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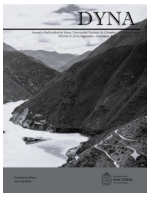

UNIVERSIDAD NACIONAL DE COLOMBIA

Governance and participatory strategies in sustainable water management: a systematic analysis

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Abstract
Sustainable water resources management is increasingly recognized as a critical challenge where effective solutions depend not only on public policies, but also on the active participation of local communities. The review utilized a structured methodology, including the PICOC and PRISMA approaches, to analyze relevant literature published from 2010 to 2024. The findings highlight that community participation empowers local stakeholders, fosters responsibility, and integrates both traditional and scientific knowledge for adaptive water management. Furthermore, inclusive water governance frameworks that promote transparency and cooperation among various stakeholders are critical for equitable and effective resource management. Challenges to implementing these strategies include limited access to information, technical capacity, and resistance from some sectors to relinquish control. The review concludes that overcoming these obstacles requires stronger political commitment, capacity building, and the development of regulatory frameworks that support community rights and inter-institutional cooperation.

Keywords: community water; collaboration; bibliometrics; water governance; water management; stakeholders; participation; water resources; literature review; sustainability water.

Gobernanza y estrategias participativas en la gestión sostenible del agua: un análisis sistemático

Resumen
La gestión sostenible de los recursos hídricos se reconoce cada vez más como un reto crítico cuyas soluciones eficaces dependen no solo de las políticas públicas, sino también de la participación activa de las comunidades locales. La revisión utilizó una metodología estructurada, incluyendo los enfoques PICOC y PRISMA, para analizar la literatura relevante publicada entre 2010 y 2024. Los resultados destacan que la participación de la comunidad empodera a las partes interesadas locales, fomenta la responsabilidad e integra tanto el conocimiento tradicional como el científico para la gestión adaptativa del agua. Además, los marcos inclusivos de gobernanza del agua que promueven la transparencia y la cooperación entre las distintas partes interesadas son fundamentales para una gestión equitativa y eficaz de los recursos. Entre los retos que plantea la aplicación de estas estrategias figuran el acceso limitado a la información, la capacidad técnica y la resistencia de algunos sectores a ceder el control. El estudio concluye que para superar estos obstáculos es necesario un mayor compromiso político, la capacitación y el desarrollo de marcos normativos que apoyen los derechos de las comunidades y la cooperación interinstitucional.

Palabras clave: agua comunitaria; colaboración; bibliometría; gobernanza del agua; gestión del agua; partes interesadas; participación; recursos hídricos; revisión bibliográfica; sostenibilidad del agua.

1 Introduction

Sustainable water resource management is a crucial challenge today, where scarcity, climate change and pollution generate adverse effects on ecosystems and thus on communities [1]. In this scenario, the participation of local communities in the structuring and implementation of governance strategies is key in the search for solutions

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adapted to real contexts. These two dimensions are closely related and mutually reinforcing, since sustainable water management depends not only on public policies and technical decisions, but also on the active collaboration of the communities, since they are the most affected by changes in the availability and quality of the resource [2,3].

Community participation in the sustainable management of natural resources is an approach that seeks to include the inhabitants of the communities in decision-making related to conservation and environmental sustainability, especially in water governance processes [4,5]. This type of participation is based on the idea that communities have direct knowledge of their environment and can therefore offer more effective and contextually appropriate solutions [6]. Similarly, the active participation of local communities in decision-making processes stimulates and increases their sense of responsibility and commitment by promoting their involvement in the implementation and monitoring of water policies [7]. In this way, sustainable water management becomes a dynamic and participatory process that integrates the knowledge, skills and experience of the community [8], [9]. On the other hand, water governance includes decision-making processes, regulatory structures and the institutional capacity to regulate water use, as well as resource allocation and conservation [10]. Effective water governance has clear mechanisms for participation and dialogue among key stakeholders, but most of all with local communities [11].

In other words, inclusive and transparent governance ensures that voices are representative within the processes and that the policies structured and implemented respond to the real contexts and situations of the different social groups, especially the most vulnerable. This is why governance should not be understood purely as rules or regulations but as a complex and continuous process of interaction and/or cooperation among key actors [12,13]. However, the implementation of community participation and water governance strategies faces several challenges. Among the most common are the lack of access to relevant information, the limited technical capacity of communities to participate in complex processes, and the resistance of some sectors to cede control of water management [14–16]. Overcoming these obstacles requires not only strong political commitment, but also the strengthening of local capacities through education, training and empowerment of community actors. It is also necessary to develop regulatory frameworks that facilitate effective participation, guarantee community water rights, and promote inter-institutional cooperation [17–19].

The main objective of this review is therefore to identify the governance or community-based strategies that have been applied in sustainable water resources management, but also to describe the main advantages of using governance or community-based strategies for sustainable water resources management. The structure of the document begins with an introduction to the subject followed by a description of the method used to achieve the objective. In addition, the results section highlights the main contexts, followed by a discussion of the impact of community participation and governance strategies on sustainable water resource management. Finally, you will find the conclusions where we contextualize and/or highlight the gaps in knowledge that can be addressed in another research.

2 Materials and methods

This systematic review seeks to identify participatory strategies in sustainable water management with a governance approach. Therefore, following the PICOC and PRISMA recommendations, this review has three phases: planning, implementation and reporting [20,21]. Likewise, the systematic analysis of the literature was supported by the use of Mendeley (Version 1.19.8) for reference management, Microsoft Excel 365 for the selection and exclusion of studies, and VOSviewer for the structuring of the cooccurrence networks (1.6.19.0) [22–24].

2.1 Planning the review

This part of the review involved structuring the search strategy for specialized information published on the topic in question in order to address the research questions posed for the analysis. Table 1 shows the questions that will guide the review.

Once the questions were defined and the scope of the systematic review of the literature on the subject was defined, we followed the PICOC method approach (see Table 4) [25,26] proposed by Petticrew y Roberts [27].

Table 1.
Questions and objectives of the research work.

	Questions	Objectives
RQ1	What governance or community strategies have been effective for sustainable water resource management?	Identify the governance or community strategies that have been implemented in the sustainable management of water resources.
RQ2	What are the main advantages of using governance or community-based strategies for sustainable water resource management?	Identify the main benefits of using governance or community-based strategies for sustainable water resource management

Source: Created by the author

Table 2.
PICOC method.

Criteria	Descriptions
Population	Publications on participatory strategies in sustainable water management with a governance approach.
Intervention	Available engagement strategies, efficiency of community engagement strategies, approaches to governance strategies.
Comparison	Compare existing community engagement strategies.
Outcome	Understanding and optimizing participatory strategies in sustainable water management from a governance approach.
Context	Conservation of water resources.

Source: Created by the author

Table 3.
List of keywords, synonyms, and relationships

Keyword	Synonyms
Water governance	Community participation, water administration, social involvement,
Water resources	Water sources, water reserves, water supply
water resource management	Water management, water resources management, water use control

Source: Created by the author

In Table 3, the keywords and synonyms were structured under the PICOC criteria, with which the organization of the problem analysed with the search of the documents within the systematic review of the literature was established.

For the search criteria, the search algorithm, inclusion criteria and exclusion criteria were considered (see Table 4). The key words used were water resources, water governance, community participation and water resource management, and the inclusion criteria were English and Spanish language, time range 2010 - 2024, open access and complete document; while the exclusion criteria were related to non-compliance with the time range, publication characteristics, as well as type of document.

The relevant aspects of the scientific articles were determined through the extraction of the information (see Table 5), allowing the effective selection of the documents related to the topic in question.

The specialized Scopus® database was searched for research articles related to the topic. The following search algorithm was used ("Community participation" OR "Social involvement" OR "Water governance" OR "water administration") AND ("water resources" OR "water sources" OR "water reserves" OR "water supply") AND ("water resource management" OR "Water management"). The final search was performed on March 09, 2025 and 1549 studies were found. Each article was evaluated for relevance to the study and articles that did not meet the eligibility requirements were eliminated (see Fig. 1).

Table 4.
Search criteria.

Key	Criteria
Search string	TITLE-ABS-KEY (("Community participation" OR "Social involvement" OR "Water governance" OR "water administration") AND ("water resources" OR "water sources" OR "water reserves" OR "water supply") AND ("water resource management" OR "Water management")) AND PUBYEAR > 2009 AND PUBYEAR < 2025 AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English") OR LIMIT-TO (LANGUAGE , "Spanish")) AND (LIMIT-TO (OA , "all"))
Intervention criteria	Academic Journals (Peer-reviewed); Filtering by Keyword: Community water, water governance, water management, water sustainability, water resources, participation and collaboration. Language: English and Spanish; Full Text; Publication Date: 2010–2024.
Exclusion criteria	Documents other than research articles, outside the time range and not fulfilling the objective of the analysis.
Search mode	Apply to title, abstract and keywords.

Source: Created by the author

Table 5.
Relevant fields for data extraction

Fields	Descriptions
Reference	It provides information necessary to locate other original documents, including authors, title, name of the journal or conference, volume, number, pages, year of publication, among other details.
Publication	Specify the medium where the work was published, such as scientific journals, books, conferences, repositories, etc. You may also include details such as the name of the publisher or the volume and number of the publication if relevant.
Year	Indicates the year in which the work was published.
Main idea	Summarizes concisely the main objective or central idea of the research work.
Gaps	This identifies areas not covered or limitations of previous research that the article or study addresses.
Major contributions	Most relevant findings or main contributions of the study
Methodology	Details the methodological approach used to conduct the study. This includes the type of research (qualitative, quantitative, mixed), data collection methods, data analysis, and any models or techniques used in the research.
Results	Provide the results of the research. They may include quantitative findings, patterns, trends, or general conclusions derived from the data analysis.
Limitations	Indicates any constraints that might have influenced the results or the generalization of the findings.

Source: Created by the author

2.2 Selection criteria

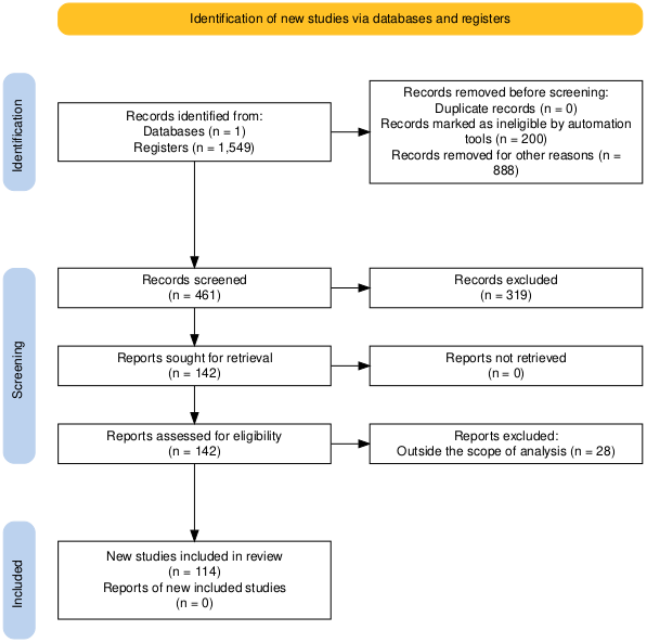

Figure 1. PRISMA 2020 flow chart for systematic reviews.
Source: Own elaboration based on Haddaway et al. [21]

2.3 Performing the review

A structured framework for data extraction was developed to systematically collect relevant information to address the research questions. This framework includes key aspects such as title, year of publication, strategy used, results, country of study,

key concepts, limitations reported, and major findings or gaps identified that require further research (see Table 5). To carry out this process, the researchers reviewed each article individually and used a detailed content analysis to extract the relevant data supported by Excel and VOSviewer (Co-occurrence and density map, which allows the structure, evolution and dynamics of a scientific field to be determined, helping to identify trends, research gaps and opportunities for collaboration).

2.4 Review report

This step corresponds to the process of documenting and presenting the findings of the review in a clear and transparent manner. Its importance lies in ensuring both the reproducibility and reliability of the results, allowing readers to assess the rigor and validity of the study. Details of the findings obtained are presented in the following section.

3 Results and discussion

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn

3.1 Literature review

RQ1: What governance or community strategies have been effective for sustainable water resource management?

Governance and community participation strategies have proven to be fundamental for the sustainable management of water resources, particularly in contexts marked by scarcity and climate change. These practices, in addition to increasing water use efficiency, contribute to strengthening the social fabric and promote equity in access to the resource, which is essential to ensure long-term sustainability.

Within this framework, one of the most effective strategies is collaborative governance, understood as the formation of networks made up of local governments, communities and other relevant stakeholders. Such networks allow the articulation of resources, knowledge and institutional capacities, which favours coordinated and more efficient water management [8,28].

Complementarily, social capital plays a key role in the success of these strategies. The generation and strengthening of bonds of trust and cooperation, both within communities (bridging social capital, this refers to the connections that individuals or social groups with different characteristics or interests have with one another. These links enable them to share information, resources or influence) and between different social and institutional groups (bonding social capital, it refers to close, trusting relationships within a group. These bonds facilitate cooperation and the fulfilment of shared duties, but must be combined with external factors to avoid exclusion and the adoption of innovations by outside actors), promotes greater social cohesion [29, 30].

In governance processes, both types of social capital complement each other, since bonding capital provides cohesion and local legitimacy, while bridging capital broadens the scale of management. This helps to introduce new ideas within groups, reducing asymmetry with external actors [31,32]. It is also crucial to identify and include central actors within governance networks. Figures such as community leaders, local authorities or key institutions can act as catalysts for dialogue and articulation between sectors [11,13,15]. Their role facilitates the circulation of information, the establishment of alliances, and, consequently, the implementation of more effective management strategies. These actors often engage through specific mechanisms that translate shared objectives into coordinated actions — such as intergovernmental coordination councils, technical development committees, sectoral intergovernmental commissions, basin councils, and water committees — which function as forums for dialogue and consultation, as well as citizen observatories for water conservation [33–35].

On the other hand, the structuring of shared objectives and agreements among key stakeholders allows the efficient allocation of resources, as well as promotes joint solutions to socio-environmental challenges. The existence of these agreements favours the alignment of interests, reinforcing the collective commitment to the integrated management of water resources [36,37]. In this sense, the use of quantitative techniques and tools such as the Water Governance Indicator Framework (36 indicators broken down into four pillars: effectiveness, efficiency, reliability and inclusiveness), the WWAP - Water Governance Score (UNESCO-WWAP; 12 dimensions), the Integrated Water Resources Management Index (33 indicators), geodata, and the Analytic Hierarchy Process for data-based decision-making are essential for monitoring and evaluating the performance of community governance networks [38–40]. These tools can highlight areas for improvement, facilitating the design of precise interventions adapted to the real needs of the territory.

Likewise, it is essential to promote spaces for dialogue and continuous communication among the actors for the creation or strengthening of trust. This continuous communication not only supports relations between institutions, but also promotes the commitment and motivation of the actors in the medium and long term, which generates greater capacity in the implementation of collective actions in sustainable water management. [41–43]. Moreover, it is necessary to adapt the strategies to the specific conditions of each territory, considering the socioeconomic, cultural and environmental factors that allow the structuring and implementation of contextualized and relevant policies that effectively respond to local challenges.

RQ2: What are the main advantages of using governance or community-based strategies for sustainable water resource management?

Water governance strategies, especially community-based ones, offer advantages that contribute to structuring more effective and equitable solutions. In the first instance, such strategies enhance the collaboration and engagement of local communities, government agencies and non-governmental organizations [44,45]. This inclusive approach gathers stakeholder perspectives, resulting in sound decisions that reflect needs and priorities [42,46–48].

In addition, the incorporation of communities provides local knowledge and traditions as a strength within the strategies, since water governance models that are based on indigenous practices, cultural perceptions and historical

conceptions of sustainable water management make solutions more adaptable, relevant to the context and accepted by key stakeholders [38,49–51]. This localized knowledge not only enriches the decision-making process but also promotes more effective and sustainable management practices.

Another key advantage is the strengthening of local actors' technical knowledge [52] and their involvement in planning and decision making generates greater ownership leading to transparent processes between local authorities and local communities [10,53–55]. This approach also increases local leadership capacities, allowing communities to learn to manage their water resources more independently and effectively over time.

Community-based governance and strategies also foster greater adaptive capacity and innovation. These practices support flexible management, enabling governance structures to respond nimbly to environmental changes such as climate variability, pollution or population growth [56–58]. This adaptive capacity is key to facing new challenges and uncertainties. In most of these strategies, the collaborative approach drives innovation, as diverse actors come together to create joint solutions and share ideas that might not emerge in more centralised or vertical management models [50,57,59].

These approaches strengthen the resilience of water systems and communities. By promoting social cohesion and trust among community members, they build stronger support networks that are better able to cope with water-related crises and environmental stresses such as droughts, floods or resource depletion [60–62]. Long-term commitment and the development of lasting relationships with stakeholders also help water management efforts to be sustained over time, favouring the ecological sustainability of water resources.

They also promote transparency and accountability. Community governance systems often have more open decision-making processes, allowing stakeholders to hold decision-makers accountable and ensure that water management is in the public interest [18,63]. This transparency is essential to build trust among stakeholders and ensure the necessary support for successful initiatives [19, 64,65]. Additionally, the collaborative nature of these strategies facilitates early detection and resolution of conflicts, helping to resolve disputes before they escalate.

Taken together, these benefits show how community-based governance and strategies can contribute to more sustainable, resilient and equitable water resources management. By integrating local knowledge, empowering communities, fostering collaboration, and promoting adaptive and innovative solutions, these strategies offer a pathway to long-term sustainable water management, both environmentally and socially.

3.2 Bibliometric analysis

3.2.1 Publication date

Fig. 2 shows the distribution of research articles published annually, reflecting the growing interest in the formulation and implementation of participatory strategies and/or governance in sustainable water management. The data obtained indicate a progressive increase in publications on the subject between the time range analyzed (2010-2024), with downward peaks in 2015, 2020, 2022 and 2024. This increase in scientific activity related to the topic can be attributed to the management of different governments, as well as to international agreements for the conservation and proper management of water resources. For the year 2020, there will be a lower number of publications, mainly due to the disruption caused by the COVID-19 pandemic, which affected the financing and implementation of multiple strategies worldwide.

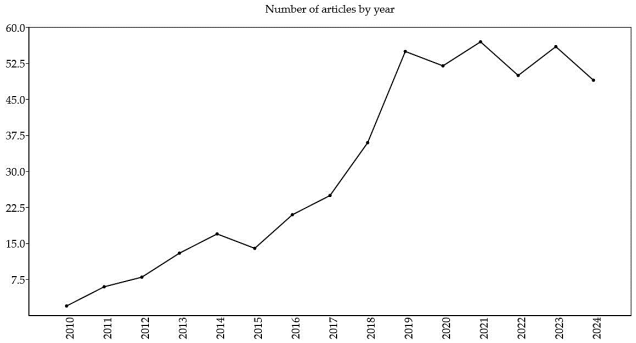

Figure 2. Published studies by year of publication.
Source: Own elaboration based on data retrieved from Scopus. The search was conducted using the keywords listed in 4, in the search string row, covering the period from 2010 to 2024.

Although in 2021, the number of publications increased, this was due to documents and issues held back in journals worldwide as they prioritized pandemic-focused research, however, by 2022 a decrease in publications can be observed due to limitations in data collection needed for community-level water management studies, the shift of interest in the subject matter redirected towards public health and water management issues.

3.2.2 Location of the studies

Fig. 3 shows the distribution of publications by country on the formulation and implementation of participatory strategies and/or governance in sustainable water management, which shows a tendency of concentration in Asian and European countries, although there is an increase in developing countries.

The United States tops the list with 96 studies, representing 12.12% of the total number of publications in the time range analyzed, reflecting the interest in facing the challenges of water resource conservation and management. This is due to changes in climate variability within the territory, specifically in the West, where overexploitation of aquifers and drought have created problems of availability, as well as pollution generated by wastewater discharges, agricultural chemicals and industrial pollutants that affect water quality.

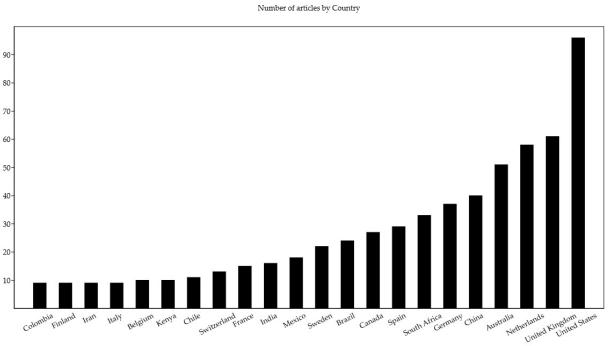

Figure 3. Geographic distribution of studies.
Source: Own elaboration based on data retrieved from Scopus. The search was conducted using the keywords listed in Table 4, in the search string row, covering the period from 2010 to 2024.

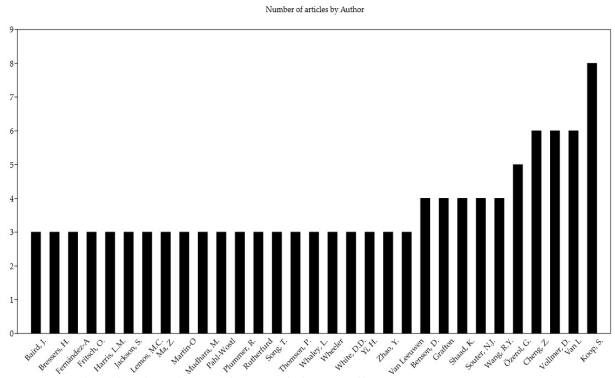

Figure 4. Distribution by authors of the studies.
Source: Own elaboration based on data retrieved from Scopus. The search was conducted using the keywords listed in Table 4, in the search string row, covering the period from 2010 to 2024.

The United Kingdom, with 7.7%, faces water resource management in relation to infrastructure modernization, storm drains and agricultural runoff. Netherlands, with 58 studies, has a high dependence on flood control systems and water resources for agriculture. Australia, with 51 studies, has frequent and severe droughts, which directly impacts water availability, as well as an excessive use of water resources in agriculture.

China, with 5.05%, struggles with increasing urban and industrial demand as well as a high percentage of polluted water resources from industrial and agricultural waste. Germany, with 37 publications, is facing the effects of climate change in relation to water availability and water quality, which in turn is caused by the presence of nitrates and chemicals in the water.

South Africa, with 4.17%, has changes in rainfall affecting water availability, especially in rural areas, where access to drinking water is limited. While Spain, Canada and Brazil (more than 3.0% of the publications) present problems to be solved in relation to watershed management and pollution in rivers, especially in urban areas.

Finally, countries such as Sweden, Mexico, India, France, Switzerland, Chile, Belgium, Kenya, Colombia, Finland, Iran, Italy, Indonesia, Nepal, Ethiopia, Japan, Pakistan, Thailand, Austria, Bangladesh, Cambodia, Denmark, Ireland, Malaysia, Philippines, Singapore, Sri Lanka, Argentina, Ecuador, Hong Kong, Peru, South Korea, Bolivia, Ghana, Greece, Mongolia, Portugal, Tanzania, Turkey, Uruguay, Vietnam, Algeria, Botswana, Costa Rica, Czech Republic, Egypt, Laos, Lebanon, Malawi, New Zealand, Nigeria, Norway, Palestine, Saudi Arabia, Slovenia, Uganda, Uzbekistan, Afghanistan, Burkina Faso, Congo, Georgia, Iraq, Kazakhstan, Nicaragua, Poland, Romania, Tonga, Tunisia, Türkiye, Zimbabwe has between 0. 13% to 2.78% of the publications; being isolated efforts but significant contributions to the conservation and management of water resources.

3.2.3 Publication by authors

The increasing production of papers suggests a growing interest and an urgent need to address water-related problems (see Fig. 4). Koop, S. stands out as the author with the highest number of papers (8), suggesting a significant contribution to the field.

Cheng, Z., Vollmer, D., and van Leeuwen, K. are also prominent authors, each with 6 publications, indicating that they are active in water-related research and strategy development.

Another prominent author with 5 publications is Özerol, G., while authors such as Benson, D., Grafton, R.Q., Shaad, K., Souter, N.J. and Wang, R.Y. each have 4 publications. The published studies reflect trends in specific topics, such as the impact of climate change on water resources or water use efficiency in agriculture.

3.2.4 Co-occurrence network analysis

The co-occurrence map generated with VOSviewer graphically (see Fig. 5) represents the interrelationships between key concepts in the field of water management and governance, allowing the identification of thematic clusters that reflect the main lines of scientific research. In the maps, thematic clusters are formed from co-occurrence networks of keywords, co-authorship, or citations; each node represents an element of analysis, while the size indicates the relative weight (frequency or link strength) [22]. Based on the analysis of the groups, different interconnected approaches that address water resources from technical, social, environmental and institutional dimensions become evident.

One of the core areas is water management, where terms such as water management, climate change, irrigation and water security are articulated to reflect the operational challenges in contexts of growing water pressure, climate variability and the need for efficiency in the use of the resource, particularly in sectors such as agriculture. This technical approach is complemented by a second group focused on water governance, which incorporates terms such as water governance, governance approach, policy making and integrated water resources management. This group reflects the need for robust institutional frameworks, integrated public policies and participatory planning that orients decision making towards sustainability.

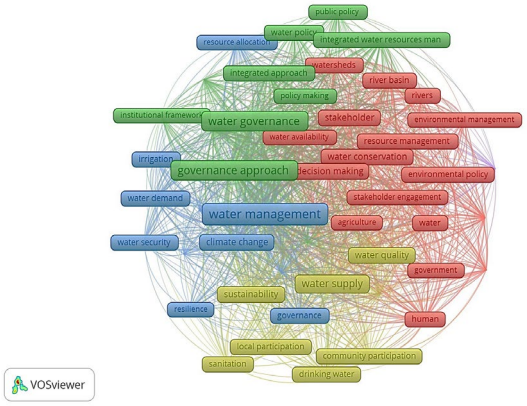

Figure 5. Co-occurrence network map keywords.
Source: Own elaboration based on data retrieved from Scopus. The search was conducted using the keywords listed in Table 4, in the search string row, covering the period from 2010 to 2024.

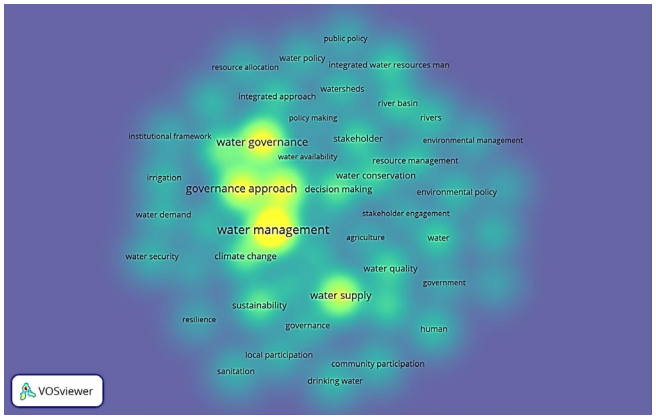

Figure 6. Keyword density map.
Source: Own elaboration based on data retrieved from Scopus. The search was conducted using the keywords listed in Table 4, in the search string row, covering the period from 2010 to 2024.

A third thematic core groups aspects related to the interaction between stakeholders and environmental management. Terms such as stakeholder, resource management, decision making, and environmental policy reflect the importance of considering the various social, economic, and institutional actors in the processes of water conservation and use. Shared decision making and multi-stakeholder participation are presented as strategic elements in the implementation of effective and equitable policies [66–69]. Finally, a group of concepts associated with sustainability, citizen participation and equitable access to water are identified. Terms such as water supply, water quality, community participation, resilience and drinking water show the need to integrate approaches focused on human wellbeing, equity and public health, also considering resilience to extreme climate events and the inclusion of local communities in management processes.

The connectivity between these clusters reveals the multidimensional nature of water governance, highlighting the importance of interdisciplinary approaches that integrate technical, environmental, institutional and social knowledge. The strong co-occurrences between terms from different clusters, such as climate change with sustainability or governance approach with stakeholder engagement, indicate that sustainable solutions require coordinated strategies that consider both management efficiency and legitimacy in decision-making processes [37,70,71]. In this sense, research and policy formulation should be oriented towards integrated models of water governance, with a territorial approach, active participation of stakeholders and a long-term vision focused on sustainability and equity.

On the other hand, in the density map (see Fig. 6) the highest density, indicated by the warmest colours (intense yellow), is concentrated around the terms water management, governance approach and water governance. This grouping reveals a strong scientific interest in the operational and institutional aspects of water resource management, highlighting the need for integrated approaches that articulate public policies, stakeholder participation, institutional frameworks and sustainability strategies [72,73]. The simultaneous presence of these concepts indicates that current studies are not limited to water use efficiency, but also critically address the governance structures that regulate water use.

The concept of climate change appears very close to the central core, indicating a strong association with water management. This proximity suggests that the impacts of climate change, such as variability in resource availability and increased extreme events, are being addressed in a cross-cutting manner in water governance and planning studies [74–76]. This relationship evidences the need to strengthen the resilience and adaptability of water management systems in the face of uncertain climatic contexts. Also, on the periphery of the main core, there is a technical cluster related to irrigation, water demand, water security, resource allocation and integrated water resources management [77–80]. This grouping points to the interest in optimizing resource allocation, especially in sectors such as agriculture, through integrated planning tools. The connection between these terms and those of the governance cluster suggests a technical-institutional approach that seeks to harmonize operational efficiency with principles of equity and sustainability.

Another thematic cluster is located towards the right side of the map, and includes concepts such as stakeholder, environmental management, resource management, decision making and environmental policy. This cluster reflects the participatory and environmental dimension of water management, in which the involvement of various social actors is crucial to reach consensual and sustainable decisions. The emergence of stakeholder engagement as a point of intersection reaffirms the relevance of the collaborative approach in water governance processes.

In the lower zone, there are terms such as sustainability, resilience, community participation, local participation and drinking water, which form a cluster more focused on the social and human aspects of access to water. This cluster highlights the importance of guaranteeing the human right to water, equity in its distribution and the active participation of local communities in its management.

Moreover, the proximity of these concepts to governance and water supply indicates an interdependence between governance structures and conditions for equitable access.

Therefore, in order to strengthen the capacities of community actors in water governance, it is essential to develop technical, leadership, and participatory planning capacities based on the integration of social, environmental, and cultural dimensions [81]. Likewise, it is necessary to structure alliances with territorial or political entities, and academic institutions, allowing them to participate in spaces such as science committees or water observatories [82]. It is essential to make traditional knowledge visible and integrate it into the dialogue with authorities, adapting it to intercultural approaches and proposing public policies that integrate territorial aspects of the right to water.

Overall, the density map reveals an interrelated thematic structure that articulates the technical, institutional, environmental, and social dimensions of water resources management. The overlapping of densities among groups of actors underscores the need for inter- and transdisciplinary approaches to enhance the integration of scientific knowledge into participatory governance and sustainability processes [83,84]. These findings also highlight the importance of strengthening community participation and multi-stakeholder networks, which has direct implications for public policy formulation. At both local and national levels, it is essential to design more participatory regulatory frameworks that recognize and formalize coordination spaces among communities, authorities, and institutions. Moreover, establishing incentives for inter-institutional collaboration and knowledge exchange is particularly important in diverse territorial contexts. Integrating local knowledge, ensuring effective consultation mechanisms, and supporting community training processes can improve the understanding of complex water systems while contributing to the design of inclusive, legitimate, and context-sensitive water governance strategies.

4 Conclusions

Within the sustainable management of water resources, community governance strategies play a fundamental role since, by promoting collaboration between parties such as local communities, social or environmental non-governmental organizations, as well as governments, it is possible to structure strategies based on integral, transparent processes that are adjusted to realities. The incorporation of ancestral or local knowledge improves relevance and increases the acceptance of sustainable management practices by the communities, promoting ownership and responsibility. Similarly, the strategies promote innovation and adaptability allowing water management systems to be more effective in relation to today's socio-environmental challenges. Ultimately, the integration of technical, institutional and social approaches to these strategies contributes to the long-term sustainability and equity of water resources management.

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