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Water And Water Security: A Bibliometric Analysis of The Last 5 Years

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Abstract:
This study aimed to conduct a bibliometric analysis of international scientific production on water and water security over the past five years (2019–2024). The adopted methodology was exploratory and descriptive in nature, based on the bibliometric analysis of data extracted from the Scopus database. The search included the terms "Water," "Water Security," and "Water Resources," initially resulting in 1,133 documents. After applying filters by subject areas, language, type of publication, and open access status, 410 articles were selected for analysis. The analyses were carried out using the VOSviewer software, which enabled the mapping of co-authorships, keyword co-occurrence, bibliographic coupling, and citations. The results revealed a peak in publications in 2022 and wide participation from countries such as China, the United States, the United Kingdom, Brazil, and India. The areas with the highest number of publications were Environmental Sciences, Social Sciences, and Agricultural and Biological Sciences, highlighting the interdisciplinary nature of the topic. The co-occurrence analysis identified seven main thematic clusters, including climate change, agriculture, environmental health, sustainability, governance, urban areas, and groundwater resources. Bibliographic coupling indicated influential authors such as Empinotti (2019), Mishra (2021), and Chawla (2020), organized in robust collaborative networks. It is concluded that scientific production on water security has intensified, reflecting global concerns about the impacts of climate change, water scarcity, and the need for integrated management.
Keywords: *Water governance. Climate change. Integrated management. Water scarcity. Bibliometric analysis.*

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I. Introduction

Water resources are under direct threat due to human activities, which cause significant changes in land cover, urbanization, industrialization, the construction of engineering works, irrigation, and the transfer of water between river basins to maximize access to water. Although supplying water to urban areas and agricultural production brings benefits, it also causes damage to ecosystems and biodiversity—often severe and difficult to quantify (Verones et al., 2017).

The water crisis faced by some regions of the planet is a complex reality, whose understanding is often limited by the lack of attention to both its political evolution and the environmental and local factors that influence it. Since the mid-20th century, access to sanitation and water has become a central topic on international agendas, alongside policies aimed at accelerated economic growth (Arsel; Hogenboom; Pellegrini, 2016; World Water Council, 2018). This growth-oriented policy initiated a predatory process of natural resource exploitation, with ecological consequences that have led to a profound water crisis, especially in relation to the overexploitation and scarcity of this resource (Cantillana, 2020).

Water resource management has gained prominence on the international agenda, as water is essential not only for economic and social activities but also for the balance of ecosystems. The complexity of the challenge is amplified by the projected 40% increase in water demand by 2030 (UNESCO, 2012). Moreover, climate change intensifies the uncertainties related to water management due to the increase in extreme hydrological events (Melo; Johnsson, 2017).

At the international level, discussions on the concept of water security began in the 1990s. However, it was only from the year 2000 onward that the topic started receiving greater attention and a growing number of publications. This interest intensified particularly after 2009 (Backer, 2012).

Since then, water security has become a relevant field of study, integrating analyses on the availability of sufficient quality water to meet human and environmental needs, as well as strategies to mitigate risks related to water scarcity and pollution. This more in-depth approach has enabled the development of more effective and sustainable water management policies and practices, reflecting a growing global concern with the impacts of climate change, population growth, and economic development on water resources.

To protect aquatic biodiversity and ensure the sustainability of water distribution systems, it is necessary to develop interventions that include conventions and scientific assessments. These interventions should rely on frameworks capable of diagnosing the main threats to water security at different spatial scales (Vörösmarty et al., 2010; Brito; Brito; Rufino, 2022).

In this context, the general objective of this study is to conduct a bibliometric analysis of scientific publications from the last five years that address the themes of water and water security, identifying research trends, main focus areas, prominent authors and articles, as well as analyzing the most cited publications.

Sustainable water resource management is crucial for economic, social, and environmental development on a global scale. In recent years, the growing demand for water, combined with the impacts of climate change, has intensified the need for a deeper understanding of water security. This study is justified by the importance of mapping the current state of scientific research in this field, providing a comprehensive overview of the main contributions and emerging directions. By identifying trends and gaps in the literature, this bibliometric analysis can guide future research and policies, promoting more effective strategies for the conservation and management of water resources.

II. Materials and Methods

To map the international scientific production on the subject in question, an exploratory and descriptive study was conducted using bibliometric analysis. Bibliometrics, or bibliometric analysis, refers to the counting of publications or citations found in scientific and academic databases, serving as a practical tool for monitoring technological developments and evaluating scientific activity (Coates et al., 2001). This method was employed to identify research trends, key areas of focus, and prominent authors and institutions in the field of water and water security over the past five years (Freitas; Araújo, 2021).

The database used for this analysis was the Scopus (Elsevier) core collection. The search was conducted in May 2024 using the keywords “Water,” “Water Security,” and “Water Resources,” with a time restriction to the last five years (2019–2024). Initially, 1,133 documents were retrieved. By applying filters for subject areas such as Environmental Sciences, Social Sciences, Earth and Planetary Sciences, and Agricultural and Biological Sciences, the number of documents was reduced to 1,042. When restricted to articles only, the search yielded 797 documents. Further limiting the languages to English, Chinese, and Portuguese, 792 documents were identified. Finally, by selecting only articles in their final publication stage and with open access, 410 articles were obtained for bibliometric analysis.

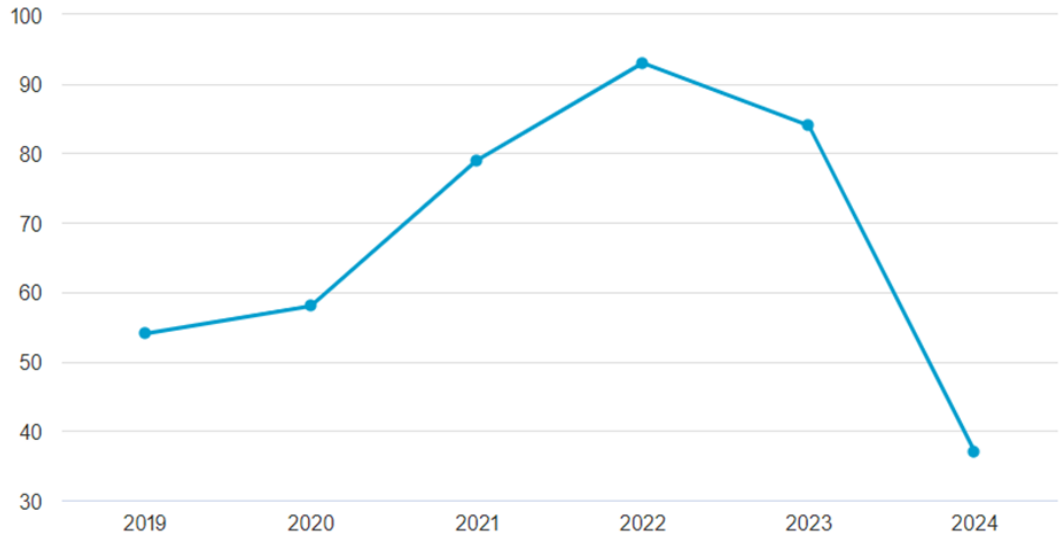
To perform the bibliometric analyses, the VOSviewer software (version 1.6.20) was used. This software is widely recognized and used in the academic community for its ability to construct and visualize bibliometric

networks. It enables the creation of co-citation, co-authorship, and keyword co-occurrence maps, facilitating the identification of patterns and trends in the scientific literature. With VOSviewer, it was possible to visualize the interrelationships between the main topics, authors, and institutions, as well as to map the temporal evolution of research on water, water security, and water resources.

III. Results

Considering the articles included in the analysis, a clearer visualization can be obtained through Graph 1 below, which shows the number of publications over the last five years in the field of water and water security, based on the applied filters.

Figure 1 – Number of publications per year on water and water security in Scopus.

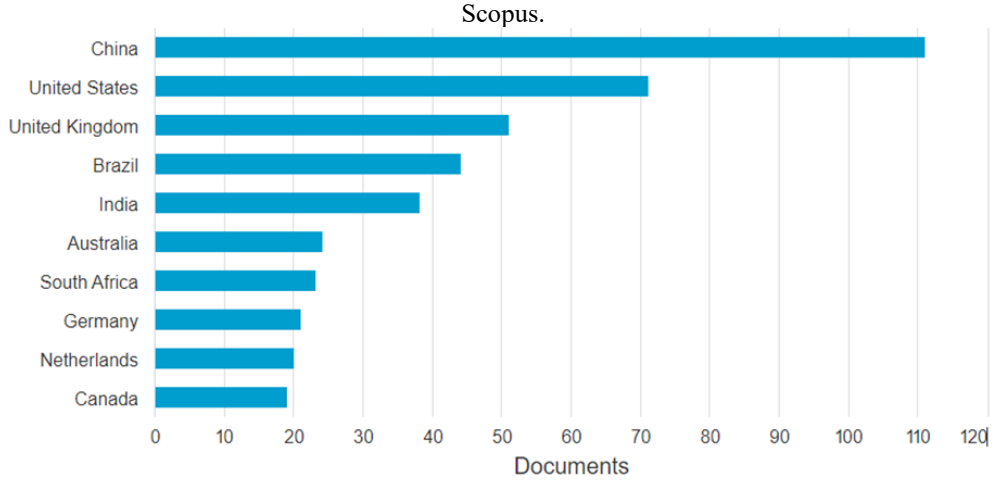


Source: Scopus, 2024.

The temporal pattern of publications, which peaks in 2022 and declines in 2023, can be interpreted not only as a response to specific events or funding cycles, but also as a reflection of socio-environmental responses to global or regional water crises. These fluctuations may indicate how attention to water security can be influenced by immediate crises, and how research may be directed toward addressing both the immediate causes and the long-term impacts of such crises on the social and environmental fabric.

Regarding the geographical distribution of publications, Figure 2 clearly illustrates the diversity and universality of challenges related to water security, with notable contributions from several countries.

Figure 2 – Publications by country on water and water security in Scopus.



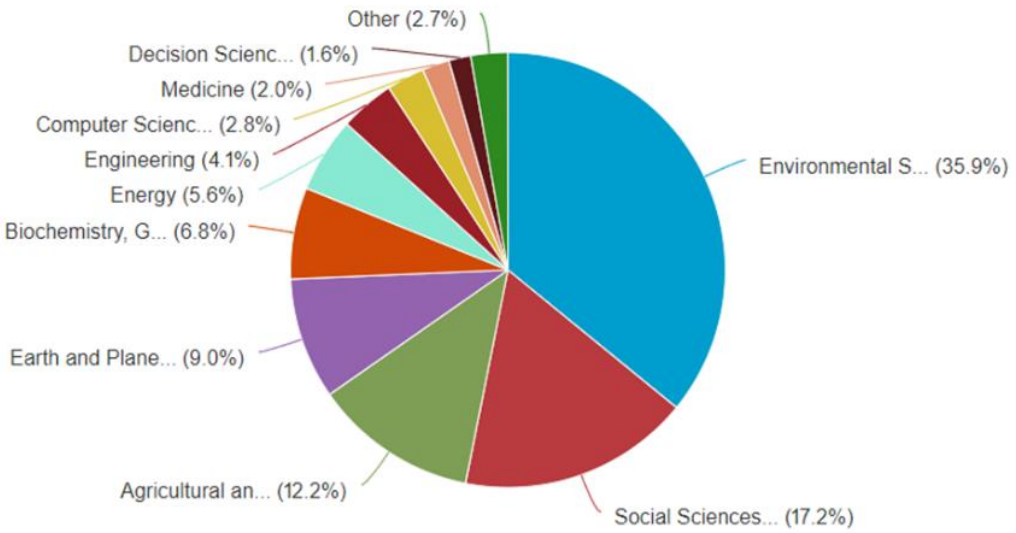
Source: Scopus, 2024.

China stands out as the leading contributor, with 112 documents, highlighting the country's substantial investment in research related to water resource management—an area of strategic importance in light of environmental challenges and growing population demands. The United States ranks second, with approximately 90 publications, reaffirming its traditional leadership in global scientific production, particularly in interdisciplinary fields such as water security.

The United Kingdom appears as the third-largest contributor, with around 55 publications, reflecting Europe's strong commitment to sustainability and water governance. Following closely are Brazil and India, with approximately 45 and 40 documents, respectively. Both countries, located in the Global South, face significant challenges related to access to and distribution of drinking water, which may explain the increasing national interest and scientific output in this field.

Other countries with notable contributions include Australia, South Africa, Germany, the Netherlands, and Canada, each with between 20 and 30 publications. These data reinforce the understanding that water security is a shared concern among nations with diverse levels of development, climates, and socioeconomic contexts.

Figure 3 – Publications by subject areas.



Source: Scopus, 2024.

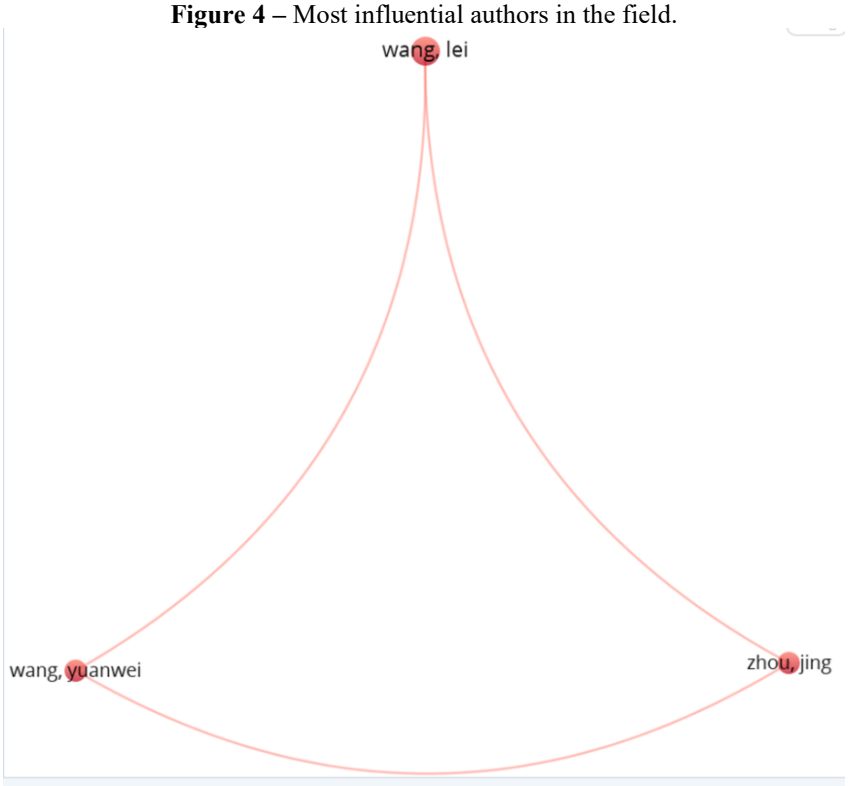
Most of the publications are concentrated in the field of Environmental Sciences, which accounts for 35.9% of the total. This figure highlights that studies on water security are strongly anchored in ecological, hydrological, and sustainability analyses, considering the environmental impacts resulting from water scarcity or mismanagement. In second place are the Social Sciences (17.2%), reflecting the recognition that political, economic, and social aspects play a crucial role in the formulation of public policies and the governance of water resources.

The third field with the highest number of publications is Agricultural and Biological Sciences (12.2%), which is consistent with the importance of water for agriculture and food security. Following that are Earth and Planetary Sciences (9.0%) and Biochemistry, Genetics, and Molecular Biology (6.8%), reflecting approaches ranging from geosciences to studies on the impact of water quality on living organisms.

Fields such as Energy (5.6%), Engineering (4.1%), and Computer Science (2.8%) are also represented, indicating the role of applied technologies and technical solutions such as modeling, sensors, and water systems management. Medicine (2.0%) and Decision Sciences (1.6%) appear with lower participation, but still demonstrate the cross-cutting nature of the topic, involving health impacts and strategic decision-making.

Finally, other areas account for 2.7%, reinforcing the interdisciplinary nature of the debate on water security. This diversity of contributions points to the complexity of the topic, which requires integrated and collaborative approaches across different fields.

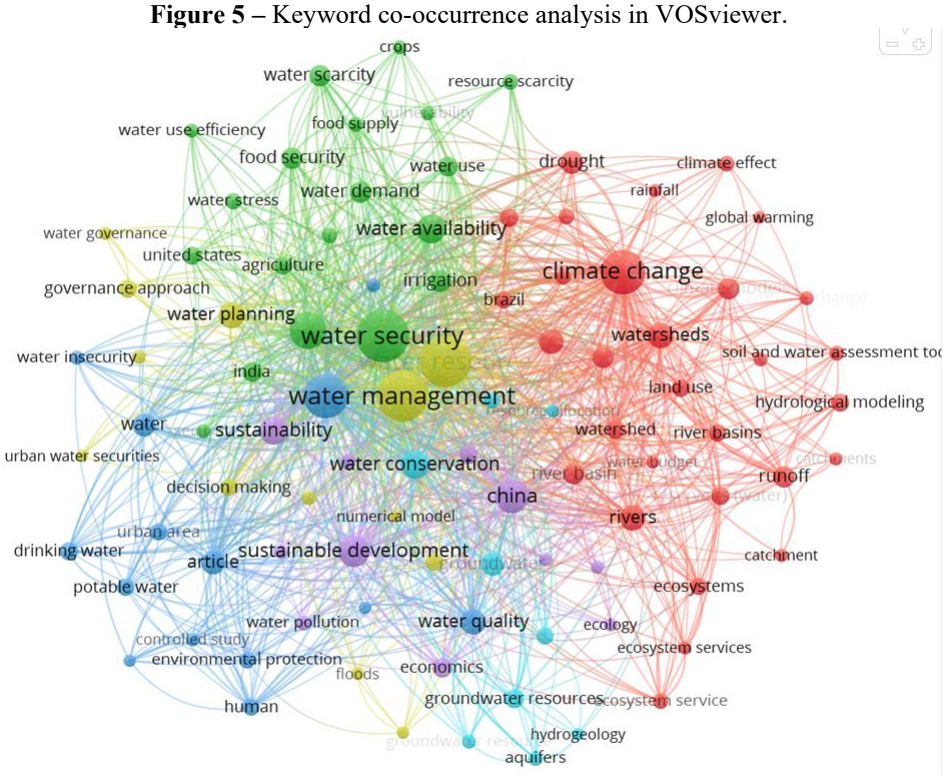
Figure 4 – Most influential authors in the field.



Source: Scopus, 2024.

The co-authorship analysis reveals three authors as the most influential in the field of Earth and Planetary Sciences. Lei Wang stands out with five published documents, 61 citations, and a total link strength of six, followed by Yuanwei Wang and Jing Zhou, both with 39 citations and six links. This indicates an extensive network of collaborations during the study period.

Figure 5 – Keyword co-occurrence analysis in VOSviewer.



Source: VOSviewer, 2024.

The keyword co-occurrence analysis generated by VOSviewer reveals a network of terms frequently used in research on water and water security. The red cluster focuses on the impact of climate change on water resources, with "climate change" as its core keyword. This cluster also highlights terms such as "drought," "rainfall," "runoff," "rivers," and "river basins," indicating a recurring concern with changes in hydrological regimes. The presence of expressions like "hydrological modeling" and "soil and water assessment tool" points to the use of simulation and modeling tools to support the forecasting and management of hydrological impacts. This cluster underscores how climate change has reshaped the debate on water security, demanding technical and scientific responses that incorporate risk scenarios and adaptation strategies.

The green cluster revolves around the interdependence between water and food security, featuring keywords such as "water scarcity," "food security," "agriculture," and "irrigation." The strong connection among terms like "water demand," "water use efficiency," and "resource scarcity" reveals the literature's efforts to understand how water scarcity affects agricultural production, particularly in the context of rising food demand. This cluster highlights the importance of sustainable water management strategies to ensure the resilience of agri-food systems amid environmental and demographic pressures.

The light blue cluster addresses issues related to water quality and its effects on environmental and human health. Terms such as "water quality," "drinking water," "water pollution," and "environmental protection" appear strongly connected, indicating a focus on the relationships among sanitation, water pollution, and social well-being. The inclusion of "economics" and "floods" suggests that studies in this group also consider the economic costs and the impacts of extreme events on water availability and quality. This cluster reflects an integrated perspective of water as a vital resource and a vector for public health and environmental protection policies.

The purple cluster gathers keywords related to sustainability and strategic development, such as "sustainable development," "sustainability," "decision making," and "water conservation." This composition highlights the role of rational governance and conservation as central elements in seeking long-term solutions to water challenges. The presence of the term "article" suggests that this cluster includes many conceptually and theoretically oriented works, indicating the consolidation of an interdisciplinary field with normative and propositional emphasis.

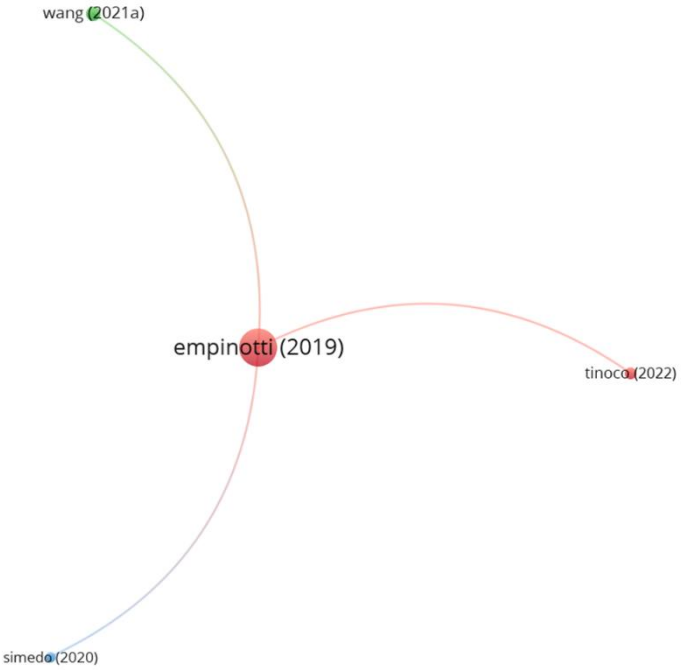
The yellow cluster contains terms associated with governance and water planning, such as "water governance," "governance approach," "water planning," and "decision making." The appearance of country names like "India" and "United States" suggests the use of case studies to analyze national models of water management. This cluster reveals the growing importance of institutional arrangements and public policies in effective water governance, pointing to the need for participatory and integrated frameworks.

The dark blue cluster focuses on urban issues, with emphasis on keywords like "urban water securities," "urban area," and "water insecurity." This group signals the challenges faced by cities in ensuring universal access to safe drinking water and adequate water infrastructure, particularly in the face of urban expansion and climate change. Connections with terms like "drinking water" and "potable water" reinforce the focus on securing the human right to water in urban contexts.

Finally, the cyan cluster is dedicated to the study of groundwater resources, including terms such as "groundwater resources," "aquifers," "hydrogeology," and "groundwater." This cluster emphasizes the importance of hydrogeology in aquifer management, especially in regions where groundwater is the primary source of water supply. The approach of this cluster is fundamental for sustainable planning, considering the risks of depletion and contamination of groundwater sources.

The keyword co-occurrence analysis using VOSviewer reveals the thematic complexity of water security and the multiplicity of interconnected approaches that define the field. The identified clusters represent complementary perspectives—climatic, agricultural, environmental, urban, institutional, and geological—that reflect the global challenges involved in ensuring water as a right, a strategic resource, and a pillar of sustainability.

Figure 6: Análise das citações no VOSviewer.



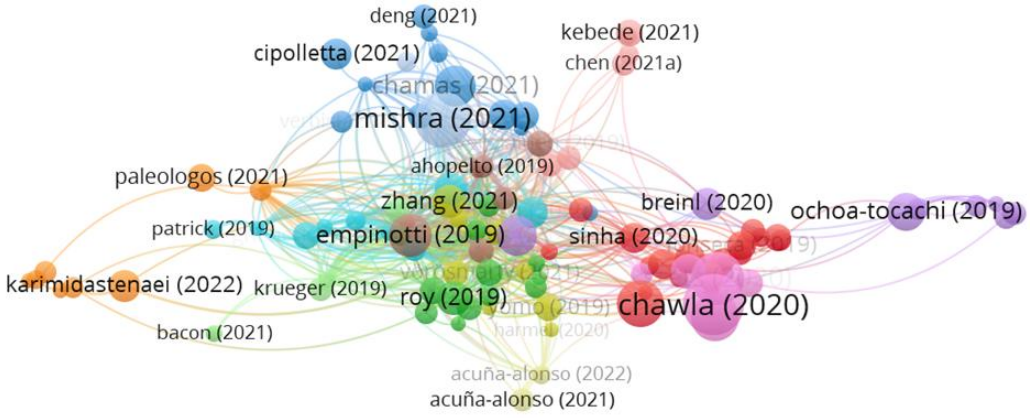
Source: VOSviewer, 2024.

In the co-citation analysis of the five most cited works over the past five years, four authors stand out, with Empinotti (2019) receiving particular emphasis, as their work shows a greater number of connections with authors such as Simedo (2020), Wang (2021a), and Tinoco (2022). This highlights the relevance of Empinotti's research from an academic environmental perspective.

It is also worth noting that among the authors with the highest number of citations are Chawla (2020) with 154 citations, followed by Mishra (2021) with 128, Stets (2020) with 114, Bangira (2019) with 96, Gronwall (2020) with 92, Empinotti (2019) with 76, Chamas (2021) and Pousa (2019) with 68, Payus (2020) with 67, Ochoa-Tocachi (2019) with 59, Tian (2021) with 55, and Makarigakis (2019).

The co-occurrence analysis of these citations, as shown in Figure 7, supports and reinforces the previous findings regarding the most relevant authors in terms of cited works, once again highlighting Chawla (2020) and Mishra (2021) as highly interconnected. However, no significant linkage was identified with Stets (2020).

Figure 7: Bibliographic coupling analysis in VOSviewer.



Source: VOSviewer, 2024.

The map shows several clusters of documents that are strongly interconnected. In this context, bibliographic coupling identifies connections between authors who share common references in their publications, allowing the mapping of scientific communities and the degree of affinity among different research lines. The

visual network is composed of nodes (authors) and edges (degree of coupling), with thematic groupings represented by clusters of different colors.

At the center of the network, the green cluster stands out as the densest and most interconnected core of the analysis. Authors such as Empinotti (2019), Zhang (2021), and Roy (2019) are key vertices in this group, forming a solid and widely shared theoretical foundation. These researchers exhibit strong co-occurrence with various other clusters, suggesting that their works provide essential methodological and conceptual frameworks for studies on water security, resource planning, water governance policies, and sustainability. Their centrality indicates their relevance as structuring axes of the field.

Another prominent group is the light blue cluster, composed of authors such as Mishra (2021), Cipolletta (2021), Chamas (2021), and Deng (2021). This group includes recent publications that interact with the central clusters, indicating an update and expansion of the debate on topics such as hydrological modeling, climate change impacts, spatial data, and technical solutions for water management. The international nature of this production, evidenced by the diversity of names and affiliations, points to a growing global articulation of research in water security.

The pink-red cluster, in turn, features authors such as Chawla (2020), Sinha (2020), and Breinl (2020). This grouping appears to focus on applied studies in climate adaptation, forecasting of extreme events, and hydrological risk analysis, such as floods and droughts. Although it has fewer links to the central clusters, its internal cohesion is evident, demonstrating the existence of a consistent research line aimed at water resilience and disaster risk management.

On the left side of the network, the orange cluster can be seen, including authors such as Karimidastenaei (2022), Paleologos (2021), and Bacon (2021). This group seems to focus on technical aspects such as hydrogeology, aquifer monitoring, and water quality studies in specific geographic contexts. Its peripheral position and fewer connections with other clusters suggest that it represents a specialized research community, which shares its own frameworks and interacts selectively with other core groups in the field.

Finally, the purple cluster, led by Ochoa-Tocachi (2019), appears on the far right of the map. It is a smaller cluster, but with strong internal cohesion and an emphasis on spatial analyses, water impact assessments, and regional variability of water resources. This marginal position does not imply lesser importance, but rather a thematic differentiation that contributes to the diversity of scientific debate, particularly with a focus on local realities and detailed geographic approaches.

The bibliographic coupling analysis reveals the existence of a consolidated and multidimensional scientific network in the field of water security. The central authors act as integrating axes of knowledge, while the peripheral clusters reinforce the methodological and thematic plurality of the area. This configuration indicates a mature and expanding field, with strong potential for the development of interdisciplinary research and international collaborations.

IV. Conclusion

The bibliometric analysis provided an overview of research on water and water security over the past five years. The results indicate a growing number of publications over time, with 2021 and 2022 standing out as the years with the highest number of articles. Furthermore, the analysis of subject areas highlights the interdisciplinary nature of the field, with multiple disciplines contributing to the discussion, including Environmental Science, Social Sciences, Earth and Planetary Sciences, and Agricultural and Biological Sciences.

Regarding the most prolific authors, Lei Wang stands out for both the volume and impact of his work, followed by other notable researchers such as Yuanwei Wang and Jing Zhou. Co-authorship and keyword co-occurrence analyses revealed collaboration patterns and key research topics, emphasizing the centrality of concepts such as water security, water management, and climate change.

The analyzed studies offer insights into water security issues, highlighting the complexity and evolution of thinking around water resource management. They underscore the importance of inclusive governance in addressing socio-environmental concerns and environmental conservation amid climate change, recognizing the regional and global contributions of countries such as China and Brazil. In addition, they address advances and challenges in integrating socio-economic approaches with water scarcity, stressing the need for a holistic and inclusive approach.

Ultimately, these studies emphasize the effectiveness of strategies for the efficient use and management of water and natural resources, ensuring scientifically robust and socially just solutions tailored to regional contexts. Collectively, these theoretical and practical perspectives offer valuable insights for the development of policies and practices that promote efficient water use and demand in the face of environmental sustainability and climate change challenges, recognizing the importance of an integrated and participatory approach that considers the complex interactions between water resource management and socio-environmental and economic issues. This approach is essential to address contemporary challenges and promote a sustainable water future for present and future generations.

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