Pol. J. Environ. Stud. Vol. XX, No. X (XXXX), 1-17
DOI: *10.15244/pjoes/205830* ONLINE PUBLICATION DATE: 2025-09-03

Review

Bibliometrics-Based Visualization and Hotspot Analysis of Water Environment and Sports Events: A Review

Han Chen[1], YinChuan Xue[2], YiNing Qin[1], Shu Xuan[1], XingHong Dai[1]*

[1]School of Physical Education, Hunan University, Changsha, China
[2]College of Athletic Sports, Beijing Sports University, Beijing, China

Received: 1 February 2025
Accepted: 2 June 2025

Abstract

With improved living standards, participation in sports events has surged, the number and scale of global sports events have been expanding, and the impact of sports events on the water environment has become increasingly prominent, triggering extensive concern and in-depth discussion among scholars across various disciplines. However, the existing research mostly focuses on individual case analysis or single-dimension exploration, lacks a systematic analysis of the macro structure, knowledge map, and evolution path of the research field of sports events and water environment, making it difficult to comprehensively describe research development trends of sports events and water environment, etc. In this study, articles about sports events and water environment in Social Science Citation Index (SSCI), Arts and Humanities Citation Index (A&HCI) and Science Citation Index Expanded (SCIE) from 2015 to 2025 were screened, and after the second screening, bibliometrics research methodology was used to visualize and analyze research hotspots and development trends, etc., of sports events and water environment in the last decade. Based on the Citespace study, it is found that the number of articles published on sports events and water environment research has shown significant growth in the past decade, and Chinese research cooperation in this field occupies a major position; the distribution of disciplines shows obvious multidisciplinary intersection characteristics, in which environmental sciences (34.57%) and water resources (25.03%) constitute the main body of the research, and the research topics of interest among scholars are different, and high impact journals are not always cited by the high impact factor. In addition, we analyzed the major scholars and institutions involved in this field of research, as well as the keywords that emerged for visual presentation, helping researchers to quickly and accurately understand the authoritative scholars and research hotspots, etc., in this field through this paper, providing a data-driven and objective frame of reference.

Keywords: water resources, citespace econometric analysis, environmental protection, environmental science

*e-mail: daixinghong@hnu.edu.cn

Introduction

Global climate change has become one of the most serious challenges facing humanity in the 21st century [1, 2]. Over the past few decades, greenhouse gas emissions from human activities have continued to increase, giving rise to a range of environmental problems. With a record high global average atmospheric carbon dioxide of 419. 3 ppm in 2023, atmospheric carbon dioxide levels are now 50% higher than they were before the Industrial Revolution. According to the Intergovernmental Panel on Climate Change (IPCC) assessment, the global average temperature has risen by about 1.1ºC compared to pre-industrial levels.

Imbalances in the distribution of water resources, water quality degradation, and ecosystem dysfunction, exacerbated by climate change, have become a major challenge to global sustainable development [3-5]. Extreme droughts, water supply shortages, rising sea levels, acidification of seawater, and acid rain are occurring around the globe [6-8], and changes in the hydrological cycle triggered by climate warming are exacerbating the complexity and severity of the water pollution problem. Warmer temperatures lead to higher water temperatures, accelerating algal growth [9, 10] and increasing the frequency of harmful algal blooms globally [11].

The water crisis not only affects ecosystem stability, but also has far-reaching implications for food security [12], public health [13] and economic development [14]. The international community has established a multilevel policy framework to address water environmental governance. The United Nations Framework Convention on Climate Change (UNFCCC) and its Paris Agreement have placed water resources management at the heart of the climate change adaptation agenda, emphasizing resource efficiency through integrated water resources management (IWRM) [15, 16]. Goal 6 of the United Nations Sustainable Development Goals (SDGs) further establishes the global requirement for the sustainable management of water resources. Water pollution problems are becoming increasingly complex, including Point source pollution (industrial wastewater, domestic sewage) [17] and non-point source pollution (agricultural runoff) [18], as well as trans-media pollution such as acid rain due to atmospheric deposition.

Synergistic effects of multiple sources of pollution seriously threaten the health of water ecosystems [19], leading to eutrophication of water bodies and loss of biodiversity [20]. The water environment has been damaged, and the balance of aquatic ecosystems has been disrupted as a result of a variety of pollutants. Examples include the overuse of synthetic dyes [21], heavy metal lead (Pb) [22], pesticide residues [23], etc. Scholars have made innovative use of materials such as industrial wastes or by-products to treat dye pollution through adsorption and other means, with remarkable results [24-26]. In addition, the water pollution caused by sports events should not be ignored. Individual injuries to athletes as a result of pollution of water resources are not uncommon in some water-dependent sporting events [27]. While water sports can bring social benefits, they can also pose significant environmental challenges. The main source of pollution of the water environment is from the activities of motorized vessels, which are burdened by engine fuels, leaded marine oil and gasoline, and organic matter from spectators [28].

In recent years, with the improvement of material living standards, the population of sports consumption has proliferated, and people's awareness of sports participation has increased [29], resulting in the organization of tournaments with increasing frequency and scale. However, as sporting events become more frequent and larger in scale, they have the potential to seriously damage the natural environment in many ways. One of the most serious threats is posed by the demand for "nature sports" (including skiing, skin scuba-diving, rock climbing, rafting, yachting, surfing, golf, paragliding, and other sports performed in an undeveloped natural environment), which is likely to increase in the future [30].

Although many major sporting events have responded to the call for "green sports" from an environmentally sustainable perspective, they often still have negative environmental impacts due to their scale and inherent activities. For example, the negative impacts of sporting events on the water environment. It has been pointed out that sustained increases in broadband underwater sound levels during the regatta (up to 17 dB re 1 μPa RMS; 0.01-24 kHz) that extended beyond racecourse boundaries (>8.5 km) and racing hours were observed. This increase, very likely attributable to heightened regatta-related vessel activity, causes marine noise pollution [31]. In addition, sporting events such as water sports are considered to be polluting the environment [32].

We believe that actively managing the organizational strategies of sports events can mitigate their negative environmental impacts to some extent. However, previous studies have paid relatively little attention to the specific impacts of sports events on the aquatic environment and lack a comprehensive review. Our research has the advantage and innovation to fill the gap in the overall research statement on the field of sporting events and the water environment. Moreover, few previous studies have been synthesized using a bibliometric approach, and there is a lack of analysis of research trends and potential future research hotspots on sporting events and the water environment. Therefore, we employ bibliometric methods to analyze existing research directions, development trends, and potential future hotspots concerning sports events and the water environment over the past decade. This analysis aims to: provide an intuitive perspective for scholars potentially entering this field; clarify research evolution; and offer theoretical and practical guidance for stakeholders.

Compared to previous studies and reviews, we believe that this study has more unique strengths

and innovations. This study was conducted in the following ways: first, we analyzed the annual trends of publications on sporting events and the water environment, as well as the disciplinary classification of the literature. Second, we analyzed the authors, institutions, and countries with a high volume of publications in this field based on the research paradigm of sports events and water environment in the last decade, aiming to clarify the macro research situation and trends of the research in this field. Third, based on the trends presented in the existing studies, we propose potential future research hotspots and research directions to provide reference for related scholars to conduct research on sports events and the water environment. Based on bibliometric research methodology, we visualize and analyze the existing research in a more intuitive graphical form to help readers understand the noteworthy research tendencies in the field more quickly and accurately. In addition, the literature included in this study was adequately screened; we chose journals that have been published in SSCI, A&HCI, and SCIE to ensure the quality of the articles; we screened the literature included for the first time for a second time, eliminating the literature whose titles and abstract contents were not related to the sporting events and water environment, to ensure that the literature we included was closely related to the sporting events and water environment.

In order to visualize the study of sports events and the water environment in a more intuitive way, we chose Citespace software for the analysis. Citespace is one of the commonly used bibliometric tools, and the software can adjust the image as needed, can meet the needs of data analysis and image export, and is easy to download and operate with high confidence to help us sort out the focus of the study. In the second part of this study, we focus on stating the inclusion and screening of the literature, the process of data importation, and the analysis to construct a more systematic research system to improve the credibility of this study.

Materials and Methods

Data Sources and Selection Process

Documents were selected from the Web of Science Core Collection (WOS-CC) database, specifically the Social Science Citation Index (SSCI), Arts and Humanities Citation Index (A&HCI), and Science Citation Index Expanded (SCIE). We believe that the above three types of databases have the following advantages:(1) The articles included in the three major databases are widely recognized by scholars and are peer-reviewed. (2) The three databases provide detailed information about the article, including title, keywords, abstract, authors, institution, country, journal, and references, which allowed us to perform a more detailed analysis. (3) More scholars use these databases, the articles are relatively more accessible, and they have global authority.

During the data retrieval process (retrieved on January 7, 2025 BST), “All fields” was used to retrieve relevant literature. In order to ensure that all the included literature (gray literature) is as complete as possible, a Boolean search was chosen to search for close synonyms of “water contamination” “sports events” from the Pubmed, and the search formula was finally set as: (“water contamination” OR “water resources”) AND (“sports events” OR “sports game” OR “sports match” OR “competition”) from 1/1/2015 to 1/1/2025. We limited the type of literature to Article and Review Article and included only English language literature. Following an initial screening based on titles and abstracts, articles meeting the following criteria were excluded: (1) Retracted articles; (2) Articles lacking full text; (3) Articles without abstracts. These exclusion criteria were applied because such literature may lack sufficient information or reliability for the analysis.

Analytical Methods and Methodology Process

In order to enhance the intuition of the study, Citespace was used for data visualization and analysis in this study. Citespace, as a commonly used tool in bibliometrics, has powerful data analysis and visualization capabilities, and using Citespace has the following advantages:(1) The ability to visualize trends in the research field, collaborative networks, and cluster analyses provides a more diverse and innovative research perspective on the study of sporting events and the water environment. (2) The ability to more clearly define the time period and research focus of the study helps scholars to quickly identify key issues and dynamics in the study of sporting events and the water environment. (3) Quantify the target literature, and it is easy to do so, making the study more efficient. The version of Citespace used in this study is 6.4.1.

A total of 5,961 documents were screened, and the documents we searched were screened again to select those that were highly compatible with our research topic by reading the titles and abstracts of the target documents. A total of 723 documents were finally included. The search steps are as follows: (1) Import the paper into CiteSpace in “.txt” format. (2) Set the parameters in Time Slicing from January 2015 to January 2025, with Years Per Slice = 1. (3) In Node Types, parameters include author, institution, country, reference, cited author, cited journal, and keyword, respectively. (4) In the selection criteria, the g-index or Top N parameters are set according to the CiteSpace suggestions. (5) In Pruning, select Pathfinder, Pruning sliced networks, and Pruning the merged network. All other settings should remain at their default values. Fig. 1 shows the data processing workflow and methodological process.

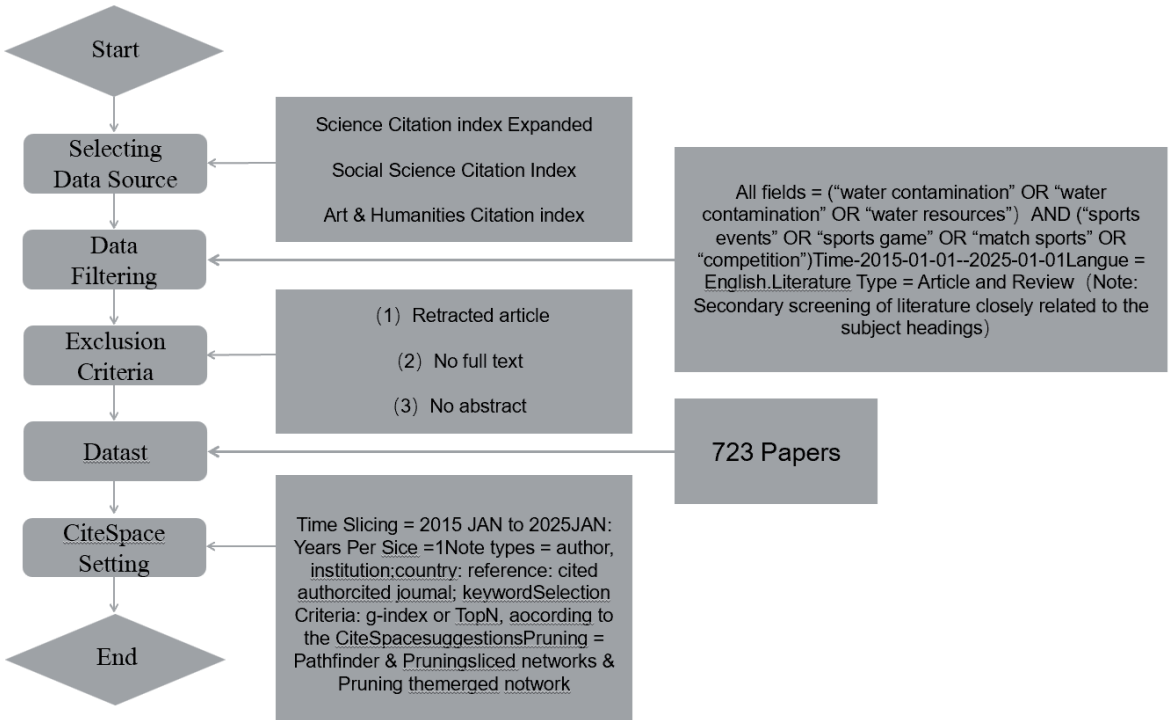

Fig. 1. Data processing workflow and methodological processes.

Results and Discussion

Statistical Characteristics

We analyzed the trend of the annual number of publications on research related to sports events and water environment after screening, as well as the number of publications according to disciplines, aiming to reveal the degree of scholars' attention to sports events and water environment in the last decade as well as the classification of disciplines involved in the field, so as to provide references for scholars who will study the field in the future.

Number of Publications by Years

Fig. 2 shows the number of annual publications over the last decade for Sporting Events and the Water

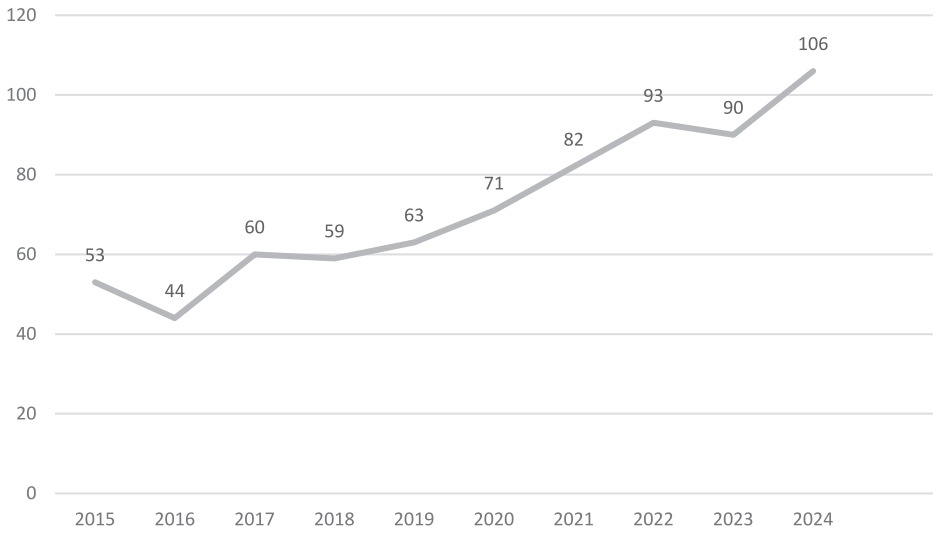

Fig. 2. Trends in the number of annual publications (showing 2015-2024 issuances only).
Note: The number of publications on January 1, 2025, was only 3. The time limit for inclusion resulted in a significant drop in the number of publications, which does not match the trend in the number of publications for this year, so the graph does not show the annual number of publications for 2025.

Environment. A clear overall upward trend in the number of annual publications can be detected from 2015-2024, with a steeper overall trend starting in 2018, when the growth rate of the number of publications increased over time. Some fluctuations in the number of publications from 2015-2018 can be detected, but the magnitude is not significant, and we believe that the reason for this may be due to fluctuations in the level of scholarly attention in the field. It is worth noting that after a brief decline in the number of annual publications from 2022-2023 (from 93 to 90), the number of annual publications from 2023-2024 rises markedly, with the number of publications reaching its highest level in almost a decade (106).

Number of Publications by Categories

Table 1 shows the top 10 disciplinary categories of published research related to sporting events and the water environment. Most of the categories can be found to be related to environmental resources. Specifically, ENVIRONMENTAL SCIENCES ranked first with 250 articles, WATER RESOURCES ranked second with 181 articles, and ECOLOGY ranked third with 96 articles, which accounted for 34.57%, 25.03%, and 13.27% of the total number of articles, respectively. The total number of publications in these three disciplines amounted to 527, accounting for 72.89% of the total. ENVIRONMENTAL SCIENCES and WATER RESOURCES each had more than 25% of the total number of publications. This suggests that the study of sporting events and the water environment is closely related to environmental resources. Sporting events and the water environment involve a variety of disciplines that together focus on solving global environmental problems, promoting the efficient use of resources, and fostering the harmonious development of society, the economy, and the environment. The study of sporting events and the aquatic environment is a multidisciplinary field of study, and these disciplines are interrelated and work together to support the development of environmental science. We suggest that scholars can more effectively address the complex environmental problems to be solved in the field of sports events and the water environment through cross-disciplinary and interdisciplinary research exchanges.

Collaborative Analysis

The collaborative analysis aims to reveal the links between different authors, institutions, and regions in research related to sporting events and the water environment. Collaboration and communication are an important way to promote the progress of scientific research, and we visualize the results of our collaboration analysis to provide scholars in related fields with a more intuitive perspective, identify scholars who are more authoritative in the field of sports events and water environment research, and find potential partners to work together in solving complex problems related to sports events and water environment. The results of the study were analyzed by bibliometric analysis through CiteSpace, and these results were further validated and applied in subsequent co-citation and co-occurrence analyses.

Author Co-Occurrence

Table 2 shows the top ten authors who have published in the study of sporting events and the water environment. The top three authors in terms of publications are Zhang, Wei (4 articles), Chen, Xi (4 articles), and Wada, Yoshihide (3 articles). It can be noticed that the top authors do not stand out in terms of the number of publications, and the top ten authors with the highest number of publications still have low centrality (centrality of 0.00). This suggests that external collaborations are not evident in studies related to sporting events and water environments, and that the authors may have only studied the water environment

Table 1. Number of publications by discipline.

Ranking	Form	Count	Percentage (%)
1	ENVIRONMENTAL SCIENCES	250	34. 57
2	WATER RESOURCES	181	25. 03
3	ECOLOGY	96	13. 27
4	AGRONOMY	47	6. 50
5	ENGINEERING, CIVIL	46	6. 36
6	ENVIRONMENTAL STUDIES	46	6. 36
7	ENGINEERING, ENVIRONMENTAL	45	6. 22
8	GEOSCIENCES, MULTIDISCIPLINARY	44	6. 08
9	PLANT SCIENCES	44	6. 08
10	FORESTRY	40	5. 52

Table 2. Author co-occurrence analysis.

Ranking	Authors	Count	Centrality	Year
1	Zhang, Wei	4	0. 00	2016
2	Chen, Xi	4	0. 00	2015
3	Wada, Yoshihide	3	0. 00	2019
4	Albiac, Jose	3	0. 00	2015
5	Wang, Wei	3	0. 00	2023
6	Sun, Shikun	3	0. 00	2016
7	Wang, Yubao	3	0. 00	2016
8	Busset, Hugues	2	0. 00	2022
9	Graf, Wolfram	2	0. 00	2023
10	Thackeray, Stephen J	2	0. 00	2021

of sporting events as a sub-direction of their research. In terms of time, it can be found that eight scholars of the top ten authors in terms of publications were published in 2015. Due to the fact that 2015 was the start of the literature we included in our analysis, the remaining two scholars may be due to the fact that they started to work in the field at an earlier time. The publication period extends from 2015 to 2023, demonstrating that the study of sporting events and the water environment has continued to be of interest to scholars. In addition, we found that different authors studied this field with different main research directions, for example, Yu Y., Wang M., and Chen X. studied more on water allocation and optimization strategies in different regions [33, 34], while Ortiz-Partida J.P. studied more on sustainability of groundwater resources and hydroeconomic modeling (HEM) for water resources management [26, 35].

Fig. 3 visualizes the co-occurrence of the authors' network collaboration in the study of sporting events and the water environment. It can be seen that in the co-occurrence graph, the author nodes amount to 908, and the number of connections is 1907 (N = 908,

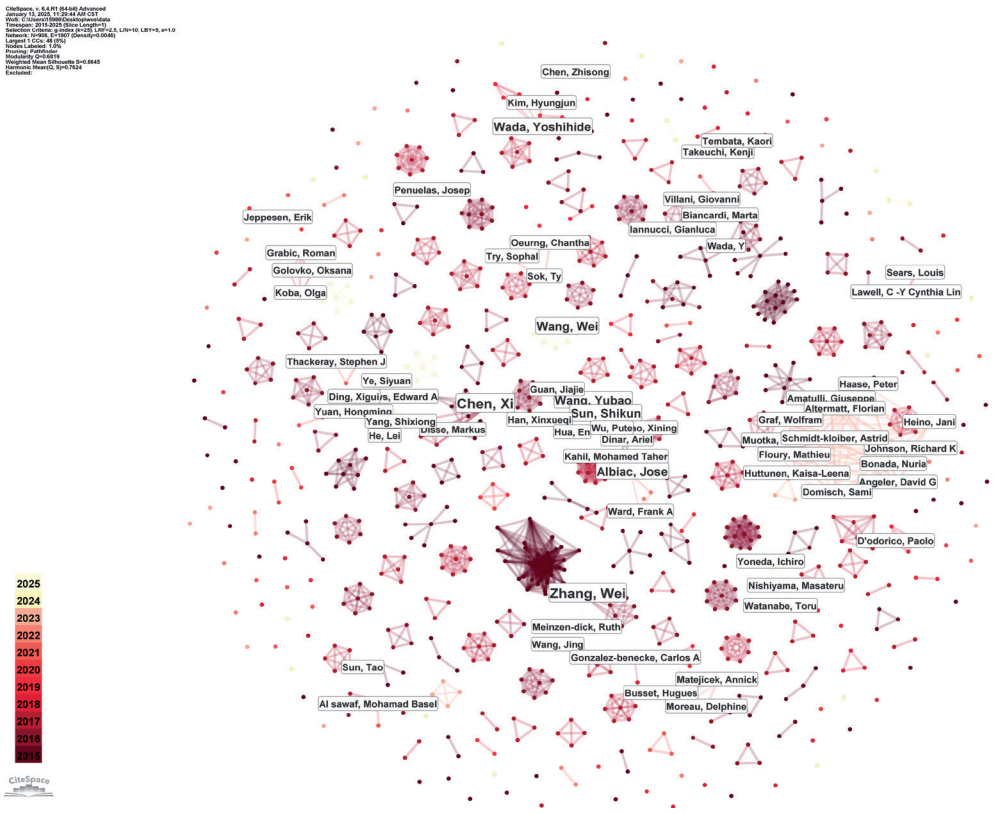

Fig. 3. Author collaboration co-occurrence map (N = 908, E = 1097).

E = 1907). We found an overall closer collaboration between the authors, forming several research clusters that can contribute to the study of sporting events, the water environment, and related areas of sustainable development. A few authors are more isolated, and we suggest that this group of authors can find potential co-authors to further develop more in-depth research. We believe that sports events and the water environment are research topics that require multidisciplinary cooperation to solve practical problems, and that promoting exchange and cooperation between authors from different disciplines can provide a new perspective for research in this field, and improve the efficiency and innovation of research on sports events and the water environment.

Institutional Collaboration

Table 3 shows the top ten institutions for institutional collaboration in research related to sporting events and the water environment. It can be noticed that out of the top ten institutions, four out of ten are located in China and three in the United States; another two are located in France, and one institution is located in Germany. This suggests that research organizations in China, the United States, and France are paying more attention to research related to sporting events and the water environment. However, although the Centre National de la Recherche Scientifique (CNRS) in France does not have the same number of publications as the Chinese Academy of Sciences in China, its centrality is the highest among the top ten institutions (centrality of 0.15), which suggests that CNRS plays an important hub role in the context of sporting events in the aquatic environment plays an important pivotal role. From the point of view of the time when the institutions issued papers, the time span ranges from 2015-2020, and the institutions that started to issue papers in 2020 have rapidly developed to be among the top 10 institutions in the research related to sports events and water environment, and at the same time, it shows that the institutions have always continued to pay attention to the research on sports events and water environment.

Fig. 4 shows the co-occurrence of institutional networks for research related to sporting events and the water environment. The graph only shows organizations with ≥ 10 institutional collaborations; the node size reflects the number of messages sent by the organization, and the connecting lines of the nodes reflect the trend and direction of that organization's collaborations. The number of institutional nodes can be found to be 296, and the number of cooperative links to be 445 (N = 296, E = 445). It is possible to find more organizations focusing on the study of sports events and the water environment, but the cluster of cooperation between the organizations is relatively more concentrated. In-depth cooperation and research exchange, particularly the cluster involving CNRS and 15 other institutions, appear to have significantly contributed to the field's development.

Co-Occurrence in the Country of Issuance

Table 4 shows the top ten issuing countries for studies related to sporting events and the water environment. China ranked first in the number of articles on sports events and water environment, with 239 articles, accounting for 33.05% of the total. The United States ranked second with 189 articles, accounting for 26.14% of the total. China and the US can be found to be significantly ahead of other countries in terms of the number of postings, which fits with the institutional co-occurrence studies we analyzed. It is worth noting that despite the high number of publications in China and the United States, the centrality is not high (0.00, 0.04, respectively). Germany and the Netherlands (ranked third and tenth, respectively) exhibited stronger collaborative links (higher centrality) with other countries in the study of sporting events and the water environment (centrality of 0.19 and 0.26, respectively).

Table 3. Co-occurrence of institutional cooperation.

Ranking	Institutional	Country	Count	Centrality	Year
1	Chinese Academy of Sciences	CHINA	66	0. 07	2015
2	Centre National de la Recherche Scientifique (CNRS)	FRANCE	25	0. 15	2016
3	University of Chinese Academy of Sciences	CHINA	24	0. 03	2015
4	University of California System	USA	24	0. 11	2015
5	Northwest A&F University - China	CHINA	17	0. 07	2017
6	INRAE	FRANCE	15	0. 02	2017
7	United States Department of Agriculture (USDA)	USA	15	0. 09	2015
8	Leibniz Association	GERMANY	15	0. 03	2019
9	United States Department of the Interior	USA	14	0. 01	2020
10	Hohai University	CHINA	13	0. 02	2020

Fig. 4. Institutional network co-occurrence (N = 296, E = 445).

By looking at the start of the study in the issuing countries, only France of the top ten countries started the study in 2016, with the remaining nine countries starting in 2015. We do not rule out the possibility that these nine countries began studying sporting events and the water environment earlier, but we only included literature from after 2015 in our analysis.

Fig. 5 shows the co-occurrence of national collaborative networks studying sporting events and the water environment. It can be found that the number of nodes in the study countries of sports events and water pollution is 99, and the number of connecting digits is 210 (N = 99, E = 210). It can be seen that the countries concerned with research related to sports events and the water environment are diverse, and international cooperation is more concentrated. We found that most of the countries with a high number of collaborations are important players in the world of sports and are well-versed in the organization of sports events and environmental management. These countries also play an important role and make outstanding contributions to environmental protection on a global scale. For example, a study featured the application of environmental science to the innovative development of major sports events in China [36], and the USA has studied the impact of climate change on physical activity and its counterproductive effects [37]. In addition, with the deepening of international exchanges and cooperation,

Table 4. Total number of countries that have issued communications.

Ranking	Regions	Count	Centrality	Year
1	CHINA	239	0. 00	2015
2	USA	189	0. 04	2015
3	GERMANY	68	0. 19	2015
4	ENGLAND	60	0. 13	2015
5	JAPAN	58	0. 08	2015
6	SPAIN	53	0. 00	2015
7	FRANCE	48	0. 16	2016
8	AUSTRALIA	45	0. 00	2015
9	CANADA	36	0. 00	2015
10	NETHERLANDS	35	0. 26	2015

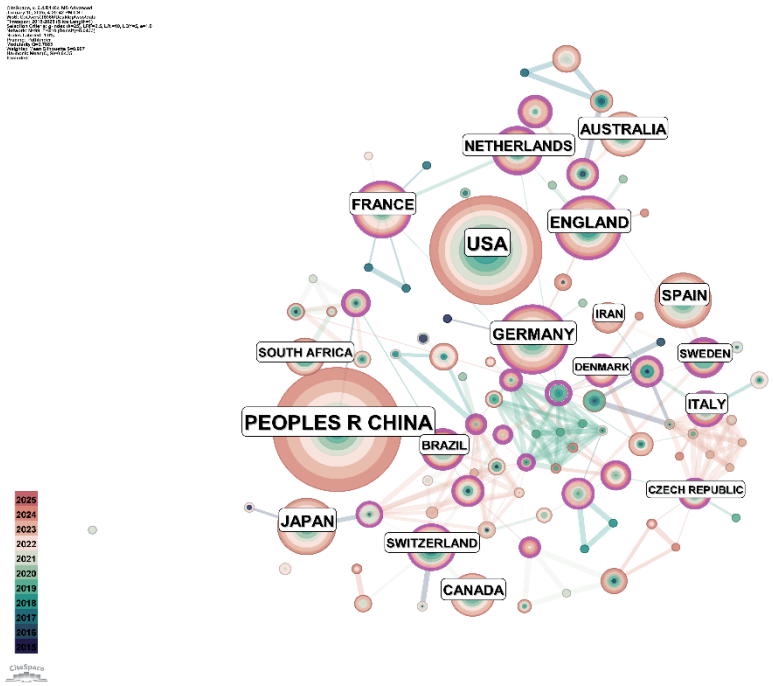

Fig. 5. Co-occurrence of country cooperation networks (E = 99, N = 210).

environmental awareness has been raised in various countries, which has led to the development of multi-dimensional research on sports events and the water environment.

Co-Citation Analysis

We visualized the cited references, authors, and institutions in the literature included in the analysis. To provide a reference for potential scholars of sports events and water environment-related research, to learn about more authoritative literature and authors in sports events and water environment research, and to more quickly identify scholars who have made outstanding contributions to the field.

Journal Co-Citations

Table 5 shows the top ten co-cited journals for research related to sporting events and the water environment. Among these journals, SCI TOTAL ENVIRON had the highest number of citations at 236, and SCIENCE ranked second with 233 co-citations. We found that centrality remained low (centrality <0.10) among the journal types in the top ten co-citations. In addition, we can find that the journals with the top number of co-citations have a higher overall level of impact factor in the last five years, especially in the top five journals. NATURE (IF = 54.5) and SCIENCE (IF = 50.3), journals with high authority, ranked highly in terms of the number of citations (in the 2nd and 4th

Table 5. Journal co-citation co-occurrence.

Ranking	Journal	5-years IF	Count	Centrality	Year
1	SCI TOTAL ENVIRON	8. 6	236	0. 01	2015
2	SCIENCE	50. 3	233	0. 00	2015
3	J HYDROL	6. 4	223	0. 01	2015
4	NATURE	54. 4	214	0. 01	2015
5	P NATL ACAD SCI USA	10. 8	210	0. 00	2015
6	WATER RESOUR RES	5. 9	190	0. 04	2015
7	PLOS ONE	3. 3	168	0. 00	2015
8	ECOLOGY	5. 5	164	0. 07	2015
9	AGR WATER MANAGE	6. 3	157	0. 01	2015
10	WATER-SUI	3. 3	147	0. 00	2016

places). Although four of the top 10 journals have a 5-yr IF <6, this suggests that such low-impact-factor journals are still focusing on and making an impact on research related to sporting events and the aquatic environment, and account for a significant portion of the total. We suggest that scholars choose different types of journals according to the situation of paper writing and different needs, not necessarily targeting journals with a high impact factor (we certainly recognize that journals with a high impact factor have higher authority), but try some journals with a relatively low impact factor but still have influence.

Fig. 6 shows the co-occurrence of the network of co-cited journals for research related to sporting events and the water environment. The number of nodes of co-cited journals in this field can be found as node number is 578, and the number of connectors is 434 (N = 578, E = 434), while the number of connectors reflects the linkage and strength between co-cited journals. It can be seen that the types of journals publishing research related to sports events and the water environment are diverse, but the research hotspots of each journal are somewhat concentrated. We found that most of the co-cited journals focus on topics that are mostly central to the field of global water resources management and are of great value for sustainable water resources utilization and environmental governance. These themes have played a positive role in promoting water resources protection and management globally and have achieved significant results. For example, "#2 Groundwater Management" explores effective strategies for groundwater management [38, 39], and "Water Scarcity" is an in-depth analysis of water scarcity [40, 41]. In addition, with the increased attention to water resources management issues, various research institutions have carried out multidimensional discussions in related fields, contributing to a more comprehensive and internationalized trend in water resources management research.

Literature Co-Citation

Table 6 shows the top ten co-cited literature for studies related to sporting events and the water environment, and it can be noticed that all of these cited literatures are more than four. Despite the high number of citations in these literatures, their centrality was generally low (≤0.01), which suggests that these literatures focus on the study of sporting events and the aquatic environment from different fields.

Author Co-Citation

Table 7 shows the co-occurrence of the top 10 most cited authors after screening out unknown authors. The top two authors in terms of frequency of cited authors have been cited more than 30 times, which indicates that these two authors are outstanding in the field of sports events and water environment. Specifically, FAO (Food and Agriculture Organization of the United Nations) was cited the most, meaning that the organization is equally involved in research related to sporting events and the water environment, and that their findings are convincing and influential. We recommend that future scholars who will be conducting research on sporting events and water environments pay attention to the

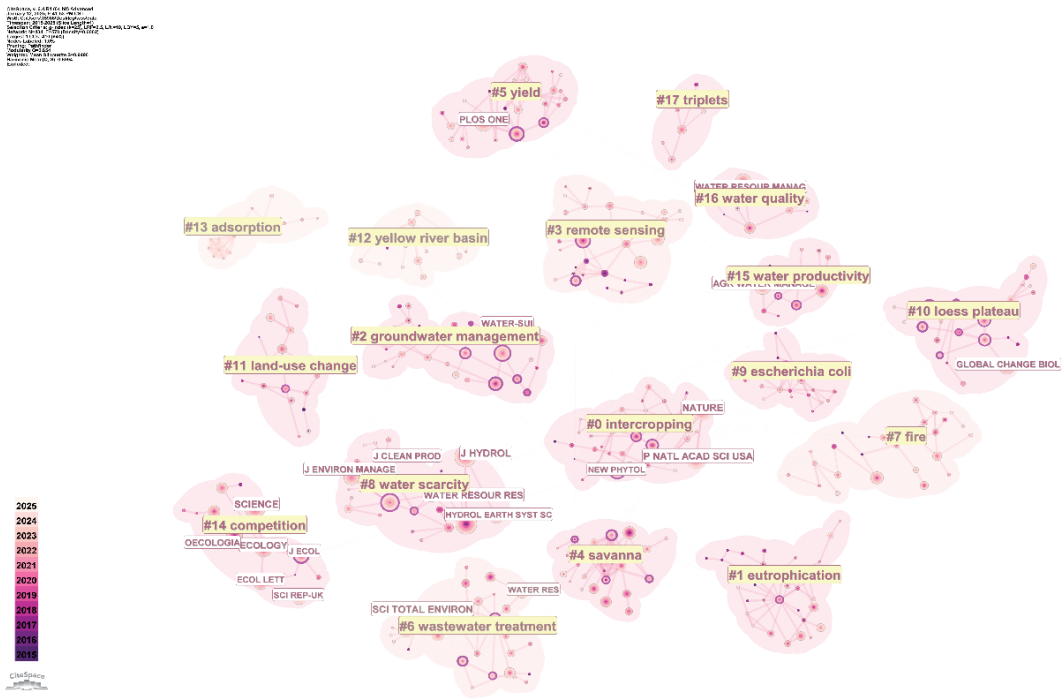

Fig. 6. Journal co-citation network co-occurrence (E = 578, N = 434).

Table 6. Co-cited literature co-occurrence.

Ranking	References	Count	Centrality	Year
1	The paradox of irrigation efficiency, 2018, SCIENCE, V361, P748, DOI 10. 1126/ science. aat9314	9	0. 02	2018
2	Four billion people facing severe water scarcity, 2016, SCI ADV, V2, P0, DOI 10. 1126/sciadv. 1500323	6	0. 00	2016
3	Multimodel assessment of water scarcity under climate change, 2010, NATURE, V467, P555, DOI 10. 1038/nature09440	5	0. 00	2014
4	CLIMATE CHANGE 2022: IMPACTS, 2022, V0, P0, DOI 10. 1017/9781009325844	5	0. 01	2010
5	R Core Team, 2019, R: A LANGUAGE AND ENVIRONMENT FOR STATISTICAL COMPUTING, V0, P0	5	0. 00	2019
6	ENERG CONVERS MANAGE, 2022, V266, P0, DOI 10. 1016/j. enconman. 2022. 115848	5	0. 01	2022
7	Li CJ, 2020, NAT PLANTS, V6, P653, DOI 10. 1038/s41477-020-0680-9	4	0. 01	2022
8	Reid AJ, 2019, BIOL REV, V94, P849, DOI 10. 1111/brv. 12480	4	0. 00	2020
9	Jägermeyr J, 2017, NAT COMMUN, V8, P0, DOI 10. 1038/ncomms15900	4	0. 00	2019
10	Hua E, 2021, AGR WATER MANAGE, V254, P0, DOI 10. 1016/j. agwat. 2021. 106941	4	0. 00	2017

Table 7. Author co-citation co-occurrence.

Ranking	Authors	Count	Centrality	Year
1	FAO	33	0. 08	2016
2	ALLEN RG	30	0. 07	2016
3	VÖRÖSMARTY CJ	29	0. 07	2015
4	R CORETEAM	29	0. 09	2016
5	TILMAN D	26	0. 11	2015
6	WANG Y	26	0. 03	2017
7	LIU Y	22	0. 07	2017
8	ZHANG Y	22	0. 00	2015
9	WANG J	21	0. 02	2017
10	EHLERINGER JR	19	0. 16	2015

literature published by these authors, who have a high level of contribution and authority in the field of sporting event environments.

Fig. 7 shows the co-occurrence network analysis of co-cited authors for sporting events and the water environment. The clustering center area focuses on two research directions, "#0 lotka-volterra model" (containing 56 author nodes) and "#1 agroforestry" (containing 47 author nodes), which suggests that these two areas may be the core themes of research. In addition, "#4 water demand", "#6 water management", and "#10 SWAT model" form the water resources; "#14 species diversity", "#15 exotic species", "#12 interspecific interaction" formed the association group for ecosystem studies; and "#10 SWAT model" formed the association group for ecosystem studies. "Interspecific interaction" formed the linkage group for ecosystem studies. It is also apparent that sporting events and the water environment are a multidisciplinary field involving water resources, biodiversity, agroforestry, and social management, and that research themes are expanding and deepening over time.

Keyword Analysis

Keyword analysis will be more intuitive for scholars who will be engaged in the research of sports events and water resources to provide reference for the evolution of research hotspots and potential research directions, highlighting the key sub and commonly used terminology that have emerged in the existing field, and helping scholars to more quickly and accurately

Fig. 7. Co-cited authors network co-occurrence.

recognize the hotspots and themes of the research of sports events and water environment.

Keyword Co-Occurrence

Table 8 shows the top 10 frequencies of keyword appearances in studies related to sports events and the water environment. As can be seen from the table, "climate change", "competition", and "management" are the most frequently occurring keywords, with 108, 93, and 82 occurrences, respectively. It shows that the issue of climate change and its competition and management with water resources is a hot topic of research in this field. It is worth noting that although the frequency of "dynamics" is only 33 times, its centrality is relatively high (centrality of 0.15), which suggests that it plays an important pivotal role in research related to sports events and the water environment. In terms of temporal distribution, 2015 was the starting year for the majority of keyword occurrences (8 out of 10), suggesting that this year was an important starting point for research attention on sporting events and the water environment. In contrast, "model" and "productivity" appeared in 2016 and 2017, respectively, indicating that emerging research themes are gradually developing and entering the research hotspot as the research progresses. In addition, taken as a whole, these keywords run through multiple points in time, illustrating the

Table 8. Keyword co-occurrence.

Ranking	Keywords	Count	Centrality	Year
1	Climate change	108	0. 12	2015
2	Competition	93	0. 09	2015
3	Management	82	0. 09	2015
4	Model	60	0. 06	2016
5	Growth	59	0. 04	2015
6	Water	43	0. 04	2015
7	Resources	40	0. 03	2015
8	Diversity	36	0. 03	2015
9	Dynamics	33	0. 15	2015
10	Productivity	32	0. 02	2017

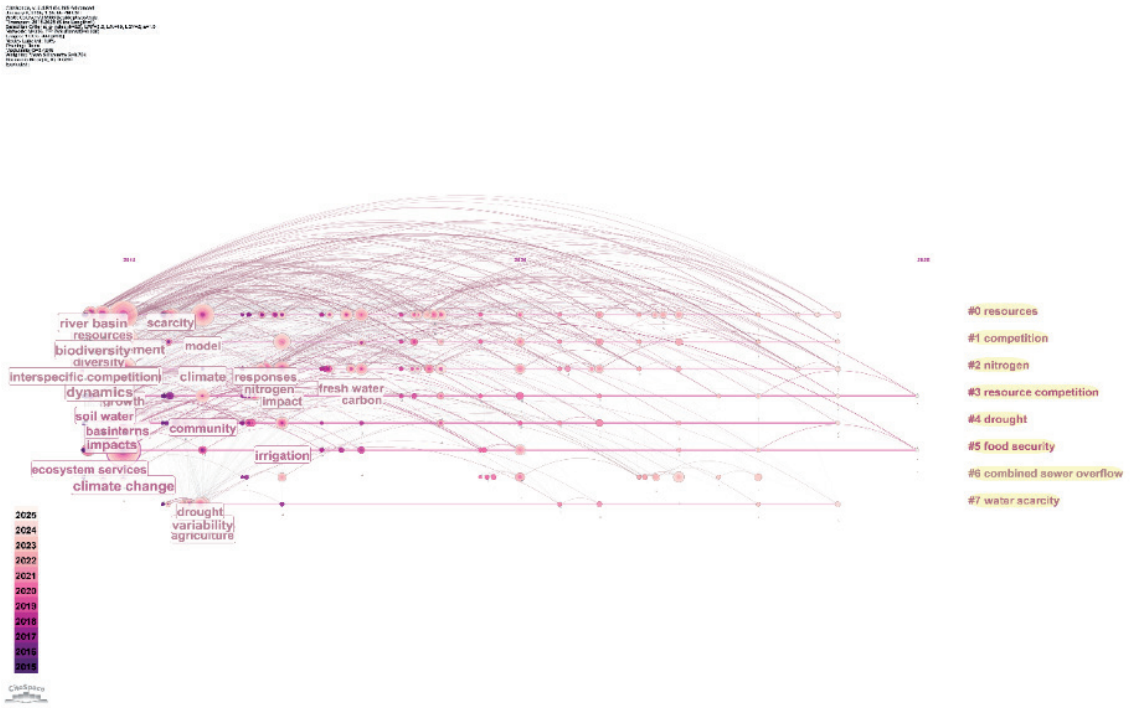

Fig. 8. Keyword time set lines (E = 356, N = 1769).

continuity and breadth of research topics on sporting events and the water environment.

The time set lines of keywords and their trends in the study of sports events and the water environment between 2015 and 2025 are presented in Fig. 8. The keyword network consists of 356 nodes and 1769 connecting lines (N = 356, E = 1,769) with a density of 0.028, indicating a wider range of associations between the research topics. As can be seen, the core keywords "climate change", "competition", and "dynamics" are used throughout. The keywords "climate change", "competition", and "dynamics" form important hubs and nodes in the network, reflecting their central position in this field of research. In addition, keywords such as "scarcity" and "nitrogen" are emerging as points of interest, suggesting that research is deepening and expanding into more specific topics. In terms of time dimension, early studies focused on macro themes such as "climate change" and "ecosystem services", while in recent years more attention has been paid to specific issues such as "drought" and "nitrogen", especially in the areas of resource management and food security. The distribution and relevance of the keywords also reflect the important role of international cooperation, with national studies driving the extension from ecological conservation to urban water management and beyond, reflecting the continuity and breadth of the field.

Keyword Emergence

Fig. 9 shows the top 25 keyword bursts for sporting events and water environment, revealing keyword research trends and potential research hotspots.

Keywords with high emergence intensity include "runoff" (2.93), "stomatal conductance" (2.85), which started to emerge in 2016-2017, and "China" (2.85), which emerged in 2021-2022. These keywords mainly relate to environmental science. In terms of time, research hotspots have shifted from environmental and resource management (e.g., "eutrophication", "runoff", "water scarcity") to agriculture and ecosystems (e.g., "biofuels", "maize", "salinity"), and have gradually focused on global development and regional strategies (e.g., "China", "strategy"). Notably, short-term surge (1-2 years) themes reflect rapidly changing hotspots in the field, while long-term surge (e.g., "soil water" "productivity") reveals a continued focus on core issues. In recent years, keywords such as "strategy", "river", and "productivity" have emerged and continue to be used, suggesting that future research will focus on the integration of issues such as productivity enhancement, river, and other water management strategies. This suggests that future research will focus on the integration of issues such as productivity enhancement and water management strategies for rivers and other water resources [42], For example, the study of changes in river levels and management strategies in the context of globalization of a warming climate [43, 44], provide important guidance in addressing global climate change,

Provide important guidance in addressing global climate change, resource management, and sustainable development challenges.

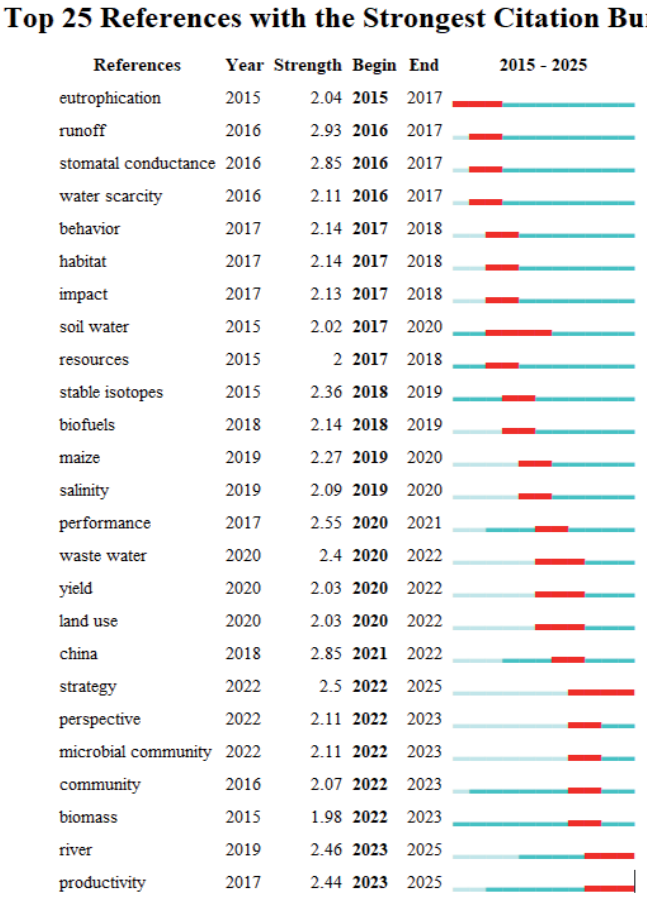

Fig. 9. Keyword bursting.

Conclusions

Key Findings of this Study

This study systematically analyzes the current status, trends, and future research hotspots of sports events and water environment research by using Citespace, which provides a new perspective for organizing sports events and water resources-related research. In the course of our research, we identified the following key points: (1) Trends in the growth of academic output: the number of academic papers in the field of sports events and water resources has continued to rise over the past decade. Especially after 2018, there has been a significant increase in publications. The journals in which the study was published focused on environmental sciences, but also showed a trend towards interdisciplinary research, with links to journals in areas such as water resources. (2) Dynamics of partnerships: in the study of sports events and water resources, there are extensive networks of cooperation between different countries and institutions. China dominates research collaboration in this area. Despite the relatively limited collaboration between researchers, different scholars continue to collaborate on topics related to sports events and water resources, and jointly publish research results. (3) Demonstration of co-citation analysis: high-impact factor journals are not always the main journals that are frequently cited in the co-cited literature on sporting events and water resources. And, in terms of co-cited authors, journals, and institutions, the direction of their focus on sporting events and the water environment varies. (4) Concentration and Evolution of Research Themes: from 2015 to 2025, research will mainly focus on the fields of environment and ecology, with emphasis on the themes of “climate change”, “competition”, and “management”. Scholars’ interest in sporting events and water resources has shown continuity and an increasing diversity of research topics covering a wider range of fields and issues. (5) Trend of interdisciplinary development: Research related to sports events and water resources has gradually developed in the direction of interdisciplinarity, with more comprehensive research themes, integrating the perspectives and methods of multiple disciplines, reflecting an increase in the depth and breadth of research.

Directions for Future Research

Based on the current research status and development trend of sports events and water environment, we propose the following suggestions for the research direction of this field for future scholars working on sports events and water environment.

1) Complex and diversified research topics and innovative research methods: The research on sports events and the water environment will become more complex and comprehensive, and the topics and research methods involved will show a diversified trend. Future research topics are likely to originate from various related disciplines, while research methods will tend to be diversified, including quantitative and qualitative research, and research methods from other disciplines may be introduced to enhance the depth and breadth of the research.

2) Interdisciplinary integration and collaborative exchange of authors, institutions, and countries: As the study of sporting events and water resources progresses, more and more disciplines will be incorporated, potentially including agronomy in addition to natural environmental sciences [45], civil engineering [46], and other areas. Future research will explore the interactions between different disciplines, and research topics may include the integrated impacts of sports events on urban ecology, social organization, and economic growth, such as water management and sustainable use of water resources for major sports events [47]. Optimization of water efficiency in venue facilities and promotion of a sustainable water cycle for sports events [48], etc. In addition, the promotion of collaborative exchanges between authors, institutions, and countries is an important initiative for the in-depth study of sports events and the water environment. We suggest that scholars should find scholars who are able to cooperate in interdisciplinary or related fields, so as to collide theoretical knowledge and practice; at the same time, international cooperation should be strengthened to promote the sharing of experience and technology among the international community, so as to jointly respond to the challenges posed by climate change to sports events.

3) Application of digital technology and innovative methods: with the rapid rise and development of digital technology, the application of digital technology to sports events and water environments has a large potential [49]. In future research, the application of technologies such as big data analysis and prediction, and monitoring and management of sports events will significantly improve the precision and efficiency of management of sports events and the water environment [50]. For example, the establishment of network testing, real-time monitoring of the hydrometeorological conditions and water environment quality of the event venues, the development of adaptive management strategies, according to the climate change trends, timely adjustments to the event planning and venue design standards, and so on.

Contributions and Innovations

This study makes a series of contributions to the field of sporting events and the water environment and features several innovations: First, this study innovatively uses bibliometric research methods to provide a new perspective on the study of sports events and water resources. By using bibliometric research methods, we reveal more intuitively to readers the current status, trends, and hotspots of the research on sports events and water environment. Second, we selected the literature published in authoritative journals such as SSCI, A&HCI, and SCIE as the raw data of this study to ensure the objectivity and scientificity of the study. By digging deep into the existing literature data, we avoided the influence of subjective bias and ensured the accuracy and reliability of our findings.

Limitations of this Study

Despite the results of this study, there are still limitations. First, the limitation of the time frame. We used the Paris Agreement as a node to go forward one year, and only included literature from 2015-2025, and did not include research-worthy literature prior to 2015, failing to clarify the complete evolutionary lineage of research on sporting events and the water environment. Second, the limitation of the linguistic scope. We only included literature where the language of publication was English. Through this study, we found that China is one of the countries that pay more attention to sports events and water environment, but we neglected valuable literature in other languages such as Chinese, French, and German. This leads to the possibility that native English-speaking countries may include a larger number of articles, which creates an error in our understanding of the overall trend of research on sporting events and water environments on a global scale.

In response to these shortcomings, we propose the following measures for improvement. (1) Expanding the timeframe of the search and refining the screening of the literature to ensure that the study covers articles that are closely related to the subject terms in the timeframe that is as far as possible in the field. To reveal more fully and accurately the development and trends of sporting events and the water environment. (2) Incorporate more languages, and in subsequent studies, we will expand the range of languages to make up for the lack of articles in Chinese, French, and other languages. And adding equally authoritative databases from different countries to the database search further expands the representativeness and completeness of the literature.

Acknowledgements

Thanks to the School of Physical Education of Hunan University for supporting this article. We appreciate the valuable comments offered by the anonymous reviewers and editors who contributed to improving the quality of our article.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

1. HE K.L., CHEN X.H., ZHOU J.Y., ZHAO D.M., YU X. Compound successive dry-hot and wet extremes in China with global warming and urbanization. Journal of Hydrology. **636**, 131332, **2024**.
2. TSYMBALYUK V.I., VADZYUK S.N., TOLOKOVA T.I., PANKIV I.B. Reproductive health under global warming. Medicni Perspektivi. **27** (4), 4, **2022**.
3. CIAMPITTIELLO M., MARCHETTO A., BOGGERO A. Water Resources Management under Climate Change: A Review. Sustainability. **16** (9), 3590, **2024**.
4. LUO M., LIU T., MENG F.H., DUAN Y.C., BAO A.M., XING W., FENG X.W., DE MAEYER P., FRANKL A. Identifying climate change impacts on water resources in Xinjiang, China. Science of the Total Environment. **676**, 613, **2019**.
5. ZENG Y.J., LIU D.D., GUO S.L., XIONG L.H., LIU P., YIN J.B., TIAN J., DENG L.L., ZHANG J.Y. Impacts of Water Resources Allocation on Water Environmental Capacity under Climate Change. Water. **13** (9), 1187, **2021**.
6. PAYUS C., HUEY L.A., ADNAN F., RIMBA A.B., MOHAN G., CHAPAGAIN S.K., RODER G., GASPARATOS A., FUKUSHI K. Impact of Extreme Drought Climate on Water Security in North Borneo: Case Study of Sabah. Water. **12** (4), 1135, **2020**.
7. MUYAMBO F., BELLE J., NYAM Y.S., ORIMOLOYE I.R. Climate-Change-Induced Weather Events and Implications for Urban Water Resource Management in the Free State Province of South Africa. Environmental Managemente. **71** (1), 40, **2023**.
8. ZOU X.Y., PENG X.Y., ZHAO X.X., CHANG C.P. The impact of extreme weather events on water quality: international evidence. Natural Hazards. **115** (1), 1, **2023**.
9. SAFAIE A., LITCHMAN E., PHANIKUMAR M.S. Decreasing Groundwater Supply Can Exacerbate Lake Warming and Trigger Algal Blooms. Journal of Geophyscical Research-Biogeosciences. **126** (9), 006455, **2021**.
10. MEI X.Y., GAO S.S., LIU Y., HU J., RAZLUSTKIJ V., RUDSTAM L.G., JEPPESEN E., LIU Z.W., ZHANG X.F. Effects of Elevated Temperature on Resources Competition of Nutrient and Light Between Benthic and Planktonic Algae. Frontiers in Environmentnal Science. **10**, 908088, **2022**.
11. WILEY D.Y., MCPHERSON R.A. The Role of Climate Change in the Proliferation of Freshwater Harmful Algal Blooms in Inland Water Bodies of the United States. Earth Interactions. **28** (1), 230008, **2024**.
12. NIU C., QI Y.F., GUO A.J., CHANG J.X. Grain yield and food security evaluation in the yellow river basin under climate change and water resources constraints. Frontiers in Water. **4**, 908945, **2022**.
13. ELMADANI M., KIPTULON E.K., KLÁRA S., ORSOLYA M. Systematic Review of the Impact of Natural Resource Management on Public Health Outcomes: Focus on Water Quality. Resources-Basel. **13** (9), 122, **2024**.
14. SANTAMARTA J.C., HERNANDEZ-ALEMAN A., CRUZ-PEREZ N., GAMALLO-PAZ I., RODRIGUEZ-MARTIN J., CASTELLANOS I.D., GARCIA-GIL A. Optimizing Water Sustainability: Revealing Cost Recovery Strategies in the Canary Islands (Spain). Stochastic Frontier Model. Environmental Processes – An International Journal. **11** (1), 13, **2024**.
15. HEINKE J., MÜLLER C., LANNERSTAD M., GERTEN D., LUCHT W. Freshwater resources under success and failure of the Paris climate agreement. Earth System Dynamics. **10** (2), 205, **2019**.
16. PIEMONTESE L., FETZER I., ROCKSTRÖM J., JARAMILLO F. Future Hydroclimatic Impacts on Africa: Beyond the Paris Agreement. Earth's Future. **7** (7), 748, **2019**.
17. MENDOZA-ESPINOSA L.G., MOJIRI A. Editorial: Wastewater and microbial contamination of water courses. Frontiers in Water. **6**, 1428714, **2024**.
18. JIANG T.H., WANG M.M., ZHANG W., ZHU C., WANG F.J. A Comprehensive Analysis of Agricultural Non-Point Source Pollution in China: Current Status, Risk Assessment and Management Strategies. Sustainability. **16** (6), 2515, **2024**.
19. DUDGEON D. Multiple threats imperil freshwater biodiversity in the Anthropocene. Current Biology. **29** (19), R960, **2019**.
20. EDITORIAL. A sporting chance: physical activity as part of everyday life. The Lancet. **398** (10298), 365, **2021**.
21. LIM D., PARK S. A Study of Measures for Sustainable Sport. Sustainability. **15** (17), 12732, **2023**.
22. PINE M.K., HAGUE E., KEBKE A., MCWHINNIE L., FINDLAY C.R. Not so silent spectators: How spectator vessels at international sailing regattas alter marine soundscapes. Marine Pollution Bulletin. **202**, 116309, **2024**.
23. ZHANG B. The Social Benefits of Water Sports Events and Their Impact on Environmental Pollution. Journal of Coastal Research. **104**, 111, **2020**.
24. WANG M., CHEN X., SIDIKE A., CAO L.Z., DEMAEYER P., KURBAN A. Optimal Allocation of Surface Water Resources at the Provincial Level in the Uzbekistan Region of the Amudarya River Basin. Water. **13** (11), 1146, **2021**.
25. YU Y., YU R.D., CHEN X., YU G.A., GAN M., DISSE M. Agricultural water allocation strategies along the oasis of Tarim River in Northwest China. Agricultural Water Management. **187** 24, **2017**.
26. ORTIZ-PARTIDA J.P., FERNANDEZ-BOU A.S., MASKEY M., RODRÍGUEZ-FLORES J.M., MEDELLÍN-AZUARA J., SANDOVAL-SOLIS S., ERMOLIEVA T., KANAVAS Z., SAHU R.K., WADA Y., KAHIL T. Hydro-Economic Modeling of Water Resources Management Challenges: Current Applications and Future Directions. Water Economics and Policy. **9** (1), 2340003, **2023**.
27. HE X.G., FENG K.R., LI X.Y., CRAFT A.B., WADA Y., BUREK P., WOOD E.F., SHEFFIELD J. Solar and wind energy enhances drought resilience and groundwater sustainability. Nature Communications. **10**, 4893, **2019**.
28. YEH C.C., HUANG C.H. An Innovative Trend of Sport Event in Environmental Perspective. In: Lecture Notes in Computer Science Innovative Technologies and Learning. Springer International Publishing, **2018**.
29. SILVA M.F., LEAO A.L.F., O'CONNOR A., HALLAL P.C., DING D., HINCKSON E., BENMARHNIA T., REIS R.S. Understanding the Relationships Between Physical

Activity and Climate Change: An Umbrella Review. Journal of Physical Activity & Health. **21** (12), 1263, **2024**.
30. ELSHALL A.S., ARIK A.D., EL-KADI A., PIERCE S., YE M., BURNETT K.M., WADA C.A., BREMER L.L., CHUN G. Groundwater sustainability: a review of the interactions between science and policy. Environmental Research Letters. **15** (9), 093004, **2020**.
31. KANG L.S., HAMM S.Y., CHEONG J.Y., JEON H.T., PARK J.H. Groundwater monitoring system and groundwater policy in relation to unified water resource management in Korea. Water Policy. **22** (2), 211, **2020**.
32. LIU J.G., ZHAO D.D. Three-dimensional water scarcity assessment by considering water quantity, water quality, and environmental flow requirements: Review and prospect. Chinese Science Bulletin. **65** (36), 4251, **2020**.
33. YU Y., YU R.D., CHEN X., YU G.A., GAN M., DISSE M. Agricultural water allocation strategies along the oasis of Tarim River in Northwest China. Agricultural Water Management. **187**, 24, **2017**.
34. WANG M., CHEN X., SIDIKE A., CAO L.Z., DEMAEYER P., KURBAN A. Optimal Allocation of Surface Water Resources at the Provincial Level in the Uzbekistan Region of the Amudarya River Basin. Water. **13** (11), **2021**.
35. HE X.G., FENG K.R., LI X.Y., CRAFT A.B., WADA Y., BUREK P., WOOD E.F., SHEFFIELD J. Solar and wind energy enhances drought resilience and groundwater sustainability. Nature Communications. **10**, **2019**.
36. UHRICH S., KOENIGSTORFER J. Effects of atmosphere at major sports events: a perspective from environmental psychology. International Journal of Sports Marketing & Sponsorship. **10** (4), 325, **2009**.
37. DOLF M., TEEHAN P. Reducing the carbon footprint of spectator and team travel at the University of British Columbia's varsity sports events. Sport Management Review. **18** (2), 244, **2015**.
38. KANG L.S., HAMM S.Y., CHEONG J.Y., JEON H.T., PARK J.H. Groundwater monitoring system and groundwater policy in relation to unified water resource management in Korea. Water Policy. **22** (2), 211, **2020**.
39. PASSIER H.F., HEERDINK R., ROZEMEIJER J., VISSER A., ZHANG Y.C., JANSEN S., BEUMER V. Groundwater quality in Dutch water management. **2011**.
40. LIU J.G., ZHAO D.D. Three-dimensional water scarcity assessment by considering water quantity, water quality, and environmental flow requirements: Review and prospect. Chinese Science Bulletin. **65** (36), 4251, **2020**.
41. OPPLIGER A., HÖHL J., FRAGKOU M. Water scarcity: disclosing its hybrid origins in the Bueno river basin, Chile. Revista de Geografía Norte Grande. (73), 9, **2019**.
42. WARD F.A. Integrating water science, economics, and policy for future climate adaptation. Journal of Environmental Management. **325**, **2023**.
43. TALCHABHADEL R., ARYAL A., KAWAIKE K., YAMANOI K., NAKAGAWA H. A comprehensive analysis of projected changes of extreme precipitation indices in West Rapti River basin, Nepal under changing climate. International Journal of Climatology. **41**, E2581, **2021**.
44. TEDLA M.G., RASMY M., TAMAKAWA K., SELVARAJAH H., KOIKE T. Assessment of Climate Change Impacts for Balancing Transboundary Water Resources Development in the Blue Nile Basin. Sustainability. **14** (22), **2022**.
45. NOGRADY B. How to address agriculture's water woes. Nature. **630** (8017), S26, **2024**.
46. TANJI K.K., KEYES C.G. Water quality aspects of irrigation and drainage: Past history and future challenges for civil engineers. Journal of Irrigation and Drainage Engineering. **128** (6), 332, **2002**.
47. BURSZTA-ADAMIAK E., SPYCHALSKI P. Water savings and reduction of costs through the use of a dual water supply system in a sports facility. Sustainable Cities and Society. **66**, **2021**.
48. MCCULLOUGH B.P., ORR M., KELLISON T. Sport Ecology: Conceptualizing an Emerging Subdiscipline Within Sport Management. Journal of Sport Management. **34** (6), 509, **2020**.
49. QU S., LV J.J., LIU J.X. Visualization Analysis for Global Water Resources Based on Digital Earth. Journal of Coastal Research. **105** (SI), 47, **2020**.
50. WALTER C. Digital Technologies for the Future of the Water Sector? Examining the Discourse on Digital Water. Geoforum. **148**, **2024**