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RESEARCH ARTICLE

Benchmarking the R&D Output of India on 'Geographic Information Systems (GIS)' for the Period 2003-2023

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Abstract

The research and development (R&D) output of India on Geographic Information Systems (GIS) for the 20-year period from 2003 to 2023 is studied in detail in this paper. A scientometric analysis is employed to trace the development, trends, and patterns in scholarly publications pertaining to GIS using the 'Web of Science' database. The study evaluates the presence of Indian R&D output at the global level and presents a comprehensive picture of the research scenario in India. A total quantum of 60,865 records are found to have been published during the period 2003-2023 in the field of GIS research. India (4,097 articles) is noted to be among the top three countries contributing to GIS R&D output just behind USA and China. It is also noted that there is considerable growth observed in the publication pattern of GIS research. IIT is found to be among the top 10 most prolific institutions publishing research on GIS. The study also compares the output at the global and Indian levels to project the evolution of GIS research. The study lines futuristic developments and spatial linkages in the development of GIS technologies through cutting edge research activities.

Keywords: GIS research; Scientometrics; R&D output; Publication pattern; Collaboration; Impact factor

1 Introduction

The evolution of GIS systems can be traced back to right from when Dr. John Snow in 1854, prepared the 'Cholera Map' to study the outbreak of cholera in London. Snow's map led to the identification of the root cause of the problem and more importantly paved for the need to visualise data. It was not until a century later that Roger Tomlinson coined the term 'Geographic Information Systems (GIS)' in the year 1963. He is also referred to as the Father of GIS, using the systems towards managing information regarding use of land effectively. The following decade saw a rise in commercialization of the GIS technology. ARC/INFO, a software program that became a cornerstone of the GIS technology was released by the Environmental Systems Research Institute (ESRI) in 1982. During this time, other GIS programs such as MapInfo and GRASS also appeared. More sectors were able to embrace and profit from spatial analysis after desktop GIS was introduced in 1986, expanding access to GIS technology. By connecting health, demographic, and environmental data, geographic

analysis has made it possible for researchers to assess and measure the connections between environmental risk factors and health-related variables at various geographic scales. A broader understanding of disease processes and their connections to the environment has been made feasible by the availability, sharing, and utilization of satellite and remote sensing data. The rise of the internet led to the development of Web GIS. Services such as Google Maps and ArcGIS Online made GIS more accessible to the public and businesses. The incorporation of GIS into other technological frameworks like GPS, remote sensing, and mobile devices broadened its applications. GIS technology has evolved immensely since its inception, the implications are widely visible in the way we capture, share, and visualise spatial data. Some of the significant improvements after the invention of the world wide web also include Real Time GIS, 3D Mapping and Visualisations, Integration with AI and Machine Learning and Cloud based GIS.

There is hence a need to capture and study the academic and research landscape of Geographic Information Systems (GIS) at the global level. Scientometric studies use parameters to study the academic landscape and present quantitatively as well as qualitatively the progression of a discipline. These studies can help project trends, identify gaps, evaluate the research performances, identify, and map collaborative networks, identify key research papers, point towards avenues of research funding and granting agencies as well detect emerging topics of discussion. Added to all of this, scientometric studies can be of great help to the policymakers while allocate resources and prioritize funding based on high impact research.

The present study is one such which aims to study, visualise, and map the R&D output on 'Geographic Information Systems (GIS)' for the last two decades. The study attempts to find answers to the following questions:

- How many research articles have been published in the last 20 years in the GIS arena?
- What are the major research areas where the GIS technology has been applied?
- Which are the most prolific countries working on producing R&D on GIS?
- What are the most popular journal titles of publication?
- Which are the global and Indian institutions leading in the publication of GIS R&D?
- Indian scientists collaborate the most with which country?

There have been numerous studies on the impact of scientometrics and bibliometrics in understanding the progression of a discipline. Similarly, studies have been carried out on understanding the applications of GIS in various fields as well as its impact on the society. A few have been discussed to further the discourse of this study.

1.1 Literature Review

It is no surprise that today Geographic Information Systems (GIS) have become integral to numerous fields, including urban planning, environmental management, public health, and more. Combining GIS with bibliometric studies offers valuable insights into the growth, trends, and focus areas within this discipline. This review will cover key research areas, methodologies, and findings from GIS and bibliometric studies. According to Ergun (2023), GIS technology has seen substantial evolution since 1960s when Roger Tomlinson created the Canada Geographic Information System (CGIS). GIS has evolved throughout the years from basic mapping tools to complicated systems that can do intricate spatial analysis. Its uses were significantly increased in the 2000s with the introduction of the internet and cloud-based GIS. Recent developments have improved GIS's analytical capabilities, such as the use of AI and machine learning. Huang et al. (2022) examined GIS-based landslide susceptibility research in another study, emphasizing the move toward hybrid models and machine learning. Kumar and Khormi (2012) [1] examined the research productivity on remote sensing GIS research in Australia. They identified 10 peer-reviewed journal publications from 1991 to 2010. They identified clusters of research hotspot, institutional collaborations as well as authorship patterns in GIS research. They found that a few clusters were very productive while others increased over time [2–5]. Pandey and Thaker (2016) [6] studied the GIS research publications contributed by Indian researchers during 25 years of study from 1991-2014. They observed nearly 97% growth of GIS research during the study period. Tian et al. (2008) [7] conducted a bibliometric analysis of global research productivity on GIS research published during 1997 to 2006 indexed on the Science Citation Index. This study confirmed the above studies which indicate the rapid growth of GIS research and also identified that the most productive countries are USA, UK, Germany and Netherlands. VOS viewer was used to visualise the most productive authors and co-authors and also identified correlation between GDP and research output. Another study carried out by Alhaider et. al (2014) [8] using SCOPUS database for the period 2000 to 2011 for a quantum of 1,376 papers to identify top productive countries, their research impact, most preferred journals, productive authors, journal, institutions, and collaboration rates. Nath and Jana (2020) examined the research trend in open access GIS research. The paper analysed global output on open access GIS research as indexed in WoS database for the period 2009 to 2018 with respect to growth rate, year-wise publications and citations, major productive countries in addition to international collaborations, most productive authors and their citation impact, preferred journals, top institutions, author's keywords and so on. Liu et al (2015) [9] carried out a study based on the SCIE & SSCI databases, a bibliometric study of published geographical information system (GIS) research was conducted

to assess current research trends both statistically and qualitatively throughout the 1961–2010 time frame. The focus of the GIS-related articles was on the distribution of subject categories, source journals, international collaboration, the geographic distribution of authors, the analysis of scientific outputs, the relationship between GIS articles and computer numbers, and the temporal patterns in keyword usage. The findings demonstrated that since 1991, scientific outputs have grown at an exponential rate, as evidenced by rising cooperation indexes, references, and citations. IJGIS was the most productive journal in the field of environmental sciences, multidisciplinary geosciences, ecology, physical geography, water resources, geography, and remote sensing, which were the most commonly used subject categories [10–17].

1.2 Objectives

The major objectives of this study are to

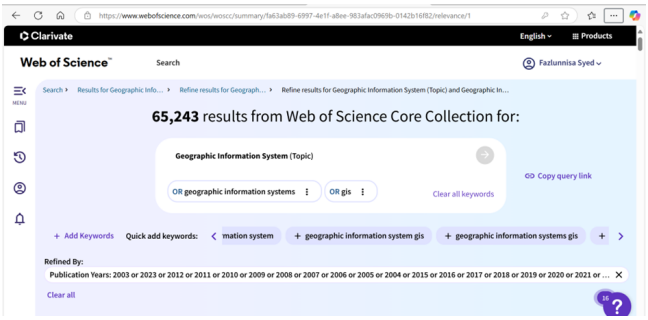
1. Quantify the global and Indian R&D output on 'Geographic Information Systems' for the period 2003-2023.
2. Determine the growth pattern of global and Indian R&D output.
3. Enumerate the most prolific affiliations producing R&D output on 'GIS'.
4. Identify the most prolific journals at the global and Indian levels.
5. Map the collaborative pattern of Indian researchers.

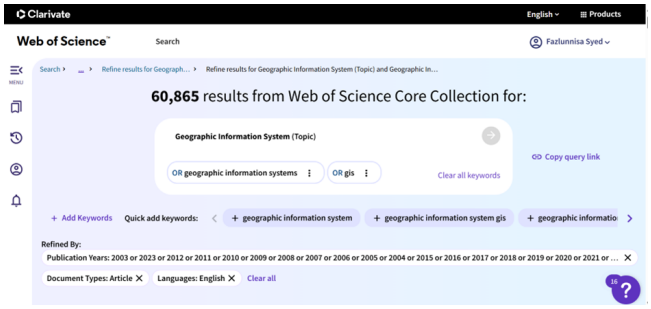
2 Methodology

The data for this study was extracted from the Clarivate Analytics Web of Science using the search query 'Geographic Information System' and 'GIS' on the WoS search box under WoS core collection for the period 2003- 2023. The weblink for the query is mentioned below:

https://www.webofscience.com/wos/woscc/summary/fa63ab89-6997-4e1f-a8ee-983afac0969b-0142b16f82/relevance/1

The search yielded a total of 65,243 results which were again filtered by document types = articles and Language = English, which yielded 60,865 results. These were then refined using paraments such as Publication years, Countries, Affiliations and Source Titles. These files were downloaded using the Analyse option into text files and incorporated into a working MS Excel file. The results were then refined using the countries option limiting the search option to India. The Indian R&D output of 4,097 articles was filtered and again refined using parameters such as Publication years, Countries, Affiliations and Source Titles. These results were also incorporated into an MS Excel file for further analysis.





3 Data Analysis and Results

The data extracted on the Excel workbook was analysed and the results are presented using quantitative analysis. The quantum of R&D output as found using the WoS database for the period of study was compared and the results are presented in the following section:

3.1 Year wise distribution of publication output:

The global publication output on the identified search terms yields a total number of 60,865 articles in the English language for a period of 2003-2023 and a total of 4,097 articles published by Indian researchers. The Figures 1 and 2 present the year wise publication profile of at the global and Indian level respectively.

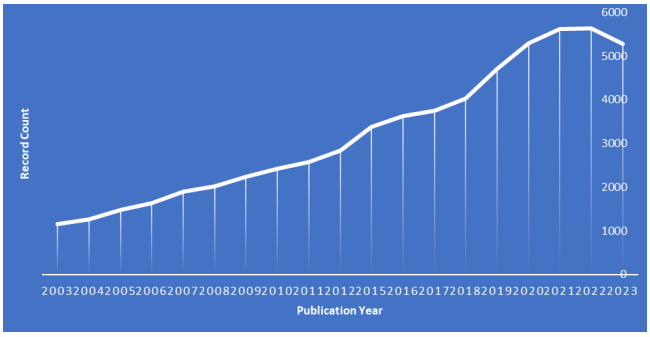


Fig. 1. Year wise productivity of GIS literature of the world for the period 2003-2023

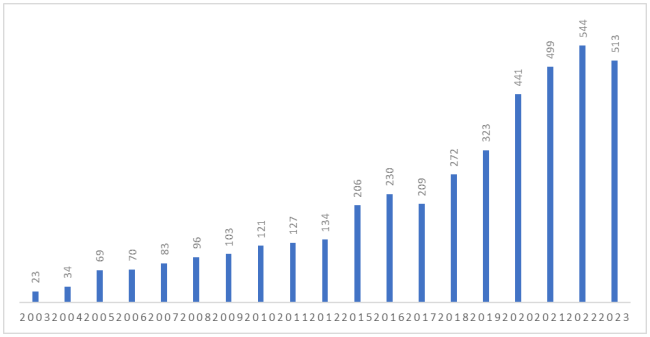


Fig. 2. Year wise productivity of GIS literature of India for the period 2003-2023

The Figures 1 and 2 show that there is steady increase in the growth of publications for the period 2003-2023. It is interesting to note that there are no publications recorded for the years 2013 and 2014. After the pandemic, there has been a surge in the R&D output on the GIS arena. India records nearly 7% of contribution to the global output and is ranked as the 3rd most productive country contributing to global output on GIS literature.

The Annual Growth Rate (AGR) is compared to understand the growth of publications at the global and Indian level. The AGR is used to measure the increase or decrease in the rate of publications over the period of a year. The Table 1 compares the AGR of World as well as Indian R&D output.

Figures 1 and 2 indicate a gradual growth of publications in the GIS arena for the study period. However, the AGR calculated indicates that as far as the world output is considered, 2015 (18.9%) is the most productive year followed by 2005 (17.1%) and 2019 (16.8%) and although, the greatest number of publications are published during 2021-2023, it is observed from the Table 1 that the AGR of 2022 (0.2%) and 2023 (-6.3%) is the lowest. The CAGR computed for the R&D output at the world level is found to be 22% which indicates a healthy growth rate of publications in the field of Geographic Information Systems. Comparatively the CAGR for R&D output of India is calculated at 30% which indicates a healthy growth rate of research publications in the GIS arena. It is also noted that the AGR increase corresponds to that of the global levels with 2005 (103%) and 2015 (54%) corresponding to the annual growth rate of the publications at the global level.

Table 1. Comparison of AGR of publication output of World and India

Year	World (60865 records)	India (4097 records)
2003		
2004	9.0%	47.8%
2005	17.1%	102.9%
2006	11.2%	1.4%
2007	15.4%	18.6%
2008	6.6%	15.7%
2009	11.0%	7.3%
2010	8.4%	17.5%
2011	6.2%	5.0%
2012	10.1%	5.5%
2015	18.9%	53.7%
2016	7.6%	11.7%
2017	3.2%	-9.1%
2018	7.5%	30.1%
2019	16.8%	18.8%
2020	12.6%	36.5%
2021	6.2%	13.2%
2022	0.2%	9.0%
2023	-6.3%	-5.7%

3.2 Most productive countries:

The country wise R&D output on GIS for the study period of the top 50 countries is presented in the Figure 3. It is observed that out of the 202 countries contributing to research output on the WoS database, USA leads with 14,752 records, the People's Republic of China with 10,711 records at the second place followed by India at the third place with 4,097 records. Together the top 3 prolific countries contribute to more than 45% of the total global output on GIS. It is a notable finding that the publication output of India has doubled, and India has evolved as the third most productive hub of GIS publications at the global level. The other prolific countries are Italy, England, Australia, Canada, Germany, Spain, Iran, and Turkey which contribute to more than 3% of the global output each. Together they contribute to 36% of the total global output.

3.3 Prolific Affiliations:

On comparing the most prolific affiliations and institutions contributing towards R&D output on GIS, it is observed that

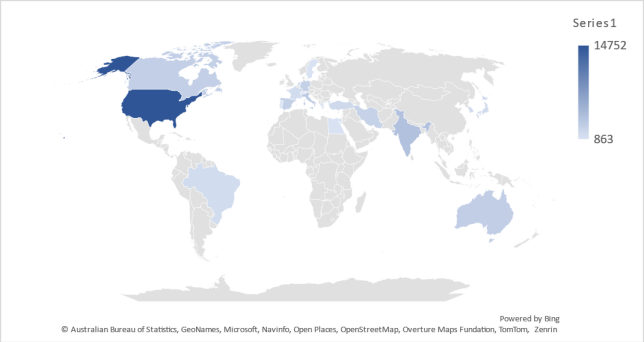


Fig. 3. Publication profile - Country wise distribution - Top 50

the Chinese Academy of Science is ranked at the top based on the quantum of publication output, followed by the University of California at the second place and the Egyptian Knowledge Bank as the third most productive institution. It is interesting to note that 4 of the top 10 institutions contributing to the world's output on GIS are located in China, while 3 are from USA, 1 each from Egypt, France and India. The Table 2 shows that the IIT system, leading group of institutes in India (7th rank) are among the top 10 most productive institutions contributing to GIS output. It is also noted that the four other Indian Institutions feature at the top 50 of the most productive institutions, this is corroborated in Table 3 which lists the top 10 prolific Indian affiliations contributing to the R&D output on GIS.

Table 2. Global top 10 prolific affiliations contributing to the world R&D output on GIS

Affiliations	Record Count	% of 60,865
Chinese Academy of Sciences	2143	3.521
University of California System	1177	1.934
Egyptian Knowledge Bank EKB	844	1.387
State University System of Florida	790	1.298
University of Chinese Academy of Sciences	737	1.211
Centre National De La Recherche Scientifique	664	1.091
Indian Institute of Technology System IIT System	649	1.066
United States Department of Agriculture USDA	632	1.038
Institute of Geographic Sciences Natural Resources Research CAS	576	0.946
Wuhan University	572	0.94

It is observed from Table 3, that the top 10 institutions together contribute to nearly 68%, more than half of the total Indian R&D output. It is also observed that one state funded university – Anna University, Chennai is among the top 10 Indian Institutions; University of Madras is at 140th position, whereas IIT Madras is at 55th rank.

Table 3. Top 10 Indian affiliations contributing to world R&D on GIS

Affiliations	Record Count	% of 4,097
Indian Institute of Technology System IIT System (Global rank 6)	649	15.84
Department of Space DOS Government of India (Global rank 27)	371	9.05
Indian Space Research Organisation ISRO (Global rank 32)	351	8.56
National Institute of Technology NIT System (Global rank 39)	304	7.4
Indian Council of Agricultural Research ICAR (Global rank 44)	295	7.2
Council of Scientific Industrial Research CSIR India	175	4.27
Indian Institute of Technology IIT Roorkee	171	4.17
Indian Institute of Technology IIT Kharagpur	170	4.14
National Remote Sensing Centre NRSC	151	3.68
Anna University	150	3.66

3.4 Prolific Source Titles:

resents the top 10 mostprolific journals that publish the highest number of articles on GIS during the study period, together they contribute to 14% of the total global output. Though these journals produce the highest quantum of journal articles, their impact factor, which is a quality indicator calculated based on the total number of citations received ranges between 1-9. The highest impact factor is that of the journal Science of the Total Environment (8th rank), a multi-disciplinary journal published by Science Direct.

Table 5 represents the top 10 journal titles, preferred by Indian researchers to share their research output on GIS. It is noted that 2 of the top 10 globally prolific journals – Environmental Earth Sciences and Environmental Monitoring and Assessment both published by Springer are among the top 10 most prolific journal avenues of Indian R&D. The impact factor is also found to be low between 1-6. It is suggested that Indian researchers must explore better avenues of research and increase their publication of higher impact factor journals.

Table 4. Top 10 Journal titles publishing world R&D output on GIS

Rank	Journal Title	Record Count	JCR Impact Factor (2023)
1	Sustainability	1662	3.3
2	ISPRS International Journal of Geo Information	1010	3.4
3	Environmental Earth Sciences	940	2.8
4	Remote Sensing	859	4.5
5	Environmental Monitoring and Assessment	800	2.9
6	Water	684	3.0
7	Natural Hazards	681	3.3
8	Science of the Total Environment	647	8.2
9	International Journal of Environmental Research and Public Health	575	2.46
10	Land	549	3.2

Table 5. Top 10 journal titles preferred by Indian authors to publish R&D on GIS

Rank	Journal Title	Record Count	JCR Impact Factor (2023)
1.	Journal of the Indian Society of Remote Sensing	246	2.2
2.	Environmental Earth Sciences	182	2.8
3.	Journal of the Geological Society of India	168	1.2
4.	GEOCARTO International	147	3.3
5.	Environmental Monitoring and Assessment	136	2.9
6.	Arabian Journal of Geosciences	124	1.82
7.	Current Science	123	1.1
8.	Environment Development and Sustainability	111	4.7
9.	Natural Hazards	97	3.3
10.	Environmental Science and Pollution Research	92	5.8

3.5 Collaborative pattern of Indian researchers:

On studying the Indian R&D output of 4,097 records, it is observed that India collaborates with a total of 118 countries and the most prolific collaborations are presented in the Figure 4. It is seen that India's collaboration is found to be the highest with USA with 5% of the total quantum. It is also found that the top 10 collaborating countries contribute to more than 25% of the total collaboration status of India. A healthy collaborative activity indicates a mutually rewarding partnerships, through sharing knowledge and resources amongst collaborating countries.

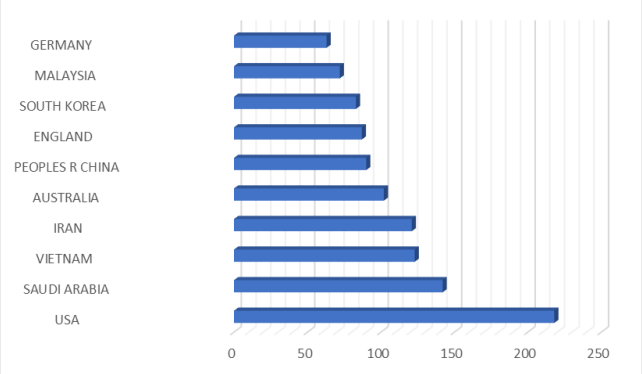


Fig. 4. Collaboration status of India

4 Discussion

GIS and bibliometric studies provide valuable insights into the research landscape, helping identify trends, gaps, and areas of growth. These studies are crucial for guiding future research and policy decisions in the field of GIS. The ongoing advancements in GIS technology and the increasing volume of research underscore the importance of continued bibliometric analysis to stay abreast of developments in this dynamic discipline. The present study demonstrates the increasing growth trend in the publication pattern of GIS research. The increase in the CAGR indicates that there is increasing research activity in the implementation and progression of GIS technologies. The study also shows the increasing amount of research carried out by Indian scientists and researchers in the field. It can be seen from the previous studies that although USA still regains the top position as the most prolific publisher, developing nations such as Peoples Republic of China and India are catching up to the global scenario. It is also noted that the topmost institution system of India – the IITs feature in the top 10 most prolific affiliations. The journals publishing the most prolific research have an impact factor that ranges between 1-10. This research is a crucial link in highlighting the active research scenario in the GIS discipline. It is suggested that the government agencies

should take note and fund R&D activities to promote research publications in the GIS arena.

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