Journal of Scientific & Industrial Research
Vol. 81, November 2022, pp. 1147-1161
DOI: 10.56042/jsir.v81i11.64456

Research on Sustainable Development Goals: How has Indian Scientific Community Responded?

Aakash Singh, Anurag Kanaujia & Vivek Kumar Singh*

Department of Computer Science, Banaras Hindu University, Varanasi 221 005, India

Received 12 July 2022; revised 25 October 2022; accepted 26 October 2022

Since the adoption of Sustainable Development Goals (SDGs) in 2015, various countries across the world have started programmes to achieve the relevant targets under SDGs. The advancements in research and development play a crucial role in achieving these targets. Motivated by this a few studies have tried to map the research publications with their relevance to specific SDGs. However, there are no existing detailed studies with reference to India. Therefore, this article attempts to measure the research activities on SDGs in India. It utilises standard bibliometrics approach and textual analysis of data collected from Dimensions database for a five-year period (2016–2020). The results show a positive response from the Indian research community towards the SDGs. About 12 percent of the total research output from India is found directly related to SDGs. The three SDGs namely SDG 3 (Good Health and Well-being), SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Change) have received most attention from the Indian research community. Technical subjects such as, Engineering, Medical and Health Sciences, and Chemical Sciences are the main contributors. The major contributing institutions, authors and journals are identified.

Keywords: Global goals, Indian science, Research trends, Science & technology

Introduction

There is an increasing focus on sustainable development in international community as the rapid industrial growth has led to various environmental, economic and societal challenges. The constitution and adoption of Sustainable Development Goals (SDGs) by United Nation signifies a universal call to act urgently and address these challenges being faced by the world.[1,2] These are a set of seventeen (17) guiding goals with 169 targets each focusing on an aspect of human development and sustainability of ecosystems. The role of research and development (R&D) is central in achieving the SDG targets and as a result, these have played an important role in promoting development of novel technologies from the various stakeholders.[3] For example, one of the targets of SDG3 (Good Health and Wellbeing) is "to reduce illness and death due to polluted air, water and soil" which warrants R&D in healthcare, transportation, chemical sciences etc. Due to this linkage between SDGs and R&D, researchers have conducted studies looking at the research and development activities related to SDGs across the world. Researchers have looked at the publications on SDGs at a global level and identified major focus areas, countries and collaboration patterns among authors.[4–6] However, in the case of India there are no detailed studies on national trends on research related to SDGs. The only know available text is from UK Research and Innovation (UKRI) India Impact Report[7], which discusses about the collaborative output between UK and India and highlights upon the part of the collaborative research which relates to SDGs. Hence, there is a need for exploring trends in SDG based research activities in India in order to address the existing knowledge gap.

Since the adoption of SDGs, India has placed special focus on climate action. This is reflected in its commitments at the international platform. India is one of the leading countries taking steps towards meeting the commitments of Sustainable Development Goals. It has made steady progress towards achieving the United Nations' SDGs in areas of health, energy, and infrastructure, as per NITI Aayog's latest SDG India Index.[8] It is leading the way in areas such as solar power, sanitation and health care, reforestation and adoption of cleaner fuels. Along with Germany, Finland and Singapore, it is among the few countries which are

*Author for Correspondence
E-mail: vivek@bhu.ac.in

meeting their nationally determined goals. The progress is a result of efforts of the various sectors of the economy adopting cleaner energy, efficient processes and sustainable practices, transition to more efficient motor vehicles and public transport in metropolitans, and use of new technologies for sustainable processes. A significant amount of this progress is thanks to the new research for eco-friendly technology development, adoption and policy interventions.[9–11] Being among the top five knowledge producers,[12] with more than 1.5 lac research papers being published every year, it is expected that Indian scientific community may have also taken steps forward in addressing the challenges in achieving the targets under various SDGs. It is in this context that the article attempts to identify the research publication activities on SDGs, by using standard bibliometric methods and textual analysis of published research articles from Indian authors.

Related Work

The research addressing challenges of sustainable development is fairly distributed across the different subject areas. As the impact of challenges covered under the SDGs (e.g., poverty, healthcare, water & sanitation, gender equality and climate change) is becoming more obvious, more research attempting to address the related challenges has been undertaken across the world.[13] However, like any other collective exercise, in absence of proper tracing and recapitulation, the cumulative impact from these exercises may end up being a zero-sum game.[14] To measure the impact, several governmental and non-governmental agencies have employed various assessment methodologies. For instance, the UN Sustainable Development Reports which are released each year, present the progress being made on the basis of 169 targets for the 17 goals based on the socio-economic and politico-cultural data contributed by the participating countries.[15–18] Reports such as the UNESCAP-SDG Report 2021 (https://www.unescap.org/kp/2021/asia-and-pacific-sdg-progress-report-2021), United Nations Economic and Social Commission for Western Asia 2016 (https://digitallibrary.un.org/record/1290039), Sustainable Development Solutions Network 2021 (https://resources.unsdsn.org/united-states-sustainable-development-report-2021); United Nations Development Group 2017-Common Country Analysis-India(https://unsdg.un.org/resources/unct-key-documents), are measuring and presenting the progress being made from different perspectives. In India, the SDG India Index published by the NITI Aayog performs a similar function on the level of individual states within India.[8] These evaluations highlight the achievements and point the areas which require attention from the policymakers.

In academic research, the estimations have focused on the engagement of researchers and academic staff in universities across the world as key players in promoting SDGs. Studies have provided useful methodologies and insights for analytical exercises in assessment of research in SDGs over the years. Keyword analysis is a widely used method for studying evolution of research topic and knowledge mapping. This has been utilised by authors to identify and study the research in SDGs.[4–6,19,20] Studies on publication metadata for global research output have explored major trends in research publications. Between the period of 2015 to 2019, United States, United Kingdom and China are among the top three active countries for research in the different SDGs. SDG 17 i.e., partnerships for SDGs, has the most research publications associated with it, followed by SDG 13, i.e., climate action. Other SDGs with high research activity include SDG 12 (responsible consumption and production), SDG 15 (life on land), SDG 3 (good health and well-being), and SDG 1 (no poverty).[6] Co-citation occurrence showed that SDG 11 and SDG 3 are closely related and are frequently referred together in research publications.[4] Most of the research corresponding to SDGs is published from research areas of Life sciences & Biomedicine, and Social Sciences.[5] These studies have started the important process of exploration of research trends in SDGs, and cover only a bird's eye view of the global research trends. For a better understanding, regional trends in research are also necessary. A review focused on data on academic and expert literature from 26 countries, highlights issues of adoption of systems thinking and integrated analytical approaches and models.[21] Role of universities and their engagement with SDGs has been explored as well.[20]

Research Gaps and Objectives

Although, globally several studies have been conducted to assess the STI activities related to SDGs, there are no detailed studies in Indian context, with only a few reports providing an oblique reference to STI activities in India related to SDGs.[7] The available bibliometric studies have largely focused on the

international scenario in the research on SDGs. This research gap is the primary motivation for the present study. It explores the research trends in India, to draw specific insights into the outlook and functionality of the research community with respect to the SDGs. More specifically, the paper attempts to answer the following research questions:

RQ1: What is the overall quantum of research publications from India that are related to the SDGs?

RQ2: What is the relative contribution of research publications in each SDG at a national level as well as in individual universities and research institutions?

RQ3: What are the main thematic areas which have the most research activities in the case of SDGs?

To answer these questions, we have used the data on publications from India and identified trends and publication patterns through a bibliometric analysis. Research publication volume in various SDGs, major contributing subject areas and institutions, and the frequently discussed themes in research publications on SDGs are identified. The insights generated from the observations of this study can form useful inputs for evidence-based policy making, decision on research funding and deciding the focus areas for research and technology development by both government as well as private organisations.

Data and Methodology

The study is based upon the publication metadata catalogued in Dimensions database (www.dimensions.ai) from 2016 to 2020. This interval covers a time period of five years after the adoption of Sustainable Development Goals by the UN General assembly in 2015. The publication metadata was accessed by the means of dedicated API granted from the database. It consisted of seventeen (17) attributes for each publication, these include, publication id (unique identification number assigned to each publication), DOI, title of the publication, abstract, disciplinary "category" assigned by Dimensions, SDG category i.e. the SDG(s) to which the publication has been associated by Dimensions' AI algorithm, author(s) of the publication, number of authors, name of the journal in which the publication appeared, year of publication, type of publication, ISSN, author affiliation, country in which author's organisation is located, concepts associated with the publication, concept scores for the associated concepts, and number of citations received by the publication. The publication metadata was retrieved in the month of August 2021.

As this study focuses only on the research output from India, the collected data was further filtered using Dimensions categories. The categories of retrieved documents were set to a) *document type* as "Article only", b) *Research organisation country* as "India" and c) *category SDG* as the 'code of 17 SDGs'.

The query to obtain the data was as follows:

```
(search publications where year in [2016:2020]
and type = "article" and research_org_countries
= "IN" and category_sdg in ["40001", "40002",
"40003", "40004", "40005", "40006", "40007",
"40008", "40009", "40010", "40011", "40012",
"40013", "40014", "40015", "40016", "40017"]
return publications [id + doi + title + abstract +
category_for + category_sdg + authors +
authors_count + journal + year + type + issn +
research_orgs + research_org_countries +
concepts + concepts_scores + times_cited])
```

This query yielded a total of 77,005 documents which were then imported to working database. Dimensions database was chosen over other available databases considering the following advantages that it offers over them. The journal coverage of Dimensions database is found to be the most exhaustive; it covers 82.22% more journals than Web of Science and 48.17% more journals than Scopus.[22–24] Specific to the requirements of this study, it has customized conceptual tags to classify publications according to the seventeen SDGs. This classification is derived by using concepts from the abstracts of the documents by using machine learning algorithms designed for this purpose. It identifies *Concepts* associated with each document, which are normalized noun phrases describing the main topics of a document. Followed by this a Concept score is calculated and the Concepts are ranked based on their relevance. A relevance score from 0 to 1 is assigned to the applicable concepts to categorise the research. These are then used for different classifications such as SDGs which can be utilised by users of the platform.

A methodology comprising of standard bibliometrics and textual analysis has been adopted for this study. The data characteristics were utilized to conduct the bibliometric analysis as follows.

Estimating the trend in research publications: The profile and volume of Indian research outputs were

categorized under the 17 SDGs during 2016–2020. A regression model was deployed on the available data using curve fitting technique. It is an iterative model that tries to estimate suitable values for the constants in an equation befitting the data points, in this case 1,00,000 was chosen to be the number of iterations in order to achieve high accuracy. Further, year-wise distribution was analysed during the same period for various SDG. The 'category_sdg' field of metadata was utilised to carry out the analysis.

Correlation Heat Map: A cosine-similarity heatmap represents the closeness between two variables. The similarity between the variables can vary from 0 to 1. For the available publications-based metadata on SDGs, this similarity coefficient was calculated and the resultant closeness was plotted to obtain a similarity heat map with the 17 SDGs against each other.

Post this analysis, top three performing SDGs were selected for further study, as these three represent 82% of the overall publications in SDGs in India. Additionally, the number of publications in the rest of the SDGs being relatively small, do not provide significantly meaningful insights into the research trends for their respective areas.

Gender distribution in authorship: To estimate the percentage of authors who are female and male, *Gender API* service was utilised. This is a machine learning algorithm which analyses the author names and predicts the gender of the author. The algorithm provides its prediction with an associated confidence level. For this study, all the results with confidence greater than or equal to 70% were included.

Subject-area wise distribution of papers: The Subject area-wise distribution of Indian research output under leading SDGs was computed in order to study the Subject area profile of Indian publications. For this purpose, 'category_for' field of the metadata was used. It provides the top-level classification of 22 subject areas defined by Dimensions database. The number of publications associated with each discipline was estimated and plotted on a pie chart.

Popular topics of research in SDG 7, 3 and 13: There was a field in metadata called 'concetps_scores' which contained array of probable concepts for the publication computed by Dimensions along with their respective relevance score. These concepts helped us to explore most buzzed thematic areas in top SDGs. The density plot was prepared by using VOS viewer.

Distribution of research activity across the country: Geo-spatial kernel density estimation plots for top SDGs were synthesized from the latitude and longitude information available in 'research_orgs' field. Here, the darkness of region is in proportional to relative amount of research output being produced at given co-ordinate.

Institutional contribution towards the SDG Research: Further, analysis was carried out keeping the research output of various institution into primary focus. A field called 'research_orgs' which contain detailed information about participating institutions and 'times_cited' that tells total citation received by the publication were present in metadata. The same was exploited to produce various other results which include Total citation vs Total publication chart, an SDG vs top producing institution bipartite graph where edge weight is in proportional with number of publications output from that institution relating to various SDGs.

Results and Discussion

The collected data was processed and results were obtained for indicators. As explained in methodology section, six indicators were explored in order to address the research questions posed in this study. These include, quantum and trends in publications related to the SDGs;

Volume of publications and their distribution among the 17 SDGs

The total number of publications relating to the SDGs was determined using the first search query in Dimensions and applying the appropriate filters for each SDG. The overall publications on SDGs in India amount to 77,005 which is about 12% of the total research publications from India in the five-year period, 2016–2020. A comparison between global and Indian publication trends is shown in Fig. 1. An

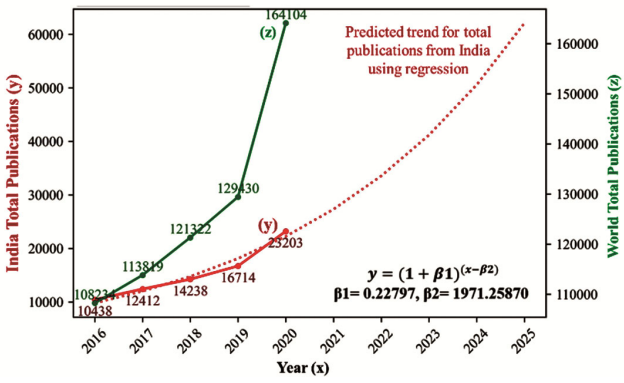

Fig. 1 — Publication pattern corresponding to the SDGs in India and the world

exponential growth in the number of publications is observed. A prediction of the publication growth using a curve fitting-based regression model on Indian research outputs has also been carried out. As the data points available were too few to fit regression-based model, all points were considered in the training phase. We have obtained a non-liner regression curve with R^2 score 0.96, the equation for the curve is shown in Fig. 1. Assuming that the trend observed will remain intact in the future, this model suggests that India will be able to produce 8,91,142 SDG based research outputs in total by the end of 2030 (2016–2030). Also, the CAGR for SDG related articles is almost twice the overall research output from the country, evidencing a positive response from the Indian research community towards the SDGs (Table 1).

Highest publication activity is observed in SDG 7 (Affordable and Clean Energy) and SDG 3 (Good Health and Well Being) both having more than 25,000 publications in the five-year period. Fastest annual growth in research activity is observed in SDG 12 (Responsible Consumption and Production, followed by SDG 9 (Industry, Innovation and Infrastructure) and SDG 11 (Sustainable Cities and Communities) with all of them showing a CAGR (Compounded Annual Growth Rate) higher than 25%. This may be caused due to low number of publications due to which the annual growth rate may be faster. The visualisation of changes in the annual number of publications in each SDG shows that SDG7 has overtaken SDG 3 since 2017 (Fig. 2). This may be related to a higher focus on Climate Change related interventions and an interest in exploring renewable energy alternatives since the adoption of the Paris Climate Agreement in December 2015. Following this Intended Nationally Determined Contributions

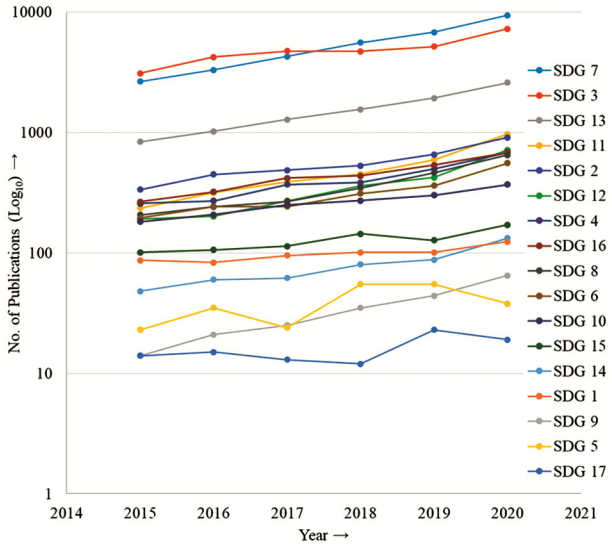

Fig. 2 — Trend of research publications from India on different SDGs. Logarithmic scale has been used to be able to show the variation patterns in case of SDGs which have low number of publications.

Table 1 — Number of research papers published on different SDGs

Category	**Number of Research Papers**						**CAGR (%)**
	2016	**2017**	**2018**	**2019**	**2020**	**Total**	
India's total research output	108,234	113,819	121,322	129,430	164,104	636,909	8.68
India research output on all SDGs	10,438	12,412	14,238	16,714	23,203	77,005	17.32
SDG	**2016**	**2017**	**2018**	**2019**	**2020**	**Total**	**CAGR (%)**
7 Affordable and Clean Energy	3,308	4,283	5,574	6,782	9,411	29,358	23.26
3 Good Health and Well Being	4,236	4,730	4,724	5,164	7,233	26,087	11.29
13 Climate Action	1,024	1,282	1,558	1,933	2,593	8,390	20.42
2 Zero Hunger	448	485	529	659	907	3,028	15.15
11 Sustainable Cities and Communities	316	391	450	592	966	2,715	25.04
16 Peace, Justice and Strong Institutions	321	418	436	536	681	2,392	16.23
4 Quality Education	270	370	383	496	682	2,201	20.36
8 Decent Work and Economic Growth	242	268	347	463	652	1,972	21.92
12 Responsible Consumption and Production	201	270	361	422	715	1,969	28.89
6 Clean Water and Sanitation	243	243	311	361	555	1,713	17.96
10 Reduced Inequalities	208	251	272	301	370	1,402	12.21
15 Life on Land	106	114	144	127	171	662	10.04
1 No Poverty	83	95	101	101	124	504	8.36
14 Life Below Water	60	62	80	88	133	423	17.26
5 Gender Equality	35	24	55	55	38	207	1.66
9 Industry, Innovation and Infrastructure	21	25	35	44	65	190	25.35
17 Partnerships for the Goals	15	13	12	23	19	82	4.84

(INDCs) were formulated by all the participating countries. These focus specifically on technology and resource management for sustainable development.[25]

It may also be noted that the SDGs which correspond to basic and applied sciences disciplines have higher research activity (refer to SDGs 7, 3, 13, 12, 6). On the other hand, SDGs which require political and/or socio-cultural issues to be addressed have lower research activity (refer to SDGs 16, 4, 8, 11, 15, 1, 5, 17). Among these, three SDGs namely 3, 7 and 13 have received the most attention from the Indian research community with 60,022 publications assigned to them out of 77,005 total publications relating to SDGs. It is also noteworthy to observe that SDG 5 on Gender Equality has low number of publications and also has a very low annual growth rate in terms of publication activity (CAGR of only 1.66%).

Correlation between research across SDGs

A similarity heat map analysis with the 17 SDGs against each SDG was carried out in Fig. 3. A cosine similarity of 0.239 can be observed between SDG 7 and SDG 13, SDG 10 also shows a similarity of 0.101 and 0.104 with SDG 1 and SDG 5, respectively. It may be noted that a correlation between two random variables or bivariate data does not necessary imply causal relationship among them. Hence the observation indicates a similarity in the disciplines and the type of research that addresses the respective SDGs. Additionally, it may be noted that the similarity coefficient in all three cases possess a low/moderate value, indicating the unique nature of each of the SDGs.

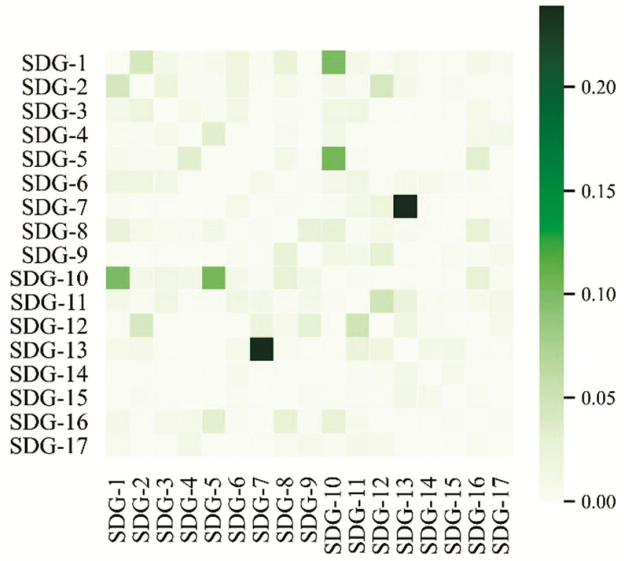

Fig. 3 — Similarity heat-map between SDGs; Prepared using Python (Matplotlib library)

Contribution of female researchers in SDG research

Out of the total 77,005 articles, gender prediction with a confidence level greater than or equal to 70% was received for 61,684 articles. It is observed that a total of 30.5% articles (18,801), have female researchers as their lead author. There are some collaborative articles which have foreign researchers as lead authors and some which have Indian researchers as lead authors. This number is higher than the overall percentage of female researchers (18.6%) in India.[26] It can be observed that SDG 5 has a higher contribution (approx. 57%) from the female authors and SDG 16 and SDG 17 have 40 and 41% contributions, respectively (Fig. 4). This trend has remained the same for all the five years under consideration for this study.

Distribution of research in contributing subject areas

As a major difference is seen in the research activity of these three SDGs (3, 7 and 13) in comparison to the rest of the SDGs, with top 3 contributing approximately, 82% of total research publications (60,022) retrieved. Further analysis was carried out to see the research activity and the corresponding disciplines contributing to the research output for top 3 researched SDGs. This was achieved by using 'category_for' field of the metadata. It provides the top-level classification of 22 subject areas defined by Dimensions database (Fig. 5).

For *SDG7*, affordable and clean energy, it is observed that, the number of publications has increased at close to 24% CAGR and reached a total of 9,411 in 2020 from 3,308 papers in 2016. Engineering, Chemical Sciences, Technology, Information and Computer Sciences and Mathematical Sciences are top contributing disciplines with an aggregated contribution of 89.14%. This highlights the nature of activity in the area which is mostly focused on developing technological solutions for the challenge of making

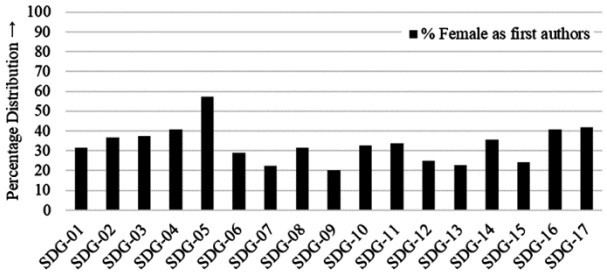

Fig. 4 — Contribution of female & male researchers in SDG research in India

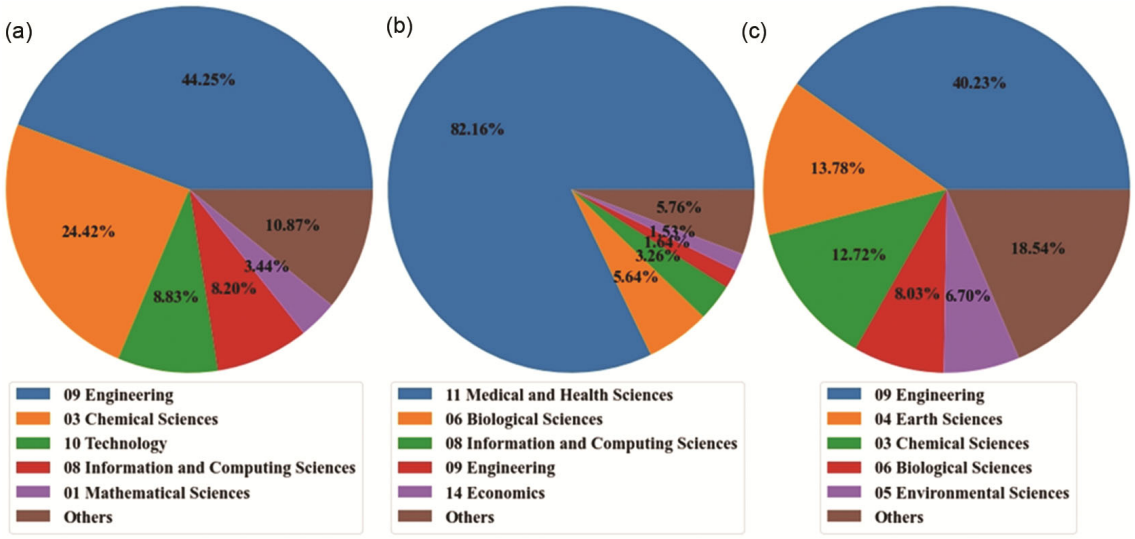

Fig. 5 — The distribution of research output from Indian institutions in the subject areas (corresponding codes noted) related to (a) *SDG 7*: Affordable and Clean Energy, (b) *SDG 3*: Good Health and Well-being, and (c) *SDG 13*: Climate Action

energy (electricity and motor vehicles) cleaner, cheaper and more accessible. This corresponds to the policy directions set for the foreseeable future, as research in advances for affordable and clean energy is highly relevant for India. This research explores new alternatives to meet the demand of electricity and fuel for the rapidly industrialising economy.[27]

Similarly, for *SDG 3*, Good health and well-being, the number of publications has increased at the rate of 11.29% from 4,236 articles per year in 2016 to 7,233 articles per year in 2020. Medical and Health Sciences, Biological Sciences, Information and Computing Sciences, Engineering and Economics contribute the major portion. Medical and Health Sciences has a dominant contribution of 82%. This reflects the nature of research being focused on developments in medical sciences, mainly on development of drugs, treatment strategies for infectious diseases, genetic and lifestyle related disorders, and applications of technology in medicine.

For *SDG 13*, Climate action, the number of publications has increased from 1,024 articles in 2016 to 2,593 articles in 2020 with a CAGR of 20.42%. Engineering, Earth Sciences, Climate Sciences, Biological Sciences and Environmental Sciences are the main contributing disciplines with major activity in Engineering. As most of the research in Climate Action is focused on reducing carbon dioxide and other greenhouse gas emissions, by using cleaner and more efficient technological solutions, the higher activity in Engineering and Chemical Sciences is clear. Earth Sciences, Biological Sciences and Environmental Sciences are also areas where research on interventions in ecosystem factors such as river deltas, directly relate to climate action.

Thematic Structure/ Topical trends

Major Themes Discussed in Publications on Each Major SDG

To observe the research trends, further analysis was conducted using concept cluster plots for each of the top three performing SDGs. These plots were developed by using concept scores obtained from Dimensions database for each publication. For this, the "concepts" from all the research papers were collected and those having relevance lower that 0.7 were dropped. The frequencies of the selected concepts for top three SDGs were visualised using VOS viewer (Fig. 6).

(a) SDG 7: The observations corresponding to the SDG 7 show that research on energy sciences and material sciences receives a very high attention from the research community. The keywords indicate that Energy Generation, Energy Storage (Battery and cells), and Consumption are highly relevant topics in the area (Fig. 6a). Terms related to clean and renewable sources of energy also have high relevance level suggesting the importance received by these areas. For instance, Wireless sensor networks, sensor networks, Internet of Things, Solar Cells, Electric Vehicles, Wind Turbines, Lithium-ion Batteries have high relevance and frequency.

(b) SDG 3: For SDG 3, patient care, diseases (both communicable and non-communicable), infant

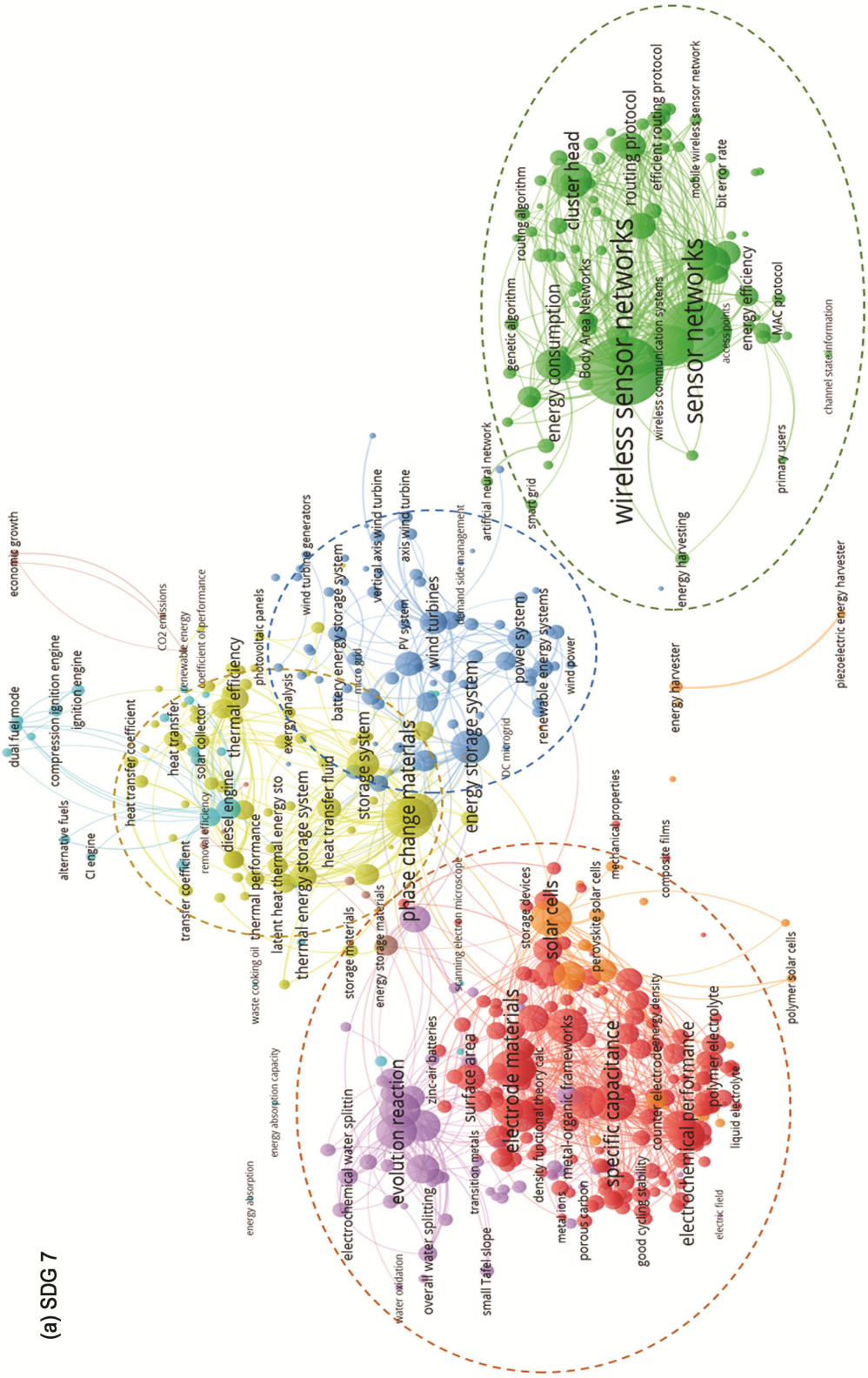

Fig. 6(a) — Concept clusters developed using VOS viewer on the basis of concept scores of research concepts in the research articles on *SDG 7*: Affordable and Clean Energy

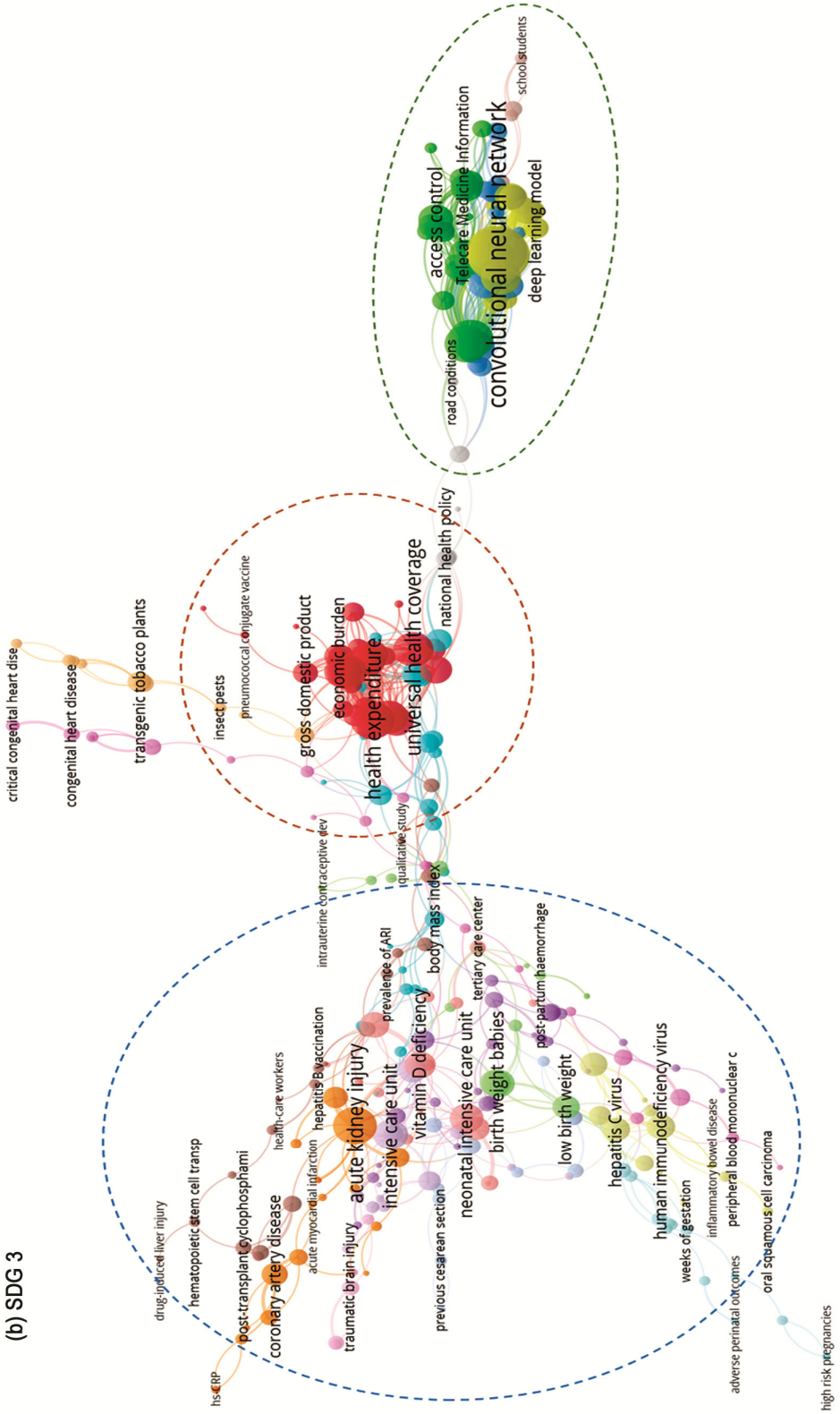

Fig. 6(b) — Concept clusters developed using VOS viewer on the basis of concept scores of research concepts in the research articles on *SDG 3*: Good Health and Well Being

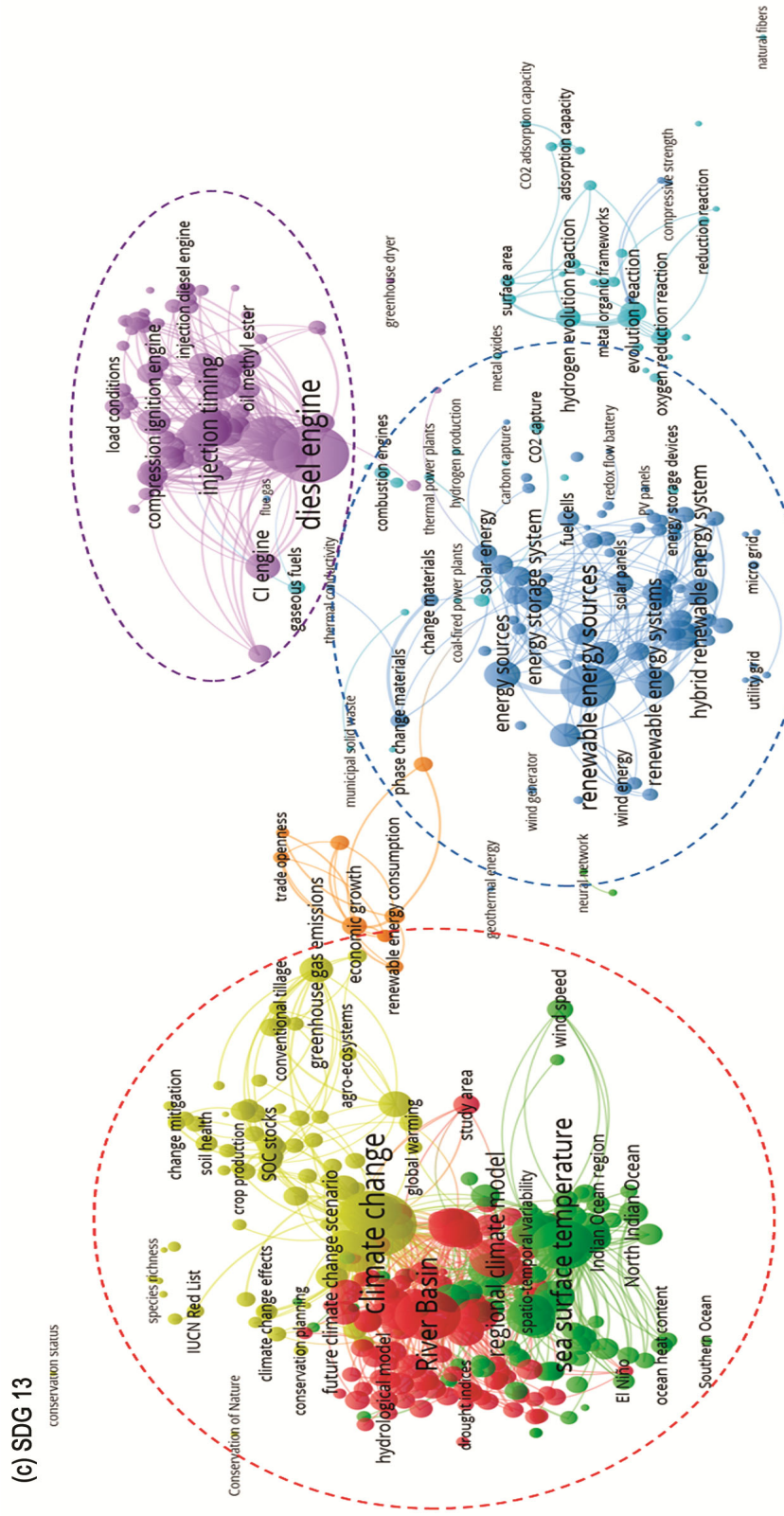

Fig. 6(c) — Concept clusters developed using VOS viewer on the basis of concept scores of research concepts in the research articles on *SDG 13*: Climate Action

care, respiratory infections and use of AI based methods for healthcare seem to be the focus areas for research (Fig. 6b). Keywords include, acute kidney injury, non-communicable diseases, neonatal intensive care unit, diabetes, HIV, Universal Health Coverage, convolutional neural networks, etc are found to have high relevance and frequency.

These form three distinct clusters on the plot indicating the different fields of study involved. The concepts which form these clusters are (a) disease and patient care (acute kidney disease, coronary artery disease, HIV and Hepatitis infections, neonatal care), (b) health services coverage and cost (universal health coverage, economic burden) and (c) adoption of Information Technology (convolutional neural networks, deep learning models, tele medicine information etc.). Some smaller clusters are also observed for concepts such as congenital health disease, insect pests, school students however these do not represent major quantum of work and can be considered under one or the other larger clusters.

(c) SDG 13: For SDG 13, climate change, diesel engines, and renewable energy sources are the most prominent keywords. On close observation, three primary clusters can be identified based on these subject areas (Fig. 6c). These clusters can be linked with the different disciplines involved in the study of climate change namely, environmental and earth sciences, mechanical engineering and renewable energy research. Six large conceptual clusters are observed, three of these are related directly to the effects and mitigation impact of Climate Change (Climate change, river basins and sea surface temperature). Other clusters are observed for renewable energy sources (solar energy, energy storage, energy sources), diesel engines (injection timings, CI engines etc.) and alternative sources of fuels (e.g., Hydrogen evolution reaction).

On closer observation, the activity on SDG research is concentrated in four regions of the country (Fig. 7). The area in Northern India includes National Capital Region of Delhi and nearby states of Punjab, is prominent for all three SDGs which were examined. In the southern region, Tamil Nadu has significantly high number of publications for SDG 3 and SDG 13. This can be an indication that the institutions in this area are equipped with facilities and expertise relevant to the disciplines related to these SDGs. It may also be noted that the states in this part of the country are leading in the area of healthcare and climate action.[8] Third hotspot is visible in West Bengal and surrounding areas, with researchers from this area having higher number of publications in SDG7 and SDG 13 when compared to SDG 3. The fourth region of activity is visible in Maharashtra and nearby areas, this is correlated to research publications from University of Pune as highlighted in the later sections of this paper.

Top institutions contributing to SDG research

The top 10 institutions with highest number of publications were identified in Table 2, and a plot was developed with the total publications vs. total

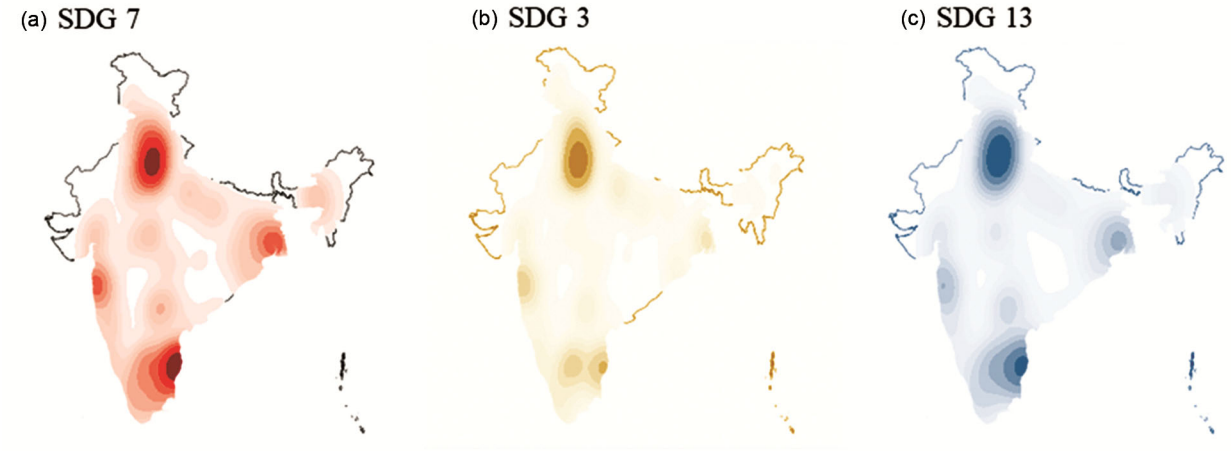

Fig. 7 — Hotspots showing the research activity in *SDG 7*, *3* and *13*: Four prominent centres can be observed, (i) North India near New Delhi, (ii) Tamil Nadu near Chennai, (iii) West Bengal where IIT Kharagpur is located, and (iv) Near Pune where University of Pune is located

Table 2 — Top Institutions publishing in the field of SDGs

Institution	TP	TC	CPP	Inter Institution Collaboration (% Publications
Anna University, Chennai	2721	28186	10.36	40.9
Indian Institute of Technology Delhi	1534	22099	14.41	49.0
All India Institute of Medical Sciences	1511	15042	9.96	55.9
Indian Institute of Technology Kharagpur	1317	16501	12.53	46.8
Vellore Institute of Technology University	1290	16812	13.03	50.5
Indian Institute of Technology Bombay	1093	13459	12.31	52.2
Indian Institute of Technology Roorkee	990	13219	13.35	45.4
Indian Institute of Technology Madras	965	10732	11.12	45.1
University of Delhi	890	7973	8.96	54.8
Indian Institute of Science Bangalore	849	9567	11.27	60.3

Table 3 — Top authors publishing on SDGs based on total publications (TP)

Author Name	Affiliation	TP	TC	CPP
Bhim Singh	Indian Institute of Technology Delhi, New Delhi, India	251	3160	12.59
Pradeep Das	Rajendra Memorial Research Institute of Medical Sciences, Patna	103	1006	9.77
Neeraj Kumar	Thapar University, Patiala	98	2603	26.56
Shyam Sundar	Banaras Hindu University, Varanasi, India	96	1366	14.23
Kuldeep Dhama	ICAR-Indian Veterinary Research Institute, Izatnagar, Bareilly, India	68	2240	32.94
Shivaprasad S. Goudar	KLE University JN Medical College, Belgaum, India	68	783	11.51
Dorairaj Prabhakaran	Centre for Chronic Disease Control (CCDC), New Delhi, India	65	1831	28.17
G.N. Tiwari	Indian Institute of Technology Delhi, New Delhi, India	62	1663	26.82
Arun Kumar Sangaiah	VIT University, Vellore, India	59	2214	37.53
B.K. Panigrahi	Indian Institute of Technology Delhi, New Delhi, India	58	951	16.39

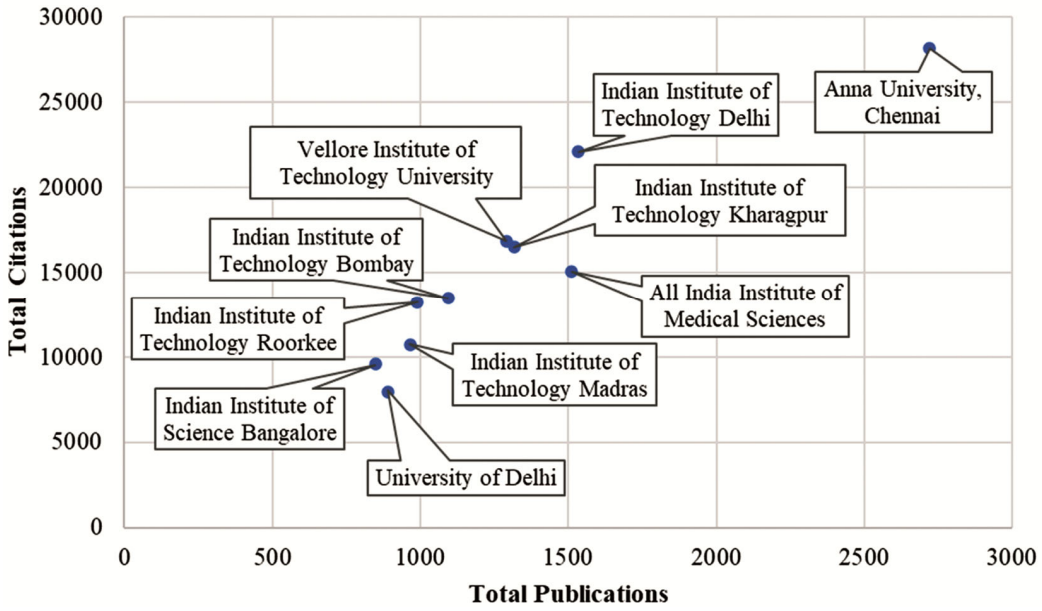

Fig. 8 —Top 10 institutions on SDG related research output

citations received by the major research institutions which have researchers publishing research articles on SDGs. This data was retrieved from the metadata using the parameter *Research_orgs*, and *times_cited*. This analysis showed that Anna University has the largest number of publications with highest number of citations. The Indian Institute of Technology at Delhi, Kharagpur, Bombay, Madras and Roorkee also have significant contribution in research publications on SDGs overall (Fig. 8). Out of the top 10 authors with publications on SDGs, three (3) belong to IIT Delhi, and one (1) author is affiliated to VIT University (Table 3).

Further analysis using a bipartite graph was carried out. This highlighted the relative importance given to the SDGs by the research institutions. Two institutions, Post Graduate Institute of Medical Education and Research (PGIMER), Chandigarh and

All India Institute of Medical Sciences (AIIMS), New Delhi have relatively high number of publications corresponding to SDG3, which relates to health care. Another institution which appears in the list for SDG3 is Christian Medical College and Hospital, Ludhiana. In this case, the most active region in the country is hotspot 1 near New Delhi and Punjab.This is justified as these institutions are among the leading research and training institutions in healthcare and medical sciences (Fig. 9).

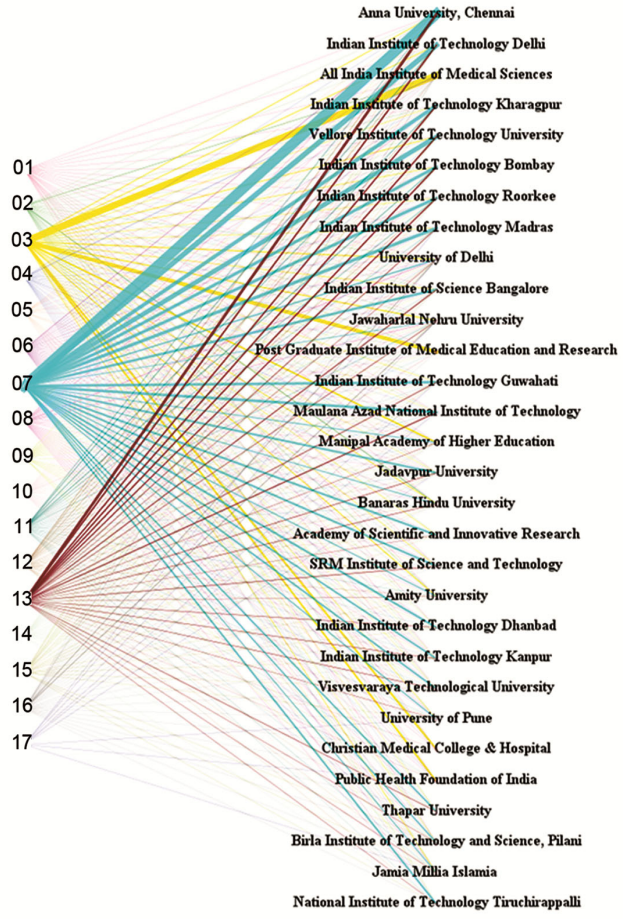

Fig. 9 — Bipartite graph of selected Indian institutions with their research output on different SDGs

The observations of this study suggest a high level of activity in areas of Engineering, Medical and Health Sciences, and Chemical Sciences in the country. It is also observed that areas such as responsible consumption and production which involve research on improving the efficiencies of existing processes, less wasteful use of available resources etc. have shown a trend towards increasing research activity and as a result these may become more important in the coming years.The top journals publishing articles related to SDGs are also identified to be related to these areas (Table 4).

Our observation shows that SDG 17 (Partnerships for the Goals) corresponds to minimum research publications. This does not conform with the previous studies conducted at a global scale by Sweileh (2020),[6] which utilised the SCOPUS database instead of Dimensions database. This may be due to difference in categorisation of articles by the two databases or due to differences in search algorithms used. In a recent study, entitled Mapping scholarly publications related to the Sustainable Development Goals, 2020,[19] authors compared the sets of publications on selected SDGs using independent queries for retrieval of publication data, namely the Bergen and Elsevier approaches. They have underlined the variance in the listing of publications among the popular databases and cautioned regarding the search and analysis parameters for bibliometric studies in SDGs.

Results from our analysis, indicate that Central universities and public funded institutions like IITs have higher publications in SDGs. The ranking systems such as the Times Higher Education (THE) Ranking for SDGs have also been conducting ranking exercises for identifying institutions working on SDGs. For India, the THE Impact ranking 2021 for SDGs features Amrita Vishwa Vidyapeetham followed by JSS Academy for Higher Education and Research, and Lovely Professional University

Table 4 — Top Journals publishing articles related to SDGs from India

Journal	TP	TC	CPP
International Journal of Reproduction, Contraception, Obstetrics and Gynecology	2068	1031	0.50
International Journal of Community Medicine and Public Health	1751	1352	0.77
Materials Today Proceedings	1142	4776	4.18
International Journal of Contemporary Pediatrics	976	617	0.63
IOP Conference Series Materials Science and Engineering	917	1064	1.16
International Journal of Research in Medical Sciences	732	456	0.62
Journal of Family Medicine and Primary Care	535	1620	3.03
Journal of Materials Chemistry A	522	14113	27.04
International Surgery Journal	470	223	0.47
Journal of Cleaner Production	440	12980	29.50

which are all private universities(https://www.timeshighereducation.com/impactrankings). In this ranking there are only these three universities that featured among the Top 200 universities on this list. However, this ranking is still in development stage.

This difference in ranking could be due to inclusion of other parameters for ranking under THE Impact ranking exercise (ranking system). As this involves voluntary participation from the universities and institutions, many of the Indian institutions have chosen not to participate in this ranking. It also includes indicators such as number of graduates, inter-university/institute/national collaboration activities, university research infrastructure, human resources, university's policy for use of available natural resources etc. in addition to their research output.

Conclusions

The study analysed the research publications on SDGs from India to develop an analytical understanding of the response of the Indian research community to the SDGs. A noticeable increase was observed in the number of research publications related to SDGs across all disciplines (CAGR = 17.32%). The top contributing SDGs were 3, 7 and 13 and the top contributing disciplines were Medical and Health Sciences and Engineering. Journals from these disciplines feature among the top 10 and most publications on SDGs were from Anna University, AIIMS,IITs, VIT and IISc.The results confirm the positive attention given by Indian scientific community to nationally relevant SDG targets. The results present useful insights and indications for scientific policy and planning activities. We argue that this will provide useful insights for researchers, policymakers, and other organisations working on achieving various targets under the SDGs. However, the study does not take into account the contributions in form of patents and technology developments, which can be taken up as a future endeavour.

References

1 UNGA, A/RES/70/1: Transforming our world: The 2030 agenda for sustainable development (United Nations General Assembly), 2015.

2 United Nations, The sustainable development agenda, 2020, [https://www.un.org/sustainabledevelopment/development-agenda/(12 Jan 2022)]

3 Sustainable Development, International Institute for Sustainable Development (IISD), 2021, [https://www.iisd.org/about-iisd/sustainable-development(7 Feb 2022)]

4 Bautista-Puig N, Aleixo A M, Leal S, Azeiteiro U, & Costas R, Unveiling the research landscape of sustainable development goals and their inclusion in higher education institutions and research centers: major trends in 2000–2017, *Front Sustain*, **2** (2021), 620743 [doi: 10.3389/frsus.2021.620743]

5 Meschede C, The sustainable development goals in scientific literature: a bibliometric overview at the meta-level. *Sustainability*, **12(11)** (2020) 4461.

6 Sweileh W M, Bibliometric analysis of scientific publications on "sustainable development goals" with emphasis on "good health and well-being" goal (2015–2019), *Glob Health*, **16(1)** (2020) 1–13.

7 UKRI India Impact Report, UK-India: Partnerships for Growth with Research and Innovation (UKRI), 2021. [UK-India: partnerships for growth with research and innovation – UKRI (3 Feb 2021)]

8 NITI Aayog, SDG India index & dashboard 2020-21: Partnerships in the decade of action (Government of India), 2021, [https://sdgindiaindex.niti.gov.in (17 Feb 2022)]

9 Fayomi O S I, Okokpujie I P & Udo M, The role of research in attaining sustainable development goals, *Mater Sci Eng*, **413(1)** (2018) 012002.

10 Thampi A, Where does India stand on the sustainable development goals? Progress and challenges, in *Social Development and the Sustainable Development Goals in South Asia*, (Routledge) 2019, 49–73.

11 Surana K, Singh A & Sagar A D, Strengthening science, technology, and innovation-based incubators to help achieve Sustainable Development Goals: Lessons from India, *Technol Forecast Soc Change*, **157** (2020) 120057.

12 Singh P, Singh V K, Arora P & Bhattacharya S, India's rank and global share in scientific research: how data sourced from different databases can produce varying outcomes, *J Sci Ind Res*, **80(4)** (2020) 336–346.

13 Moyer J D & Hedden S, Are we on the right path to achieve the sustainable development goals?, *World Dev*, **127** (2020) 104749.

14 Chasek P S, Wagner L M, Leone F, Lebada A M, & Risse N, Getting to 2030: Negotiating the post-2015 sustainable development agenda, *Rev Eur Comp Int Environ Law*, **25(1)** (2016) 5–14.

15 OECD, Measuring distance to the sdg targets 2019 an assessment of where OECD countries stand: An assessment of where OECD countries stand (OECD Publishing), 2019, ISBN 9789264762886.

16 Schmidt-Traub G, Kroll C, Teksoz K, Durand-Delacre D & Sachs J D, National baselines for the sustainable development goals assessed in the SDG index and dashboards, *Nat Geosci*, **10(8)** (2017) 547–555.

17 WHO, World health statistics 2021: monitoring health for the SDGs, sustainable development goals. WHO Headquarters. 2021, ISBN: 9789240027053.

18 Annual report, World Bank group partnership fund for the sustainable development goals (World Bank) 2020, [https://www.worldbank.org/en/programs/sdgs-2030-agenda (15Feb 2022)].

19 Armitage C S, Lorenz M, Mikki S, Mapping scholarly publications related to the Sustainable Development Goals: Do

independent bibliometric approaches get the same results? *Quantitative Science Studies*, **1(3)** (2020) 1092–1108.

20 Vargas G M, Gonzalez-Campo C H & Brath D I, Mapping the integration of the Sustainable Development Goals in universities: Is it a field of study? *J Teach Educ Sustain*, **22(2)** (2020) 7–25.

21 Allen C, Metternicht G & Wiedmann T, Initial progress in implementing the Sustainable Development Goals (SDGs): A review of evidence from countries, *Sustain Sci*, **13(5)** (2018) 1453–1467.

22 Gavel Y & Iselid L, Web of science and scopus: A journal title overlap study, *Online Inf Rev*, **32(1)** (2008) 8–21.

23 Stahlschmidt S & Stephen D, Comparison of Web of Science, Scopus and Dimensions databases (German centre for higher education research and science studies, DZHW, GmbH, Hannover), 2020. [https://bibliometrie.info/downloads/DZHW-Comparison-DIM-SCP-WOS.PDF.(20 Feb 2022)].

24 Singh V K, Singh P, Karmakar M, Jacqueline L & Mayr P, The journal coverage of Web of Science, Scopus and Dimensions: A comparative analysis, *Scientometrics*, **126** (2021) 5113–5142, [doi: 10.1007/s11192-021-03948-5].

25 What is an INDC? (World Resources Institute), 2021 [www.wri.org/indcc-definition (29 Dec 2021)].

26 Research and Development Statistics at a Glance, Department of Science and Technology (DST),Government of India, 2020, [(https://dst.gov.in/sites/default/files/R%26D%20Statistics%20at%20a%20Glance%202019-20.pdf)(18 Feb 2022)]

27 India Energy Outlook, (IEA, Paris), 2021. [https://www.iea.org/reports/india-energy-outlook-2021 (12 Jan 2022)]