Synthesizing a Decade of Water Conservation Studies Through Bibliometric Analysis

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ABSTRACT

Purpose – The paper aims at analyzing literature available on the topic water conservation using bibliometric analysis. The purpose is to explore important information such as publication growth, citation trends, prominent sources, most contributing countries, frequent keywords, apex organizations, and to figure out existing co-authorships in the field.

Design / Methodology / Approach – For conducting Bibliometric analysis, 395 articles published in English language, are extracted from Web of Science (WoS) database for a decade specifically from 2015 to 2024. The analysis is done by using two softwares namely, Biblioshiny in R studio (version 4.4.1) and VOSviewer (version 1.6.20).

Findings – The study highlights a significant growth in number of publications, along with some decline in citation trend. 'Sustainability' and 'Water' are found to be the pertinent journals in the field. Further, China is the most contributing country in terms of publications and citations received. Also, the apex affiliation in terms of number of publications is from China specifically from 'China University of Mining and Technology'. Moreover, Management, Water, Impact, Model, Performance, Climate-Change, Conservation, Systems, Soil, and Irrigation are highlighted as the trendy keywords of the decade.

Originality / Value – In this bibliometric analysis, water conservation has been linked to the solution and answer keywords. However in prior literature, bibliometric analysis on water conservation has not been performed using this kind of viewpoint. Hence, the analysis becomes significant due to this paper's unique findings.

Keywords – Water Conservation, Bibliometric Analysis, Sustainable Development Goals (SDGs), Web of Science (WoS), Biblioshiny, VOSviewer.

Paper Type – Literature Review

1. INTRODUCTION

The level of natural resource use is rising rapidly as a result of population growth. Naturally, overconsumption is the problem, albeit there may be other reasons why people exploit natural resources. Overconsumption is the term used to describe when people consume more than they need or require. Ehrlich and Ehrlich (2004) defined overconsumption as resources consumed above a basic level needed and beyond reasonable comfort. It is the main cause of lots of environmental issues and depletion of natural resources. Amongst all natural resources, water is a prime life-sustaining resource. There are numerous uses for water; however, seeing its

careless and excessive use is troublesome. This resource requires conservation due to its prodigality. It is also a verity that water-related problems are interlinked and solvable only by interactions between stakeholders (Bammer, 2013). Hence, all sectors, including the government, business community, and consumers must work together in the direction of its conservation. Even Sustainable Development Goal (SDG) 17 recognizes partnerships of stakeholder as important aspect for mobilizing and sharing technologies, knowledge, expertise, and financial resources to support countries to fulfil their SDG goals (Bulmer & Yáñez-Araque, 2023). In fact, the idea of conserving water is not new; it has deep historical origins. As mentioned by Gelt (1999) early research for solving water related issues focused on managing water resources, particularly for agriculture and irrigation even before the contemporary idea of water conservation came into being. Water conservation efforts were observed with the construction of dams and reservoirs to store water for irrigation and other uses. Then, the system developed to drip irrigation and sprinkler systems and focus was shifted towards erosion control, water management techniques, and household water conservation etc.

Further, the concept of environmental stability was stressed in Millennium Development Goals: MDGs based on Millennium Declaration 2000. These goals were to be achieved by 2015. The MDG 'Goal 7: Ensure Environmental Sustainability' had many targets within its brackets. Target 7C of Goal 7 set the objective of sustainable access to safe drinking water and basic sanitation, which falls under water management category (Mishra et al., 2024; Weststrate et al., 2019; Truslove et al., 2019). MDGs were redefined in 2015 and named Sustainable Development Goals (SDGs) including 17 goals, to be achieved by 2030. SDG 6 titled 'Clean Water and Sanitation' deals with the objective of water management which includes many sub objectives, like water conservation, proper sanitation system etc (Weststrate et al., 2019; Ortigara et al., 2018). SDGs encompasses water sustainability challenges and offers a framework for evaluating sustainable development from an environmental, social, and economic standpoint (Glass & Newig, 2019). Moreover, Sreenath et al. (2021) mentioned that while studying sustainability frameworks, three domains i.e. economy, environment, and social are considered. SDGs have attracted considerable attention from a broad spectrum of stakeholders, such as those involved in environmental policy, the business and finance sectors (Di Vaio et al., 2022), and also professionals in water services, especially in terms of governance, management practices, and technical innovations (Di Vaio et al., 2021).

There are other examples of water conservation too. For instances, under the Consumption Based Fixed Rates (CBFR) model, pricing is done based on the usage or consumption of water in California (Spang et al., 2015). Furthermore, Valizadeh et al. (2021) suggested to begin water conservation initiatives exclusively concentrated on restructuring the human values as it will automatically increase the level of awareness and sense of responsibility of humans towards water conservation. Related to water conservation, Hove & Osunkun (2020) mentioned the importance of utilising social media platforms imparting water conservation knowledge handled by municipalities. Indeed, water conservation has become a key area of research in response to global water scarcity, driven by factors such as population growth, industrial demands, climate change, and agricultural needs and many more. To address these challenges, scholars have explored the topic of water conservation from diverse perspectives. Academicians including Singha et al. (2022) worked on social, behavioural interventions and psychological aspects of water conservation. Researches of certain other academicians revolve around urban water conservation strategies (Liu et al., 2016). Furthermore, evidence of literature is also found in household water conservation (Addo et al., 2019; Fielding et al., 2012; Lu et al., 2019; Hurd, 2006; Thiam et al., 2021). Accordingly, numerous studies are being accumulated in the literature of water conservation. As the number of publications continues to expand at a rapid pace, the task of accumulating knowledge becomes more complicated (Aria & Cuccurullo, 2017). Consequently, academicians started focussing on summarizing the researches by using bibliometric and systematic review methodologies.

As the prime objective of this paper is also conducting a bibliometric analysis; so, the next section presents a review of literature on water conservation for those researches which have exercised either bibliometric analysis or systematic literature review or both. Further, the paper is divided into four sections of bibliometric methodology, analyses and results, conclusion and discussions, and implications and further research directions.

2. LITERATURE REVIEW AND OBJECTIVES

2.1 Literature Review

Zhang et al. (2015) conducted bibliometric analysis on water resource planning i.e. Interbasin water transfers and diversions for records of time period 1900 and 2014. They concluded that the rate of annual publication of interbasin water transfer research grew steadily after 1972 and is growing rapidly at present. Wang et al. (2016) searched literature related to river water quality assessment and simulation, and analyzed 3701 articles. The study concluded that there was a significant growth in total publications over the past 15 years. USA took a leading position of being apex country, followed by China and UK. Moreover, 'Chinese Academy of Sciences' was highlighted as the most significant contributor in this field of research. Next, Zhang et al. (2017) presented a bibliometric analysis on water footprint. They concluded that 'Journal of Cleaner Production', 'Environmental Science and Technology', and 'Ecological Indicators' are the top journals with the maximum number of publications in this field. They also mentioned that United States, China and Netherlands had high productivity in terms of number of publications. Furthermore, 'University of Twente' took the leading position of apex institutions. Velasco-Muñoz et al. (2018) reviewed studies on water use efficiency in agriculture research over the last 30 years. A bibliometric analysis was done based on Scopus database and included 6063 articles. They found that main journal was 'Agricultural Water Management'. Furthermore, China, United States of America, and India were the countries with the highest number of articles. The institution that published the most articles was 'Chinese Academy of Sciences'. Additionally, frequently used keywords were water supply, irrigation, crop yield, and crops. Wang et al. (2019) conducted bibliometric analysis using keywords related to soil and water conservation in the tableland-gully region of China. The study included a total of 2753 Science Citation Index (SCI) and 1294 Chinese National Knowledge Infrastructure (CNKI) studies published from year 1987 to 2016. CiteSpace tools were utilized for visual representations of results. Further, Li et al. (2019) conducted bibliometric analysis to check research status of water ecological environment protection related studies. Articles were extracted from Web of Science for the period of 2008-2019. CiteSpace software was used to conduct co-occurring keywords analysis, annual frequency analysis of papers, countries and research institutions analysis, clustering analysis and research frontier. Another dimension was to examine water resources management in agriculture by utilising multicriteria methods as studied by Troian & Gomes (2020). Publications were generated from Scopus database and were 519 in number but only 30 articles were included in final interpretation. They concluded that the structuring of multicriteria models was designed to better understand the problem and its decision-making process rather than to make the decisions baselessly. Almulhim et al. (2021) examined studies on water planning and management using bibliometric analysis. The study was set limited to the Saudi literature only. The Web of Science was used as a data source and analyzed total of 685 documents. MS Excel, VOSviewer, Biblioshiny, and BibExcel software packages are employed for data analysis. The study answered set research questions like apex countries, co-occurrence citation network, organizations, prolific authors, frequently used keywords, highly cited researcher, preferred source, collaboration pattern, publication source, etc. Meng et al. (2022) investigated the literature on water rights using bibliometric analysis. Data was based on the Science Citation Index Expanded (SCI-E) and Social Sciences Citation Index (SSCI). This paper presents a comprehensive review of publications from 1971 to 2020. This research mainly focused on water resources, environmental studies, law, environmental sciences, agronomy, and political science. Sanchez et al. (2023) conducted a systematic and bibliometric literature review with a motive to identify determinants underlying household water-conservation behaviours. This review included 155 papers published from 1984

to early 2023.The study concluded that factors such as attitude, perceived efficacy, emotions, and habits emerge as pivotal in understanding water conservation. Again, Vasconcelos et al. (2023) conducted bibliometric analysis on surface water resources for South America. Their results showed the most relevant contributions from Brazil and Argentina. Next in line, Imaduddin and Eilks (2024) presented a bibliometric analysis on water literacy and water education. They included data sets from eight renowned databases i.e. Web of Science, Scopus, Dimensions, Lens, PubMed, ScienceDirect, ERIC, and Google Scholar. The analysis of 568 articles was done by using Bibliometrix software in R-Package. They focused on Experiential Learning Theory and found learning is the main mechanism through which humans adopt. Moreover, they found community-based education as a prominent theme in the field. At last, they suggested Community-Based Experiential Learning can be implemented. So, that students can understand more on ecology and participate more in sustainable activities.

2.2 Research Gap and Objectives

Literature showed that water conservation is studied from diverse angles. Water protection was considered by Li et al. (2019). Using multi-criteria approaches to analyze agricultural water resource management was another aspect which was taken by Troian & Gomes (2020). Velasco-Muñoz et al. (2018) reviewed studies on water use efficiency in agriculture research. Additionally, Almulhim et al. (2021) analyzed studies on water planning and management from Saudi literature only. Meng et al. (2022) investigated the literature on water from water rights perspective. Further, Zhang et al. (2017) focused on bibliometric analysis of water footprints, while Sanchez et al. (2023) studied household water conservation behaviour. Imaduddin and Eilks (2024) offered a unique analysis on literacy in water education, considering both formal and informal settings. Other works include water resource planning (Zhang et al., 2015) and assessments of river water quality (Wang et al., 2016; Vasconcelos et al., 2023). Some authors linked water conservation with soil retention (Wang et al., 2019). It is thus confirmed by this literature review that authors may have varied perspectives when it comes to conducting bibliometric analysis on water conservation. Nevertheless, almost all bibliometric analysis address typical queries; indeed, the search phrases and articles retrieved may vary. Therefore, similar to any bibliometric analysis, this paper also focuses on addressing questions that an investigation into bibliometric analysis must resolve.

Accordingly, the objective is to find out answers to the following questions:

1. What is the current publication growth in this field?
2. What is the citation trend in the field?
3. Which sources have been opted by researchers more frequently?
4. Which country has the highest production and citations of researches in water conservation research area?
5. Which keywords have been utilized a lot in this research area?
6. Which organization acts as leaders in this field?
7. In what patterns co-authorship exists?

3. METHODOLOGY

Bibliometric analysis adopts a quantitative approach and makes it possible to create a visual representation of the bibliography of already published work in any field of study (Ding & Yang, 2022; Boyack & Klavans, 2010). According to Donthu et al. (2021), bibliometric analysis has gained immense popularity in research scenario in past few years as it provides quantitative-cum-holistic overview of the wide spread literature and offers a convenient method to identify what is happening. Performance analysis and science mapping are the two procedures under which bibliometric analysis can be reported (Zhang et al., 2017). Reporting of pertinent affiliations, authors, nations, journals, citations, etc. is done under performance analysis and science mapping

is used to summarize word analysis, co-authorship, bibliographic coupling, and other tasks (Donthu et al., 2021; Zhang et al., 2017). To find answers to the set objectives of this study, both of reporting techniques are utilized.

Here, Bibliometric analysis process is conducted as per the recommendations of Zupic and Čaters (2015). They suggested five steps to conduct bibliometric analysis that are Research design, Compilation of bibliometric data, Analysis, Visualization, and Interpretation.

To fulfil the said objectives, next step is to extract the data file from any database. Followed by, the selection of analysing softwares. Hence, the methodology has been divided into two parts.

3.1 Database and Query Selection, Data Set Filtration and Extraction

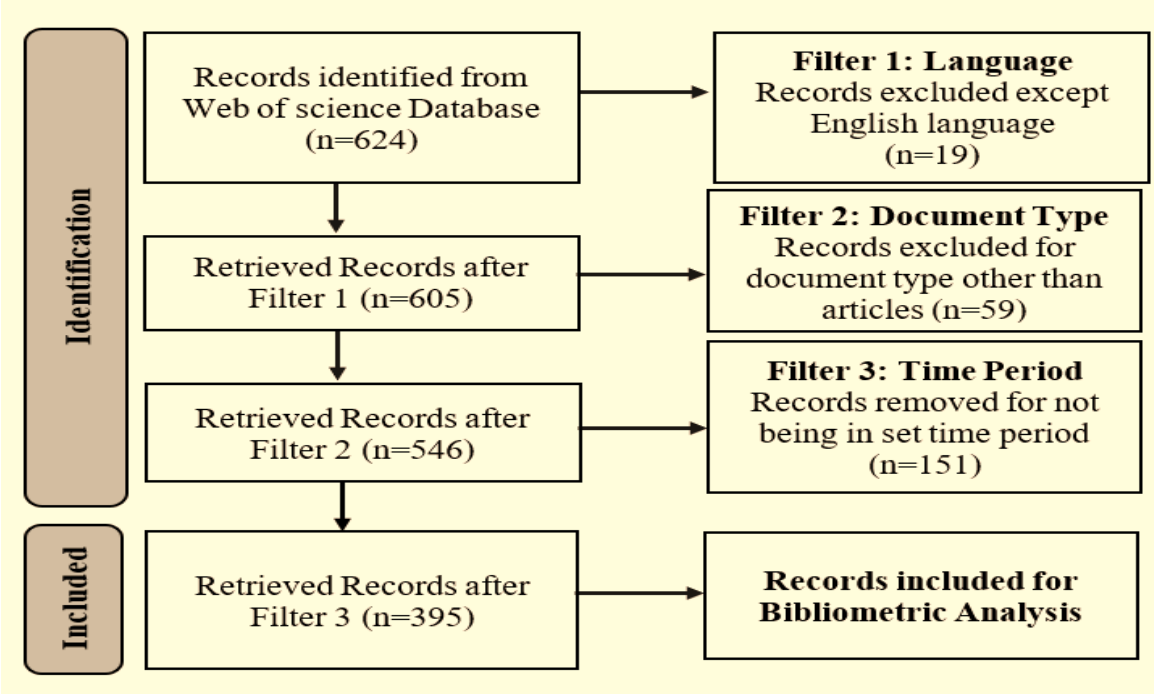
Data are extracted from one of the esteemed recognised databases i.e. Web of Science (WoS) and the search has been completed on 23 July 2024. This database is chosen because it has been widely adopted for bibliometric analysis in various fields of studies (Leung et al., 2017; Goyal & Kumar, 2021; González-Serrano et al., 2020; Pelit & Katircioglu, 2022) and it is the most recommended database (González-Serrano et al., 2020; Fauzi, 2023).

To make search string of water conservation for retrieving published articles, literature is again seen from the viewpoint of, which queries have been used in existing literature. It was found that Water Conservation (Wang et al., 2019; Liu et al., 2021), Surface Water (Vasconcelos et al., 2023), Water Footprint (Fardnia et al., 2025; Zhang et al., 2017; Zhu et al., 2019) are main keywords included. However, none of the study was seen using word solution; indeed, 'Solutions for Conserving Water' is an ordinary saying. So, the search string here adds words 'Solution and Answers' which have not been used in existing literature.

As WoS allows users to enter multiple advanced queries to be searched. In first advanced query keywords water conservation or surface water management or water protection is searched in quotation marks, and in second advanced query keywords solution or answer are entered. The two queries are combined using 'add' boolean term. The search was performed in the topic field as per the suggestions of Paul and Criado (2020), because when selecting the topic field, database searches the keywords in the title, abstract, keywords plus, and author keywords of the documents.

Further, the data extraction is shown in a flowchart (Figure 1). Initially, records found are 624 in number. The reduction process of records is done by applying various filters. The first filter applied is of language and the study is limited to 'English' language only. Accordingly, records get reduced to 605 records. Then, second filter applied is of document type, and set to be 'article' only which is the most prominent used document type (Zhai et al., 2024). With this filter, 546 articles are sorted. Then, third filter of time period is applied to articles and set to include publications only after 2015. Although, agenda of water conservation research is quite old; but, SDGs are considered in 2015, giving new aspect to the concept. So, the time period is set to be 2015 onwards. Finally, 395 articles are included in analysis. After finalising the dataset, the files are downloaded in various formats like 'text', 'bibtex', 'xls' formats to be used further.

Figure 1: Flowchart Depicting the Data Extraction Process



Source: Constructed by Authors as per search in Web of Science database

3.2 Bibliometric Tools

The analysis is done using Biblioshiny in R studio (version 4.4.1) and VOSviewer (version 1.6.20) softwares. For making data user friendly, some features of Microsoft Excel (version 2410) are also used. Biblioshiny in R studio helped in finding out core authors, journals, countries, etc (Wei & Jiang 2023; Thangavel & Chandra 2023). VOSviewer helped in conducting bibliographic coupling, co-occurrence and co-authorship analysis (Van Eck & Waltman, 2023; Pelit & Katircioglu, 2022; Fauzi, 2023). Co-occurrence analysis is applied to find keywords and their network or patterns in the literature and also how frequently two keywords are used simultaneously in the literature. Co-authorship analysis helped in identifying the academic collaboration between different authors, organizations, countries, etc.

Now, in the next section, analysis is presented with suitable graphs, charts, and tables for easy understanding of readers.

4. ANALYSES AND RESULTS

At the outset, the overview of the complete data set is presented. Then, the results are shown as per the objectives.

Figure 2: Overview

Source: Using Biblioshiny in R studio (version 4.4.1)

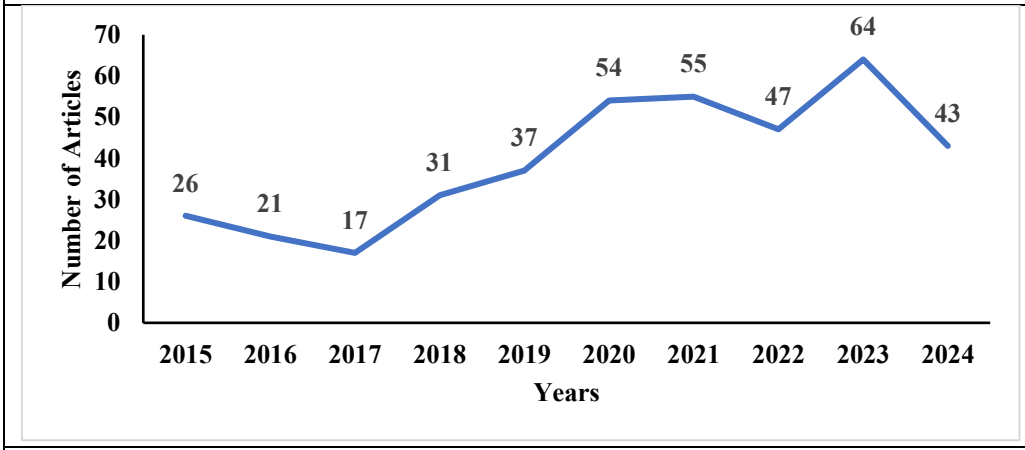
The overview of the literature (Figure 2) shows that 395 articles are used for analysis published during the time span of 2015 to 2024. The total of 1825 authors selected 231 sources for the publication of their research works. The annual growth rate of articles is 5.75 per cent, which shows a great scope and growth in the studied field. The single authored documents are 20 in number. The international co-authorship rate is 33.42 per cent. Co-authors per documents are 5.11 in count. Total author's keywords are 1754. The references used are 20510 in number. Document Average Age is 4.62 years which represents the average time period of articles from their publication date and average citation per document is 12.68.

Now, the analysis is presented as per research questions.

4.1 Publication Growth

In line with first research question, the current publication growth in the field is analyzed through the number of publications on the bases of time.

Figure 3: Annual Scientific Production



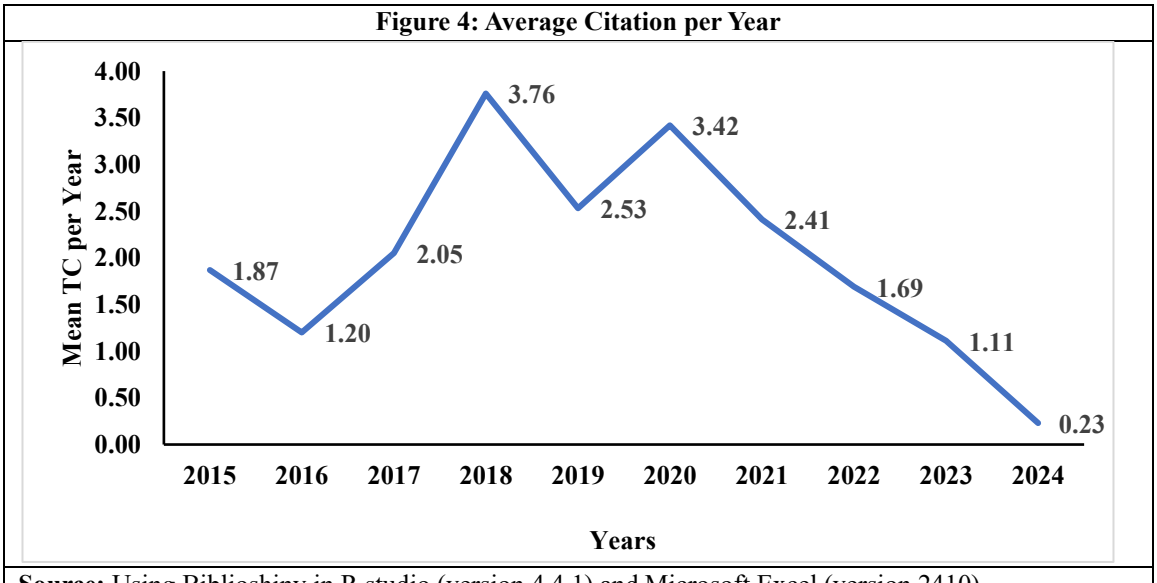
Source: Using Biblioshiny in R studio (version 4.4.1) and Microsoft Excel (version 2410)

Figure 3 depicts publications of the articles which are summarized annually. Years are placed on horizontal axis and number of articles on vertical axis. According to the line diagram obtained from Biblioshiny in R studio, it can be seen that the interest in the field is increasing from only 26 articles published in 2015 to 64 articles in 2023 and 43 articles in 2024. The annual growth rate is 5.75 per cent which has already been shown in figure 2.

4.2 Citation Trend

To find out answer to the second research question, the citation trend is found out by analysing the Mean of Total Citation per Year.

Figure 4: Average Citation per Year



Source: Using Biblioshiny in R studio (version 4.4.1) and Microsoft Excel (version 2410)

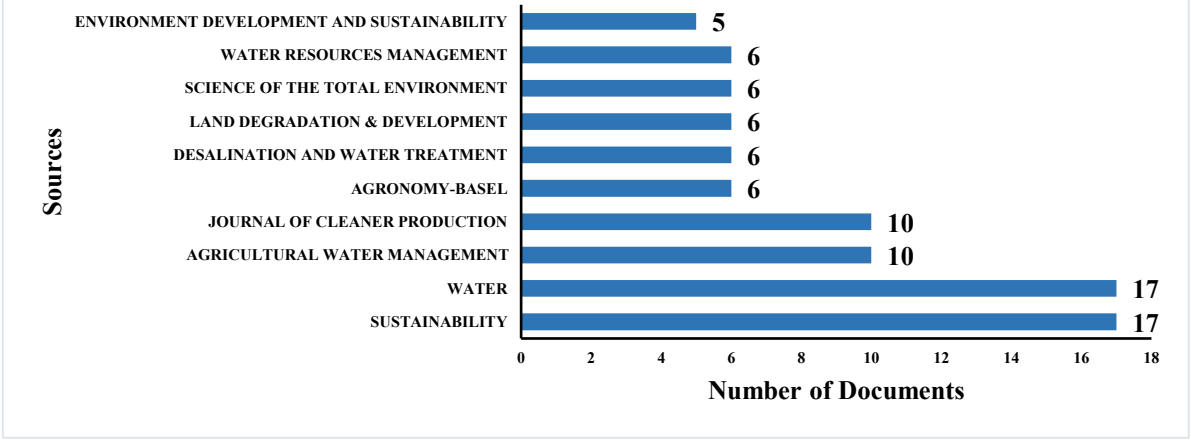
Figure 4 shows a line diagram of the average citation per year. On X-axis, time is presented in terms of years, and on Y-axis Mean Total Citation (TC) per Year is given. The maximum Mean Total Citation per Year received is 3.76 in 2018, followed by 3.42 in year 2020. There is a decline in average citation which can be due to the reason as more articles are published each year, the overall number of citations might be spread thinner amongst many papers.

4.3 Sources Opted by Researchers

The sources more frequently adopted by researchers are analyzed in two ways, firstly on the basis of number of publications and secondly, by bibliographic coupling of the sources.

Figure 5 denotes top ten sources that frequently being chosen by the renowned researchers. On X-axis the number of documents and on Y-axis title of the sources is evident. After analysing the figure, it can be concluded that 'Sustainability' and 'Water' are the most relevant journals in this field with 17 articles each, contributing 4.30 per cent each (17/395*100) to the total publications extracted in the data set. The journals titled 'Agricultural Water Management' and 'Journal of Cleaner Production' are at second position with 10 documents each with the contribution of (10/395*100) 2.53 per cent each to the total publications extracted.

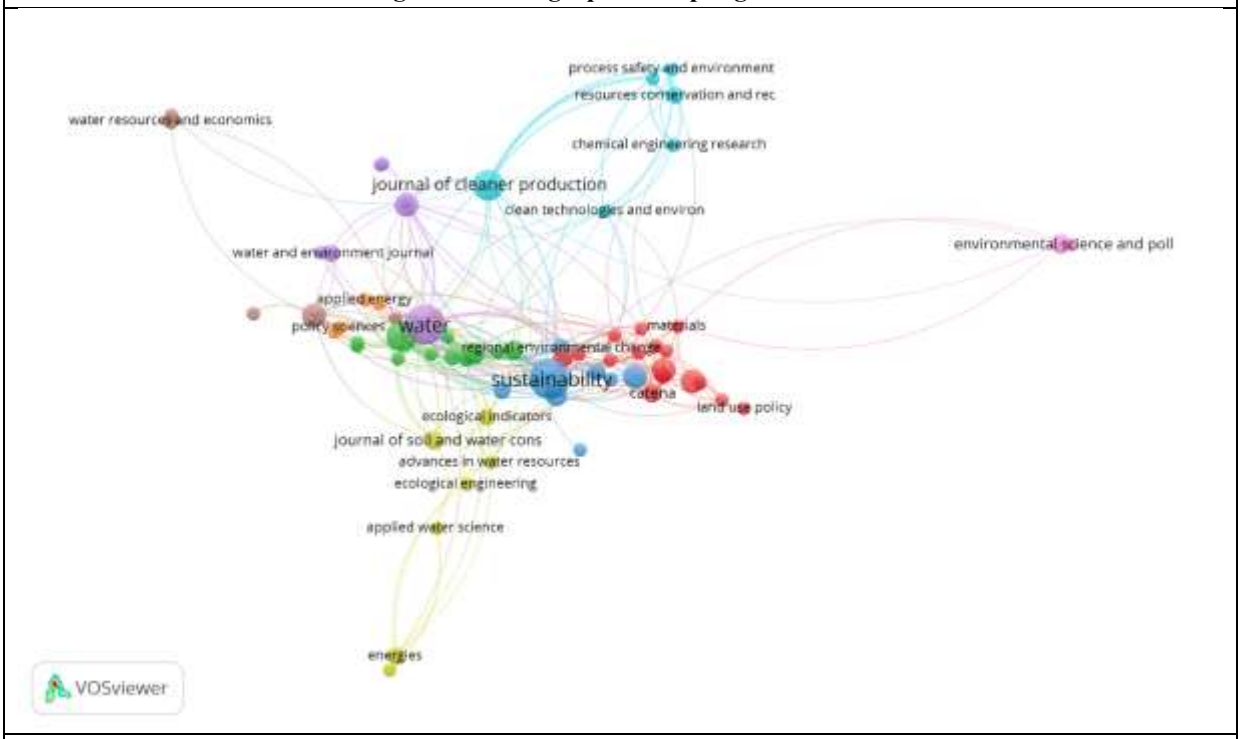
Figure 5: Most Contributing Journal in Terms of Publications



Source: Using Biblioshiny in R studio (version 4.4.1) and Microsoft Excel (version 2410)

Now, the bibliographic coupling of sources is given.

Figure 6: Bibliographic Coupling of Sources



Source: Using VOSviewer (version 1.6.20)

Bibliographic coupling can be done of documents, sources, authors, organizations, and countries (Van Eck & Waltman, 2023). In present context, sources are selected for bibliographic coupling.The minimum number of documents and citations of a source is set to be two. Out of 231 sources, 70 sources meet the threshold limit. Then, out of 70 sources, there are 3 sources titled 'Agriculture-Basel', 'Applied Sciences-Basel', and 'Separation Purification Technology'; which are not connected to other sources. Therefore, they are excluded and 67 sources are presented in Figure 6. The size of the circle denotes the amount and relevance of contributions of the given source. The 'Sustainability' and 'Water' sources are having biggest circles. Therefore, it can be derived that they are the most contributing sources in the field. The highest contribution of these journals is already highlighted by figure 5.

Based on figure 6, data set compromising 67 sources has been grouped into 9 clusters. After analyzing journals falling in each cluster, the clusters are named as 'Environmental and Geophysical Research', 'Water Management and Environmental Science', 'Sustainable Agriculture and Food Systems', 'Ecological Engineering and Renewable Energy', 'Water and Environmental Sustainability', 'Chemical Engineering and Industrial Environmental Solutions', 'Environmental Policy and Conservation', 'Water Resources and Management' and 'Environmental Chemistry and Pollution'.

Cluster 1: Environmental and Geophysical Research

This cluster is portrayed by using red colour and included 16 sources, studying the relation between environment and geophysical research. Journals that group here are Acta Geophysica, Catena, Desalination and Water Treatment, Environmental Management, Environmental Progress and Sustainable Energy, Environmental Research, Frontiers in Environmental Science, International Journal of Environmental Research and Public Health, International Soil and Water Conservation Research, Journal of Environmental Management, Journal of Water Resources Planning and Management, Land, Land Degradation & Development, Land Use Policy, Materials, and Plants-Basel. Hence, title is justified.

Cluster 2: Water Management and Environmental Science

This cluster is presented in green colour. It includes 11 sources like Agricultural Water Management, Construction and Building Materials, Environmental Earth Sciences, Environmental Modelling & Software,

Environmental Research Letters, Environmental Science and Policy, Hydrology and Earth System Sciences, IEEE Access, Journal of Hydrology, Journal of Soil Science and Plant Nutrition, and npj Clean Water. After examining sources, it is revealed that sources focus on water management within the context of environmental science, thereby making the title both relevant and credible.

Cluster 3: Sustainable Agriculture and Food Systems

Cluster 3, represented in Blue Colour includes 8 sources, whose scope is mainly based on agriculture. Sources included are Agronomy-Basel, Cogent Food and Agriculture, Environment Development and Sustainability, Frontiers in Sustainable Food Systems, Regional Environmental Change, Sustainability, Urban Forestry and Urban Greening, and Water International. Hence, title is well supported.

Cluster 4: Ecological Engineering and Renewable Energy

This Cluster is presented in yellow colour, incorporating 7 journals: Advances in Water Resources, Applied Water Science, Ecological Engineering, Ecological Indicators, Energies, Journal of Soil and Water Conservation, and Renewable Energy. Cluster included sources devoted to engineering aspect. Thus, title is adequately supported.

Cluster 5: Water and Environmental Sustainability

Cluster 5 is shown in violet colour. This cluster includes 7 sources in it, covering scope of environmental sustainability. Sources like Journal American Water Works Association, Nature Sustainability, Science of the Total Environment, Water, Water and Environment Journal, Water Research, and Water Science and Technology are included. Therefore, title is fully warranted.

Cluster 6: Chemical Engineering and Industrial Environmental Solutions

The cluster includes 6 sources presented in light blue colour. The titles of included sources are Chemical Engineering Research and Design, Clean Technologies and Environmental Policy, Industrial and Engineering Chemistry Research, Journal of Cleaner Production, Process Safety and Environmental Protection, and Resources Conservation and Recycling. After reviewing sources, it can be established that sources have a common interest in engineering connecting it with industrial solutions. Thus, title is logically affirmed.

Cluster 7: Environmental Policy and Conservation

Cluster 7 is presented in orange colour to distinct its 5 sources namely, Applied Energy, Aquatic Conservation-Marine and Freshwater Ecosystems, Environmental Sciences Europe, Policy Sciences, and Water SA. Sources studying polices and conservation is combined in this cluster. Hence, title of cluster is thoroughly justified.

Cluster 8: Water Resources and Management

This cluster is represented in brown colour and included 5 distinct sources titled Journal of the American Water Resources Association, Polish Journal of Environmental Studies, Water Air and Soil Pollution, Water Resources and Economics, and Water Resources Management. Sources take water as a precious resource and devote efforts for researches finding its proper management. Thus, title is well founded.

Cluster 9: Environmental Chemistry and Pollution

Cluster 9 is presented in pink colour. The cluster included only 2 sources having vision in chemical study referring with pollution named Environmental Science and Pollution Research, and Journal of Environmental Chemical Engineering. Thus, title is logically valid.

4.4 Country-Wise Highest Production and Citations

This section is devoted to the analysis of countries. It is done by analyzing the countries in terms of highest production of research articles and in terms of citations received and also with the bibliographic coupling.

Table 1: Most Relevant Countries

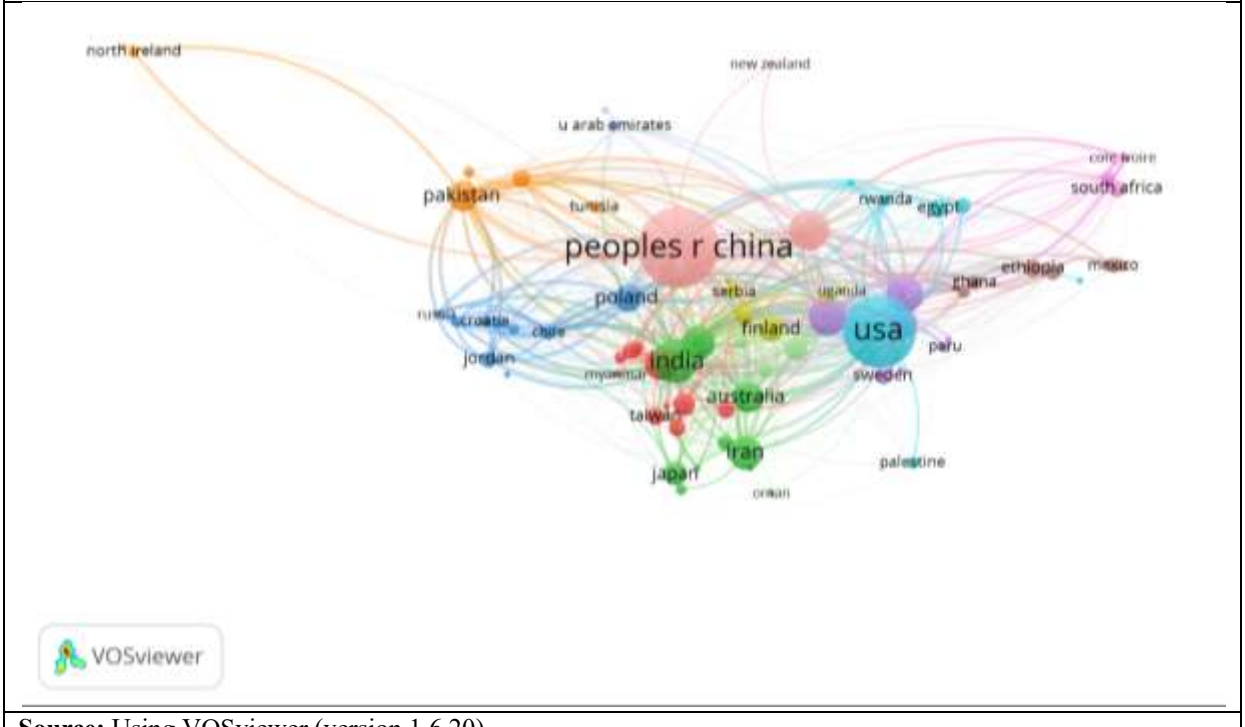
In Terms of Production of research articles			In Terms of Citations received		
Sr. No.	**Country**	**Production**	**Sr. No.**	**Country**	**Citations**
1	China	386	1	China	1768

2	USA	233	2	USA	641
3	India	90	3	Iran	269
4	United Kingdom	69	4	Canada	209
5	Germany	59	5	Australia	193
6	Canada	55	6	India	190
7	Iran	52	7	Italy	190
8	Italy	48	8	United Kingdom	157
9	Australia	44	9	Spain	122
10	Pakistan	39	10	Finland	121

Source: Using Biblioshiny in R studio (version 4.4.1)

Table 1 presents the most contributing countries in the field. China with 386 articles has become the most relevant country in terms of production of research aticles. USA with 233 articles stands at second position. India is at third position with 90 publications. While conducting the analysis of countries in terms of citations received, China again topped the list with 1768 total citations received. Once again, USA is at second rank with 641 citations. But, the third place is secured by Iran with 269 total citations instead of India. India is at sixth rank with 190 citations. Countries like India, United Kingdom are at good ranks in terms of production but far behind in terms of citations. Another set of countries like Canada, Iran, Italy, Australia, have shown a jump in positions in terms of citations from positions in terms of publications. This shows that production of publications are not directly linked with citations. Rather citations may depend upon quality and worth of publication, and also linkage of one country with the outside world. This has been shown in figure 7 bibliographic coupling.

Figure 7: Bibliography Coupling of Countries



Source: Using VOSviewer (version 1.6.20)

In figure 7, bibliographic coupling is given and unit of analysis is chosen to be countries. Minimum number of documents of a country and minimum number of citations of a country is set to be one. Out of 82 countries,

78 countries qualify the standard set. One country (Azerbaijan) is not connected to other, so it is dropped in visual representation by the software. The size of the circle depends on the relevance of the country. It is visible from the figure that China is the most relevant country in terms of both production and citations as shown with a biggest circle. So, it is reconfirmed that China is the most relevant country. Also, China has 66 links. Similarly, USA with 56 links becomes the second most relevant country. Thereby, the presumption that citations may depend upon linkage between countries is reinforced here.

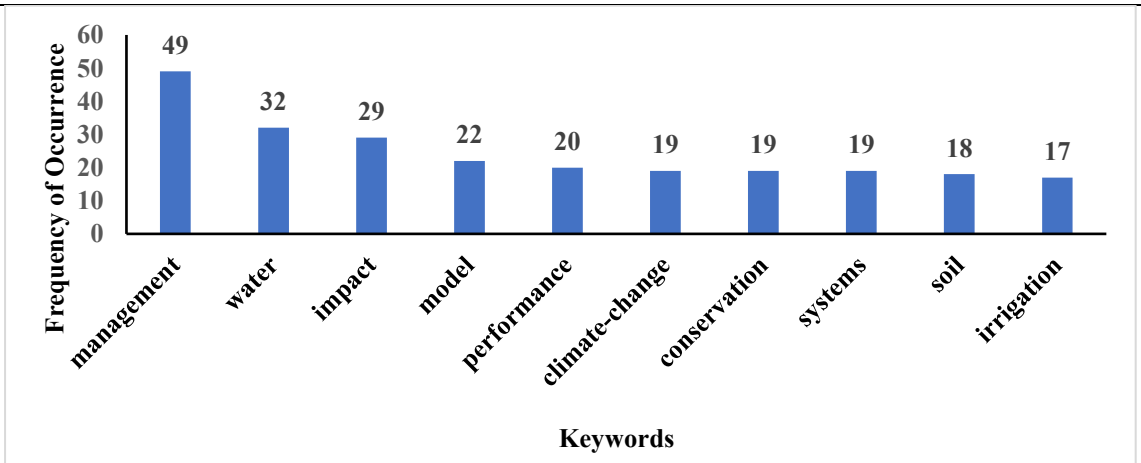
4.5 Usage of Keywords

To analyze the keywords, keyword analysis is performed in various ways. Word cloud is made along with the bar graph. A tree map is shown to find out percentage of one keyword's frequency to the sum of all keyword's frequency. Lastly, trendy keywords are searched to build the scope for further studies.

Figure 8: Word Cloud of Keywords

Source: Using Biblioshiny in R studio (version 4.4.1)

Figure 9: Bar Chart of Keyword's Frequency

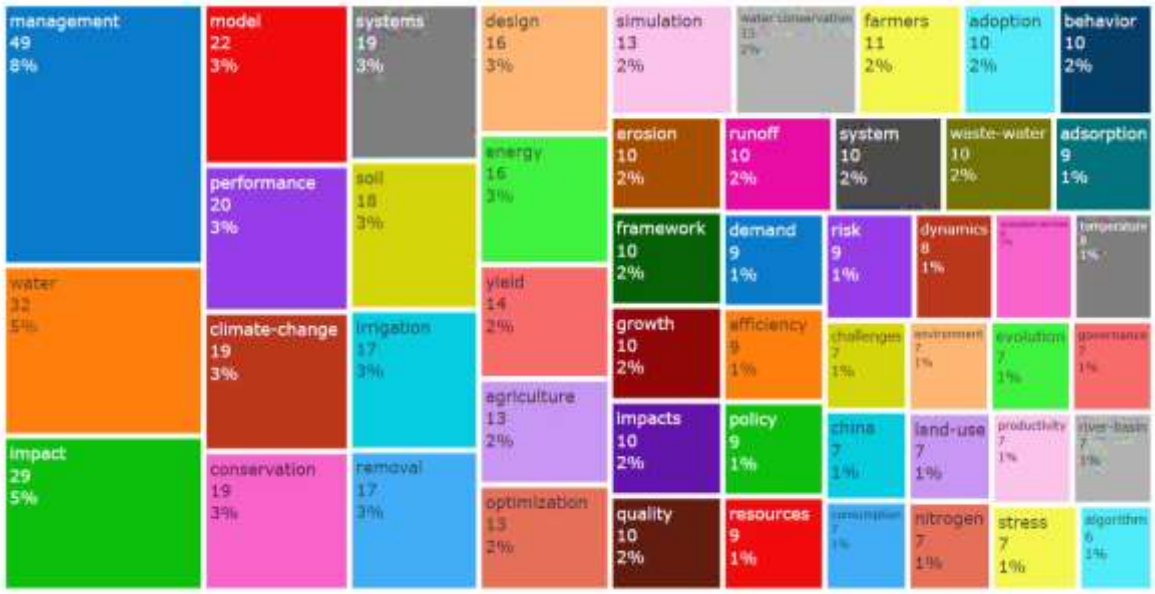


Source: Using Biblioshiny in R studio (version 4.4.1) and Microsoft Excel (version 2410)

A word cloud of keywords representing pertinent terms associated with the topic of water conservation is appearing in Figure 8. The keyword's magnitude indicates how relevant it is based on how many times it appears. Word clouds alone are insufficient since they do not allow the reader to determine the frequency of each keyword's occurrences or the distinctions between them. Bar graphs are therefore used to make data easier to understand. The bar graph of the top ten keywords according to their word cloud frequency is shown in Figure 9. According to the word cloud's size, 'Management' is the leading keyword. By examining the bar

graph, one can again establish that, with 49 reoccurrences, it is the most often occurring keyword. Similarly, 'Water' keyword with 32 reoccurences also stands second in position.

Figure 10: Tree Map



Source: Using Biblioshiny in R studio (version 4.4.1)

Figure 10 denotes the analysis of keywords in the form of Tree Map. The size of the quadrilateral denotes the frequency of the keywords. The figure contains keywords with their frequency of occurrences in the data set. Then percentage of each keyword's frequency is given. It is calculated by dividing one keyword's frequency by the sum of frequencies of all keywords. Like, the sum of frequencies is calculated (49+32+29+…+6) and found to be 631. Then the percentage of each keyword is calculated. For instance, the keyword 'Management' is having 49 frequencies; so, it is having 7.765 per cent share calculated as 49/631*100. After rounding off, the figure shows it as 8 per cent and the same case is with other keywords. One can conclude from figure 10 that 'Management' keyword is having highest frequency of reocurrences and percentage of keyword's frequency, which is similar to the results of figure 8 and 9. Therefore. it became the most relevant keyword in water conservation field. 'Water' having 32 frequencies with 5 per cent of total keyword's frequency become the second most frequent used keyword. Figure 10 also mentions some least occurred keywords like 'Algorithm' with only 6 frequencies denoting 1 per cent of total keyword's frequency.

Lastly, keywords trend is understood.

Table 2: Trendy Topics

Term	Frequency	Year (Q1)	Year (Median)	Year (Q3)
Management	49	2019	2021	2023
Water	32	2019	2020	2023
Impact	29	2019	2021	2023
Design	16	2019	2020	2022
Optimization	13	2019	2020	2021
Framework	10	2018	2019	2022
Challenges	7	2018	2018	2021
Governance	7	2017	2019	2021
Sustainability	6	2017	2019	2022
River	5	2017	2017	2023

Source: Using Biblioshiny in R studio (version 4.4.1)

Table 2 demonstrates that the term management is having maximum frequency with 49 reoccurrences. It has already been mentioned earlier; however, with frequency, this table calculates first (Q1) and third (Q3) quartiles and median (M) of years. Q1 shows in which year the keyword started gaining traction. Median highlights that half the instances came before this year, half after and Q3 indicates recent prominence. Hence, it can be said that with Q3 values extending to 2023, keywords including management (N=49), water (N=32), and impact (N=29) are amongst the most often cited. This suggests that there has been consistent and perhaps growing attention in recent years to these keywords. In a similar vein, keywords design and optimization indicates a more recent spike in interest. With Q1 values between 2017 and 2018, terms like governance, sustainability, framework, and challenges appeared earlier and might represent enduring ideas that have seen consistent but less intense in recent years. Interestingly, keyword river shows a broad temporal (Q1=2017; Q3=2023) span with significance lasting into 2023, but very low frequency (N=5) suggests only a niche interest.

4.6 Depiction of Leader Organizations

For getting the answer to the question of leading organizations, water conservation field is studied on the basis of number of articles published under their affiliations. Here, Citation Analysis is also conducted.

Table 3: Most Relevant Organizations

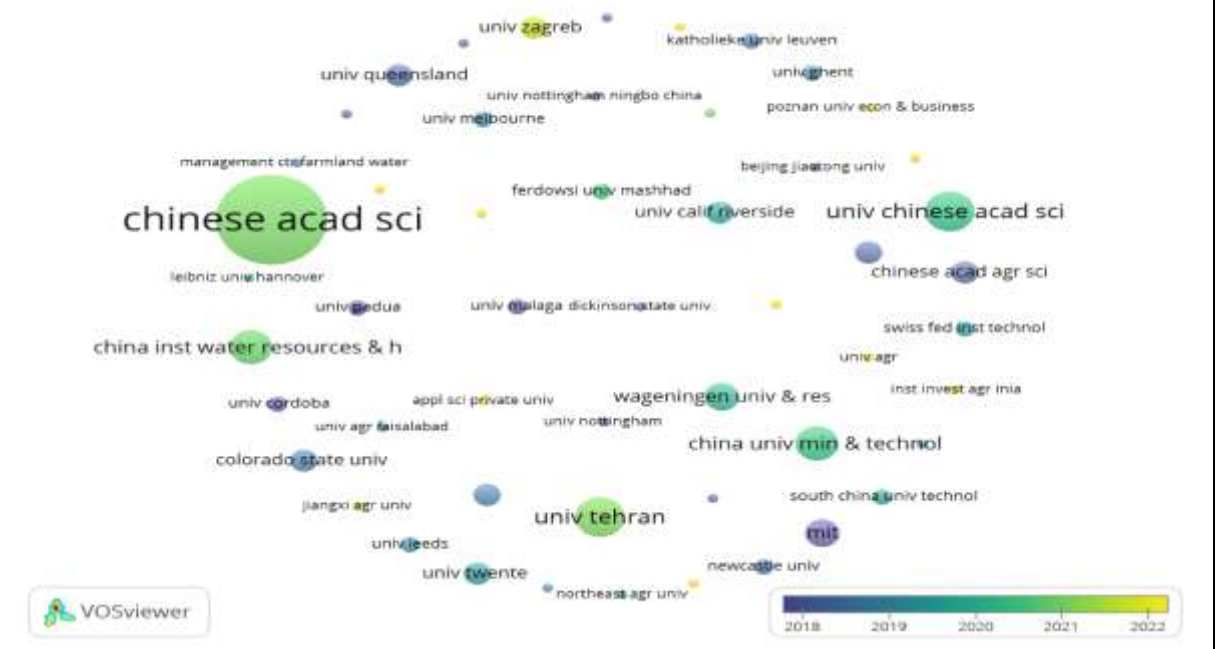
Name of the Affiliation	Articles
China University of Mining & Technology	14
Indian Institutes of Technology	14
Colorado State University	11
Hohai University	11
University of Eastern Finland	11
University of Tehran	11
China Institute of Water Resources and Hydropower Research	10
Institute of Geographic Sciences and Natural Resources Research	10
Peking University	10
University of Helsinki	10

Source: Using Biblioshiny in R studio (version 4.4.1)

Table 3 represents the list of top 10 organizations in terms of articles published under their affiliation. China University of Mining and Technology along with Indian Institutes of Technology topped the list with 14 articles each, followed by Colorado State University, Hohai University, University of Eastern Finland and University of Tehran with 11 articles each. The affiliations named China Institute of Water Resources and Hydropower Research, Institute of Geographic Sciences and Natural Resources Research, Peking University and University of Helsinki are at third rank with 10 articles each.

In figure 11, the Citation Analysis of the Organizations is presented.

Figure 11: Citation Analysis of the Organizations



Source: Using VOSviewer (version 1.6.20)

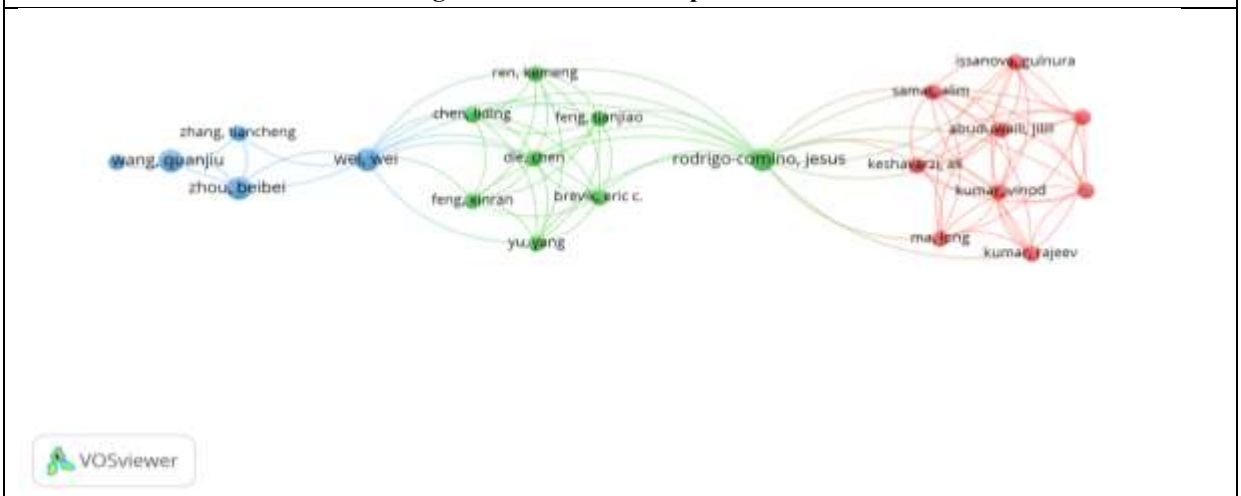
The Overlay Visualization is done by setting the threshold limits as 1 for the minimum number of documents of an organization and 50 for the minimum number of citations of an organization. Out of 765 organizations, only 53 organizations met the threshold limit. Different colours represent different years ranging from colour purple for the year 2018 to colour yellow for the year 2022.

4.7 Co-Authorship Analysis

Co-authorship analysis is a method that uses social network analysis (SNA) to evaluate collaboration patterns and identify prominent researchers, organizations and countries (Wasserman & Faust 1994). In co-authorship analysis, a bibliometric network reflects the links between scholars, organizations, and countries grounded on the quantity of articles, they have authored conjointly. For answering the research question 7, co-authorship analysis is completed. In following sections, co-authorship analysis is conducted on three bases,that are authors, organizations, and countries.

4.7.1 Co-Authorship Analysis on the Basis of Authors

Figure 12: Co-Authorship of Authors

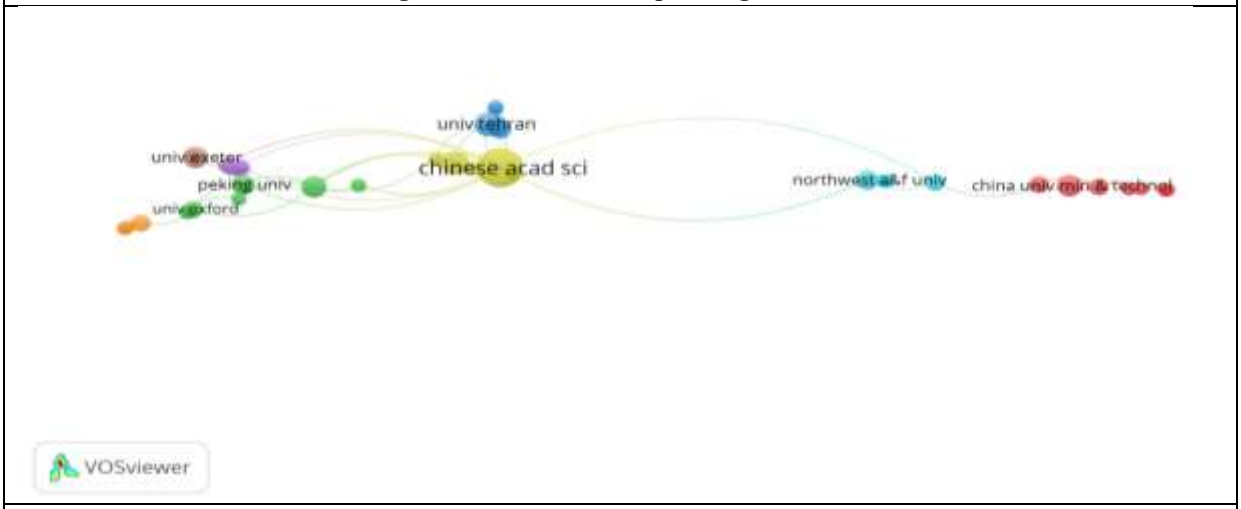


Source: Using VOSviewer (version 1.6.20)

Figure 12 shows the co-authorship network with reference to authors. The threshold limit of minimum number of documents of an author is chosen to be 1 and minimum number citations of an author is set 0. The largest set of connected items consists of 22 items. The output is in the form of 3 clusters, shown using blue, green and red colours. The links are showing the collaboration between the authors. There are total 88 links between the authors. Blue cluster is presented on the left corner of the figure containing 5 items in it. The author named Wei,Wei became the key contributor of the cluster with 2 documents and 11 links. The green cluster presented in the middle of the figure is having 8 items in it and the most co-authored author is Rodrigo-comino, Jesus having 2 documents with 17 links. The right side cluster presented in red colour shows a unique result that all the 9 authors are having same number of documents and links; for instance, 1 document with 9 links per author.

4.7.2 Co-Authorship Analysis on the Bases of Organizations

Figure 13: Co-Authorship of Organizations



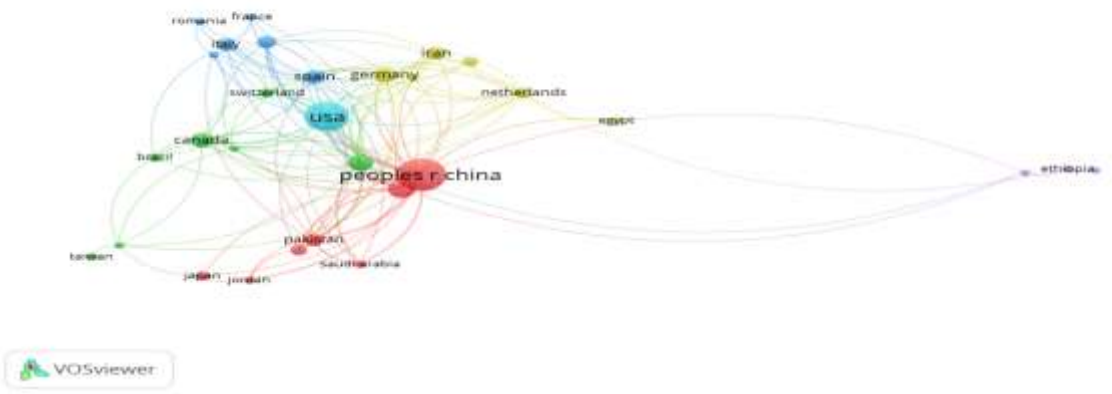
Source: Using VOSviewer (version 1.6.20)

Figure 13 denotes the co-authorship amongst various organizations. The threshold limit of minimum number of documents of an organization is chosen to be 2 and citation threashold limit for organization is set 0. There are total 765 organizations and only 121 meet the set criteria. The largest set of connected items are having 38 items. The Output contains 8 clusters represented in 8 vibrant colours. Cluster 1 presented in red colour is having 7 items. China University of Mining and Technology having 2 links with 5 documents and Kind Saud University having 4 links with 3 documents becomes the central contributors of the cluster. Cluster 2 is having

6 items, differentiated using green colour. China Institute of Water Resources and Hydropower Research is having 7 links with 5 documents and Peking University is having 7 links with 4 documents are the apex organizations of this cluster. Cluster 3 is shown in blue colour and contains 6 items at all. Tehran University with 6 links and 6 documents became the key affiliation in it. Another cluster, Cluster 4 in yellow colour includes 5 items in it. Chinese Academy of Sciences having 14 links with 16 documents turned out to be the star contributor of the cluster. In cluster 5, the 4 items are shown in purple colour, University of Queensland having 5 links with 3 documents acts as the leader of the cluster. In cluster 6, items included are 4 in number. Northwest A&F University became the shinystar of the cluster with 3 links and 4 documents, and it is denoted using light blue colour in the figure. Cluster 7 is displayed using orange colour with 3 items in it, University of Waterloo is having 2 links with 3 documents and be the key player of the cluster. In cluster 8, items included are 3 in the count, as shown by using brown colour. Guangzhou Institute of Geography is having 5 links with 2 documents and University of Exeter is having 2 links with 5 documents are significant organizations of the cluster.

4.7.3 Co-authorship analysis On the bases of the Countries

Figure 14: Co-Authorship of Countries



Source: Using VOSviewer (version 1.6.20)

In Figure 14, co-authorship network is studied based on countries. The threshold limit of minimum number of documents of a country is chosen to 5 and country's minimum number of citations is set 0. Out of the 82 countries, 30 meet the threshold limit. The results are presented using six clusters, discriminated using different colours. Cluster 1 in red colour is having 7 items in it. The People's Republic of China with 104 documents and 19 links and India with 33 documents and 16 links, stands out to be most co-authored country. For cluster 2, green colour is used to differentiate its 7 items from others, England having 19 links with 27 documents became the star country of the cluster. For cluster 3, blue colour is devoted having 6 items in it. Spain topped the cluster's item list with 18 documents and 17 links. In cluster 4, yellow colour is used to differentiate its 6 items, Germany be the highlight of the cluster having 22 documents with 15 links. Cluster 5 shown in purple colour is having 3 items in it. Ethiopia with 3 links and 6 documents and Belgium with 4 links and 5 documents are the most co-authored countries in it. Cluster 6 in light blue colour included only one item in it. The most co-authored country in cluster 6 has to be USA with 84 documents and 18 links as there is only one country in it.

Now, next section deals with conclusion, implications, limitations, and directions for further researches.

5. CONCLUSION AND DISCUSSIONS

Overall, it can be concluded that there is a significant growth in the number of publications in this field and this result is parallel with the results of Imaduddin and Eilks (2024), Zhang et al. (2015), Wang et al. (2016), and Wang et al. (2019). Strangely, there has been noticed a decline in citation trend. But this may be attributed to a greater number of publications where citations spread amid many researches. 'Sustainability' and 'Water' are found as the most relevant journals. This result is in line with the findings of Imaduddin and Eilks (2024) but contradict Wang et al. (2016) because of mentioning journal 'Science of the total Environment' as the most relevant. Also, bibliographic coupling grouped the sources into nine clusters. These clusters are designated as: 'Environmental and Geophysical Research', 'Water Management and Environmental Science', 'Sustainable Agriculture and Food Systems', 'Ecological Engineering and Renewable Energy', 'Water and Environmental Sustainability', 'Chemical Engineering and Industrial Environmental Solutions', 'Environmental Policy and Conservation', 'Water Resources and Management' and 'Environmental Chemistry and Pollution'. Further, China and USA originated as the most contributing countries in terms of publications and citations received. China, USA, UK are some of the most contributing countries as per Zhang et al. (2015), Wang et al. (2016), and Imaduddin and Eilks (2024). So, these authors are in support for similar results. The 'Management' keyword is having highest frequency and also one of the trendy keywords in the last few years. 'Water' also found as significant keyword. However, this result is contrary to the findings of Imaduddin and Eilks (2024) and Zhang et al. (2015) who found 'climate change' as the trendy keyword in their study. Certain keywords like governance, sustainability, framework, and challenges appeared earlier in literature but in less use now-a-days. A keyword river reveals a long-lasting time span till 2023 of its usage; however, very low frequency suggested interest of only a small group of authors. Also, 'China University of Mining and Technology' is having a significant number of articles published under their affiliation. University of Tehran, Peking University, Hohai University, Colorado State University, China Institute of Water Resources and Hydropower Research are few of the apex institutions as per the findings of this study. Zhang et al. (2015) is sustained here for presenting similar results. In addition, there exists a significant co-authorship which is confirmed with extracting different clusters of authors, organizations and countries. When co-authorship is seen from the perspective of researchers, three clusters emerged. Seeing from the perspective of organizations, eight clusters have been found. When countries are considered, these form six clusters. USA originated as the only country in a cluster.

6. IMPLICATIONS, LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

There are various practical implications of the study. After getting the idea of annual growth rate, one can foresight a bright future of researches in this field. One can collaborate with renowned authors after getting details of co-authorship networks from this study. After getting the idea of relevant sources, one can consider these sources for the publication of research work. Also, by identifying connections amongst various countries, researchers can collaborate to address complex research issues. Over and above that, keywords analysis provided most frequent keywords along with least repeated keyword. One can easy identify less explored area of the field and work on it. Besides, after studying apex organizations, future researchers who have keen interest in the field, can try to enrole themselves in apex organizations and begin their research work.

Furthermore, there may also be certain other avenues for further researchers. One database, the Web of Science (WoS), is used for the analysis. Other databases, such as Dimensions, Google Scholar, and Scopus, might be used for additional research. Usage of other keywords may produce different results; researchers might consider this point into account. Since the time frame is set for 2015-2024, data analysis conducted beyond that time frame may yield different findings. There is an urgent need to identify innovative approaches to conserve water; therefore, a thorough search with a variety of viewpoints is needed in this area. For

example, further studies might try to assess how successful different water conserving initiatives are. Indeed, in this area, future researchers may potentially think about performing a meta-analysis.

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