International Journal on Advanced Science Engineering Information Technology

Vol.14 (2024) No. 3
ISSN: 2088-5334

An Analysis of Research Trends on Groundwater Utilization in Indonesia: A Bibliometric Study

Buyamin [a,*], Istiana Herawati [a], Budi Rahayu [b], Zaenal Abidin [a], Khairul Ismed [c], Zulfia Hanum Alfi Syahr [a]

[a] *Pusat Riset Kebijakan Publik, Badan Riset dan Inovasi Nasional, Jakarta 12710, Indonesia*
[b] *Pusat Riset Lingkungan dan Teknologi Bersih, Badan Riset dan Inovasi Nasional, Jakarta 12710, Indonesia*
[c] *Pusat Riset Kependudukan, Badan Riset dan Inovasi Nasional, Jakarta 12710, Indonesia*
*Corresponding author: *buya001@brin.go.id*

***Abstract*—This study uses the Biblioshiny-R tool to assess the impact of elements in articles related to groundwater use in Indonesia. Groundwater is a renewable energy source that needs to be considered in terms of quantity and availability. Groundwater that is not managed correctly will pose a threat to scarcity and sustainability in its availability. This research utilizes the Scopus database, which was published in 1980. The first article was "Water Resources for Bandung City," written by Riemer Wynfrith and published by Technical Review - Mitsubishi Heavy Industries. The analysis shows top authors such as Putra DPE, Wilopo W, and Abidin HS had the highest h-index. Gadjah Mada University and the IOP Conference Series appeared as affiliates of most publications, and "Chaussard E, 2013, Remote Sens Environ" was the most cited theme in the publication, followed by the theme "Indonesia" and "land subsidence." Many discussions on the theme "Groundwater" are not followed by discussions on the theme of groundwater pollution, so the theme of groundwater pollution is interesting to discuss in further scientific research most collaborations, especially with Japan. This research also found that the age of a document does not significantly affect the number of citations a document receives. This research provides a comprehensive picture of groundwater utilization in Indonesia. In addition, this research examines the impact of groundwater decline and the need for integrated water management on the sustainability of groundwater availability in Indonesia.**

***Keywords*—Groundwater; renewable energy; Indonesia; bibliometrix.**

Manuscript received 26 Dec. 2023; revised 16 Apr. 2024; accepted 10 May. 2024. Date of publication 30 Jun. 2024.

I. INTRODUCTION

Groundwater is a natural resource that is abundantly available on this earth. Experts consider groundwater a renewable resource because it can be replenished over time. It is seen as a valuable and widely distributed resource but is essentially a local entity. Depletion and degradation of groundwater pose a significant threat to its quantity and quality. Despite scientific advances in understanding groundwater, there is a lack of a comprehensive governance framework for its management [1]. Groundwater systems cannot be classified as renewable or nonrenewable by themselves, but rather concerning how they are used. Renewable groundwater enables a stable rebalancing of groundwater levels and quality over human timescales. A four-quadrant framework for groundwater management has been proposed to assess sustainability [2]. Groundwater management is critical due to the increasing pressure on this resource caused by unplanned and excessive use. Various technological advances, such as desalination and membrane filtration, are being explored to address groundwater management issues [3]. Groundwater pollution is a significant concern, and natural bio-coagulants are effective in treating polluted groundwater [4]. Groundwater management related to environmental sustainability is a broad field of research that contributes to efforts to create groundwater sources that provide a sustainable water supply [5].

Groundwater utilization is a global concern due to its indiscriminate use and potential impacts on water resources. Several articles have discussed this issue in various international journals. Lal et al. [6] conducted a bibliometric analysis of groundwater access and management, highlighting the need to sustain this vital resource. Dimple et al. [7] reviewed the impact of low-quality groundwater on crop yields and soil properties, emphasizing the importance of water quality for irrigation. Bernado Mundim et al. published a paper in the Journal of Sustainable Development of Energy, Water, and Environment Systems discussing environmental

laws regulating specific pollutants' removal [8]. Bisen et al. [9] focused on the consequences of indiscriminate groundwater use in Madhya Pradesh, highlighting the need for balanced economic development. Reinelt et al. [10] presented a collection of economic research articles in a theme issue entitled "The Economics of Groundwater Management," emphasizing the interdisciplinary collaboration necessary for effective groundwater management.

Groundwater is a vital resource for sustaining human life globally, with billions of people relying on it for their water needs. Biologists and ecologists often overlook the importance of groundwater despite its ecological significance [11]. The importance of groundwater is in supporting all types of life forms and helping the growth of human civilization, providing water for drinking, household purposes, and irrigation [12]. The use of groundwater must, of course, be adjusted to needs. However, the balance between human and ecosystem needs is difficult to maintain, leading to problems such as water depletion, water quality degradation, water-energy nexus, and transboundary water conflicts [13]. It is critical to collect and share information through common data standards and leverage advances in remote sensing for better understanding and management of groundwater resources [14].

Groundwater use in Indonesia is influenced by various factors such as aquifer connectivity, health-seeking behavior, and agricultural growth. Research by Bukhari et al. [15] identified four groundwater groups in Raimanuk and its surroundings, with hydraulic connections between the two groups. Groundwater use is also related to health problems, environmental security, agricultural businesses, and groundwater scarcity. Widayanti et al. [16] reviewed Indonesians' health-seeking behavior, highlighting the determinants of treatment choices and underutilization of medical services. Taufik et al. presented daily groundwater depth data for peatlands in Batanghari and Kubu Raya, emphasizing the importance of groundwater in peat fire vulnerability and restoration projects [17]. Liyantono et al. [18] analyzed groundwater exploitation for irrigation in the Nganjuk Regency, emphasizing the need for integrated management to reduce exploitation. The Gunungsewu karst area, as explained in the abstract [19], experiences severe water scarcity and relies on various water sources, including underground rivers. Regarding groundwater utilization, Indonesia is among the top 7 countries with fresh groundwater extraction worldwide in 2020 [20]. Figure 1 shows Indonesia's ranking among 25 countries with fresh groundwater extraction worldwide in 2020.

Across the sprawling Indonesian archipelago, the dynamics of groundwater resources are a varied and exciting story. For example, in the Ternate Basin, a volcanic island in North Maluku, groundwater resource characteristics are understood through geoelectric measurements and drill log points [21]. Moving to Bojonegoro District, East Java Province, groundwater not only meets the daily needs of the community but also becomes the flow of the Bengawan Solo River, illustrating the close connection between groundwater sources and river ecosystems [22].

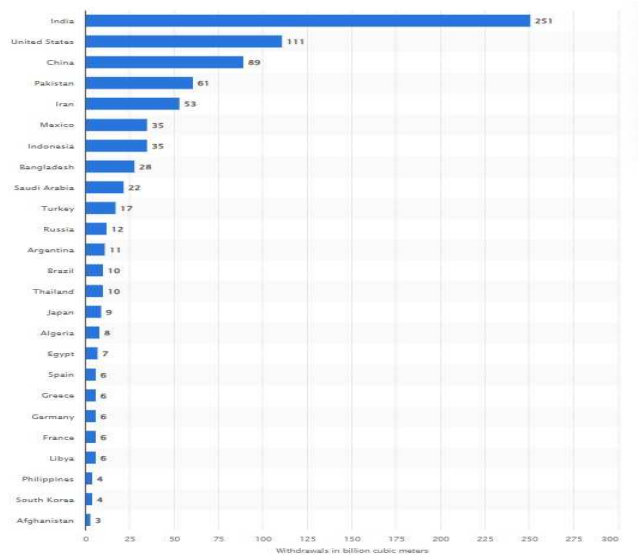

Fig. 1 Top 25 Countries Fresh Groundwater 2020 (https://www.statista.com)

Mount Merapi, which towers over the Indonesian Maritime Continent, is a beautiful natural panorama and a groundwater source for the surrounding population. The hydrogeological significance of Mount Merapi is manifested in the differences in groundwater characteristics in the southern and southeastern parts, forming a unique hydrological landscape [23]. Raimanuk, a potential agricultural area, shows the complexity of groundwater with different groups and hydraulic interconnections that influence land fertility [15].

In addition, in Tegal Regency, Central Java Province, potential groundwater resources were found in the sand layers, illustrating the geological diversity that influences groundwater distribution [21]. These examples highlight the importance of understanding local and local geological characteristics in managing groundwater resources. This entire narrative provides an overview of the complexity and diversity of Indonesia's hydrological ecosystem, which needs to be understood more deeply in the context of sustainable management and conservation of water resources.

While utilizing groundwater in Indonesia, the Government has rolled out many policies to ensure the availability and sustainability of water resources. However, complex challenges accompany the implementation of this policy, primarily related to the financial and operational aspects faced by local water supply companies [24]. The current regulatory environment, which tends towards commercialization, harms society by marginalizing traditional users and creating long-term administrative challenges [25].

As one of the policies adopted, full cost recovery had significant consequences. Regional Drinking Water Companies (RDWC) have become reluctant to expand services to less fortunate groups, creating inequality in water access, which should be every citizen's right. In addition, invitations to the private sector to manage water supplies raise questions about whether this is in the best interests of public services [26]. The implications of this policy are manifested in regulations and law enforcement, which have proven to be inadequate, provide loopholes for excessive groundwater extraction, and have an impact on environmental degradation and reduced soil quality [27].

However, amidst the complexity of these challenges, there is a ray of hope. Efforts to protect groundwater resources appear in the form of the Groundwater Directive issued by the European Commission, providing clear guidance regarding the objectives of groundwater protection in Europe [28]. The awareness that groundwater protection cannot be carried out in isolation has become the main focus, emphasizing the need for an integrated approach and coordination between related institutions [29]. This is the key to reducing excessive groundwater use and formulating better water resource management strategies in Indonesia. Faced with complex challenges, steps towards sustainable groundwater use in Indonesia must continue to be pursued through stakeholder collaboration, improved regulations, and strengthened law enforcement. Only with an integrated and comprehensive approach can Indonesia move towards sustainable and equitable groundwater use for all levels of society.

The use of groundwater in Indonesia involves several related stakeholders. The stakeholders identified in the abstract include the Central Government, Regional Government, Regional Energy and Mineral Resources Offices, Industrial Area Developers, Farmers, and the community in general. All components, among others, play a role in determining appropriate water-saving models in various situations [23]. These stakeholders play various roles in groundwater management, such as developing regulations, monitoring and evaluating activities, providing guidance, mediating conflicts, and reporting. For example, the Central Government and Regional Government. The Central Government has the authority to coordinate all arrangements for planning efforts, technical planning, supervision, exploitation, and maintenance, as well as protection and use of water and water sources [30]. Meanwhile, regional governments, through regional autonomy, are expected to increase the role of regional governments efficiently and effectively in managing and handling water resources [31]. Furthermore, industrial area developers should make efforts to conserve and utilize groundwater [32]. Farming communities using groundwater are required to understand better the use of groundwater as the primary water source in agricultural irrigation [33]. Apart from that, communities play an essential role in utilizing groundwater for daily consumption [34].

If groundwater management is not managed correctly, it will become a threat in the future. Improper management and regulation of groundwater use in Indonesia can cause various threats. The decline in groundwater levels in certain areas, such as southern Cimahi in West Java, is a significant problem that needs to be addressed [35]. In addition, the ecosystem around Mount Merapi in Yogyakarta is facing a potential water crisis due to poor management and declining springs [36]. The issue of water privatization also raises challenges, including equitable distribution of water, access to water, and violations of water rights [37]. Additionally, extensive groundwater extraction in Indonesia, particularly in Bangka Belitung, has resulted in sustainability problems and a lack of basic water service infrastructure [38]. The adverse impacts of groundwater abstraction, such as lowering groundwater levels and land subsidence, further highlight the need for appropriate management and regulation [39].

As with previous research, it is hoped that this research will: a) provide a deeper understanding of how groundwater works in the agricultural, industrial, and domestic sectors. This can help policymakers to identify areas where changes or improvements are needed. b) help identify trends in groundwater use. c) use this information to design more effective policies. d) support literature studies to obtain a comprehensive and in-depth understanding of the study topic.

II. Materials and Method

A. Data Analysis Objectives

This bibliometric research uses a bibliometric approach to analyze trends in research publications, authors, journals, or specific topics related [40], in this case to the use of groundwater in Indonesia. This method involves analyzing available literature on groundwater management in Indonesia to understand research trends and identify potential research topics.

B. Data Collections

This research uses data sourced from the Scopus Database. The data search follows the steps in determining the Scopus database as a data source related to the research topic [41]. The data search uses specific keywords, namely utilization, groundwater, and Indonesia [42] published in an international journal [43]. Search for documents in the Scopus database on November 11, 2023, at 09:37 AM, using TITLE-ABS-KEY (use* AND groundwater* AND Indonesia*), and find 653 documents. Search strategies depend on the database and interface, one of which is the universal Boolean operator, which allows it to be used [44].

C. Data Analysis

Analysis using Bibliometrix RStudio [45] is a unique tool developed for computerizing statistical data and the R graphic language according to logical bibliometric steps. System R is one of the dynamic software tools used for data analysis and visualization, widely regarded as the de facto standard platform for statistical algorithm development [46]. The data analysis is in the form of a year of publication, author, publisher, organization, country, and keywords used in the document under study.

III. Results and Discussion

A. Publications Trends

In 1980, publications with this theme began with an article entitled "Water Resources For Bandung City," written by Riemer Wynfrith and published by Technical Review - Mitsubishi Heavy Industries. This article discusses surface resource challenges in Bandung, Indonesia, and argues that the solution to increasing water production in the city lies in groundwater development but is limited by aquifer pollution [47].

The publication experienced periods of absence in 1981, 1982, 1984-1987, 1991-1992, 1996, and 1998-2000. However, since 2005, there has been a significant increase in the number of articles, reaching a peak in 2021 with 106 articles. This continued increase reflects a positive trend in the exploration of this topic. Figure 2 clearly shows a positive

trend over time, reflecting the increasing interest and focus in research on water resources in Indonesia.

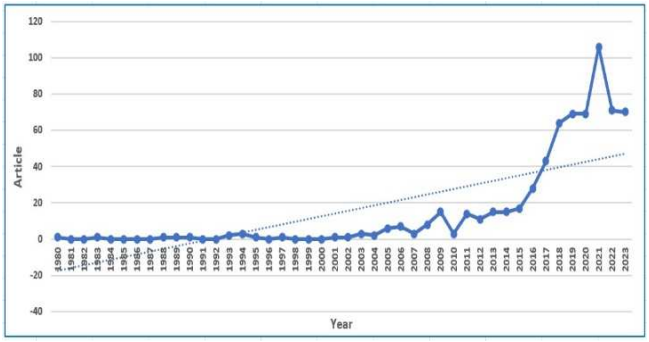

Fig. 2 Annual Scientific Production *(Bibliometric Analysis Results using Bibliometrix Rstudio)*

B. Citation of Document

Through Global Cited Document analysis using Bibliometrix RStudio on 653 research documents, it was found that 66.31% of documents, or 433 of the total, received citations from other articles. Meanwhile, 33.69% of documents, or 200 others, did not receive citations. Variations in the number of citations varied greatly, with 12 documents (1.84%) receiving 100 citations or more, 18 documents (2.76%) with 50 to 100 citations, and several others with varying ranges of citations.

The document that received the most citations was "Chaussard E, 2013, Remote Sens Environ," with 388 citations. This article discusses interferometric synthetic aperture radar (InSAR) to overcome land subsidence in various locations in Indonesia. Groundwater extraction for industrial and agricultural purposes is the main cause of land subsidence, at a rate of up to 22 cm/year (Chaussard et al., 2013).

Interestingly, the findings show that the number of citations is not only related to the type of article but also applies to other documents. In addition, the age of the document does not significantly affect the number of citations received. For example, a document that is 11 years old can get more citations than an older document, as is the case with a document that is 19 years old. Further information can be found in Table 1, which displays the documents with the most citations in this research.

TABLE I
THE TOP 12 DOCUMENTS HIGHEST CITED

No.	Document	Doc. Age	Document Type	Total Citations
1	Chaussard E, 2013, Remote Sens Environ	11	Article	388
2	Abidin Hz, 2011, Nat Hazards	13	Article	255
3	Wösten Jhm, 2008, Catena	16	Article	217
4	Anbumozhi V, 2005, Ecol Eng	19	Conf.Paper	168
5	Jauhiainen J, 2012, Biogeosciences	12	Article	137
6	Hirano T, 2009, Ecosystems	15	Article	134
7	Abidin Hz, 2008, Gps Solut	16	Article	123
8	Furukawa Y, 2005, Nutr Cycl Agroecosyst	19	Article	123
9	Comte I, 2012, Adv Agron	12	BookChap	121
10	Jago-On Kab, 2009, Sci Total Environ	15	Article	118
11	Marfai Ma, 2007, Environ Geol	17	Conf.Paper	112
12	Umezawa Y, 2008, Sci Total Environ	16	Article	104

Sources: Bibliometric Analysis Results using Bibliometrix RStudio

C. Research Theme

Through bibliometric analysis, this research identified 1,453 keywords used by the authors. Variations in keyword usage are visible: Nine keywords (0.62%) appear more than ten times, 50 (3.44%) appear four to nine times, and several others have varying appearance levels. Through bibliometric analysis, this research identified 1,453 keywords used by the authors. Variations in keyword use are visible: nine keywords (0.62%) appear more than ten times, 50 (3.44%) appear four to nine times, and several others have varying appearance levels.

The nine keywords with the most occurrences are "groundwater" (66 times), "Indonesia" (40 times), "land subsidence" (29 times), "water quality" (22 times), "Jakarta" (13 times), " groundwater level" (12 times), "aquifer" and "land use" 11 times each. "Groundwater" is the author's keyword that appears most often. Most keywords (84.24%) only appear once in the article. Figure 3 displays a word cloud of the author's keywords to provide a clear visual picture. This word cloud visually represents the distribution of keywords and highlights the most dominant keywords in this research.

Fig. 3 Words Cloud of Authors Keywords (Bibliometric Analysis Results using Bibliometrix Rstudio)

Through bibliometric analysis, it was revealed that this research included 653 documents from 259 sources. Of the total sources, ten (3.86%) had significant contributions with ten or more documents each, while 171 sources (66.02%) only contributed one document. The IOP Conference Series: Earth And Environmental Science is the most extensive resource, with 129 documents.

Of the 259 sources, 188 (72.59%) have an influence that can be measured through the h-index achievement. Eight sources (4.26%) achieved an h-index of four or more, 15 (7.98%) with an h-index of three, 28 (14.89%) with an h-index of two, and 137 (72.87%) with an h-index of one. Science of the Total Environment has the highest h-index, namely nine, while other sources have an h-index of eight or less.

Keyword analysis was also carried out in four different research periods. In the first period (1981-2017), the main

keywords involved groundwater, water quality, and groundwater level. Significant changes occurred in the second period (2018-2019), with the emergence of keywords such as peatland, Jakarta, groundwater level, land subsidence, Indonesia, and global warming potential. In the third period (2020-2021), the keywords changed to groundwater, groundwater fluctuation, southeast Asia, Indonesia, and land subsidence. Finally, in the fourth period (2022-2023), keywords include rainfall, land subsidence, groundwater level, Southeast Asia, groundwater, and heavy metals. These changes reflect the evolution of research focus over several decades.

From a total of 1,453 author keywords used in this research, 45 keywords were identified which were trending in the research topic. The distribution of occurrences of these keywords provides an idea of the researcher's focus and interests in the research period. Of the 45 trending topics, three (6.67%) appeared significantly, each appearing between 103 and 350 times. Four other topics (8.89%) also emerged, appearing between 50 and 74 times. A total of 25 topics (55.56%) appeared between 10 and 46 times, and another 13 topics (28.89%) had five to nine appearances.

The three topics that dominate the number of appearances are "groundwater" with 350 appearances, followed by "Indonesia" with 282 times, and "water quality" with 103 times. This shows that topics related to groundwater, Indonesia, and water quality are the main focus and trends in the academic literature studied in this research. So, it can be concluded that author keywords related to Indonesia are one of the most trending topics in the research period. The topic "groundwater" was trending in the first quarter of 2016, mid-2018, and third quarter of 2021. The topic "Indonesia" was trending in the first quarter of 2013, mid-2018, and third quarter of 2021. The topic "water quality" became trending in the first quarter of 2015, the middle of 2018, and the third quarter of 2020.

D. Influence of Authors

Through analysis using Bibliometrix RStudio on 653 research documents, it was found that 2,044 authors were involved in publications with a significant level of variation, ranging from 1 to 16 papers per author. A small number of authors, 7 (0.34%), reached the level of involvement in ten or more documents, while 1,731 authors (84.69%) were involved in one document. Putra DPE and Wilopo W are the most productive authors, producing 16 articles. Putra DPE's article that received the most citations was entitled Impacts of Precipitation, Land Use Change and Urban Wastewater on Groundwater Level Fluctuations in the Yogyakarta-Sleman Groundwater Basin, Indonesia, which was published in 2021 in Springer Science and Business Media Deutschland GmbH, with 15 citations. This article discusses the influence of rainfall, changes in irrigated agricultural land, and trends in urban wastewater volume on fluctuations in groundwater levels in the Yogyakarta-Sleman groundwater basin, Indonesia [48]Furthermore, Wilopo W's article, which received the most citations, was the same as Putra DPE's article because it was a joint work between them and other authors.

Of the authors, 1,481 individuals (72.46%) influenced publications, as reflected in the h-index. Abidin HS is the most influential writer with the highest h-index, 9. Even though most writers (88.79%) have an h-index of 1, some writers with high article production do not always have the same h-index. There are striking differences between authors with the same number of articles, where only a tiny percentage achieve the highest h-index.

In the context of affiliations, 494 affiliates were involved, with Gadjah Mada University standing out as the only affiliate engaged in more than 175 articles, namely 185. Most affiliates were involved in fewer publications, indicating the diversity of contributions from different institutions. This analysis provides an in-depth look at the role of authorship, influence, and collaborative affiliation in the academic literature investigated. Table 2 shows the top 14 authors' productiveness.

TABLE II
TOP 14 AUTHOR PRODUCTIVENESS

No.	Authors	Total Articles	Corresponding Country	H-index
1	Aydin C	2	United States	1
2	Bonino S	2	United Kingdom	1
3	Carr M	2	Italy	1
4	Carrick FR	2	United Kingdom	1
5	Choudhury MA	2	Oman	2
6	Chrissis NG	2	Greece	1
7	Ghodsee K	2	United States	2
8	Hankir A	2	United States	1
9	Hussain S	2	India	1
10	Islam A	2	Malaysia	1
11	Rahbari L	2	United States	2
12	Touraine A	2	France	1
13	Usman AH	2	Malaysia	1
14	Zaman R	2	United Kingdom	1

Sources: Bibliometric Analysis Results using Bibliometrix RStudio

E. Authors Corresponding Countries

Through bibliometric analysis, it was found that out of 653 research documents, 465 documents (71.21%) had a corresponding author, while 188 other documents (28.79%) could not be identified using bibliometrics. 25 countries act as corresponding authors, and Indonesia has the most significant contribution, covering 325 articles.

Of the 25 countries corresponding authors, two of them (8.00%) were involved in more than 100 articles, four (16.00%) were involved in 12 to 50 documents, and nine (36.00%) were involved in one document. All 25 countries managed to get citations, with the number varying from one to more than a thousand. Indonesia and Japan stand out as the countries with more than a thousand citations, with 1,673 and 1,352 citations, respectively. Indonesia is the country with the most citations overall.

This research involved contributions from 36 countries, which produced research articles. Two countries (5.56%), Indonesia and Japan, dominated with significant contributions, producing 1,823 and 274 articles, respectively. Furthermore, 15 countries (41.67%) had articles contributing between ten and 76, indicating quite active participation in scientific research.

In addition, two other countries (5.56%) contributed between four and nine articles, while two more countries (5.56%) were involved in three articles. Seven countries (19.44%) contributed two articles, and eight countries (22.22%) contributed one article. Most of these countries'

contributions were distributed relatively evenly between ten and 76 articles.

It should be emphasized that Indonesia stands out as the country with the highest contribution to this research, producing the highest number of articles, 1,823. Meanwhile, Japan also made a significant contribution, with 274 articles. The active presence of these countries reflects global diversity and collaboration in scientific research.

In the research, analysis of the number of publications in a country uses two categories, namely SCP and MCP [49]. Both SCP and MCP each indicate the number of publications by a corresponding author in one or more countries [50]. Figure 4 shows the level of collaboration between 19 countries in publications, with Indonesia (SCP 274, MCP 51) and Japan (SCP 18, MCP 32) at the top of the ranking.

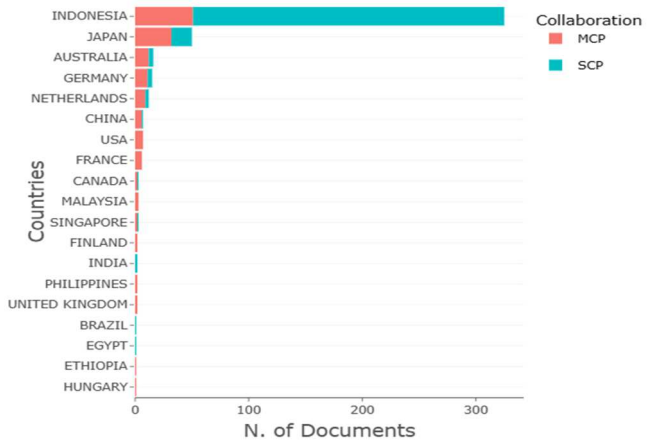

Fig. 4 Collaboration Publication Countries (Bibliometric Analysis Results using Bibliometrix RStudio)

Bibliometrix RStudio found 17 countries collaborating with other countries in article publication. The number of collaborations with different countries varies between one country and 30 countries. The frequency of a country collaborating with other countries differs significantly, ranging from one to 215. Of the 17 countries, four countries (23.53%) each collaborate with ten countries to 30 countries, 4 more countries (23.53%)) with four to eight countries, two countries (11.76%) with three countries, 3 countries (17.65%) with two countries, and 4 countries (23.53%) with one country. The remaining eight countries do not collaborate with other countries in publishing articles. The four countries with the most collaboration are Indonesia (30 times), Japan (16 times), France (10 times, and the USA (10 times). Indonesia is the country that collaborates the most with other countries. Table 3 shows the number of collaborations and their frequency. countries in collaboration.

TABLE III
COLLABORATIONS WORLDS

No.	Country	Total Collaboration	Frequency
1	Indonesia	30	215
2	Japan	16	29
3	France	10	14
4	USA	10	16
5	Germany	8	10
6	Netherlands	8	16
7	India	5	5
8	Australia	4	7
9	Thailand	3	4
10	United Kingdom	3	6
11	China	2	2
12	Malaysia	2	2
13	Singapore	2	2
14	Canada	1	1
15	Finland	1	1
16	Iran	1	1
17	Switzerland	1	3

Sources: Bibliometric Analysis Results using Bibliometrix RStudio

F. Discussion

The exploration of groundwater utilization in Indonesia traces back to the seminal work "Water Resources for Bandung City" by Riemer Wynfrith in 1980. Following a brief hiatus, scholarly publications on this subject experienced a remarkable surge from 2005 onwards, reaching their zenith in 2021 with 106 articles. The in-depth analysis, conducted using Bibliometrix RStudio on 653 research documents, unraveled a collaborative effort involving 2,044 authors. Among the prominent contributors, Putra DPE and Wilopo W emerged as prolific authors, yet Abidin HS stands out as the most influential, boasting the highest h-index.

Gadjah Mada University is central to this extensive publication landscape, contributing 185 articles. The Institute of Physics (IOP) Conference Series is the primary source of publication, boasting a significant collection of 129 documents. In global citations, 66.31% of the 653 research documents garnered citations from other scholarly articles. Notably, the most cited piece is "Chaussard E, 2013, Remote Sens Environ," delving into the land subsidence phenomenon across various Indonesian regions.

International collaboration is a prevailing theme, with 68% of the 25 countries acting as corresponding authors engaged in collaborative efforts. Indonesia leads global partnerships with Japan, France, and the United States. The extensive use of 1,453 keywords by authors reveals "groundwater" as the most recurrent, appearing a remarkable 66 times, followed by "Indonesia" (40 times), "land subsidence" (29 times), and various others. Intriguingly, a document's age does not significantly influence the number of citations it accumulates. This bibliometric research, therefore, provides a comprehensive overview of the evolutionary trajectory of groundwater-related publications in Indonesia. It underscores the positive trends, robust international collaborations, and notable contributions of specific authors and affiliations, offering valuable insights into the region's dynamic landscape of groundwater research. This research helps understand policy, the dynamics of aquifer recharge, the impact of climate change on groundwater resources, and the effectiveness of groundwater remediation technology in utilizing water as a renewable energy source.

IV. CONCLUSION

Publications regarding groundwater utilization in Indonesia have a long history, starting with one article, which then experienced a significant increase. Many authors contributed to publications with varying productivity and influence on other authors. This influence can be seen from the number of citations and the achievement of the relevant h-index. Gadjah Mada University is the most dominant affiliate with IOP: Earth and Environmental Sciences is the dominant

publication source. The article "Chaussard E, 2013, Remote Sens Environ" is the most cited, discussing land subsidence in several regions in Indonesia. Indonesia emerged as the country most actively collaborating, especially with Japan, France, and the United States. In terms of the author's keywords, "groundwater" appears most frequently, followed by "Indonesia" and "land subsidence." The document's age does not significantly affect the number of citations obtained, and this bibliometric research provides a comprehensive picture of the development of groundwater utilization publications in Indonesia, highlighting progress, international collaborations, and contributions from authors and affiliates. This study discovered that scholarly papers seldom ever address groundwater pollution. This research is useful in helping understand policy in utilizing water as a renewable energy source.

ACKNOWLEDGMENT

This research was conducted independently. We did not receive any financial assistance.

AUTHORS' CONTRIBUTION

Author 1: Article preparation planning, conceptualization, formal analysis, draft writing;
Author 2: Preparing methodology, preparing analysis, writing drafts;
Author 3: Preparing analysis, editing the manuscript, adjusting to journal template;
Author 4: Preparing analysis, table, and figure;
Author 5: Preparing conceptualization and editing the manuscript;
Author 6: Research data search, analysis, draft writing, manuscript finalization. All authors have read and approved the published version of the manuscript.

CONFLICTS OF INTEREST

In preparing this manuscript, we declare no conflict of interest.

REFERENCES

[1] P. Kumar, P. K. Thakur, B. K. S. Bansod, and S. K. Debnath, "Groundwater: a regional resource and a regional governance," *Environ. Dev. Sustain.*, vol. 20, no. 3, pp. 1133–1151, Jun. 2018, doi:10.1007/S10668-017-9931-y/metrics.

[2] M. O. Cuthbert, T. Gleeson, M. F. P. Bierkens, G. Ferguson, and R. G. Taylor, "Defining Renewable Groundwater Use and Its Relevance to Sustainable Groundwater Management," *Water Resour. Res.*, vol. 59, no. 9, p. e2022WR032831, Sep. 2023, doi: 10.1029/2022WR032831.

[3] S. Ganguly, "Groundwater—from freshwater source to green energy: an overview from concern to solution," *Int. J. Energy Water Resour. 2021 64*, vol. 6, no. 4, pp. 555–567, Sep. 2021, doi: 10.1007/S42108-021-00150-4.

[4] G. V, M. K, and G. M, "Cost-Effective Treatment for Polluted Groundwater Using Eco-Friendly Bio-Coagulants," Mar. 2022, doi:10.21203/RS.3.RS-1375291/V1.

[5] D. Polomčić, D. Bajić, and J. Zarić, "Determining the Groundwater Balance and Radius of Influence Using Hydrodynamic Modeling: Case Study of the Groundwater Source Šumice in Serbia," *[Journal Sustain. Dev. Energy, Water Environ. Syst.*, vol. 3, no. 3, p. 217-229, Sep. 2015, doi: 10.13044/j.sdewes.2015.03.0017.

[6] P. Lal *et al.*, "A Bibliometric Analysis of Groundwater Access and Its Management: Making the Invisible Visible," *Water (Switzerland)*, vol. 15, no. 4, Feb. 2023, doi: 10.3390/W15040806.

[7] Dimple, H. K. Mittal, P. K. Singh, K. K. Yadav, S. R. Bhakar, and J. Rajput, "Groundwater quality parameters for irrigation utilization," *Indian J. Agric. Sci.*, vol. 92, no. 7, pp. 803–810, Apr. 2022, doi:10.56093/ijas.v92i7.114186.

[8] B. Mundim, I. Volschan Junior, and B. S. Hoffmann, "Evaluation of the environmental and economic performance of wastewater treatment technologies of warm climate regions," *Journal Sustain. Dev. Energy, Water Environ. Syst.*, vol. 11, no. 4, p. 1-17, 2023, doi:10.13044/j.sdewes.d11.0472.

[9] S. Bisen, P. Choudhary, M. K. Awasthi, and D. Patle, "Kharif Fallow utilization for Groundwater Recharge," *Int.J.Curr.Microbiol.App.Sci*, vol. 8, no. 12, pp. 284–290, 2019, doi: 10.20546/ijcmas.2019.812.039.

[10] P. Reinelt, N. Brozović, M. E. Qureshi, and P. Hellegers, "Préface: Economie de la gestion des aquifères," *Hydrogeol. J.*, vol. 20, no. 5, pp. 817–820, Aug. 2012, doi: 10.1007/S10040-012-0878-7/metrics.

[11] D. Wardle, "Storying with Groundwater," *Swamphen a J. Cult. Ecol.*, vol. 7, p. 2020, Apr. 2020, doi: 10.60162/swamphen.7.14367.

[12] D. Wardle, "Sustainable Groundwater Stories – From Disasters to Epical Narration," *Junctures J. Themat. Dialogue*, vol. 2020, no. 21, pp. 22–30, Nov. 2020, doi: 10.34074/junc.21022.

[13] C. I. Voss and A. C. (Carla. Skinner, "Editor's Message: 25 years of Hydrogeology Journal," *Hydrogeol. J.*, vol. 25, no. 8, pp. 2217–2220, Dec. 2017, doi: 10.1007/S10040-017-1674-1/metrics.

[14] M. Liyantono; Takemi and T. Kato, "Exploitation of Groundwater for Irrigation in Nganjuk District, East Java, Indonesia," pp. 203–207, 2006.

[15] A. M. W. Bukhari, H. Hendrayana, and H. Setiawan, "Aquifer connectivity assessment using stable isotope and hydrochemical analysis in the Raimanuk and its surrounding area on the Timor island," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1039, no. 1, 2022, doi:10.1088/1755-1315/1039/1/012005.

[16] A. W. Widayanti, J. A. Green, S. Heydon, and P. Norris, "Health-Seeking Behavior of People in Indonesia: A Narrative Review," *J. Epidemiol. Glob. Health*, vol. 10, no. 1, pp. 6–15, Mar. 2020, doi:10.2991/jegh.k.200102.001.

[17] M. Taufik, M. TW, Awaluddin, A. K. Mukharomah, and B. Minasny, "Groundwater table and soil-hydrological properties datasets of Indonesian peatlands," *Data Br.*, vol. 41, Apr. 2022, doi:10.1016/j.dib.2022.107903.

[18] Y. Yang *et al.*, "Study on the Exploitation Scheme of Groundwater under Well-Canal Conjunctive Irrigation in Seasonally Freezing-Thawing Agricultural Areas," *Water 2021, Vol. 13, Page 1384*, vol. 13, no. 10, p. 1384, May 2021, doi: 10.3390/W13101384.

[19] E. Haryono, T. N. Adji, A. Cahyadi, M. Widyastuti, U. Listyaningsih, and E. Sulistyowati, "Groundwater and livelihood in Gunungsewu karst area, Indonesia," *Groundw. Sustain. Livelihoods Equitable Growth*, pp. 1–23, Mar. 2022, doi: 10.1201/9781003024101-1.

[20] E. B. Salas, "Global groundwater withdrawals by select country, Statista," Statistita.com.

[21] W. Wilopo, M. H. Rachman, and D. P. E. Putra, "Assessment of groundwater resources potential using geoelectrical method and slug test in Tegal District, Central Java Province, Indonesia," *E3S Web Conf.*, vol. 200, no. December, 2020, doi:10.1051/e3sconf/202020002003.

[22] W. Wilopo, D. P. E. Putra, and R. Susatio, "Aquifer distribution and groundwater geochemistry in Bojonegoro Sub-district," *J. Degrad. Min. L. Manag.*, vol. 7, no. 4, pp. 2327–2335, 2020, doi:10.15243/jdmlm.2020.074.2327.

[23] H. Hendrayana, A. Harijoko, I. A. Riyanto, A. Nuha, and Ruslisan, "Groundwater Chemistry Characterization in The South and Southeast Merapi Volcano, Indonesia," *Indones. J. Geogr.*, vol. 55, no. 1, pp. 10–29, 2023, doi: 10.22146/ijg.76433.

[24] N. Riyanti, H. M. Riban Satia, M. Nur, and T. Putra, "Kebijakan Dan Potensi Pajak Air Tanah Di Kota Palangka Raya," *J. Ilmu Sos. dan Hum.*, vol. 6, 2023.

[25] W. Hadipuro, "Indonesia's water supply regulatory framework: Between commercialisation and public service?," *Water Altern.*, vol. 3, no. 3, pp. 475–491, 2010.

[26] Y. Ding Id and C. Gong, "Can intergovernmental cooperative policies promote water ecology improvement—An analysis based on water quality data from China's general environmental monitoring station," *PLoS One*, vol. 18, no. 11, p. e0294951, Nov. 2023, doi:10.1371/journal.pone.0294951.

[27] S. Wangsaatmaja, A. D. Sutadian, and M. A. N. Prasetiati, "A Review of Groundwater Issues in the Bandung Basin, Indonesia: Management and Recommendations.," *Int. rev. environ. Strateg.*, vol. 6, no. 2, pp. 425–441, 2006.

[28] N. Robins, "Groundwater Science and Policy: An International Overview," *Eos, Trans. Am. Geophys. Union*, vol. 89, no. 31, pp. 283–

283, Jul. 2008, doi: 10.1029/2008EO310005.
[29] S. P. Wiharja, "Tantangan Birokrasi dan Koordinasi dalam Pengelolaan Sumber Daya Air Jakarta Tantangan Birokrasi dan Koordinasi dalam Pengelolaan Sumber Daya Air Jakarta," no. October, 2023.
[30] C. I. Rachman, J. S. Sawah, and L. Syamsumardian, "Dimensi Kewenangan Pengelolaan Sumber Daya Air antara Pemerintah Pusat dan Pemerintah Daerah dalam Sistem Otonomi Daerah di Indonesia".
[31] A. Sri, R. Wulandari, A. Ilyas, F. Hukum, and U. Hasanuddin, "Pengelolaan Sumber Daya Air di Indonesia: Tata Pengurusan Air dalam Bingkai Otonomi Daerah," vol. 6, no. November, pp. 287–299, 2019.
[32] D. Valentino, "Kajian Pengawasan Pemanfaatan Sumberdaya Air Tanah di Kawasan Industri Kota Semarang," *J. Wil. Dan Lingkung.*, vol. 1, no. 3, pp. 265–274, 2013.
[33] A. Tonggiroh, B. Hidayah, B. R. Maulana, A. Maulana, A. M. Imran, and A. Jaya, "Sosialisasi Pemanfaatan Air Tanah Untuk Lahan Pertanian dengan Metode JIAT Daerah Pallantikang, Kabupaten Bantaeng," *J. TEPAT Appl. Technol. J. Community Engagem. Serv.*, vol. 3, no. 2, pp. 73–81, 2020, doi: 10.25042/jurnal_tepat.v3i2.142.
[34] M. Naslilmuna, C. Muryani, and S. Santoso, "Analisis Kualitas Air Tanah dan Pola Konsumsi Air masyarakat Sekitar Industri Kertas PT Jaya Kertas Kecamatan Kertososno Kabupaten Nganjuk," *J. GeoEco*, vol. 4, no. 1, pp. 51–58, 2018.
[35] M. Y. Purnawan, H. Hendrayana, and L. D. Setijadji, "Reducing groundwater use and mitigating floods through increasing surface water utilization in the Cimahi Region of West Java Indonesia," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1071, no. 1, 2022, doi:10.1088/1755-1315/1071/1/012003.
[36] S. L. Harjanta and D. P. Ningrum, "Inhibiting Factors for Collaborative Water Governance: A Case Study of Mount Merapi Ecosystem in Yogyakarta, Indonesia," *CHANNEL J. Komun.*, vol. 11, no. 1, pp. 81–86, 2023, doi: 10.12928/channel.v11i1.225.
[37] S. Hermawan and S. A. Hananto, "Issues on Water Privatization Under New Regulation: Evidence in Indonesia," *Comp. Law Rev.*, vol. 28, pp. 341–366, 2022, doi: 10.12775/CLR.2022.011.
[38] R. Arlianda, "Architectural typology of water infrastructure: Case study of green open space and heritage site of perigi pekasem in Bangka Belitung," *J. Teknosains*, vol. 12, no. 1, pp. 56–71, Dec. 2022, doi: 10.22146/teknosains.78507.
[39] T. T. Putranto, T. Winarno, and A. P. A. Susanta, "Risk assessment of groundwater abstraction vulnerability using spatial analysis: Case study at Salatiga Groundwater Basin, Indonesia," *Indones. J. Geosci.*, vol. 7, no. 2, pp. 215–224, 2020, doi: 10.17014/ijog.7.2.215-224.
[40] C. et al. Paez-Quinde, "Bibliometrics: Methods for studying academic publishing," *Perspect. Med. Educ.*, vol. 11, no. 3, pp. 173–176, Jun. 2022, doi: 10.1007/S40037-021-00695-4.
[41] C. Páez-Quinde, D. P. Molina-Mora, D. Reyes-Bedoya, and F. Carrera-Calderon, "Quantitative Big Data Analytics for Scientific and Bibliometric Mapping with Industry 4.0 Technologies," *Proc. - Int. Conf. Augment. Intell. Sustain. Syst. ICAISS 2022*, pp. 787–793, 2022, doi: 10.1109/ICAISS55157.2022.10010905.
[42] N. Z. M. Afandi, R. Umar, N. H. Sabri, S. Safei, and C. C. Lau, "Revealing trends: A bibliometric analysis of 28 years of space weather event research publications using the Scopus databases (1994–2022)," *Adv. Sp. Res.*, vol. 72, no. 12, pp. 5753–5766, Dec. 2023, doi: 10.1016/J.ASR.2023.09.029.
[43] A. Rosyida, R. Utami, J. Arlinwibowo, G. N. Fatima, and A. I. A. Himayati, "Trend Modeling in Responding to Pandemic Case: Bibliometric Analysis," *Inpr. Indones. J. Pure Appl. Math.*, vol. 5, no. 1, pp. 72–81, 2023, doi: 10.15408/inprime.v5i1.28873.
[44] L. F. Trivisonno, C. Escobar Liquitay, L. Vergara-Merino, J. Pérez-Bracchiglione, and J. V. A. Franco, "Conceptos clave para la búsqueda de evidencia: una introducción para profesionales de la salud," *Medwave*, vol. 22, no. 1, p. e8512, Jan. 2022, doi:10.5867/medwave.2022.01.002512.
[45] B. A. Prata, L. R. Abreu, and M. S. Nagano, "Applications of constraint programming in production scheduling problems: A descriptive bibliometric analysis," *Results Control Optim.*, vol. 14, p. 100350, Mar. 2024, doi: 10.1016/j.rico.2023.100350.
[46] B. T. Y. Widemann, C. F. Bolz, and C. Grelck, "The functional programming language R and the paradigm of dynamic scientific programming (Position paper)," *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 7829 LNCS, pp. 182–197, 2013, doi: 10.1007/978-3-642-40447-4_12.
[47] W. Riemer, "Water Resources for Bandung City," *Vol. 1, Pages 27 - 39*, vol. 1, pp. 27–39, 1980.
[48] W. Wilopo, D. P. E. Putra, and H. Hendrayana, "Impacts of precipitation, land use change and urban wastewater on groundwater level fluctuation in the Yogyakarta-Sleman Groundwater Basin, Indonesia," *Environ. Monit. Assess.*, vol. 193, no. 2, pp. 1–14, Feb. 2021, doi: 10.1007/S10661-021-08863-z/metrics.
[49] H. Liu, K. Peng, W. Li, and Y. Cao, "Investigation on the trends and characteristics of articles on submerged macrophytes: perception from bibliometrics between 1991 and 2018," *J. Freshw. Ecol.*, vol. 34, no. 1, pp. 703–713, Jan. 2019, doi: 10.1080/02705060.2019.1676319/suppl_file/tjfe_a_1676319_sm6983.docx.
[50] R. Atlasi, O. Tabatabaei-Malazy, F. Bandarian, N. Rezaei, P. Khashayar, and B. Larijani, "Scientometric Analysis of Global Scientific Publications on COVID-19 and Diabetes with an Emphasis on Middle Eastern Countries," *Int J Endocrinol Metab*, vol. 20, no. 3, p. 120812, 2022, doi: 10.5812/ijem-120812.