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# Tracking the Impact and Trends in Water Resources Research in India: A Scientometric Analysis

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**ABSTRACT**

*This study intends to analyse the research trends, growth, and collaboration patterns in the field of Water Resources in India. The source for the data collection is the Web of Science (WoS) Core Collection Database. A total of 797 publications published during the period from 2016 to 2021 satisfying these search criteria were pulled out to perform further analysis. This study revealed that Water Resources Management is the most productive journal with 26 articles (3.26%), followed by Arabian Journal of Geosciences 22 (2.76%), Environmental Earth Sciences 21 (2.63%) publications got 2nd and 3rd rank respectively. the year 2020 highest number of articles 236 (29%) were published on water resources followed by the year 2019 with 149 (18.69%).The Most productive author Malik, Anurag from Punjab Agricultural University is in the top position with 16 (2.007%) published articles. 177 (22.2%) of the total publication have two authored contributions taking the first position. Indian Institute of Technology Bombay published the highest number of articles i.e., 48 (6.02%) occupy 1st rank. Department of Science & Technology India funded 6.27%of published articles in the field of Water Resources Research.USA has the highest number of collaborative research work with India. China comes second with AFI value of 8.50. The Internationalization Index of Indian Water Resources literature is 73.77.Co-operative efforts show that there are 580 scientific links created between other countries, depicting most publications collaborated with authors from more than two countries.*

**KEYWORDS:** *Water Resources; Scientometric Evaluation; Network Visualization; Research Publications; Web of Science; India.*

## INTRODUCTION

Water resources are sources of water that are very useful not only for humans and animals but also for plants. Without water, there is no existence of life. There are so many uses of water including agricultural, industrial, household, recreational and environmental activities. Awareness of the global importance of preserving water for ecosystem services has only recently emerged as, during the 20th century, more than half the world's wetlands have been lost along with their valuable environmental services. Ramaswamy, P.R. (2003) stated that the management of water as a national resource for sustainable development is the need of the hour in developed and developing countries because of the current onslaught of globalization.

Due to the importance of water and water resources, we can assume that much literature is being published in this area. As such, it is very difficult to know in what quantity the literature is being published because there is probably no such source which can give us a glimpse of the published literature on water resources. So, we did a random search on Google for "water resource literature statistics" and it showed 17,00,00,000 web results. After doing a little deep analysis of web results, it came to know that result includes all types of literature, and institutions which are working in this area. It has become clear from this that a lot of work is being done in this field in India as well as abroad. Institutions and writers from India and abroad are collaborating and trying to publish good literature. This article is an outcome of a curiosity i.e. to know about the literature being published in this area, about the authors, institutions and countries contributing and collaboration status and pattern.

### Review of Literature

Sun & Yuan (2020) conducted a study on the top papers published on water resources. They analyzed 798 top papers in the subject category of Water Resources from 2008 to 2018. The 798 top papers include 797 highly cited papers and 21 hot papers in the field. Results showed that 798 papers, all written in English, were from 2,845 authors, 80 countries/territories and 1,107

organizations, listed in 49 journals in the field of water resources. The top 5 core journals with higher impact factors ranked as Water Research, Journal of Hydrology, Desalination, Catena and Advances in Water Resources. The top 5 countries and regions were USA, China, Australia, England and Germany. The top 5 organizations were Chinese Academy of Sciences, University of California System, Helmholtz Association, Delft University of Technology and Eth Zurich.

Chen, et .al (2018) conducted a bibliometric analysis of water research on the Yangtze River from 1996 to 2016. This analysis revealed a quantitative and visual global scientific research review from the aspects of document type and language, publication year, authorship, subject categories and journals, countries or territories and institutions, the most frequently cited publications, author keywords and research trends. The 20 most productive authors were all Chinese. The Journals of Environmental Science and Pollution Research, Environmental Earth Sciences and Journal of Hydrology were the three most common journals. China produced 90.4% of all pertinent publications followed by the USA (13.7%) and Japan (4.0%). The Chinese Academy of Sciences was the major institution, producing 31.9% of all publications. The most frequently cited publications and author keywords provided clues for research focuses.

Husain, Raza & Gul (2018) conducted a bibliometric analysis of the published research articles on the river Ganga for the period of 25 years (from 1991 to 2016), using Science Citation Index expended. Results of the study revealed that India is the top contributor in terms of total publications followed by USA. The impact of countries, institutions, and authors was assessed by TC 2016. The authors with the highest contributions were mainly from India, and few were from France and Bangladesh. Indian institutes also retain the top position in terms of article contribution, most prolific institutes are: Indian Institute of Technology, Lucknow University.

Zare et. al (2017) used bibliometric analysis techniques to provide quantitative insights into the general landscape of Integrated Water

Resource Assessment and Modelling (IWAM) research from 1970 to 2015. Keywords, terms in titles, abstracts and full texts are used to distinguish the 13,239 IWAM articles in journals and other non-grey literature.

Wambu & Ho (2016) carried out a study on bibliometric analysis of drinking water research in Africa. A total number of 1917 publications of drinking water research in Africa from 1991 to 2013 were identified from SCI-Expanded. The top three subject areas were 'water resources', 'environmental science', and 'environmental and occupational public health'. The ten most productive institutions were located in South Africa and Egypt, and the University of Pretoria was the overall most productive institution. They found that articles became increasingly collaborative with greater numbers of authors, page counts and bibliographies. More than half of the internationally collaborative articles were co-authored with researchers from Europe. French and US institutions contributed to the highest number of collaborative articles.

Wang et al. (2016) identified certain characteristics of literature related to river water quality assessment. There were 3701 articles pertinent to river assessment and simulation published by SCIE and SSCI databases from 2000 to 2014. The result showed that the USA took a leading position out of 104 countries/territories, followed by China and the UK. Similarly, Chinese Academy of Sciences was the most significant contributor in this field of research. Environmental sciences and water resources were the top two most central subject categories and Journal of Hydrology was the most productive journal. Singh K. P ranked first in terms of a comprehensive index in all core authors. Five clusters were identified in terms of keywords networks. And temporal trend of keywords indicated nutrient and eutrophication is the hot topics and SWAT is widely accepted as the model to study water quality in the past 15 years.

Qian et al. (2015) conducted a study on pharmaceutical wastewater treatment from 1994 to 2013. The results showed that the annual output of related scientific articles had increased steadily, with approximately 88% of all articles on pharmaceutical wastewater treatment during 1994–2013 published since 2003. Water Research, chemosphere and environmental science and technology were the three most common journals in pharmaceutical wastewater treatment research. The United States takes the dominant position in this field, followed by Spain and Germany.

Zhang et.al (2015) presented a bibliometric analysis of global inter basin water transfer research between 1900 and 2014. The results showed that the rate of annual publication of inter basin water transfer research grew steadily after 1972 and is rising quickly at present. The United States produced the largest number of single-country publications (37.4%) and international collaborative publications (46.6%). However, China had a high growth rate of publications after 2001 and surpassed the United States and ranked 1st in 2012, with the Chinese Academy of Sciences playing a leading role in the emergence of China's research output. The results of keyword evolution generally indicate that the research on inter basin water transfers expanded from 1991 through 2014.

Fu, Wang &Ho (2013) carried out research to provide insights into research activities and tendencies of global drinking water from 1992 to 2011. The results indicated that the annual output of the related scientific articles increased steadily. Water Research, Environmental Science & Technology, and Journal American Water Works Association were the three most common journals in drinking water research. The USA took a leading position out of 168 countries/territories, followed by Japan and Germany. A summary of the most frequently used keywords obtained from words in paper title analysis, author keyword analysis and KeyWords Plus analysis provided the clues to discover the current research emphases. Commonly researched drinking water contaminants concerned arsenic, nitrate, fluoride, lead, cadmium, and pharmaceuticals emerged as the frequently studied contaminants in recent years.

Chuang, Wang & Ho (2011) used Essential Science Indicators (ESI) database to analyse the trends and characteristics of papers in the

subject category of water resources. Results showed that 265 papers, all written in English, were listed in 27 journals in the field of water resources. Journal of Hydrology published the most papers. The USA and UK were the two leading nations. ESI papers published in the US were more likely to involve inter-institutional collaboration than papers published in the UK. The University of Arizona was the most productive institute.

Khan & Ho (2011) reviewed articles to bring out the toxicological effects caused by arsenic on biological systems. The review covers a bibliometric analysis of drinking water from 1991 to 2008 covering 2,299 publications on the subject. The major findings of the study are articles per year increased from 8 in 1991 to 292 in 2007 and 269 in 2008, reflecting the increasing interest in this topic of research. 55% of the records were published during the period 2005 to 2008. In total, 1,908 articles were published in 441 journals. 14 core journals contained 34% of the total articles. Environmental Health Perspectives ranked first with 5.2% published papers followed by Environmental Science & Technology with 4% publications.

Wang, Li & Ho (2011) designed the study to evaluate the global scientific output in the ISI subject category of "water resources" and data were based on the online version of the Science Citation Index Expanded, Web of Science, from 1993 to 2008. Of all the 61,334 articles with author addresses, 49,338 (80%) were single-country articles and 12,006 (20%) were internationally collaborative articles. Among the top 20 productive countries/territories were two North American countries, ten European countries, six Asian countries, South Africa, and Australia. Most of the 7 major industrial countries (G7: Canada, France, Germany, Italy, Japan, the UK, and the USA) were among the top 10 productive countries except for Japan (ranked 11th). The USA, the UK, and Canada had high productivity in terms of total, independent, internationally collaborative, first author.

Hu et al. (2010) carried out a bibliometric study to identify the global research related to lead in the drinking water field from 1991 to 2007. The

results indicated that there had been an increasing number of annual publications mainly during two periods: from 1992 to 1997 and from 2004 to 2007. United States produced 37% of all pertinent articles followed by India with 8.0% and Canada with 4.8%. Science of the Total Environment published the most articles followed by Journal American Water Works Association and Toxicology. Summary of the most frequently used keywords are also provided. "Cadmium" was the most popular author keyword in the 17 years.

Shan Ho (2008) bibliometric analysis was based on the Science Citation Index. Study was carried out on biosorption technology-related publications from 1991 to 2004. Results showed that yearly production has sharply grown. The US and Canada respectively produced 13% and 12% of the total output. In the five years after publication, 34% of papers were cited more than 10 times, while 5.7% were never cited in the same period. Nine papers of the top 20 most frequently cited articles were published in Water Research.

Singh, Mittal & Ahmad (2007) conducted a study to find out the growth and characteristics of digital library literature. For this purpose, over 1,000 articles were collected for the period 1998-2004 from LISA Plus. They found that most of the articles (61%) are single-authored; author productivity is not in agreement with Lotka's Law, except in one case where number of articles is three; the maximum number of articles were published in 2003 with English being the most productive language; maximum articles were published in the journal D-lib Magazine; distribution of articles nearly follows Bradford's Law; and USA ranked first for maximum number of journals.

**RESEARCH QUESTIONS**

1) How many papers are published on water resources?
2) Which journals are core journals on water resources?
3) What is the year-wise distribution of articles?
4) Who are the most prolific authors?

5) What is the authorship pattern in water resources research?
6) Which are the highly productive institutions?
7) What is the average page length of articles?
8) What are the frequently occurring keywords in Water Resources research?
9) How many countries are associated with India for research in the area of water resources and with which country India has more publications highlighting the closeness of the publication relationship?
10) How many countries are collaborating to publish articles and what is the number of their publications?

## OBJECTIVES OF THE STUDY

The objectives of this research study are to depict/find out/identify/study the:
1) Number of papers published on Water Resources during 2016-2021.
2) Core journals on Water Resources.
3) Year-wise distribution of articles.
4) Most prolific authors.
5) Authorship pattern in Water Resources research.
6) Highly productive institutions.
7) Average page length of articles.
8) Frequently occurring keywords in Water Resources research.
9) Number of countries associated (affinity) with India for research in the area of water resources and with which country India has more publications.
10) Number of countries collaborating to publish articles and the number of their publications.

## RESEARCH METHODOLOGY

The source for the data collection is the Web of Science (WoS) Core Collection Database. The search syntax used for the purpose was "*(TS= ("Water Resources") And AD=("India")) And Language: (English) And Document Types: (Article) Indexes=SCI-Expanded, SSCI, A & HCI Time Span=2016-2021*"

As on 04 March 2021, Web of Science retrieved 797 records. It covers all documents in article form in the English language from India on Water Resources published during the period from 2016 to 2021. The Bibliographical data of 797 publications were exported into MS Excel worksheets from the database and tabulated and analyzed. Raw data were examined, filtered, tabulated, and analyzed quantitatively to make data analysis using scientometric indicators, approaches, and methods. The VOS viewer software was also used to evaluate and visualize the map.

## DATA ANALYSIS AND INTERPRETATION

Data is exported from the Web of Science Core Collection Database and necessary editing, and omissions have been made as per the objectives of the study. Data has been presented through one-way, two-way, and manifold tables and visual presentations through graphs.

Table 1 presents an overview of articles which provides information on the total number of documents, time span, average number of citations, total number of articles etc.

**Table 1**: General Information

| Description | Records |
|---|---|
| Time span | 2016:2021 |
| Documents | 797 |
| Average citations per document | 7.605 |
| Average citations per year per doc | 1.894 |
| **Document Types** | |
| Article | 752 |
| article; data paper | 4 |
| article; early access | 22 |
| article; proceedings paper | 19 |

| Authors | |
|---|---|
| Authors | 2479 |
| Authors of single-authored documents | 19 |
| Authors of multi-authored documents | 2460 |
| **Authors Collaboration** | |
| Single-authored documents | 30 |
| Documents per Author | 0.322 |
| Authors per Document | 3.11 |
| Co-Authors per Documents | 4.29 |

**Core Journals**

The analysis of core journals is important because it helps to find out core journals to publish relevant studies, the top 10 core journals with their impact factor that published documents on water resources are presented in Table2. Water Resources Management is the most productive journal with 26 top articles (3.26%), followed by Arabian Journal of Geosciences 22 (2.76%), Environmental Earth Sciences 21 (2.63%) publications got 2nd and 3rd rank respectively. On the other hand,

Theoretical and Applied Climatology 2%, Water 2% and Water Policy 1.88% got 6th and 7th rank respectively. Table 2 also shows the impact factor of core journals Science of the Total Environment has the highest impact factor of 10.75 followed by the Journal of Hydrology with 6.71and Water Resources Management with 4.43impact factor got 2nd and 3rd ranks respectively. Among these top 10 core journals, Water Policy has the least impact factor 1.73.

**Table 2: Top 10 Core Journal**

| S. No. | Journal Titles | Publications | Share | Impact Factor | Rank |
|---|---|---|---|---|---|
| 1 | Water Resources Management | 26 | 3.262 | 4.43 (2021) | 1 |
| 2 | Arabian Journal of Geosciences | 22 | 2.76 | 1.83(2021) | 2 |
| 3 | Environmental Earth Sciences | 21 | 2.635 | 3.12 (2021) | 3 |
| 4 | Journal of Hydrology | 21 | 2.635 | 6.71(2021) | 3 |
| 5 | Science of The Total Environment | 19 | 2.384 | 10.75 (2021) | 4 |
| 6 | Environmental Monitoring and Assessment | 17 | 2.133 | 3.31 (2021) | 5 |
| 7 | Environment Development and Sustainability | 16 | 2.008 | 4.08 (2021) | 6 |
| 8 | Theoretical and Applied Climatology | 16 | 2.008 | 3.41 (2021) | 6 |
| 9 | Water | 16 | 2.008 | 3.53 (2021) | 6 |
| 10 | Water Policy | 15 | 1.882 | 1.73 (2021) | 7 |
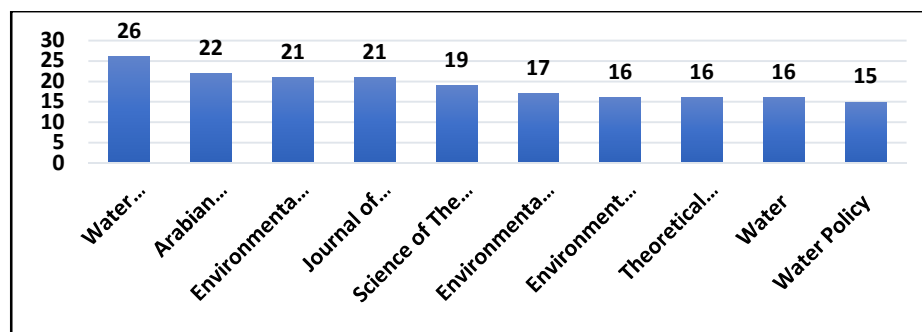


**Figure 1:** Top 10 Core Journal

**Year-wise distribution of articles**

Table 3 shows year-wise articles on water resources from 2016-2021. It is clear from the given table that in the year 2020 highest number of articles 236(29%) were published on water resources followed by the year 2019 with 149(18.69%) documents and in the year 2021 lowest number of articles 51(6.39) were published.

**Table 3:** Year-wise distributions of articles

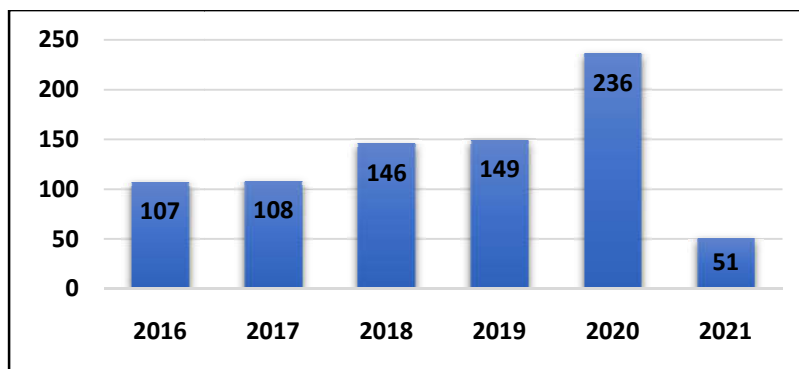| Years | Articles | | |
|---|---|---|---|
| | **Frequency** | **Cumulative frequency** | **Share %** |
| 2016 | 107 | 107 | 13.42 |
| 2017 | 108 | 215 | 13.55 |
| 2018 | 146 | 361 | 18.32 |
| 2019 | 149 | 510 | 18.70 |
| 2020 | 236 | 746 | 29.61 |
| 2021 | 51 | 797 | 6.40 |
| Total | 797 | | 100.00 |



**Figure 2:** Year-wise distributions of articles

**Most Prolific Authors**

In order to identify the productive authors, individual authors were ranked in terms of their productivity based on the number of publications over the years. Table 4 shows the top 10 productive authors. Among these productive authors Malik, A. is in the top position with 16 (2.007%) followed by Mishra, V. got second rank with 14 (1.75%), Kumar, A., Sivakumar, B., and Imran, A. with the contribution of 11 (1.38%), 11(1.38%) and 11 (1.38%) got 3rd respectively while T. I. Eldho and Manish Kumar Goyal contributed 7 (0.87%) publications and got 7th rank respectively.

**Table 4:** Most Prolific Authors

| S. No. | Authors | Affiliation | Publications | Share | Rank |
|---|---|---|---|---|---|
| 1. | Anurag Malik | Punjab Agricultural University | 16 | 2.007 | 1 |
| 2. | Vimal Mishra | Indian Institute of Technology, Gandhinagar | 14 | 1.756 | 2 |
| 3. | Anil Kumar | Delhi Technological University | 11 | 1.38 | 3 |
| 4. | Bellie Sivakumar | Indian Institute of Technology, Bombay | 11 | 1.38 | 3 |
| 5. | Imran Ali | Jamia Millia Islamia University | 11 | 1.38 | 3 |

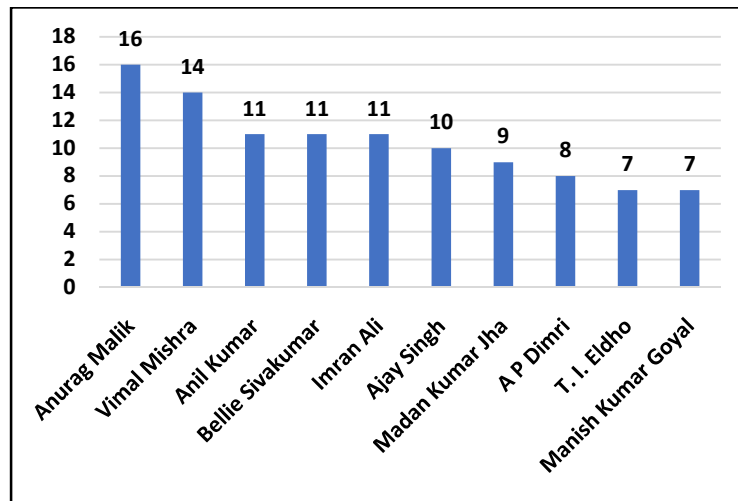| 6. | Ajay Singh | Indian Institute of Technology, Kharagpur | 10 | 1.254 | 4 |
| 7. | Madan Kumar Jha | Indian Institute of Technology, Kharagpur | 9 | 1.129 | 5 |
| 8. | AP Dimri | Jawaharlal Nehru University, New Delhi | 8 | 1.003 | 6 |
| 9. | T.I. Eldho | Indian Institute of Technology, Bombay | 7 | 0.878 | 7 |
| 10. | Manish Kumar Goyal | Indian Institute of Technology, Indore | 7 | 0.878 | 7 |



**Figure 3:** Most Prolific Authors

## Authorship Pattern

Authorship analysis of the publications was carried out based on different Bibliometric indicators namely single-authored articles, collaboratively authored articles and corresponding authored articles. Table 5 shows the authorship pattern of articles published on water resources it was noted that two authored contributions take the first position occupying 177 (22.2%) of the total publication. The next place is recorded by three authored papers having 172 (21.9%) of the total research contributions. Four authored collaborations occupy 3rd position with 143 (17.9%) of the total publication. Data indicates that the single-authored work 30 (3.76%) is extremely less than that of the multi-authored collaboration.

**Table 5: Authorship Pattern**

| Year | Authorship Pattern | | | | | Total |
|---|---|---|---|---|---|---|
| | | Collaborative | | | | |
| | Single | Two | Three | Four | More than four | |
| 2021 | 2 | 6 | 14 | 9 | 20 | 51 |
| 2020 | 3 | 52 | 47 | 46 | 88 | 236 |
| 2019 | 5 | 38 | 25 | 28 | 53 | 149 |
| 2018 | 8 | 38 | 25 | 27 | 48 | 146 |
| 2017 | 5 | 22 | 29 | 19 | 33 | 108 |
| 2016 | 7 | 21 | 32 | 14 | 33 | 107 |
| Total | 30 | 177 | 172 | 143 | 275 | 797 |
| Percentage | 3.764 | 22.208 | 21.581 | 17.943 | 34.504 | 100 |

## Highly Productive Organizations

Table 6 shows highly productive organizations in India that produce articles on water resources. It is clear from the table that the Indian Institute of Technology Bombay published the highest number of articles i.e., 48 (6.02%) occupy 1st rank followed by the Indian Institute of Technology Roorkee with 47 (5.89%) and Indian Institute of Technology Kharagpur 42 (5.26%) got 2nd and 3rd rank respectively. While the Indian Institute of Sciences and Jamia Millia Islamia published only 15 (1.88%) articles on water resources got the position 9th and 10th respectively.

**Table 6:** Highly Productive Organizations

| S. No. | Organizations | Publications | Share | Rank |
|---|---|---|---|---|
| 1. | Indian Institute of Technology, Bombay | 48 | 6.022 | 1 |
| 2. | Indian Institute of Technology, Roorkee | 47 | 5.897 | 2 |
| 3. | Indian Institute of Technology, Kharagpur | 42 | 5.269 | 3 |
| 4. | National Institute of Hydrology, Roorkee | 36 | 4.516 | 4 |
| 5. | Jawaharlal Nehru University | 19 | 2.384 | 5 |
| 6. | Indian Institute of Technology, Delhi | 19 | 2.384 | 5 |
| 7. | G.B. Pant University of Agriculture and Technology | 16 | 2.008 | 6 |
| 8. | King Saud University | 16 | 2.008 | 6 |
| 9. | Indian Institute of Science | 15 | 1.882 | 7 |
| 10. | Jamia Millia Islamia | 15 | 1.882 | 7 |
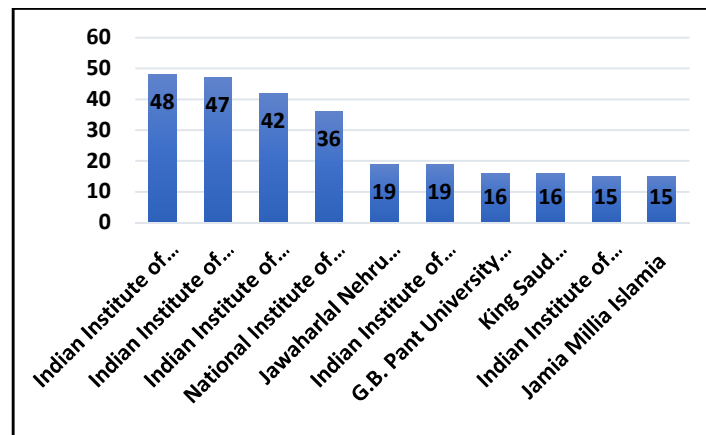


**Figure 4:** Highly Productive Organizations

## Funding Agencies

There are so many funding agencies that publish articles on water resources. The table shows the top 10 funding organizations. It is clear from the table that the Department of Science &Technology India published 50 articles with 6.27% getting first rank followed by the University Grants Commission India (UGC) published 27 (3.38%) documents and UK Research Innovation with 17(2.13%) second and third rank respectively. On the other side, the Consultative Group for International Agricultural Research (CGIAR) and the National Natural Science Foundation of China have at least 7 (0.87%) publications with 9th rank respectively.

**Table 7: Funding Agencies**

| S.N. | Funding Agencies | Publications | Share | Rank |
|---|---|---|---|---|
| 1. | Department of Science &Technology, India | 50 | 6.274 | 1 |
| 2. | University Grants Commission, India | 27 | 3.388 | 2 |
| 3. | UK Research Innovation | 17 | 2.133 | 3 |
| 4. | Natural Environment Research Council | 15 | 1.882 | 4 |
| 5. | Council of Scientific & Industrial Research, India | 14 | 1.757 | 5 |
| 6. | National Science Foundation, USA | 10 | 1.255 | 6 |
| 7. | King Saud University, Saudi Arabia | 9 | 1.129 | 7 |
| 8. | European Commission | 8 | 1.004 | 8 |
| 9. | Consultative Group for International Agricultural Research(CGIAR) | 7 | 0.878 | 9 |
| 10. | National Natural Science Foundation of China | 7 | 0.878 | 9 |

**Page Length of Articles**

Table 8 indicates details about the page length of articles. Out of the total 797 articles, 595 contributions have page lengths of more than 10 pages, 50 articles have page lengths of 10 pages, 46 contributions have page lengths of 9 pages, 39 contributions have page lengths of 7 Pages and the lowest length of articles (1) appeared in less than 4 pages.

**Table 8:** Page Length of Articles

| Page Length (No. of pages) | Years | | | | | | |
|---|---|---|---|---|---|---|---|
| | **2016** | **2017** | **2018** | **2019** | **2020** | **2021** | **Total** |
| Less than 4 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| 4 | 0 | 0 | 2 | 0 | 1 | 0 | 3 |
| 5 | 2 | 1 | 2 | 1 | 1 | 0 | 7 |
| 6 | 6 | 1 | 5 | 3 | 3 | 0 | 18 |
| 7 | 8 | 8 | 5 | 12 | 5 | 1 | 39 |
| 8 | 6 | 10 | 6 | 5 | 9 | 2 | 38 |
| 9 | 6 | 6 | 10 | 11 | 11 | 2 | 46 |
| 10 | 7 | 6 | 12 | 13 | 8 | 4 | 50 |
| More than 10 | 72 | 75 | 104 | 104 | 198 | 42 | 595 |
| **Total** | 107 | 108 | 146 | 149 | 236 | 51 | 797 |
| **Percentage** | 13.425 | 13.551 | 18.318 | 18.695 | 29.612 | 6.399 | 100 |

**Keywords Analysis**

Table 9 shows the keywords used for retrieving data for author keywords analysis. It is clear from the data that Water Resources occupy the top rank with 84 articles of the total articles, followed by Climate change (80), Precipitation (75), River Basin (73), Model (72), and last 'Evapotranspiration' which occurs in 21 articles.

**Table 9:** Keywords Analysis

| S. No. | Keywords | Occurrence |
|---|---|---|
| 1. | Water-Resources | 84 |
| 2. | Climate-Change | 80 |
| 3. | Precipitation | 75 |

| 4. | River-Basins | 73 |
|---|---|---|
| 5. | Model | 72 |
| 6. | Impacts | 61 |
| 7. | Management | 54 |
| 8. | Variability | 53 |
| 9. | Systems | 52 |
| 10. | Water | 47 |
| 11. | Rainfall | 46 |
| 12. | Temperature | 40 |
| 13. | India | 37 |
| 14. | Basin | 36 |
| 15. | Quality Assessment | 36 |
| 16. | Simulations | 35 |
| 17. | Runoff | 32 |
| 18. | Resources | 31 |
| 19. | Area | 30 |
| 20. | Prediction | 30 |
| 21. | Performance | 29 |
| 22. | Removal | 29 |
| 23. | River | 29 |
| 24. | Catchment | 28 |
| 25. | Waste-Water | 28 |
| 26. | Climate | 27 |
| 27. | Trends | 27 |
| 28. | Groundwater | 26 |
| 29. | GIS | 25 |
| 30. | Identification | 25 |
| 31. | Adsorption | 23 |
| 32. | Irrigation | 23 |
| 33. | Evapotranspiration | 21 |

**Scientific indicators:**

Affinity Index (AFI) is the measure of research collaboration between countries in a given area of research. Affinity Index is the indicator used to evaluate the relative rate of scientific exchanges between one country (A) and another (B) overall given period and in relation to all international co-operations between the same two countries over the same period. It is mathematically expressed as:

$$AffinityIndex\ (AFI) = \frac{No.\ of\ co\text{–}operation\ links\ between\ A\ and\ B}{No.\ of\ co\text{–}operation\ links\ between\ A\ and\ rest\ of\ the\ world} \times 100$$

**AFI value >1 more production in collaboration, while <1= reverse.**

**Table 10:** Top Country Collaboration and Affinity Index

| Country | Publications | Share | Affinity Index |
|---|---|---|---|
| USA | 74 | 9.285 | 12.58 |
| China | 50 | 6.274 | 8.50 |
| England | 37 | 4.642 | 6.29 |
| Germany | 32 | 4.015 | 5.44 |
| Iran | 27 | 3.388 | 4.59 |
| Vietnam | 22 | 2.76 | 3.74 |
| Australia | 21 | 2.635 | 3.57 |
| Saudi Arabia | 20 | 2.509 | 3.40 |
| Canada | 19 | 2.384 | 3.23 |
| South Korea | 17 | 2.133 | 2.89 |
| Rest Countries | 269 | 33.752 | 45.75 |
| Total Links | 588 | | |

Out of the 797 publications, 310 articles (38.89%) were published in collaboration with other countries of the world. These 310 articles contain 588 cooperation links from other countries. One cooperation link is counted even if a country appears more than one time in a single article.

It is found from the table, that the top 10 countries have an AFI value of more than 1 (>1).

Which shows that there exists a positive affinity between India and the top 10 collaborating nations. The AFI value of USA are 12.58. Hence, it is understood that the USA has the highest number of collaborative research work with India. China comes second with an AFI value of 8.50. England's AFI value is 6.29 whereas Germany and Iran have the values 5.44 and 4.59.
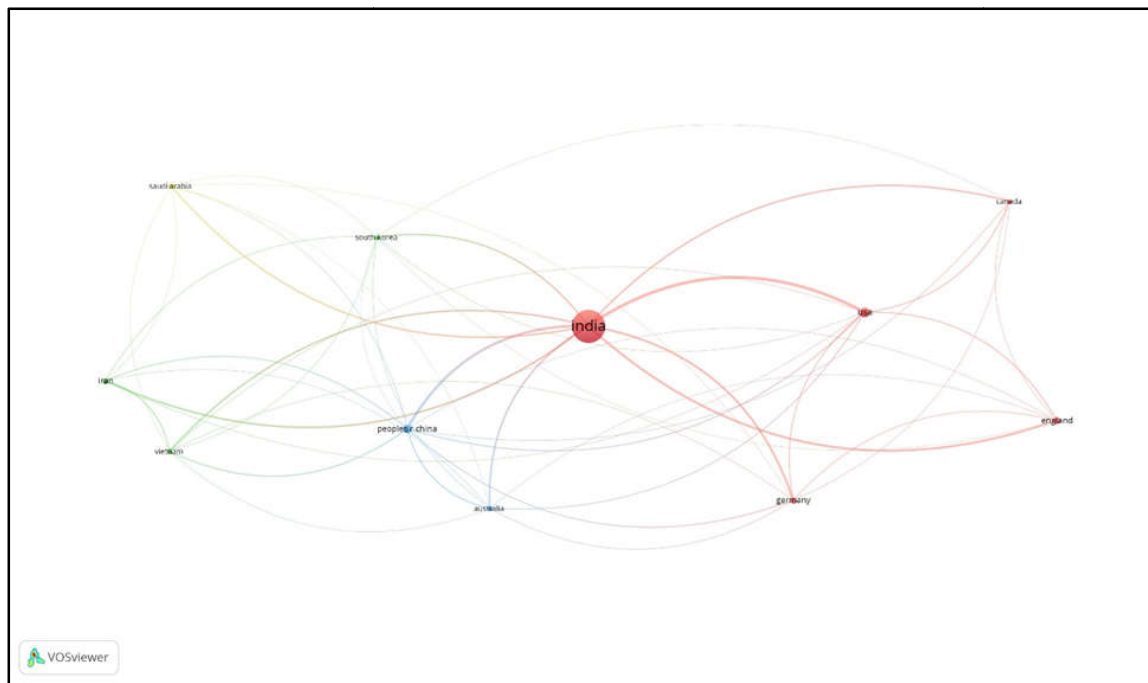


**Figure 5:** Top 10 Collaborative Countries Co-authorship Network Visualization

The above figure shows the network visualization of the top10 collaborative countries (with India) co-authorship network map using VOS viewer software. The size of each circle represents the number of articles of each country and denotes the activity of the country. A line is established when two countries have a collaborative relationship. The thickness of each line reflects the tightness of cooperation and the number of collaborations between countries. There are many colorson the map, which shows the diversification of research directions.

Country co-authorship reflects the degree of communication between countries. In this map, the top 10 countries are divided into 4 clusters in which links are 45, and the total link strength is 447.The first cluster consisted of 5 countries (red color), Canada, England, Germany, India, USA. The second cluster consisted of 3 countries (green color), Iran, South Korea, and Vietnam. The third cluster consisted of 2 countries (blue color), Australia and China. The fourth cluster consisted of 1 country (yellow color), Saudi Arabia.

**Internationalization Index (INI)** is a percentage of the total number of COA (international institutional co-authored articles) of a country published during a given period in a given field over the total number of articles published during the same period in the same research field.

**Mathematically expressed:**

$$InternationalizationIndex\ (INI) = \frac{No.\ of\ international\ links}{Total\ no.\ of\ papers\ from\ the\ country} \times 100$$

From the above Table, it is observed that the number of international links is 588. The total number of papers contributed by India is 797 in the given period. According to the formula given by Frame and Carpenter,

$$\text{Internationalization Index (INI)} = \frac{588}{797} \times 100 = 73.77$$

Therefore, the internationalization index of Indian Water Resources literature is 73.77.

**Co-operative Efforts (COP)** are the cooperative efforts made by countries through writing articles and the number of scientific links created between countries through common works.

**If n countries are cooperating in a paper, then there are (n-1) links.**

**Table 11:** Scientific Links (Co-operative efforts)

| Publications | No. of countries collaboration | Scientific links |
|---|---|---|
| 187 | 2 | 187 |
| 62 | 3 | 124 |
| 32 | 4 | 96 |
| 13 | 5 | 52 |
| 7 | 6 | 35 |
| 1 | 7 | 6 |
| 3 | 8 | 21 |

| 2 | 10 | 18 |
|---|---|---|
| 1 | 12 | 11 |
| 1 | 14 | 13 |
| 1 | 18 | 17 |
| **Total=**310 | 89 | 580 |

Table 3 indicates that between 2016 and 2021, a total of 797 papers on Water Resources were published in India. Out of these 797 articles, 310 were written in collaboration with authors from outside the country. There are 580 scientific links created between other countries, depicting most of the publications involved authors from more than two countries.

**FINDINGS AND CONCLUSION**

This study revealed that Water Resources Management is the most productive journal with 26 articles (3.26%), followed by Arabian Journal of Geosciences 22 (2.76%), Environmental Earth Sciences 21 (2.63%) publications got 2nd and 3rd rank respectively. the year 2020 highest number of articles 236 (29%) were published on water resources followed by the year 2019 with 149 (18.69%). The Most productive author Malik, Anurag from Punjab Agricultural University is in the top position with 16 (2.007%) published articles. 177 (22.2%) of the total publication have two authored contributions taking the first position. Indian Institute of Technology Bombay published the highest number of articles i.e., 48 (6.02%) occupy 1st rank. Department of Science & Technology India funded 6.27% of published articles in the field of Water Resources Research. Out of the total 797 articles, 595 contributions have page lengths of more than 10 pages. The most common keywords in the literature are 'Water Resources', 'Climate change', 'Precipitation', and 'River Basin', which suggests that these topics continue to be of significant interest to researchers in the field. USA has the highest number of collaborative research work with India. China comes second with an AFI value of 8.50. The Internationalization Index of Indian Water Resources literature is 73.77. Co-operative efforts show that there are 580 scientific links created between other countries, depicting most publications collaborated with authors from more than two countries.

The implications of these findings are significant for the Water Resources research. By identifying the most influential authors and topics in the literature, this study provides a valuable resource for those looking to stay up-to-date with the latest research in the field. Additionally, the findings of this study could inform the development of future research agendas and funding priorities.

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