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Research Article

# Mapping the Knowledge Landscape of Artificial Intelligence Research in Water Resources Management: A Bibliometric and Co-word Analysis

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**Abstract**

Recent advances in artificial intelligence (AI) technologies, particularly machine learning, artificial neural networks, decision support systems, and big data analytics, have created new opportunities for monitoring, forecasting, and decision-making in water resources management. Despite the growing body of literature in this field, the intellectual structure and thematic evolution of AI-related research in water resources management have not yet been comprehensively examined through co-word network analysis. Therefore, this study aims to conduct a bibliometric investigation to identify scientific publication trends and map the conceptual landscape of research at the intersection of artificial intelligence and water resources management. This study adopts a descriptive bibliometric approach. The dataset comprised publications indexed in the Scopus database up to May 2025 that addressed the application of artificial intelligence in water resources management within their titles, abstracts, or keywords. Following data extraction and document-type screening, the records were analyzed using VOSviewer software through co-word analysis, thematic clustering, and network visualization techniques. The findings revealed that a total of 3,657 documents were retrieved from Scopus, of which 3,314 journal articles, conference papers, and review articles were selected for the main analysis. Scientific output in this field has experienced marked acceleration since 2014, with 2024 representing the most productive publication year. China, the United States, India, and Iran emerged as the leading contributors to the field, with Iran ranking fourth globally with 319 publications. Co-word analysis identified five major thematic clusters: (1) machine learning and predictive modeling, (2) decision support systems, (3) water resources management, (4) water sustainability, and (5) emerging applications of artificial intelligence. These clusters indicate a clear shift in the knowledge base of the field from the description of water-related challenges toward predictive modeling, optimization, intelligent decision-making, and smart monitoring systems.

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# 1. Introduction

The effective regulation, allocation, and protection of water resources depend fundamentally on the existence of comprehensive legal and institutional frameworks for water governance and management [1]. Water is an indispensable resource for both ecological systems and human development, serving not only as a prerequisite for the survival of living organisms but also as a critical driver of economic growth and social well-being. Available water resources have been extensively exploited across many regions of the world, and increasing pressures arising from population growth, expanding development activities, and climate change have intensified concerns regarding water availability and sustainability. Rapid economic development, industrialization, and urbanization have substantially increased water demand, contributing to both water scarcity and declining water quality [2]. Furthermore, the growing frequency and intensity of extreme climatic events has heightened the risk of natural disasters such as droughts and floods, posing significant threats to water security [3]. In many regions, agricultural productivity, food security, and sustainable regional development are directly affected by water shortages and inefficient resource management [4]. These challenges underscore the urgent need for sustainable water management strategies and more efficient approaches to water resource utilization.

In this context, artificial intelligence has emerged as a powerful bridge between large-scale environmental data, predictive modeling, and operational decision-making in water resources management. Advanced AI techniques—including machine learning, deep learning, artificial neural networks, fuzzy logic, support vector machines, random forests, and optimization algorithms—have demonstrated considerable potential for identifying complex and nonlinear patterns in hydrological and environmental datasets, including precipitation, river discharge, groundwater levels, water quality indicators, and water demand records. Consequently, AI should not be viewed merely as a computational tool; rather, it has evolved into a knowledge-driven framework that supports drought and flood forecasting, water quality monitoring, reservoir operation, irrigation planning, and evidence-based decision-making in water management systems [12–14].

Previous studies in this domain can generally be classified into three major categories. The first category comprises bibliometric and scientometric investigations focusing on water resources management as a broader research field. A scientometric review of sustainable water resources management literature based on the Web of Science and Scopus databases revealed that Scopus provides broader coverage of publications in this area and identified China and the United States as the leading contributors to sustainable water management research [6]. Similarly, a bibliometric analysis of articles published in water resources journals between 1993 and 2008 demonstrated that groundwater-related issues and water quality assessment received the greatest attention from researchers [7].

The second category includes studies examining decision-making approaches and analytical methodologies in water resources management. For example, a bibliometric analysis of multi-criteria decision-making applications in water management between 2000 and 2017 highlighted the importance of multi-criteria models for improving problem understanding and addressing challenges related to water allocation and pollution control [8].

The third category encompasses more recent studies addressing the application of artificial intelligence and machine learning techniques in water management. These investigations have primarily focused on technical reviews and practical applications, including streamflow forecasting, water quality monitoring, groundwater management, and the optimization of water infrastructure and management systems [12–14].

Despite the growing volume of research in this area, a critical examination of the literature reveals a significant gap in understanding the intellectual and conceptual structure of AI-related research in water resources management. Existing studies have largely emphasized descriptive indicators, such as publication output, prolific countries, influential institutions, and leading journals, while providing limited insight into the co-occurrence of concepts, thematic knowledge clusters, and the relationships between AI technologies and water management challenges. Consequently, important questions remain unanswered: What are the dominant conceptual domains within this field? Which technologies and concepts serve as key intellectual bridges across research themes? How have research priorities evolved over time?

Addressing these questions requires an analytical framework capable of uncovering the conceptual architecture of the field beyond conventional publication metrics. In this regard, science mapping and knowledge visualization techniques provide valuable tools for exploring the structure and evolution of scientific domains. Science maps offer visual representations of relationships among research topics and knowledge areas, facilitating a deeper understanding of how scientific fields are organized and how they develop over time [5]. Among these approaches, co-word analysis is particularly effective for identifying thematic patterns, conceptual linkages, and emerging research directions within a body of literature.

Accordingly, the primary objective of the present study is to map the scientific and conceptual landscape of artificial intelligence research in water resources management using publications indexed in the Scopus database. Specifically, this study seeks to answer the following research questions:

1. What are the publication trends and characteristics of the field in terms of growth patterns, language distribution, leading countries, institutions, and journals?
2. What thematic clusters emerge from the co-word analysis of research related to artificial intelligence in water resources management?
3. Which concepts and technologies play the most influential roles in shaping the intellectual structure of this research domain?

## 2. Methodology

This study employed a descriptive design with a scientometric approach. The research population consisted of all scientific documents related to artificial intelligence and water resources management indexed in the Scopus database from the earliest available records up to May 2025. Scopus was selected because of its broad interdisciplinary coverage across environmental sciences, engineering, and computer science, as well as its capacity to provide structured bibliometric data, including author keywords, institutional affiliations, countries, document types, and citation data for network-based analyses. Moreover, comparative studies have indicated that Scopus provides suitable coverage for scientometric analyses in several water- and resource-management-related fields [6, 15].

To retrieve the research data, the main keywords and related synonyms were first identified from the literature based on two core domains: “artificial intelligence” and “water resources management.” In the revised search strategy, to reduce noise arising from the general use of the abbreviation “AI” and to improve the coverage of specialized terminology, the artificial intelligence domain included not only “Artificial Intelligence” and “AI” but also terms such as “Machine Learning,” “Deep Learning,” “Artificial Neural Network,” “Neural Network,” “Support Vector Machine,” “Random Forest,” “Fuzzy Logic,” “Decision Support System,” “Internet of Things,” and “Explainable Artificial Intelligence.” The water management domain was covered using keywords such as “Water Resource,” “Water Management,” “Water Resource Management,” “Groundwater,” “River Flow,” “Water Quality,” “Irrigation Water,” and “Reservoir Operation.”

The final search string was formulated as follows:

TITLE-ABS-KEY (("artificial intelligence" OR "AI" OR "machine learning" OR "deep learning" OR "artificial neural network" OR "neural network" OR "support vector machine" OR "random forest" OR "fuzzy logic" OR "decision support system" OR "internet of things" OR "explainable artificial intelligence") AND ("water resource*" OR "water management" OR "water resource management" OR "groundwater" OR "river flow" OR "water quality" OR "irrigation water" OR "reservoir operation"))

To focus on core scientific outputs, the document type was limited to journal articles, conference papers, and review articles.

The initial search retrieved 3,657 documents. After applying the document-type limitation, 3,314 records, including journal articles, conference papers, and review articles, were selected for the main analysis. The inclusion criteria were topical relevance to artificial intelligence and water resources management, indexing in Scopus, availability of extractable metadata, and publication within the study period.

Among the various scientometric techniques, co-word analysis was selected as the main analytical method. This choice was made because the objective of the present study was not merely to assess citation impact or author collaboration patterns, but rather to identify the conceptual structure and dominant themes of the field. While co-citation analysis is more appropriate for identifying the theoretical foundations and reference bases of a research domain, and co-authorship analysis focuses on collaboration networks among researchers, co-word analysis enables the identification of relationships among concepts, technologies, and applied problems through the co-occurrence of author keywords. Therefore, this method is particularly well suited to the purpose of the present study, namely mapping the thematic structure of artificial intelligence research in water resources management [5, 16].

The data were exported from Scopus in plain text format and, after preliminary screening and standardization, were analyzed using VOSviewer software. In VOSviewer, "author keywords" were selected as the unit of analysis, and "co-occurrence" was selected as the type of analysis. To construct the network, author keywords meeting the minimum occurrence threshold were included in the analysis. The scientific map was then generated through clustering based on total link strength. In the resulting visualization, node size represents the frequency or weight of author keywords, link thickness indicates the strength of association between author keywords, and colors denote thematic clusters.

# 3. Findings

## 3.1. Document Types

Based on data extracted from the Scopus database, a total of 3,657 documents on the application of artificial intelligence in water resources management were indexed from 1973 to May 2025. As shown in Table 1, journal articles constituted the most common publication format, with 2,050 records, accounting for 56% of the total output. Conference papers ranked second, with 982 documents and a share of 27%, followed by review articles, with 282 documents and a share of 8%. Together, these three document types accounted for approximately 91% of all retrieved documents. However, as noted in the methodology section, the main analysis focused on 3,314 documents, including journal articles, conference papers, and review articles.

**Table 1.** Distribution of document types indexed in Scopus on the application of artificial intelligence in water resources management

| Document type | Number |
|---|---|
| Journal article | 2,050 |
| Conference paper | 982 |
| Review article | 282 |
| Book chapter | 207 |
| Conference review | 47 |
| Book | 43 |
| Editorial | 17 |
| Retracted article | 11 |
| Short survey | 5 |
| Note | 5 |
| Data paper | 3 |
| Erratum | 3 |
| Letter | 2 |
| Total | 3,657 |

### 3.2. Trends in Scientific Publications on the Application of Artificial Intelligence in Water Resources Management

The annual growth pattern of scientific publications on the application of artificial intelligence in water resources management from 1973 to May 2025 can be examined in two broad phases: (1) the initial and gradual growth phase and (2) the rapid growth phase. The annual publication trend is presented in Figures 1 and 2.

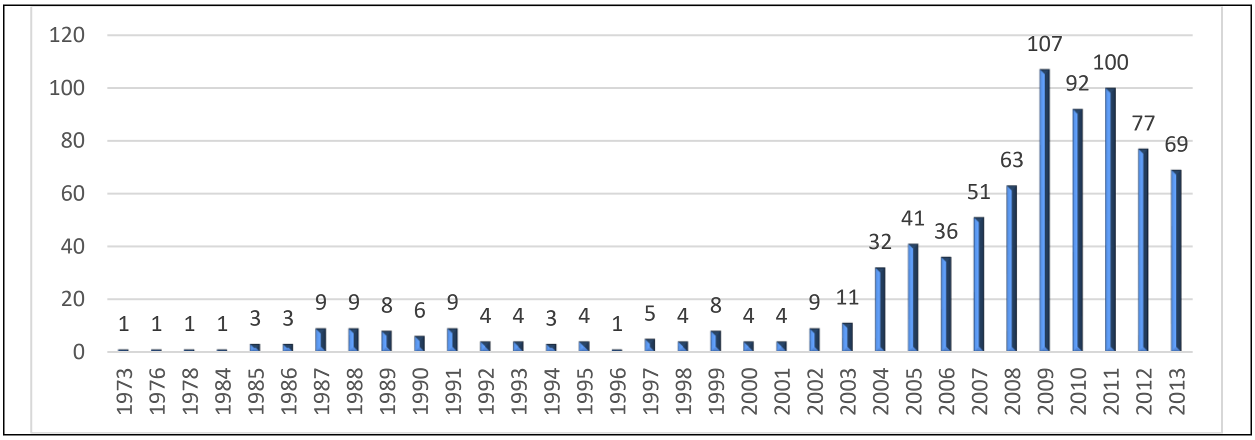


**Figure 1.** Annual trend of scientific publications on the application of artificial intelligence in water resources management indexed in Scopus: first phase

During the initial phase, from 1973 to 2013, scientific production in this field was limited and increased gradually. In this period, artificial intelligence and water resources management were primarily studied at the intersection of environmental sciences, engineering, and computer science. Authors such as Brumbelow, Camas, and Molina each published eight papers, placing them among the most productive contributors during this phase. Journals such as *Water Science and Technology*, *Water Resources Management*, *Environmental Modelling & Software*, and *Journal of Water Resources Planning and Management* played a more prominent role in disseminating research in this area. From an institutional perspective, the Commonwealth Scientific and Industrial Research Organisation, Universitat Politècnica de València, Texas A&M University, the University of Exeter, and The Hong Kong Polytechnic University were among the most active organizations during this period. The United States, China, and the United Kingdom were also the most active countries in this phase.

The second phase can be considered to have begun in 2014, marking a period of accelerated publication growth. During this phase, 2024 was identified as the most productive year, with 563 documents. Authors such as El-Shafie, Kisi, and Yaseen, as well as journals such as *Water*, *Water Resources Management*, and *Hydrology*, made substantial contributions to the literature during this period. In terms of institutional productivity, the Chinese Academy of Sciences, the University of Tabriz, the Ministry of Education of China, and the University of Tehran emerged as leading organizations. China, India, the United States, and Iran were among the most active countries, respectively. A notable finding is that Iran substantially improved its position during this phase and became one of the four most productive countries in this research domain.

### 3.3. Contributions of Countries and Journals

The findings revealed that the 3,657 retrieved documents were produced by researchers from 132 countries. Among them, China ranked first with 591 publications, followed by the United States with 557 publications and India with 426 publications. Iran ranked fourth with 319 publications. Australia (168 publications), Spain (155), Italy (151), the United Kingdom (141), Canada (138), and both Germany and Türkiye (125 publications each) occupied the subsequent positions.

Regarding publication outlets, *Water* was the most productive journal in the field, publishing 131 articles, followed by *Water Resources Management* with 115 articles and *Hydrology* with 82 articles. These findings indicate that knowledge production in this area has expanded not only in technologically advanced countries but also in countries facing significant water-resource challenges, highlighting the growing global importance of artificial intelligence applications in water resources management.

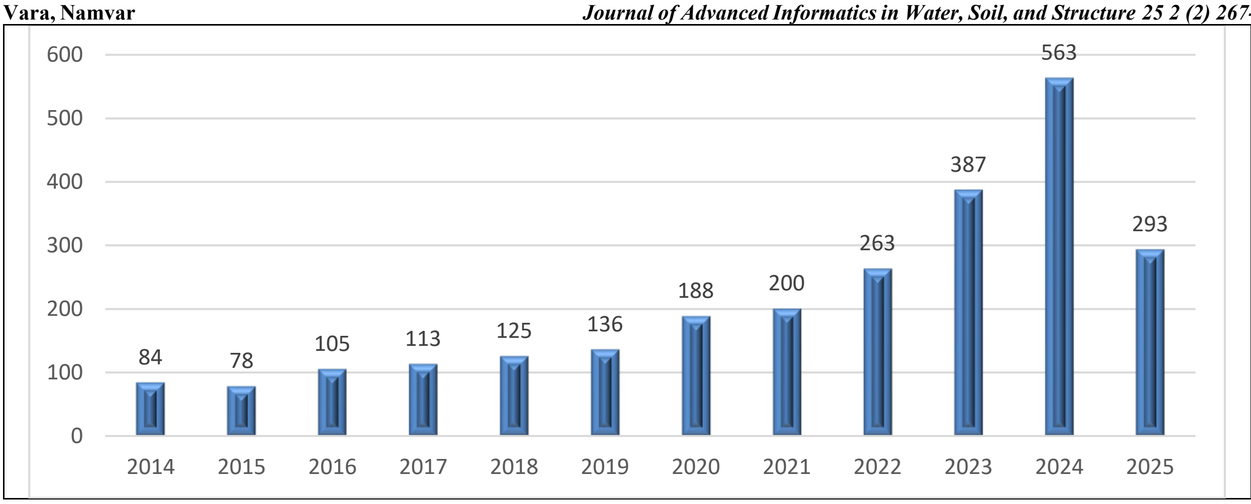


Figure 2. Annual trend of scientific publications on the application of artificial intelligence in water resources management indexed in Scopus: second phase

### 3.4. Language Distribution of Publications

The results showed that the final analytical dataset consisted of 3,314 scientific documents, including journal articles, conference papers, and review articles, indexed in Scopus between 1973 and May 2025. These publications were distributed across 14 languages, with English accounting for more than 96% of the total output. The distribution of publication languages is presented in Table 2.

**Table 2.** Language distribution of publications indexed in the Scopus database

| Language | Number of Publications |
|---|---|
| English | 3,202 |
| Chinese | 57 |
| German | 11 |
| Spanish | 10 |
| Korean | 9 |
| Persian | 7 |
| French | 6 |
| Turkish | 4 |
| Russian | 2 |
| Portuguese | 1 |
| Italian | 1 |
| Polish | 1 |
| Hungarian | 1 |
| Ukrainian | 1 |

The overwhelming dominance of English-language publications demonstrates its role as the primary medium of scholarly communication in this field. The relatively limited number of publications in other languages suggests that research on artificial intelligence applications in water resources management is largely disseminated through international scientific channels, thereby enhancing global visibility and knowledge exchange.

### 3.5. Subject Areas

Figure 3 illustrates the distribution of subject areas and the prevailing scientific orientations within research on the application of artificial intelligence in water resources management. Environmental Science ranked first, accounting for 1,852 publications, followed by Engineering with 962 publications and Computer Science with 888 publications. These findings indicate that the intellectual core of this research domain is inherently interdisciplinary, emerging from the convergence of environmental sciences, engineering, and computer science.

The prominence of Environmental Science reflects the central role of water-related environmental challenges in shaping research priorities, while the substantial contributions of Engineering and Computer Science highlight the increasing adoption of computational and data-driven approaches to water resources management. In this context, artificial intelligence serves as a critical enabling technology that strengthens the connection between environmental problems and computational solutions through modeling, simulation, monitoring, forecasting, and optimization techniques.

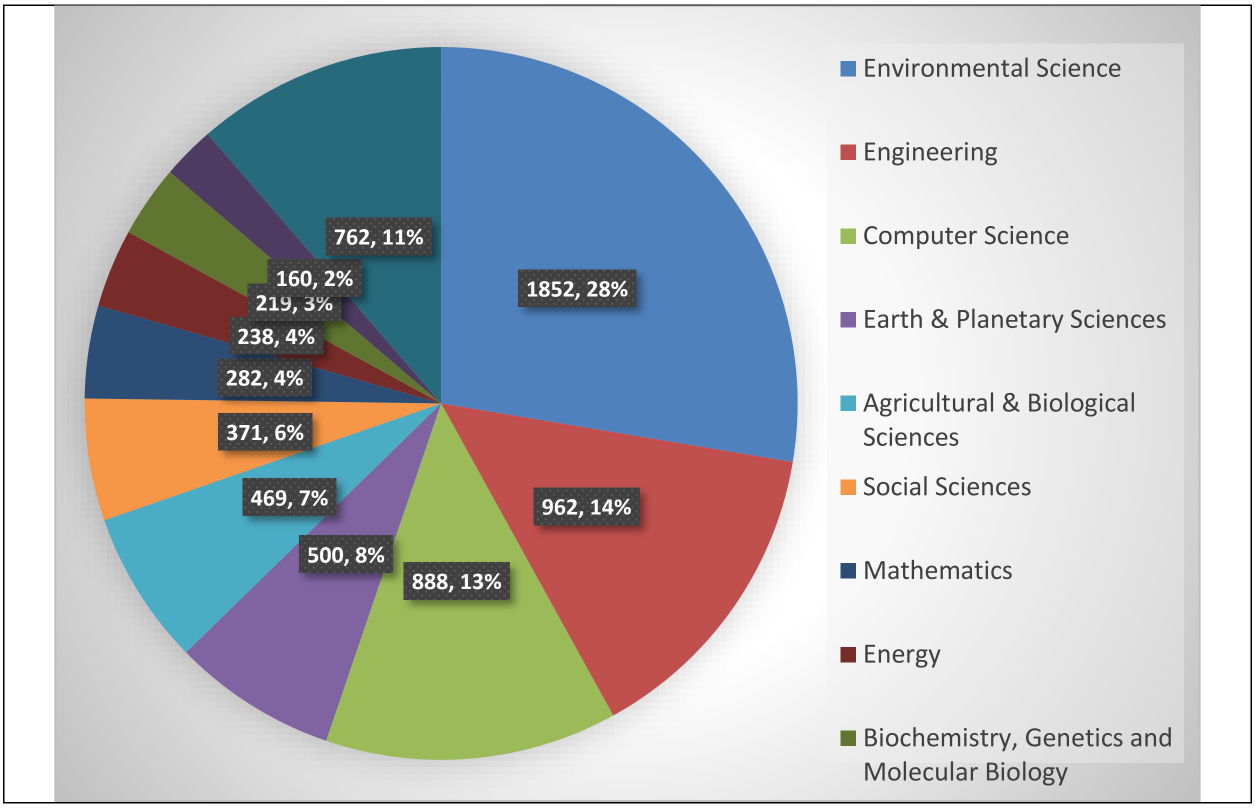


**Figure 3.** Subject-area distribution of research on the application of artificial intelligence in water resources management

## 3.6. Most Active Authors, Universities, and Research Institutions

The distribution of authorship in studies on the application of artificial intelligence in water resources management showed that a large number of researchers have contributed to the scientific output of this field. Among the most productive authors, El-Shafie ranked first with 30 publications, followed by Kisi with 27 publications and Yaseen with 20 publications.

In terms of institutional and research contributions, the Chinese Academy of Sciences had the largest share, with 74 publications, ranking first among all organizations. It was followed by the University of Tabriz with 64 publications and the University of Tehran with 49 publications. The presence of two Iranian universities among the three most productive institutions indicates the strong engagement of Iranian researchers in applying intelligent methods to water resources management.

## 3.7. Scientific Mapping of Publications

Figure 4 presents the co-occurrence map of author keywords extracted from publications on the application of artificial intelligence in water resources management. In this analysis, node size represents the frequency or weight of each author keyword, link thickness indicates the strength of association between author keywords, and colors denote thematic clusters.

Author keywords generally reflect the most essential content and thematic focus of published documents [10]. To map the knowledge domain of artificial intelligence and water resources management, a keyword co-occurrence network was constructed using VOSviewer software. Co-occurrence between two author keywords occurs when both appear in the same document [11]. A co-occurrence network consists of nodes, representing author keywords, and links, representing relationships between pairs of author keywords. The strength of the link between two author keywords indicates the degree of conceptual proximity and association between the corresponding knowledge areas.

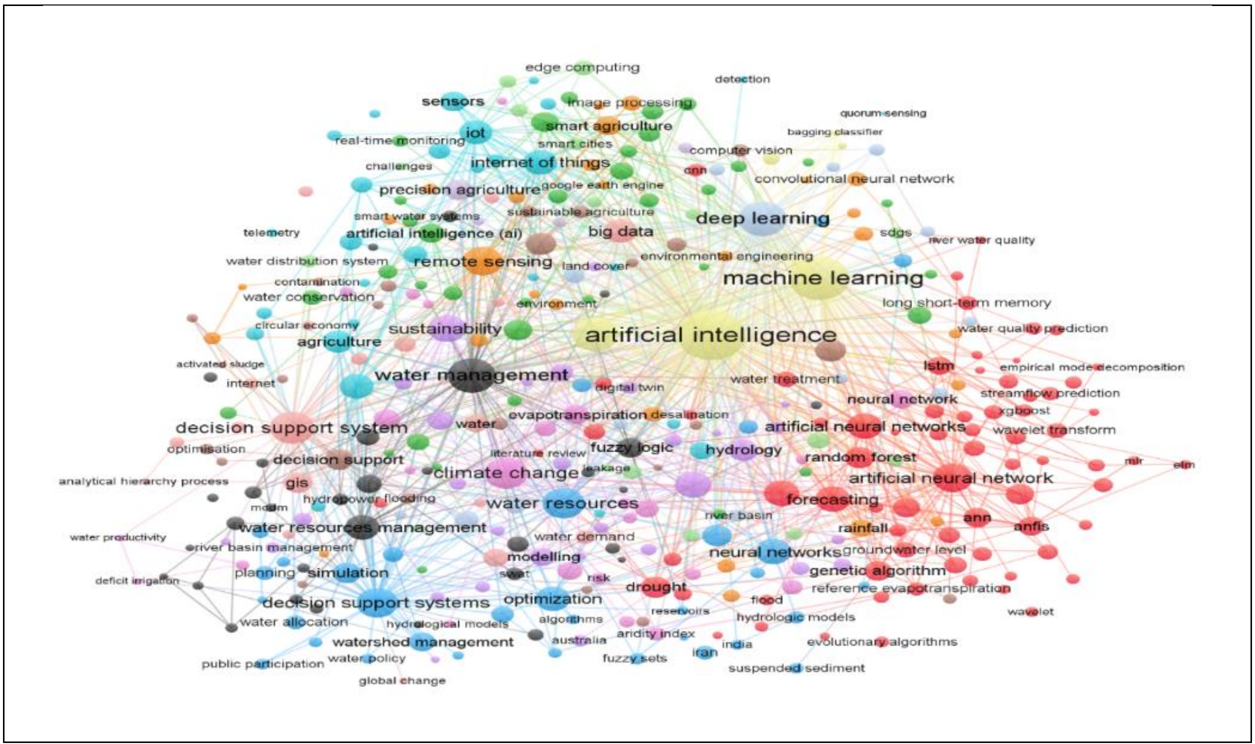


Figure 4. Co-occurrence map of author keywords in publications on the application of artificial intelligence in water resources management

## 3.8. Major Thematic Clusters Identified in the Co-occurrence Network

The co-word analysis resulted in the identification of five thematic clusters comprising a total of 7,703 author keywords, 4,244 links, and a total link strength of 7,119. Cluster labels were assigned based on an examination of central author keywords, total link strength, and the relative weight of connections generated in VOSviewer. The five major clusters were identified as: (1) Machine Learning and Predictive Modeling, (2) Decision Support Systems, (3) Water Resources Management, (4) Water Sustainability, and (5) Emerging Applications of Artificial Intelligence.

The first cluster, **Machine Learning and Predictive Modeling**, represents the most influential cluster in terms of network connectivity, with 1,649 links and a total link strength of 2,403. This cluster emphasizes the use of predictive techniques such as artificial neural networks, random forests, support vector machines, and recurrent neural networks in water resources management. By integrating historical datasets, mathematical models, and AI-based computational capabilities, these approaches support decision-makers in forecasting future water demands, assessing climate variability, analyzing drought conditions, predicting river flows, and estimating water quality and consumption patterns. The most prominent author keywords within this cluster include *artificial neural networks* (TLS = 189), *random forest* (TLS = 85), *support vector machine* (TLS = 80), *river flow* (TLS = 68), and *recurrent neural network* (TLS = 59).

The second cluster, **Decision Support Systems**, comprises 891 links with a total link strength of 1,433. The most influential author keywords in this cluster include *optimization* (TLS = 120), *simulation* (TLS = 81), *modeling* (TLS = 69), *watershed management* (TLS = 60), and *reservoir* *operation* (TLS = 42). This cluster demonstrates that research has evolved beyond the mere application of predictive algorithms and increasingly focuses on the development of decision-support tools capable of addressing the complexities of water allocation, reservoir management, and long-term planning.

The third cluster, **Water Resources Management**, contains 628 links and a total link strength of 960. Key concepts within this cluster include *fuzzy logic* (TLS = 69), *decision support systems* (TLS = 53), *multi-objective optimization* (TLS = 32), *environmental flows* (TLS = 25), and *geographic information systems* (TLS = 24). The prominence of these concepts indicates that intelligent technologies are increasingly being incorporated into planning processes, resource allocation strategies, and the evaluation of alternative management scenarios.

The fourth cluster, **Water Sustainability**, includes 655 links and a total link strength of 939. The author keywords within this cluster primarily relate to sustainability, monitoring, and conservation of water resources. *Groundwater* (TLS = 133), *hydrology* (TLS = 91), *water system simulation* (TLS = 56), and *continuous monitoring of water parameters* (TLS = 51) are among the most influential concepts. The thematic focus of this cluster highlights the growing importance of sustainability and water security as major application areas for artificial intelligence in contemporary water-resource studies.

The fifth cluster, **Emerging Applications of Artificial Intelligence**, comprises 672 links and a total link strength of 895. Prominent author keywords include *water resources management* (TLS = 82), *Internet of Things* (TLS = 70), *water quality control* (TLS = 52), *sustainable development* (TLS = 49), and *explainable artificial intelligence* (TLS = 47). This cluster reflects the emergence of research integrating artificial intelligence with real-time data streams, smart monitoring systems, Internet of Things technologies, and interpretable AI models. These developments are particularly important for enhancing practical implementation and increasing decision-makers' trust in AI-driven systems.

# 4. Discussion

The findings indicate that artificial intelligence in water resources management has evolved from a fragmented and emerging research topic into a well-defined interdisciplinary field with a recognizable thematic structure. The rapid growth in publications after 2014 can be attributed to several interconnected developments, including increased availability of environmental data, advances in sensor technologies, expanding computational capabilities, significant progress in machine learning algorithms, and the growing urgency of addressing global water-related challenges.

From a geographical perspective, the prominent contributions of China, the United States, India, and Iran suggest that scientific productivity in this field is influenced not only by technological capacity but also by the severity of water-resource challenges faced by individual countries. This pattern highlights the dual role of artificial intelligence as both a technological innovation and a practical response to pressing environmental concerns.

The distribution of subject areas further suggests that the field has evolved beyond traditional water management studies toward a more integrated framework in which advanced analytical methods and intelligent systems are increasingly employed to address complex water-resource challenges. The convergence of Environmental Science, Engineering, and Computer Science confirms the interdisciplinary nature of AI applications in water resources management and reflects the increasing need for data-driven, computational, and systems-oriented approaches.

The co-word analysis demonstrates a clear shift in research priorities from general modeling approaches toward predictive tools, decision support systems, and more advanced intelligent technologies. The dominance of the Machine Learning and Predictive Modeling cluster confirms that forecasting river flow, drought events, water quality, and water demand remains the central focus of the field. At the same time, the increasing prominence of concepts such as the Internet of Things and explainable artificial intelligence suggests that future research is moving toward more operational, data-driven, transparent, and trustworthy systems.

These findings are broadly consistent with previous studies that have highlighted the growing role of data-driven approaches and machine learning techniques in addressing water-resource challenges. However, the present study extends prior work by revealing the conceptual structure of the field and identifying the relationships among its dominant research themes through co-word analysis of author keywords. In this respect, the study provides a more detailed understanding of how AI-related concepts, technologies, and water-management problems are interconnected within the scientific literature.

From a science-policy perspective, these findings imply that future research efforts should extend beyond improving model accuracy alone. Greater attention should be directed toward model interpretability, contextual adaptation, access to real-time data, integration with operational decision-making processes, and assessment of social and environmental impacts. For countries such as Iran, which face substantial water-resource constraints while maintaining strong research capabilities, prioritizing problem-oriented AI applications in water management may contribute significantly to improving water resilience and evidence-based decision-making.

# 5. Conclusion

Using scientometric techniques and co-word analysis, this study examined the scientific structure of research on the application of artificial intelligence in water resources management. The results revealed that scientific production in this field has accelerated considerably since 2014 and has attracted increasing attention from both academic and industrial communities in recent years. Analysis of publication trends showed that China, the United States, India, and Iran are the leading contributors to knowledge production in this area. Iran's position among the most productive countries reflects the growing engagement of Iranian researchers and the expanding adoption of intelligent methods in water-resources studies.

The scientific mapping analysis demonstrated that research in this field is organized around five major thematic clusters: Machine Learning and Predictive Modeling, Decision Support Systems, Water Resources Management, Water Sustainability, and Emerging Applications of Artificial Intelligence. The Machine Learning and Predictive Modeling cluster, which exhibited the highest level of network connectivity, highlights the critical role of machine learning models in forecasting droughts, water-level fluctuations, river discharge, water quality, and water demand. Likewise, decision support systems, through optimization and simulation techniques, have the potential to significantly enhance both scientific and operational decision-making processes in water resources management.

Overall, the findings highlight the transformative role of artificial intelligence in advancing data-driven, sustainable, and adaptive water resources management. By enabling predictive modeling, optimizing resource utilization, reducing water losses, monitoring water quality, and supporting managerial decision-making, AI can play a crucial role in the sustainable conservation and utilization of water resources. The findings further suggest that future developments in this field will increasingly involve the integration of predictive models with real-time data, Internet of Things technologies, intelligent decision support systems, and explainable artificial intelligence frameworks.

## 5.1. Practical Implications

- Expanding the application of artificial neural networks, random forests, and support vector machines for forecasting droughts, river flows, water quality, and agricultural and industrial water demands.
- Implementing optimization- and simulation-based decision support systems for watershed management and reservoir operation.
- Integrating real-time monitoring systems, Internet of Things technologies, and machine learning models to improve operational water management.
- Strengthening international collaborations, particularly with countries that are leading contributors to this field, to facilitate knowledge transfer, shared datasets, and problem-oriented research initiatives.

## 5.2. Directions for Future Research

- Investigating advanced decision support systems that integrate real-time data streams with machine learning techniques.
- Identifying emerging trends and newly developing research gaps in AI applications for water resources management.
- Examining the barriers to and opportunities for localizing artificial intelligence technologies in water management, with particular attention to cultural, linguistic, institutional, and infrastructural contexts.
- Comparing findings derived from the Scopus database with those obtained from the Web of Science database to enhance the generalizability of results.

### 5.3. Limitations

This study has several limitations. First, the dataset was derived exclusively from the Scopus database; therefore, relevant publications indexed in Web of Science or other databases may not be fully represented. Second, co-word analysis depends heavily on the quality and consistency of author keywords assigned by authors and indexers, and variations in terminology may influence cluster formation. Third, although substantial efforts were made to incorporate major artificial intelligence concepts into the search strategy, the rapid evolution of the field may have resulted in the underrepresentation of certain emerging topics. Future studies could combine co-word analysis with co-citation and co-authorship analyses to provide a more comprehensive understanding of the intellectual structure and collaborative networks within this research domain.

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### Declaration of competing interest

The authors declare no conflict of interest in preparing this article.

### Date Availability

The data supporting this study's findings are available from the corresponding author upon reasonable request.

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