the largest and fastest urbanizing countries, with challenges in jointly mediating economic growth and environmental sustainability.[17,18] Studies have shown how urbanization and industrialization exert pressure on natural resources, biodiversity and ecosystem services.[19,20] Therefore, sustainable practices in urban planning, resource management, and policymakingare emerging as important research areas.[21] For the last several years, research has studied the linkages between economic growth and environmental sustainability with the goal to find equilibrium that fosters long term development without destroying ecosystems.[22] However, research on climate change in India requires specific focus on examining its economic ramifications. Dua and Garg (2024) investigated the impact of climate change induced extreme weather events on three essential economic sectors: agriculture, manufacturing and infrastructure.[23] Kumar and Maiti (2024) analyzed climate change financial risks which demonstrated that growing natural disasters alter both investment behavior and sustained economic stability.[24] These studies prioritise that economic resilience must be integrated with climate adaptation policies because of the current critical situation.

Climate change impacts like changing monsoon patterns, increasing frequency of extreme events, and rising sea levels render India highly vulnerable.[25] Numerous studies have shown that India is exposed to substantial climate-related risks in case of increase in droughts, floods and heat waves which affect agricultural productivity and human health.[26,27] India is projected to undergo temperature increase, higher frequency of extreme events, and ecological disruptions, with projections made by the Intergovernmental Panel on Climate Change.[28] A huge body of literature has explored the climate change impacts on different sectors in India, especially in the agriculture, water resources and health sectors. Climate change makes the situation worse by changing crop yields and bringing about droughts more often.[29,30] In addition, urban areas of India like Mumbai, Delhi and Kolkata are exposed to greater risks of climate-induced extreme events, which may exceed the capacity of infrastructure systems.[31] Therefore, comprehensive adaptation and mitigation strategies are required.

India's battle against climate change hinges on transitioning to renewable energy. The apprehensions of excessive dependence on fossil fuels to meet the energy demand in India have been fuelling the interest in exploring renewable sources such as solar, wind and hydropower.[32] However, in India, we also have ambitious targets of 175 GW capacity of renewable energy by 2022 and 500 GW of renewable energy by 2030.[33] Solar energy is already the biggest renewable energy source in the country, and they have made great strides already. Research on the challenges as well as the potential of scaling up renewable energy infrastructure in India, including solar power in the grid and how policy frameworks can support this transition, has been the subject of numerous studies.[34] The second area of critical research is the circular economy, where resources must be reduced, re-used, and recycled to reduce waste and maximise resource use to follow the tactic of Chamleon's strategy within the boundaries of sustainability.[35] For instance, the circular economy approach has taken root in the manufacturing, construction and waste management sectors in India.[36] Therefore, the potential of circular economy practices for reducing resource consumption, facilitating sustainable industrial processes, and creating green jobs, in addition to SDG achievement, has been studied.

Bibliometric analysis is the quantitative study of academic literature to extract patterns, trends and impact in a region of research. It is instrumental for mapping the development of the scientific fields themselves, for evaluating the scientific productivity and for making policy decisions.[37] Bibliometric studies in the field of climate change and sustainability provide growth of the literature, collaborative network, and emergence of the research area. In the same vein, Wang *et al*. (2023) performed a detailed bibliometric study of climate change research, which shows upward trends in publication rates and the accentuation of interdisciplinary research.[38]

Research trends on sustainability and climate change have been studied by several bibliometric studies. Fu and Waltman demonstrated the extraction of a sectoral view of global climate change research published between 2001 and 2018, detecting that this research was focused on key fields, such as physical science, paleoclimatology, climate change ecology, climate technology and climate policy.[39] Bibliographic analyses in the Indian context have shown the country's role in global sustainability research. An overview of sustainable development, remote sensing and climate change research in India, using Shukla *et al*., this paper further highlights the critical need to integrate approaches and initiatives across these varied fields in order to address this interconnected issue.[40] Bibliometric studies that use maps and other visualisations suggest that research in the areas of sustainable development and climate change is characterised by dynamism and the importance of interdisciplinary approaches for solving global and local problems.

Materials and Methods

The Web of Science (WoS) has been chosen as the primary database to conduct bibliometric study of the research trends of sustainable development and climate change in India. The WoS database is a strong option for bibliometric studies due to its coverage of various multidisciplinary subjects' peer review articles, conference proceedings, and review papers.[41,42] Additionally, WoS is well known as a reliable index and search tool for conducting robust bibliometric analyses.[43,44] A systematic search was conducted on the 22th of December 2024 in the WoS database in retrieving relevant scientific literature. The search query was structured using Boolean operators and included the following terms: TS = (("Sustainable Development" OR "Sustainability" OR "Climate Change")) AND TS = ("English") (Language)) and ("India") (Country)), TS= (("Articles") (Document Types)), and TS= (("SCI-EXPANDED" OR "SSCI" OR "A&HCI") (Web of Science Index)).

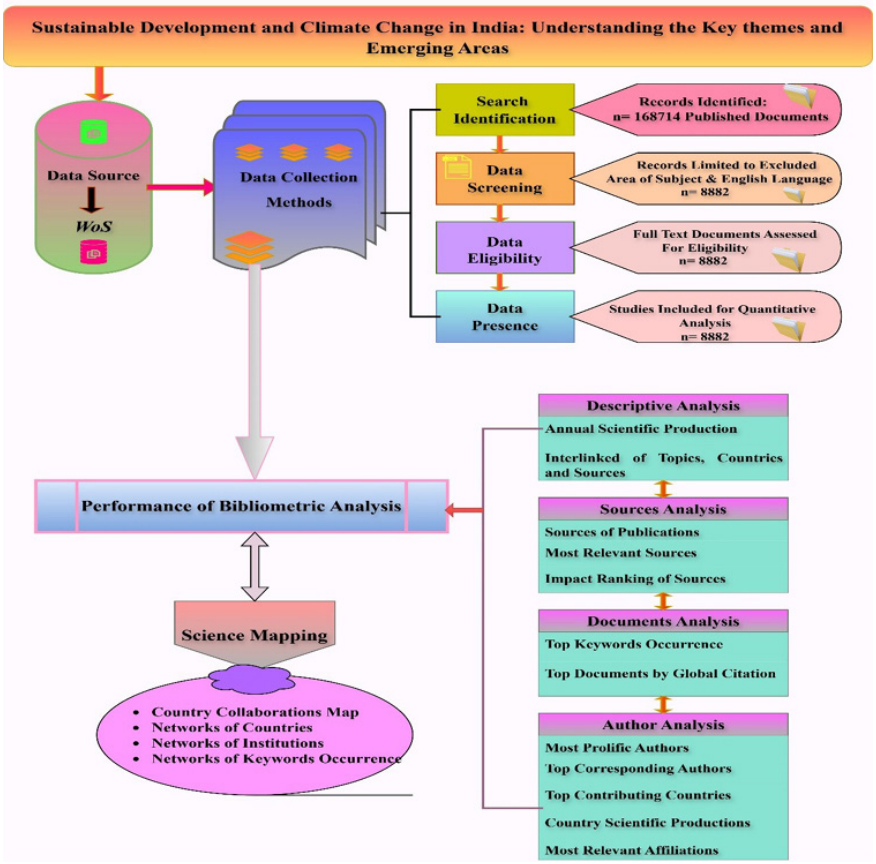

Fig. 1: Research Design and Methodology

To make sure that the publications include those that concern sustainable development along with climate change in the Indian context and so only publications that cover from 2015 to 2024 were included in this query. After applying inclusion and exclusion guidelines, 8882 records were retrieved. Inclusion criteria focused on English-language, peer-reviewed documents within the study's thematic scope, while non-relevant publications, such as editorials or letters, were excluded. Two advanced bibliometric tools were used for analysis: Biblioshiny (based on the R package Bibliometrix) was utilized for descriptive and keyword analysis. VOSviewer facilitated network visualization of collaborations and thematic clusters. The bibliometric analysis was conducted across three dimensions: Descriptive Analysis: Annual publication trends, citation analysis, and productivity metrics. Content Analysis: Keyword co-occurrence and thematic evolution. Network Analysis: Co-authorship, institutional collaboration, and thematic clusters were visualized. The study is limited by its reliance on a single database, language bias (English-only publications), and the scope of analysis algorithms. These constraints were acknowledged to provide a balanced interpretation of results.

Results

Important Information

The dataset for this study covers a time span of 2015 to 2024, reflecting nearly a decade of research focusing on sustainable development and climate change, ensuring the relevance and timeliness of the findings. The data was sourced from 1,805 different publications, including journals, books, and conference proceedings, and thus, the research in this area is multidisciplinary. This analysis included 8,882 documents, largely peer-reviewed articles, reviews, and other academic papers. The remarkable annual growth rate of the research publications is 14.58%, which shows an increasing and consistent rate of scholarly activity on sustainability and climate change over ten years (Table 1). The documents' average age is quite young at 2.13 years, indicating that most of the research into this area is quite recent and reflects the current times. The high impact and high recognition of the research by the academic community is shown by the average of 18.89 citations attributed to each of these documents.

Table 1: Details of the Dataset

Description	Results
Study Period	2015:2024
Publication Sources (Journals, Books, etc.)	1805
Total Documents Analysed	8882
Annual Publication Growth Rate (%)	14.58
Average Age of Documents (Years)	2.13
Average Citations per Document	18.89
DOCUMENT CONTENTS	
Keywords Plus (ID)	15323
Author's Keywords (DE)	24777
AUTHORSHIP DETAILS	
Total Authors	31913
Unique authors with single-authored docs	216
Total single-authored docs	251
AUTHORSHIP COLLABORATION	
Average Co-Authors per Document	6.7
International co-authorships %	44.55
DOCUMENT TYPES	
Articles	8882

Source: Prepared by the authors

From the contents of the documents, the dataset comprises many Keywords Plus (15 323) and Author's Keywords (24 777). Keywords Plus presents a comprehensive thematic view of these domains from the perspective of the database, while Author's Keywords express authors' specific domains of interest. The dataset consists of contributions from 31,913 authors, of whom 216 have authored at least one single-authored document. In addition, 251 are single-authored documents, which shows that while individual contributions exist, collaborative research is the significant trend in this research area. The analysis reveals that each document, on average, has 6.7 co-authors, highlighting the collaborative and often interdisciplinary of research in sustainable development and climate change. Notably, nearly 44.55% of the documents involved international co-authorship, which emphasizes the global scope and the international collaboration that drives much of the progress in this field. The entire dataset consists of articles (8,882 documents), reflecting the publication preference for peer-reviewed journal articles in this area.

Annual Trends in Publications and Citation Metrics

The bibliometric analysis reveals significant trends in publications and citations related to sustainable development and climate change in India from 2015 to 2024. The total number of publications has grown substantially, from 116 in 2015 to an impressive 2683 in 2024 (Figure 2). This indicates a sharp increase in academic interest in these critical topics, particularly during the years 2022–2024, likely influenced by heightened global and national focus on sustainability and climate issues. The Mean Total Citations (TC) per Article reveals that earlier publications received higher average citations, with 45.19 in 2015 and 53.46 in 2016, highlighting their long-term influence (Table 2). As expected, more recent publications from 2023 and 2024 have lower mean citation values (9.66 and 2.50, respectively), reflecting the shorter time span available for citations to accrue. The Mean TC per Year provides additional insights, showing consistent impact for publications from 2017 to 2018, with values ranging from 6.39 to 6.87, while more recent years exhibit a decline due to their recency.

Table 2: Annual Trends in Publications and Citation Metrics on Sustainable Development and Climate Change in India (2015–2024)

Years	Number of Publications	Mean TC Per Art	Mean TC Per Year	Citable Years
2015	116	45.19	4.52	10
2016	218	53.46	5.94	9
2017	224	51.12	6.39	8
2018	359	48.09	6.87	7
2019	452	41.16	6.86	6
2020	633	32.64	6.53	5
2021	1005	30.07	7.52	4
2022	1423	20.47	6.82	3
2023	1745	9.66	4.83	2
2024	2683	2.50	2.50	1

The analysis also tracks the Citable Years of publications, which naturally decreases from 10 years for 2015 publications to just 1 year for 2024. This metric underlines the importance of considering a time-frame when evaluating citation performance, as older articles have had more opportunities to gain citations. They show that not only is there a developing body of academic literature on sustainable development and climate change, but also developing trends in citations. The recent works are indicative of how topical and urgent these themes are becoming, and the prior works have exerted considerable scholarly influence. These trends offer critical insights into the way this field is developing and, in so doing, help to demonstrate the significance of this field for researchers and policymakers.

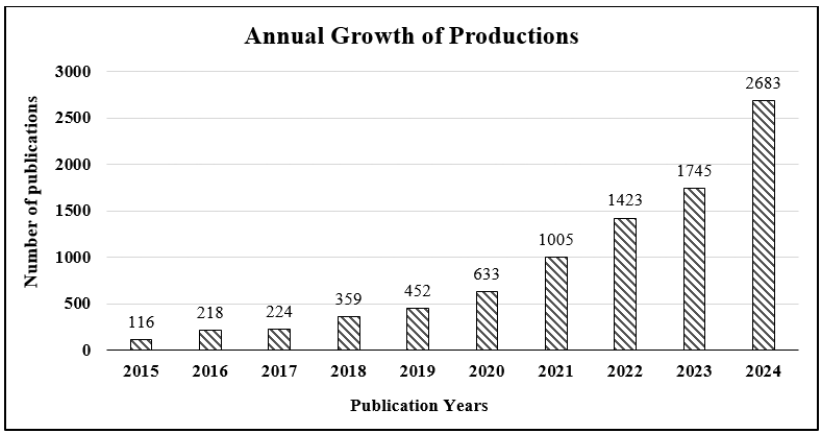

Fig. 2: Publication Trends Over Time

Three-Fields Plot Analysis

Visualization of the relationships between organizations, countries and keywords in sustainability development and climate change research is provided in the Three-Fields Plot (Figure 3). This plot plots out the collaborative dynamics and thematic focus of this essential field of research. Tehran University of Medical Science, University of London, King Saud University, IIT, and CSIR happen to be contributing more than other prominent organizations. The output of these institutions is a further demonstration of their strong emphasis on research into sustainability-related themes, which include SDCC, and Sustainable Development Goals (SDGs). For instance, IIT and CSIR have a striking dominance of applied research (especially in GIS and renewable energy) reflecting their supremacy in technical and developmental studies. Geographically the plot gives contributions from major countries such as Iran, India, USA, Australia, UK and Ethiopia. Further, India is a dominant contributor and stands out by pursuing a growing thrust on addressing sustainability and climate change challenges. There are clear international collaborations, e.g. strong links between India and the USA and Australia, which points to this being a truly global area of research. These partnerships provide for shared resources and the joining of perspectives from many different sources, thus enlarging the field's intellectual base.

The keyword analysis of the research shows the research's thematic priorities. The global environmental challenges that the field aims to address-from sustainable development to sustainability, SDGs, and climate change have been traced in the language explored. New topics such as circular economy and renewable energy point towards interdisciplinary approaches, which means including innovative solutions in aspects of sustainable research. Plot connections show strong signals and thicker lines imply more frequent co-authorship or more frequent thematic links like Tehran University of Medical Science and Iran or IIT and India.

Leading Sources and Publication Trends

The top ten journals were listed considering their contribution to the topic with metrics serving as performance indicators mentioned in Table 3. The quantity of articles published places Sustainability in the top journal position (288), while being in second place with the JCP (287) (Figure 4). These journals dominate in promoting research related to sustainability and climate change. When it came to citation impact, the JCP fared the best, with a total of 13,420 citations, the best of any, along with an h-index of 66 and a g-index of 104. As this demonstrates, the metrics reflect the journal's ability to generate research with prominence that is felt broadly across the academic community.

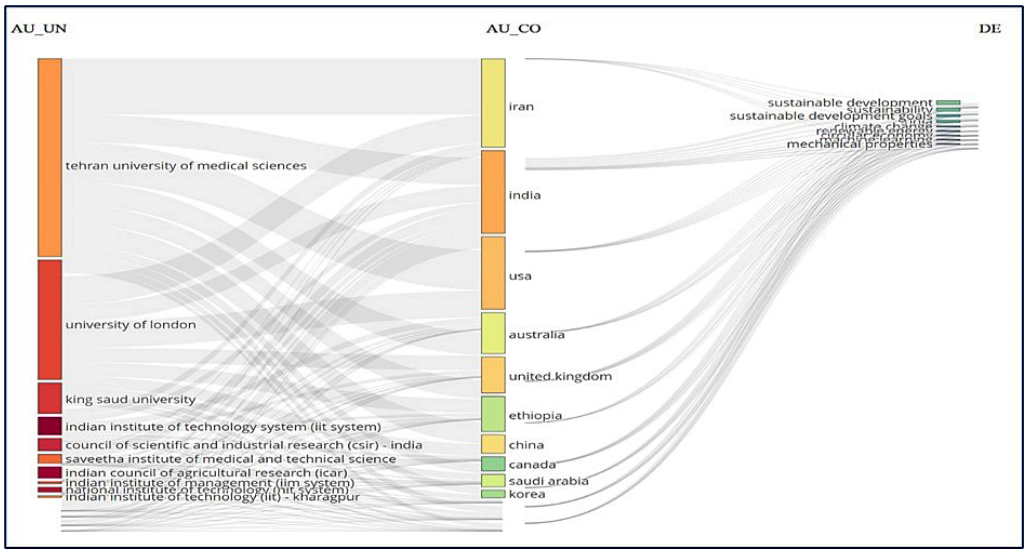

Fig. 3: Three-Fields Plot illustrating relationships among organizations, countries, and keywords

Table 3: Ranking of Top 10 Journals Publishing on Sustainable Development and Climate Change

Rank	Sources	Articles	H-Index	G-Index	M-Index	TC	PY-Start
1	Sustainability	288	28	41	2.8	3142	2015
2	Journal of Cleaner Production	287	66	104	6.6	13420	2015
3	Environment Development and Sustainability	207	27	43	2.7	2447	2015
4	Environmental Science and Pollution Research	176	35	54	3.889	3717	2016
5	Journal of Environmental Management	94	30	47	3	2495	2015
6	Biomass Conversion and Biorefinery	87	11	16	3.667	394	2022
7	Scientific Reports	80	15	27	1.667	858	2016
8	ACS Sustainable Chemistry & Engineering	73	30	48	3	2485	2015
9	International Journal of Hydrogen Energy	66	19	32	2.111	1164	2016
10	Science of the Total Environment	66	30	55	3	3094	2015

For example, the emerging journal Biomass Conversion and Biorefinery, started in 2022, was very productive and had a high m-index (3.667). This serves as a testament to how much its influence is growing in themes revolving around sustainability, but most especially in renewable energy and the circular economy. Overall, the findings show that these Journals play a substantial role in building knowledge in the arena of sustainability and climate change in India.

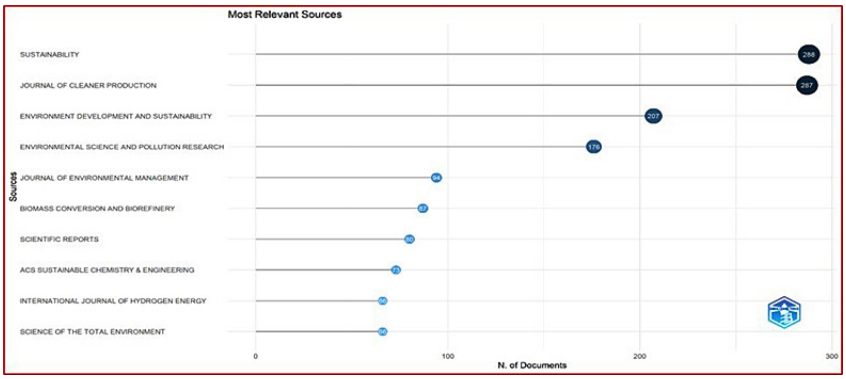

Fig. 4: Most Relevant sources (2015–2024)

Table 4: Distribution and publications trends across top journals (2015–2024)

Rank	Sources	Years of Publications									
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
1	SUS	2	1	1	4	11	19	48	63	95	44
2	JCP	6	8	9	26	25	28	44	51	38	52
3	EDS	2	5	4	3	1	13	26	27	31	95
4	ESPR	0	2	2	2	9	8	18	39	82	14
5	JEM	1	1	0	1	3	3	24	16	13	32
6	BCB	0	0	0	0	0	0	0	9	32	46
7	SR	0	1	2	1	2	3	6	12	13	40
8	ACS	4	7	7	5	4	11	6	10	13	6
9	IJHE	0	1	1	1	1	3	6	4	9	40
10	STE	1	0	0	7	6	10	9	8	14	11

A detailed study on publication trends over the last decade (2015 to 2024) in the top ten journals depicts that there is a steep increase in research on sustainable development and climate change in India (Figure 5). Among these journals, Sustainability stands out as a leader of young journals, which are growing in quantity exponentially. Starting with modest contributions (2 articles in 2015), it peaked at 95 publications in 2023, indicating its pivotal role in disseminating interdisciplinary research on sustainability (Table 4). The Journal of Cleaner Production consistently maintained high output throughout the study period. With a notable surge starting in 2018 (26 articles) and peaking at 52 in 2024, this journal's focus on cleaner production practices aligns well with the evolving research priorities in sustainable development. Similarly, Environment Development and Sustainability demonstrated sharp growth, particularly in 2024, with 95 publications, reflecting its increasing relevance in addressing sustainability challenges in the Indian context. Environmental Science and Pollution Research also exhibited a significant rise, especially from 2021 onwards, with 82 publications in 2023. This growth underscores the escalating focus on environmental impacts and pollution-related studies within the broader sustainability framework. Conversely, some journals exhibited fluctuating trends. For instance, ACS Sustainable Chemistry & Engineering showed high activity between 2015 and 2020 but recorded fewer publications in recent years. Similarly, Science of the Total Environment displayed inconsistent output, suggesting a shift in its thematic focus.

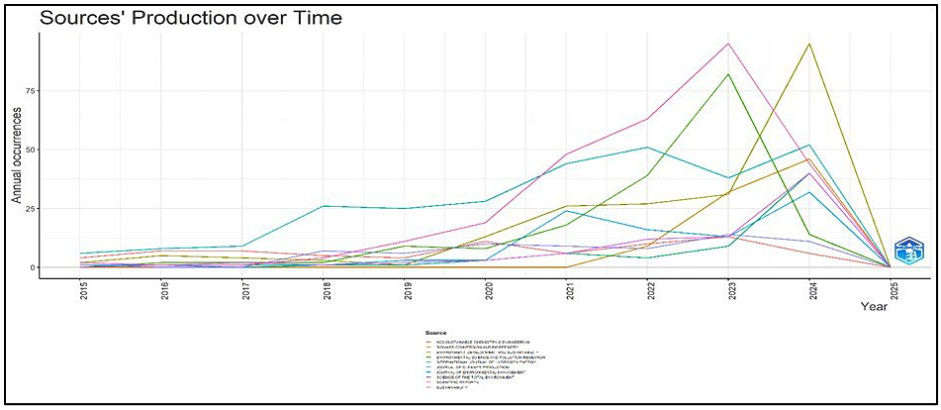

Fig. 5: Publication Trends of Leading Journals (2015–2024)

Bradford's Law

Core Journals Analysis

Applying Bradford's Law to analyse the publication trends in SDCC research highlights the concentration of high-impact journals that *significantly* contribute to this field. Zone 1, representing the core journals, includes publications that account for the majority of the research output (Table 5). These journals demonstrate their centrality in advancing knowledge and fostering interdisciplinary studies in sustainable development and climate change within the Indian context. The journal Sustainability tops the list with 288 publications, followed by the *Journal of Cleaner Production* with 287 articles, reflecting their dominance in the field. Other significant contributors include Environment Development and Sustainability (207 publications) and *Environmental Science and Pollution Research* (176 publications). Together, these journals form the foundation of Zone 1, contributing a cumulative total of 1,424 publications. This underlines their pivotal role in shaping the discourse and providing a platform for scholarly exchange.

Table 5: Core Journals Identified by Bradford's Law

Sources	Rank	Frequency	Cumulative Frequency
Sustainability	1	288	288
Journal of Cleaner Production	2	287	575
Environment Development and Sustainability	3	207	782
Environmental Science and Pollution Research	4	176	958
Journal of Environmental Management	5	94	1052
Biomass Conversion and Biorefinery	6	87	1139
Scientific Reports	7	80	1219
ACS Sustainable Chemistry & Engineering	8	73	1292
International Journal of Hydrogen Energy	9	66	1358
Science of the Total Environment	10	66	1424

Additionally, the presence of specialized journals such as *Biomass Conversion* and *Biorefinery* and *ACS Sustainable Chemistry & Engineering* reflects an increasing focus on sustainable technologies and innovative solutions. *Science of the Total Environment* further highlights the interdisciplinary research, addressing environmental, social, and technological dimensions. The corresponding graphical representation of Bradford's Law distribution (Figure 6) illustrates the steep dominance of Zone 1 journals

compared to the flatter curve of Zones 2 and 3. This visualization reinforces the idea that a small number of journals contribute disproportionately to the total body of research.

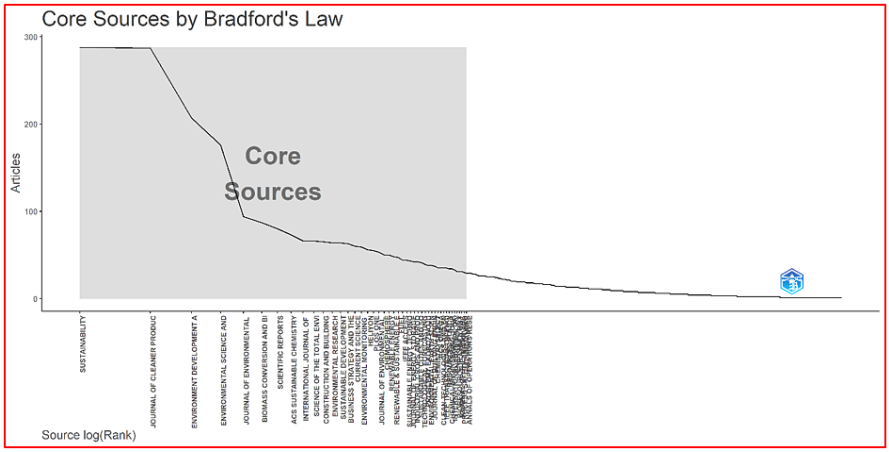

Fig. 6: Core sources by Bradford's Law in SDCC research

Most Prolific Authors

Table 6 presents an overview of the research productivity and impact metrics of leading authors in SDCC. Among the top contributors, Kumar A stands out as the leading author with 287 publications, the highest h-index of 39, and a total citation count of 5503, indicating exceptional productivity and influence in the field since its first publication in 2015. Trailing him closely is Kumar S, who has produced such a rich academic output since 2016 with 200 publications, an h-index of 29 and 4418 citations. The impact metrics suggest that Singh A is the best performer in authoring highly cited papers, as shown by their g-index of 66. Additionally, the m-index (normalized h-index by years active) of 3.9 for Kumar A points to a sustained and high-impact research trajectory.

Table 6: Productivity and Impact of Top Authors in SDCC Research

Rank	Authors	Articles	Articles Fraction-alized	H-Index	G-Index	M-Index	TC	PY-Start
1	Kumar A	287	63.87	39	62	3.9	5503	2015
2	Kumar S	200	43.62	29	61	3.222	4418	2016
3	Kumar R	172	36.06	27	42	3	2284	2016
4	Singh A	148	36.27	26	66	2.6	4616	2015
5	Singh S	133	27.76	26	45	2.6	2368	2015
6	Kumar P	124	22.78	25	50	2.5	2806	2015
7	Kumar V	106	20.38	22	49	3.143	2582	2018
8	Sharma S	102	19.6	19	36	1.9	1464	2015
9	Singh R	96	19.16	20	32	2	1252	2015
10	Ghosh S	87	20.35	23	42	2.875	1910	2017

Kumar V and Ghosh S have contributed to the PY with promising contributions made in 2018 and 2017 PY-Starts, respectively. Their high m-index values of 3.143 and 2.875 indicate a huge potential to guide future research directions. Moreover, authors such as Singh A and Singh S show balanced productivity and citation profiles, pointing out their good collaborative as well as multidisciplinary

involvement in research. Figure 7 also depicts the relative productivity and citation impact of these authors via the bar chart and shows that the leading contributors, such as Kumar A and Kumar S are in the light of dominating contributors. In addition, it underlines the measurable achievements of young researchers, whose publishing history is shorter but whose signals are pervasive. Collectively, these observations underline the dynamic nature of sustainable development and climate change research in India.

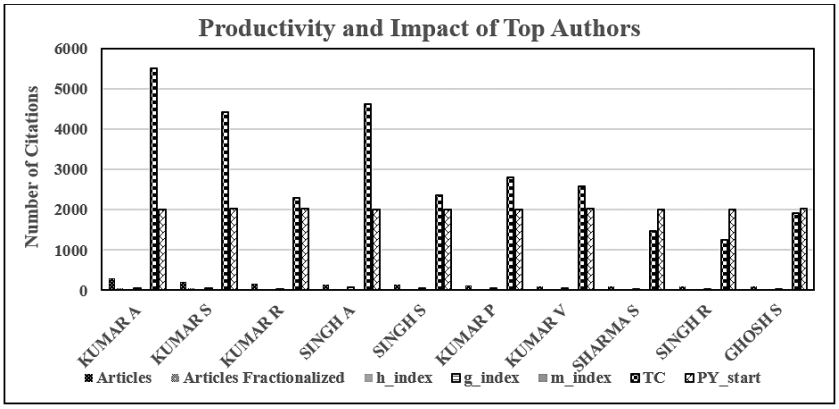

Fig 7: Productivity and impact of top authors

Most Leading Affiliations

Table 7 shows the top 10 contributor institutions towards sustainable development and climate change in India. These affiliations were chosen based on how many articles they published during the study period (2014–2024). The greater number of articles published fortifies the position of the institution in the ongoing research in these domains. Remarkable is the Indian Institute of Technology System (IIT System), which published 1733 articles, even more than the Indian Council of Agricultural Research (ICAR) with 1023 articles. As such, these institutions are among the main producers of scholarly work in these areas and epitomize strong research capabilities in the areas of climate and sustainability. Remarkably, King Saud University and Tehran University of Medical Sciences together with other international universities as well play a significant role in these domains by publishing 348 and 274 articles respectively.

Table 7: Most leading affiliations

Rank	Affiliations	Articles
1	Indian Institute of Technology System (IIT System)	1733
2	Indian Council of Agricultural Research (ICAR)	1023
3	National Institute of Technology (NIT System)	838
4	Council of Scientific and Industrial Research (CSIR) - India	610
5	King Saud University	348
6	University of London	310
7	Indian Institute of Management (IIM System)	288
8	Saveetha Institute of Medical and Technical Science	277
9	Indian Institute of Technology (IIT) - Kharagpur	275
10	Tehran University of Medical Sciences	274

A large number of articles from Indian institutions like IITs, NITs and CSIR represent the robust research infrastructure that India boasts, particularly in technology, agricultural sciences and industrial research areas that contribute significantly to meeting challenges of sustainability and climate change. Closely linked to technological innovation, renewable energy, and environment studies, these institutions closely coincide with sustainable development goals (SDGs) India wants to focus on. Participation by King Saud University and Tehran University of Medical Sciences indicates that climate change research is a global priority and a growing trend of collaborated work across geographical borders to solve environmental problems. The research field is collaborative and interdisciplinary, of which these are just a few of the many affiliations and collaborations that constitute the fields of technology, agriculture, policy, health sciences, etc.

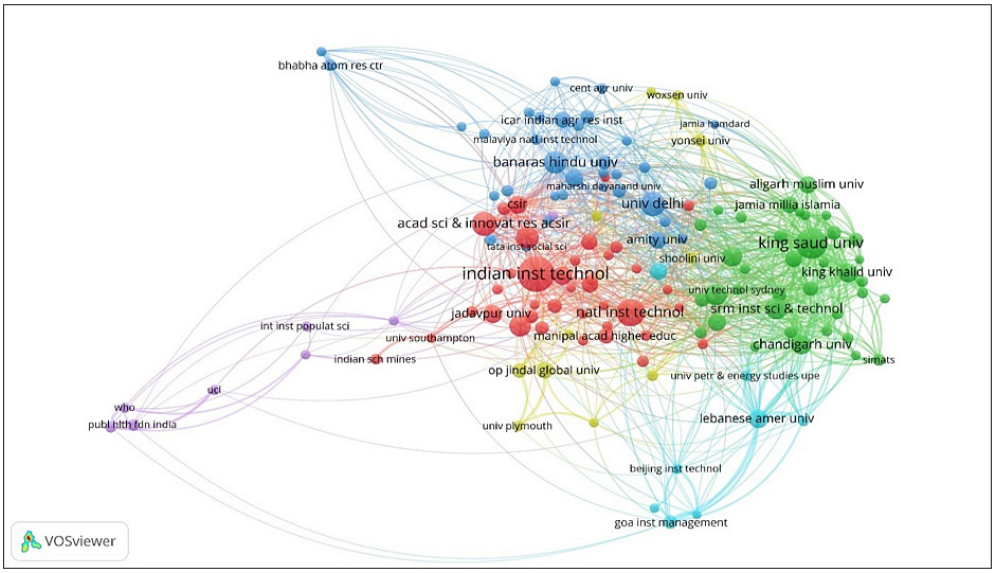

Fig. 8: Network Visualization of Institutional Collaborations on Climate Change and Sustainable Development

Table 9: Leading Countries by Corresponding Authors

Rank	Country	Articles	Articles %	SCP	MCP	MCP %
1	India	6506	73.2	4921	1585	24.4
2	China	371	4.2	0	371	100
3	USA	242	2.7	0	242	100
4	United Kingdom	241	2.7	0	241	100
5	Australia	129	1.5	0	129	100
6	Korea	113	1.3	1	112	99.1
7	Malaysia	79	0.9	0	79	100
8	Saudi Arabia	77	0.9	0	77	100
9	Canada	65	0.7	0	65	100
10	Germany	65	0.7	0	65	100

This is further supported by the figure 8 which shows how these institutions are linked and how they are working together to propel climate change solutions and sustainable development strategies.

The existence of strong positive links between Indian institutions and their world counterparts reveals the need for international cooperation in dealing with complex global issues such as climate change and sustainable resource management.

Most Relevant Countries by Corresponding Author

The distribution of articles by country for research on sustainable development and climate change, with special reference to India, is shown in table 9. It shows the total number of articles published by the corresponding authors in different countries, the percent of total articles contributed by different countries and single country publications (SCP) versus multi-country publications (MCP).

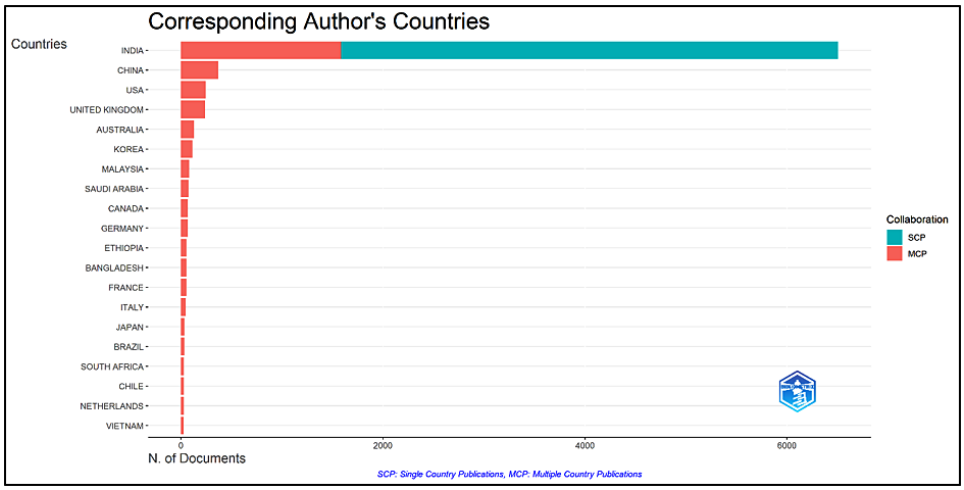

Fig. 9: Corresponding authors' countries

It is found that India stands out as the largest contributor to research on sustainable development and climate change in this study, with 73.2% of the total articles published by corresponding authors from India. Out of these, 4921 articles are SCP, and 1585 articles are MCP, indicating a considerable proportion of international collaborations (Figure 9). The MCP percentage for India is 24.4%, suggesting that while India leads in research output, international collaborations also play a significant role. China, the USA, and the United Kingdom have significantly fewer contributions compared to India, each contributing around 2.7% to 4.2% of the total articles. All their publications are multi-country collaborations (MCP=100%), indicating strong international research partnerships but no single-country publications in the dataset. Australia, Korea, Malaysia, Saudi Arabia, Canada, and Germany also show active participation, with all of their publications being multi-country collaborations (MCP =100%), suggesting global cooperation in research efforts related to sustainable development and climate change.

Most Cited countries

Figure 10 presents data on the most frequently cited countries in research on sustainable development and climate change. From Table 10, we can observe that India has the highest total number of citations (158153) despite having a relatively low average article citation rate (17.88). This suggests that India has a large volume of publications, but individual papers may not be as highly cited as those from other countries. In contrast, Spain has the highest average article citation rate (101.90), indicating that their articles are highly influential within the field, although their total citation count is lower than countries like the USA or India. Countries like the USA and China have relatively high total citations but moderate average citations per article, which

may suggest that they have a large volume of research output across various fields, with certain influential studies contributing to their citation totals. Conversely, countries such as Australia and Malaysia exhibit moderate citation counts but higher-than-average article citation rates, indicating that their research tends to have a more significant impact per publication.

Table 10: Countries with the highest citation counts

Rank	Country	Total Citations	Average Article Citations
1	India	158153	17.88
2	USA	16497	68.20
3	China	12215	32.90
4	United Kingdom	9194	38.10
5	Australia	3124	24.20
6	Canada	2833	43.60
7	Korea	2819	24.90
8	France	2109	41.40
9	Malaysia	2025	25.60
10	Spain	1732	101.90

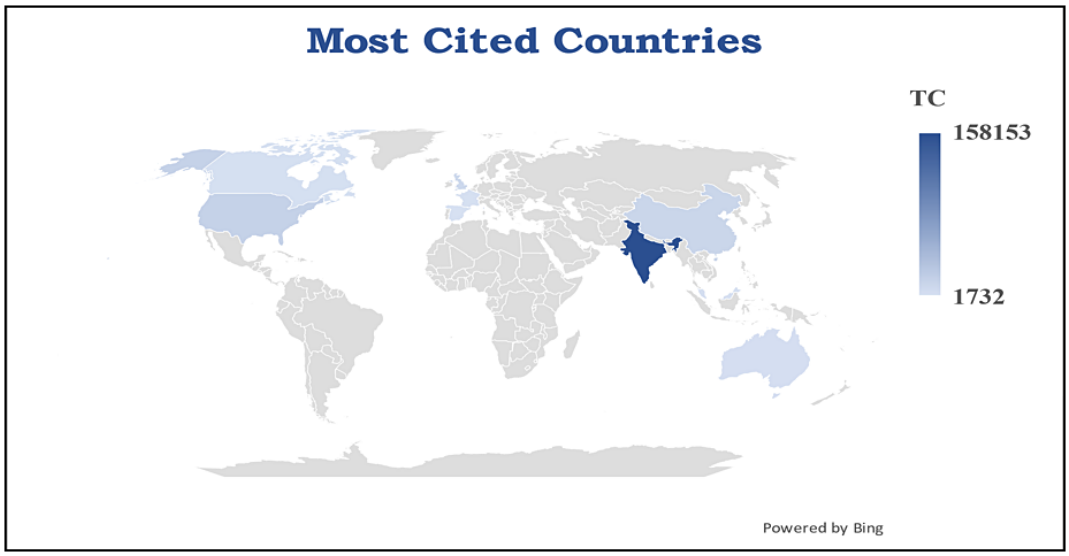

Fig. 10: Most cited countries

Papers that have substantially contributed and widely cited in subsequent research have been included in Table 11. The Total Citations column is basically a summation of the number of citations to all other documents related to this document since its publishing. The TC per Year is an indicator of the average number of citations that a specific paper gets each year and an indicator of its effect in time. Normalized TC are the citations normalized by a document's age, to compare fairly papers published at different times. This metric is very useful to measure when one recent article outweighs others, in comparison to older ones. Taking the example of the study done by KRUK ME (2018) in Lancet

Global Health that contains a total of 1707 citations, has a high 243.86 TC per Year, and has a normalized TC of 35.49, it therefore suggests that the paper is clinging to the minds of researchers even after some time. In contrast, older documents such as KASSEBAUM NJ (2016) include fewer total citations but display a more moderate (though steady) citation trend.

Table 11: Most globally cited documents

Rank	Papers	DOI	Total Citations	TC per Year	Normal -ized TC
1	KRUK ME, 2018, LANCET GLOB HEALTH	10.1016/S2214-109X (18)30386-3	1707	243.86	35.49
2	AKINYEMIJU T, 2017, JAMA ONCOL	10.1001/jamaoncol. 2017.3055	1490	186.25	29.15
3	KASSEBAUM NJ, 2016, LANCET-a	10.1016/S0140-6736 (16)31460-X	1263	140.33	23.62
4	FITZMAURICE C, 2019, JAMA ONCOL	10.1001/jamaoncol. 2019.2996	1052	175.33	25.56
5	KASSEBAUM NJ, 2016, LANCET	10.1016/S0140-6736 (16)31470-2	694	77.11	12.98
6	GINSBURG O, 2017, LANCET	10.1016/S0140-6736 (16)31392-7	679	84.88	13.28
7	ANDERSON I, 2016, LANCET	10.1016/S0140-6736 (16)00345-7	646	71.78	12.08
8	WILKINSON JL, 2022, P NATL ACAD SCI USA	10.1073/pnas.211394 7119	645	215.00	31.51
9	ROCKSTRÖM J, 2017, AMBIO	10.1007/s13280-016-0793-6	617	77.13	12.07
10	BARDGETT RD, 2021, NAT REV EARTH ENV	10.1038/s43017-021-00207-2	584	146.00	19.42

Analysis of Co-occurrence of Authors' Keywords

The quantitative summary of the top ten most frequently used keywords as shown in Table 12, provides a holistic impression of the prevalent themes and their interconnectivity. Sustainable Development is the most central keyword (620 occurrences; 560 link strength) in the network due to its top status in the world and national agendas and its alignment with global and national priorities, the Sustainable Development Goals (SDGs). Sustainability (494 occurrences, 486 total link Strength) is closely associated with a focus on the balance of environmental, social and economic dimensions. The keyword India (319 occurrences, 252 total link strength) highlights the geographical focus of research, addressing region-specific sustainability challenges. A targeted focus on SDGs (317 occurrences, 242 total link strength) underscores the growing interest in evaluating India's progress toward achieving these goals. Themes like Renewable Energy (163 occurrences, 217 total link strength) and Climate Change (170 occurrences, 200 total link strength) highlight their critical roles in energy transitions and mitigation strategies. Emerging technologies such as Machine Learning (119 occurrences, 142 total link strength) and Artificial Intelligence (65 occurrences, 101 total link strength) signify the increasing use of data-driven approaches in addressing sustainability issues. The focus on the Circular Economy (136 occurrences, 174 total link strength) reflects the emphasis on resource efficiency, resonating with India's National Resource Efficiency Policy.

Table 12: Most Relevant Co-occurrence-authors' keywords

Rank	Keywords	Occurrences	Total Link Strength
1	Sustainable Development	620	560
2	Sustainability	494	486
3	India	319	252
4	Sustainable Development Goals	317	242
5	Renewable Energy	163	217
6	Climate Change	170	200
7	Circular Economy	136	174
8	Machine Learning	119	142
9	Artificial Intelligence	65	101
10	Environment	62	97

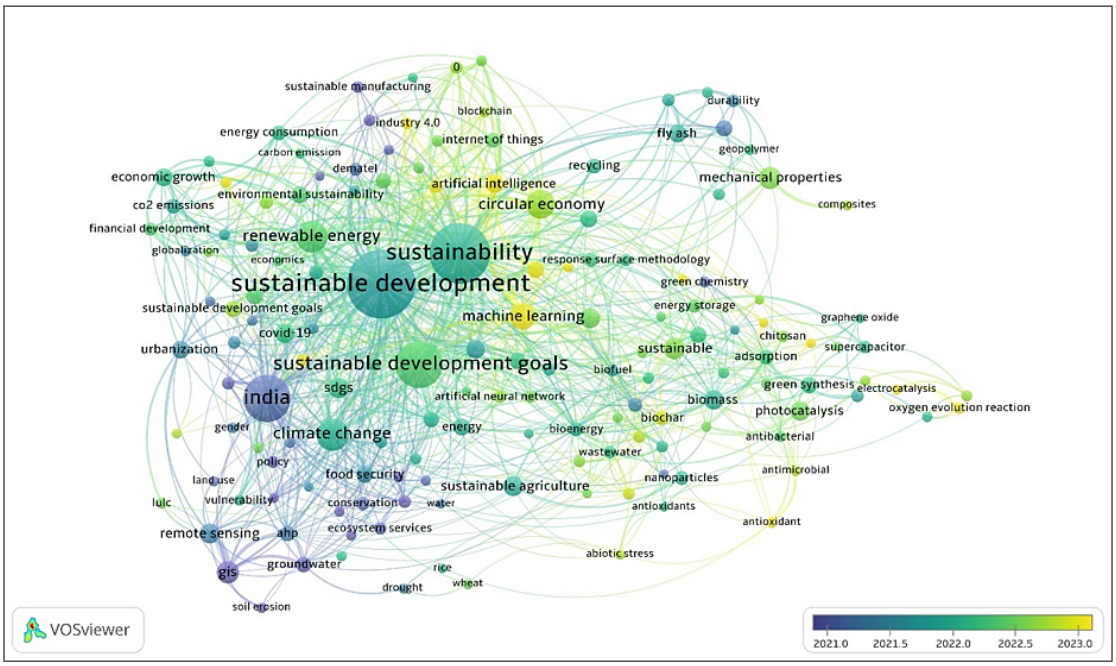

Fig. 11: Visualisation of Co-occurrence of Authors' Keywords

Figure 11 illustrates the co-occurrence network of authors' keywords, revealing the thematic clusters and their interrelationships. The dense connections around "Sustainable Development" and "Sustainability" indicate their integrative role across multiple research domains. Keywords such as "Renewable Energy," "Circular Economy," and "Climate Change" form distinct clusters, reflecting specialized areas of research.

Thematic Mapping of Research Trends

The thematic map visualizes the landscape of research trends by categorizing themes into four quadrants based on their relevance (centrality) and development (density). Figure 12 shows the evolution of research trends in sustainable development and climate change, categorizing themes based on their prominence and development stage. The motor theme, "sustainable," stands at the core, reflecting its

foundational importance across various disciplines. Basic themes include Sustainable Development, Sustainability, Sustainable Development Goals (SDGs), Climate Change, India, and Environmental Sustainability, which form the backbone of research in this domain. Emerging or declining themes, such as mechanical properties, indicate a decline in relevance compared to other more central topics like climate change and renewable energy. Niche themes, including GIS, Remote Sensing wastewater treatment, and adsorption, represent specialized areas gaining attention for their potential in addressing environmental challenges. In this thematic map, the research landscape is overviewed, showing both prominent and emerging trends in the research field.

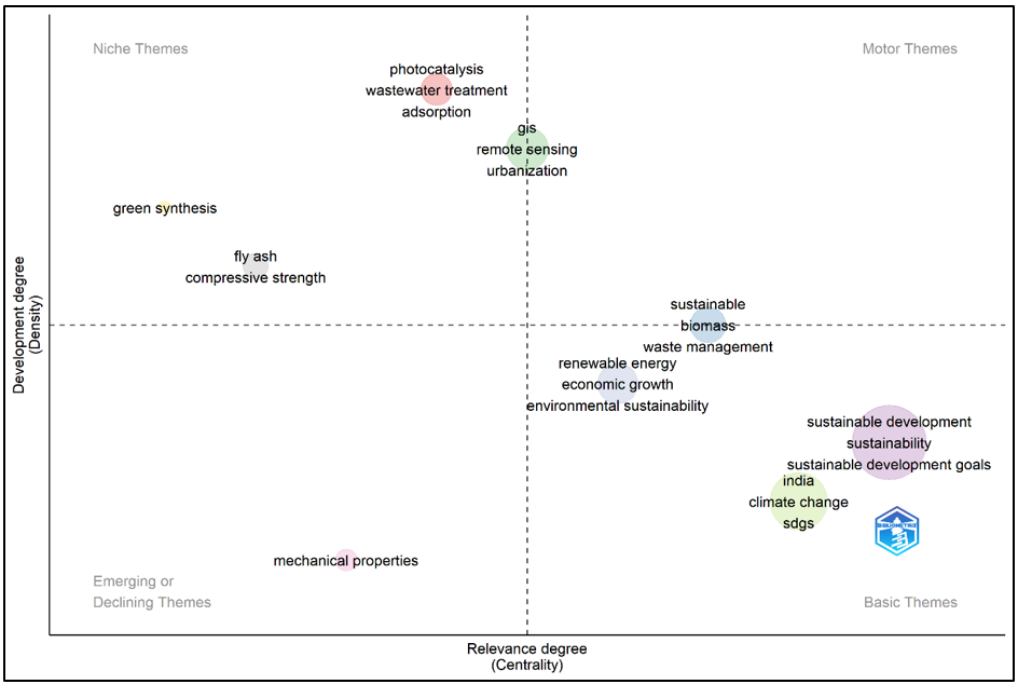

Fig. 12: Thematic Mapping of Research Trends

Country Collaboration Network

The global collaborations in sustainable development and climate change research are shown in Figure 13 through the country collaboration network. Dense and thick connections with countries like China, the US, the UK, Saudi Arabia, Iran, Russia and South Korea can be seen in India in the figure. These strong tie connections confirm India's active roles and frequent collaboration in research and highlight India's important role in the global research network and its participation in the global effort of sustainability and climate change-related research. The strength and frequency of collaborations are reflected in the thickness of the lines, with larger, continuous collaborations corresponding (and being) the thicker lines. On the contrary, London's thinner lines indicate countries with comparatively feeble interactions or far less frequent interactions with India in this regard.

Co-authorship Analysis by Country

The global collaboration in research of sustainable development and climate change is shown in Table 13, which gives the overview of the top 10 contributing countries. With 8,844 documents, 158,153 citations, and link strength of 9,082, India takes a leading position by a huge magnitude addressing local challenges and contributing to policy and technological solutions. The second-ranked country USA possesses strong linkages with India through 742 documents and 24,435 citations in interdisciplinary areas such as renewable

energy and GIS application. Working together on shared issues in urban sustainability and climate adaptation, China has 649 documents, 216 of them documents, with 24,664 citations. England (573 documents) and Saudi Arabia (636 documents) also show strong collaborative ties, contributing to thematic areas such as circular economy and urbanization. Emerging contributors like Australia, Canada, Malaysia, and South Korea are increasingly involved, focusing on technological innovations and policy development, with high citation-per-document ratios reflecting impactful research contributions.

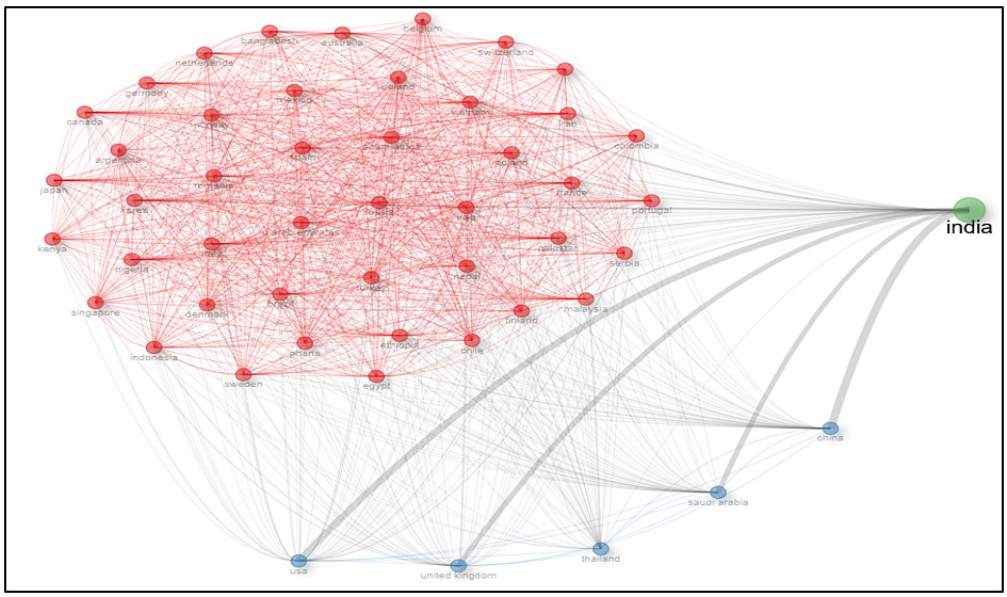

Fig. 13: Visualisation of Country Collaboration Network

Table 13: Co-authorship Countries

Rank	Country	Documents	Citations	Total Link Strength
1	India	8844	158153	9082
2	USA	742	24435	2496
3	Peoples R China	649	24664	2358
4	England	573	20534	2164
5	Saudi Arabia	636	9698	1888
6	Australia	396	11475	1594
7	Canada	257	8489	1240
8	Malaysia	301	7900	1186
9	South Korea	371	8340	1080
10	South Africa	182	8356	967

Figure 14 illustrates the global collaboration network, emphasizing India's central role in connecting researchers worldwide. The thickness of the nodes visualises the quantity of documents contributed by each country, while the thickness of the edges indicates the strength of collaborative ties. The largest node, India, serves as the nexus point for research activities connecting prominently to developed countries such as the USA, England, and Australia, as well as emerging economies such as China and Malaysia.

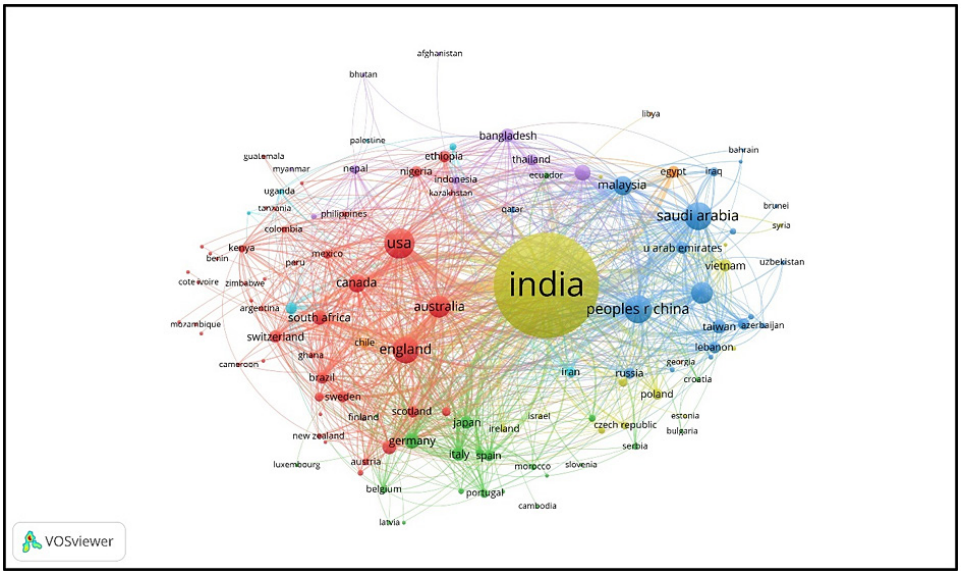

Fig. 14: Visualisation of Co-authorship Countries

Co-Authorship Analysis

Summarized in Table 14, the findings show the individual authors' productivity, influence and the strength of their collaborations in the field. Avik Sinha is by far the most productive author on this list, with 55 publications, 5349 citations, and total link strength (TLS) of 51. Sunil Luthra claims 45 documents, 2,358 citations, and a TLS of 58, and also shows the strongest co-author networks, confirming his productivity. Other prolific authors like Sachin Kumar Mangla (42 documents, 2348 citations, TLS 45) and Anil Kumar (43 documents; 1258 citations; TLS 42) exhibit substantial contributions and robust collaboration. In addition, Anil Kumar Patel and Reeta Rani Singhania are emerging contributors with fewer publications (14 documents each); nevertheless, they have much lower TLS scores, i.e., 35, and are both actively participating in collaborative research. Total Link Strength (TLS) highlights the extent and strength of an author's co-authorship network, with Sunil Luthra and Avik Sinha showcasing extensive, multidisciplinary collaborations, while contributors like Cheng-Di Dong (TLS: 32) and Chiu-Wen Chen (TLS: 29) have smaller, yet possibly significant networks. The trends of these highlight the need for a strong collaborative environment to promote sustainable development and climate change research.

Table 14: Top 10 Co-authorship-authors

Rank	Author	Documents	Citations	Total Link Strength
1	Luthra, Sunil	45	2358	58
2	Sinha, Avik	55	5349	51
3	Mangla, Sachin Kumar	42	2348	45
4	Kumar, Anil	43	1258	42
5	Patel, Anil Kumar	14	187	35
6	Singhania, Reeta Rani	14	187	35
7	Dong, Cheng-Di	12	77	32
8	Chen, Chiu-Wen	10	76	29
9	Dogan, Buhari	16	901	29
10	Singh, Rajesh	20	334	28

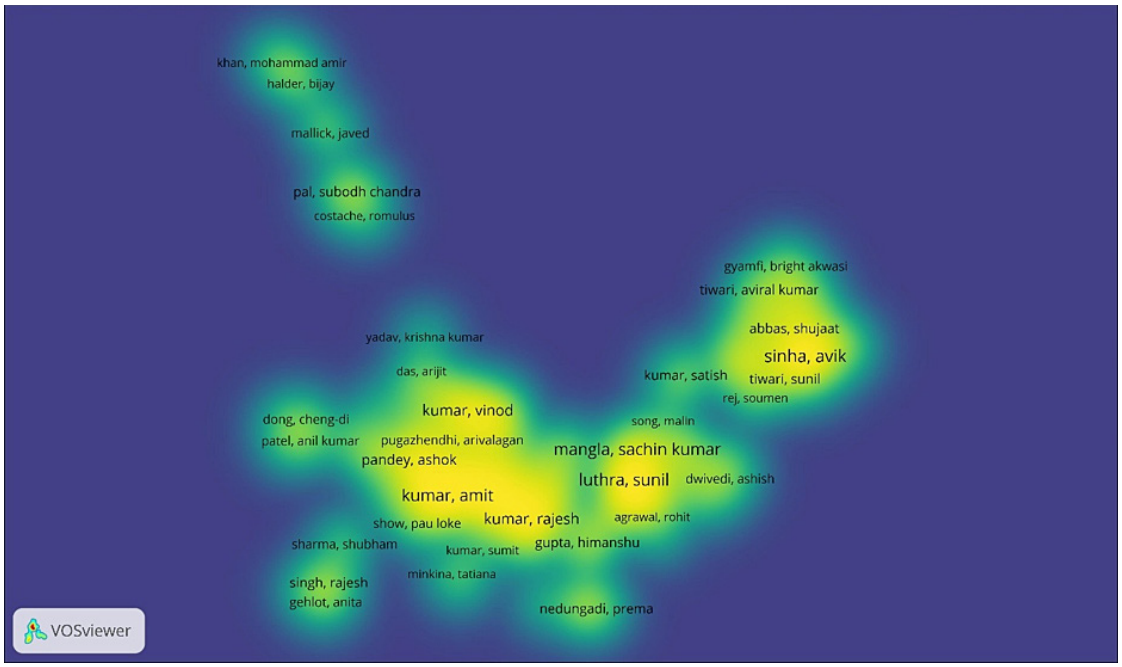

Fig. 15 Visual Representation of the co-authorship network

Figure 15 shows a density map of the co-authorship network to show the level of interconnectedness and collaboration among authors. Higher productivity and citation impact are proxied by larger nodes, and stronger collaborations are proxied by thicker links. Thematic collaborations and research hotspots are shown through distinct clusters that demonstrate that teamwork is critical in advancing sustainable development and climate change research.

Factorial Analysis of Conceptual Structure Map

The Multiple Correspondence Analysis (MCA) was conducted based on the author's keywords, allowing for the identification of key terms and their relationships within the research landscape. The analysis identified two principal dimensions (Dim1 and Dim2), which represent the underlying conceptual structure of the topics (Table 15). The factorial analysis showed that Cluster 1 contains sustainability terms which frequently join together in academic literature (Figure 16). Sustainable Development (-1.37, -0.55), Sustainability (0.04, 1.74), India (1.13, -0.89), and Sustainable Development Goals (1.32, -0.64) cluster together as they are strongly linked in influencing sustainability discourse. Research in sustainable development relies on these keywords for establishing conceptual and policy-focused content. The cluster includes terms Climate Change (0.04, 0.01) and Renewable Energy (-0.35, -0.17) as well as Circular Economy (0.10, 0.31) and Machine Learning (0.15, -0.02) and Mechanical Properties (0.15, 0.07) and GIS (0.45, -0.53) although they have varying placement along the dimensions.

Table 15: Factorial Analysis of Author's Keywords

Words	Dim1	Dim2	Cluster
Sustainable Development	-1.37	-0.55	1
Sustainability	0.04	1.74	1
India	1.13	-0.89	1
Sustainable Development Goals	1.32	-0.64	1
Climate Change	0.04	0.01	1
Renewable Energy	-0.35	-0.17	1
Circular Economy	0.10	0.31	1
Machine Learning	0.15	-0.02	1
Mechanical Properties	0.15	0.07	1
GIS	0.45	-0.53	1

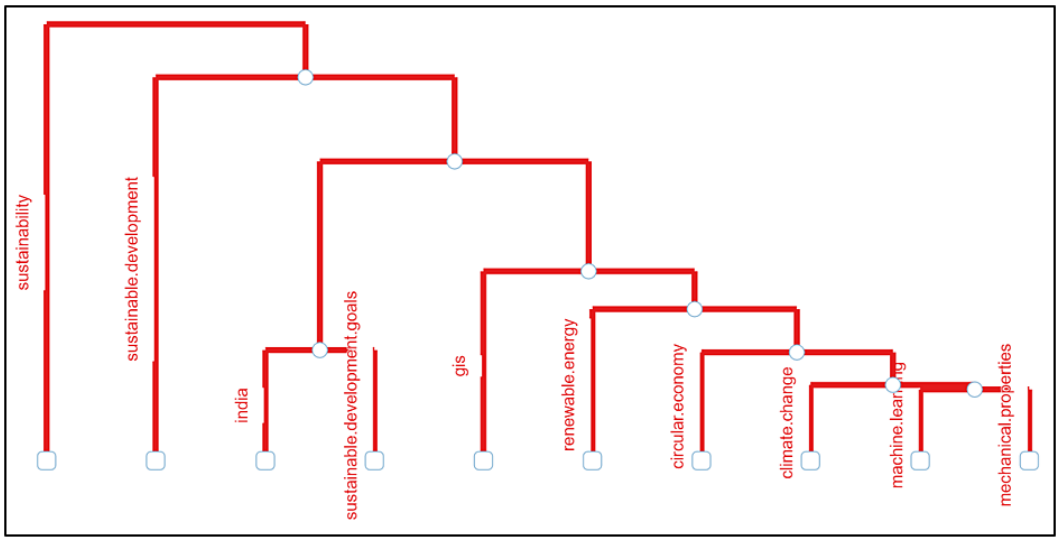

Fig. 16: Factorial analysis of conceptual structure map

The analysis demonstrates new directions in sustainability investigation because research incorporates technical improvements such as GIS systems as well as Machine Learning capabilities. Mechanical Properties within the cluster extend sustainability research boundaries to material sciences and engineering studies about sustainable materials and renewable energy technology development. Sustainable Development Goals display proximity to India in the research map, indicating that the country has established a dedicated policy framework for SDG implementation and climate action methods. The cluster demonstrates emerging data-driven sustainability research because Machine Learning and GIS have started to appear together. Climate Change, together with Circular Economy, covers extensive areas within the two dimensions because these concepts merge sustainability elements between environmental and economic domains and technological advancements. The factorial analysis confirms that sustainability research is going through structural change by identifying traditional research areas along with novel technological connections which define upcoming research terrain.

Discussion

The analysis of sustainable development research alongside climate change shows significant trends in scholarly publications, including author recognition and international research consortiums. Research output statistics show a substantial upward trend over the years because of mounting interest in sustainability-based research methods for addressing critical environmental hazards and social problems. The unprecedented rise in publications reflects the expanding influence of sustainability science throughout different subject fields because of policy initiatives, international agreements, and technological breakthroughs.

The source-wise distribution of documents indicates that leading journals such as Sustainability, JCP, and RSER serve as key platforms for disseminating research findings. These journals emphasize the research that combines multiple points of view about sustainability including economic aspects together with social perspectives and environmental dimensions. Open-access publications demonstrate growing influence in facilitating both knowledge circulation and user accessibility. The study reveals how prominent researchers have fundamentally guided sustainability research development. Leading authors demonstrate the critical role of academic collaboration followed by high citation benchmarks in establishing research influence. Academic researchers such as Avik Sinha, Sunil Luthra, and Sachin Kumar Mangla maintain high research productivity and impact, and their scientific work continues to be recognized extensively throughout sustainable practice discussions. The extensively cited research papers illustrate how

investigations about renewable energy transits coupled with circulatory economy systems together with climate protection protocols have substantively shaped official policy frameworks and practical implementations.

Integration of deeper sustainability keyword analysis reveals major research themes in the field of sustainability. The frequent appearance of Sustainable Development Goals and Climate Change, along with Renewable Energy and Circular Economy in literature, indicates globally active researchers are deeply focused on long-term environmental challenges. The appearance of technological terms GIS, Machine Learning, and Big Data signals how sustainability research adopts data-oriented computational approaches. The factorial analysis results confirm these theoretical frameworks through concept clustering, which showcases the multidisciplinary within sustainability science research. Research publications concerning sustainability originate mainly from India along with the USA and China. The increasing research impact characterizing India shows that the country commands a major position in both publications and citation records for managing domestic and international sustainability issues. Transnational collaboration networks between India and the USA demonstrate that sustainability research continues to grow as a global joint effort. This academic field sees growing investments from emerging economies including Malaysia and Saudi Arabia because they focus on developing sustainability research while advancing technological capabilities and designing policy frameworks.

The institutional collaboration analysis displays top research institutions, including the IITs, the University of Oxford, and Tsinghua University as leaders in sustainability research. Through their research operations, these institutions combine publication quality with international partnerships to produce impactful work. Developing academic institutions actively participate in sustainability research, showing progressive global participation in scientific sustainability investigations. Both co-authorship analyses identify the networked nature of sustainability research through an assessment at the country level as well as the author level. Prolific scholarly connections between leading researchers and academic institutions censure the critical need for collective work to solve challenging environmental and social issues. India stands as a core connector in international research networks as confirmed by co-authorship network visualizations. The lower total link strength (TLS) scores among new researchers reveal exciting prospects for reaching out to both early-career scholars and research centres located in regions that lack representation in the academic community. The factorial analysis of the conceptual structure map illuminates core research themes connected through their relationships. The terminology groupings, including Sustainability, Renewable Energy, and Climate Change, reflect research momentum dedicated to energy system changes combined with nature preservation and governmental regulation approaches. Recent advancements in modern analytical technologies incorporating GIS and machine learning drive the evolution of sustainability research.

The analysis shows that research accomplishments related to sustainability and climate change have achieved substantial progress during this period. The global distribution of research efforts, the increasing role of international collaboration, and the integration of technology-driven methodologies all point towards an evolving research landscape. The notable research prominence of India needs improved multidisciplinary partnerships alongside expanded international relations to meet sustainable development needs. Future research endeavours should build enhanced collaborative networks alongside regional research expansions in under-represented areas and technological innovations which will fuel impactful sustainability solutions.

Conclusion

In this study, a bibliometric analysis of research trends in sustainable development and climate change in India is provided, analyzing the research landscape in detail. This research has used Web of Science and Biblioshiny or VOS viewer, thereby, identifying the key themes and main authors and the dynamics of global research collaborations. Analysis showed a robust orientation towards the main themes, primarily Sustainable Development, Sustainability, Climate Change, and Renewable

Energy, as they are key components and central to ongoing future discourse in the context of India. Noteworthily, niche topics like Photocatalysis, Wastewater Treatment, and Adsorption are growing in importance indicating new emerging areas. Thus, it shows a tendency to address corresponding technological and environmental problems with sustainable approaches. Moreover, the Sustainable Development Goals (SDGs) are increasingly becoming important in the research; in line with India's commitment to global sustainability framework.

This work also points to the importance of collaborative research networks for moving the field ahead. Interestingly, India has really good relations with countries such as China, the USA, the UK, Saudi Arabia, Iran, Russia, and South Korea and has dense co-authorship ties. By collaborating, we implement a multidisciplinary method to identify climate change and sustainability challenges, improving upon a united global effort. Using factorial analysis of keywords, there is a clustering of concepts with regard to Sustainable development and India tightly co-occurring with core research areas, but newer issues such as Machine learning and mechanical properties indicate the inclusion of advanced technologies within sustainability and climate change research. It reflects the emerging interface of traditional environmental research with technological innovations.

Despite the increasing research output, there are, however, still some limitations. The scope of the study is limited to some of the databases and keywords, hence ignoring the works published outside of the given time frame or databases. In addition, the geographic concentration on India provides a rich study, but it hinders the capacity for global comparison. Finally, this bibliometric analysis characterizes the dynamic and changing state of SDCC research in India. The growing importance of interdisciplinary research, the rise of niche research themes, as well as the involvement of India in the global research community is demonstrated. Future research should further investigate these emerging trends, focusing on deepening collaborative efforts and expanding the integration of advanced technologies into sustainability initiatives.

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The authors do not have any conflict of interest.

Data Availability Statement
The manuscript incorporates all datasets produced or examined throughout this research study.

Ethics Statement
This research did not involve human participants, animal subjects, or any material that requires ethical approval.

Informed Consent Statement
This study did not involve human participants, and therefore, informed consent was not required.

Author Contributions
- **Md Mainul Sk:** Conceptualization, Methodology, Analysis, Writing – Original Draft.
- **Priyanka Chakraborty:** Writing – Review & Editing, Supervision.
- **Md Kaiyum Shaikh:** Literature Review, Data Collection, Data Curation, Visualization, Writing – Original Draft.
- **Tapas Ranjan Patra:** Formal Analysis, Writing – Review & Editing.
- **Subodh Ranjan Mishra:** Writing – Review & Editing.
- **Diptimayee Naik:** Resources, Supervision.
- **Amit Sardar:** Writing – Review & Editing.

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