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Article

Bibliometric Analysis of Research Trends in Water Management Aimed at Increasing the Sustainability of the Socio-Economic Development of a Region

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Abstract: The growing negative anthropogenic impact on the environment causes scientific interest in the problems of water management. The increasing number of publications in this scientific field requires their intellectual systematization. The purpose of this study is to conduct a bibliometric review of scientific publications related to water management issues in the context of solving the problems of increasing the sustainability of the socio-economic development of a region for better understanding of current research trends. To achieve this goal, bibliometric analysis using the VOSviewer software product (Manual for VOSviewer version 1.6.17) was used. The international database Scopus was taken as the source of information. This study examined 10,208 articles on water management issues from 2012 to 2022. The basic criterion for including a publication in the selection was that the topic of the work belongs to the subject areas of economics, econometrics and finance and business, management and accounting. As a result of the analysis, it was determined that the problems of water resources management have not lost their popularity in the global research community and the research methodology is evolving towards the concept of "water–energy–food". The centers of knowledge forming the vector of scientific research are the USA and the Netherlands; however, in recent years, the research of Chinese scientists has become increasingly important. It is concluded that the potential for the development of research in the field of water resources management in the context of solving the problems of the sustainable development of regions is associated with the search for opportunities for revealing the synergy of intersectoral interactions while taking into account their sectoral and regional specifics.

Keywords: water resources; bibliometric analysis; sustainable development; water resources management; economics of water resources; VOSviewer; knowledge centers; research geography

Citation: Mingaleva, Z.; Chernova, O.; Mitrofanova, I.V. Bibliometric Analysis of Research Trends in Water Management Aimed at Increasing the Sustainability of the Socio-Economic Development of a Region. *Water* **2023**, *15*, 3688. https://doi.org/10.3390/w15203688

Academic Editor: Francesco De Paola

Received: 8 September 2023
Revised: 16 October 2023
Accepted: 17 October 2023
Published: 22 October 2023

1. Introduction

Water resources are essential for achieving the goals of sustainable development for national economies, providing significant competitive advantages to states that have them in abundance [1]. The increasing technogenic demands of society have led to an increase in worldwide water consumption, significantly outstripping its natural renewal. This will activate the search by scientific researchers around the world for ways to improve the efficiency of water management. The modern scientific literature presents a significant amount of scientific research on the issues of water resources management in environmental and socio-economic aspects. The number of articles on water management issues is constantly growing. Therefore, it is important to understand the direction in which world science is moving in an effort to ensure solving the problems of the sustainable development of regions based on effective water resources management. Despite the growing interest in sustainable water management, we did not find any bibliometric studies devoted to a comprehensive review of publications in this subject area. The research of Xu H., Berres A. et al., Phan Th., and Bertone E. et al. are devoted to reviewing analytics applications in water resources management [2,3] and a review of publications devoted to the modeling of water planning processes was conducted by A. Hernández-Cruz et al. [4]. At the same time, most of the research was based on a content analysis of existing publications. This is due to the relative paucity of papers on individual subject areas of research. At the same time, there are single publications that use bibliometric methods of analysis in the study of certain issues of water management. In particular, one can note the study by Yang X. and Sun B. et al., which analyzes studies of the carrying capacity of water resources [5]; the study of publications by Bennett A. and Demaine J. et al., which was devoted to the safety of drinking water [6]; and reviews of publications on desalination issues by Ahmed et al. and A. Nikitaeva et al. [7,8].

Existing article reviews in the field of water management, as a rule, have the form of theoretical comments and touch upon certain aspects of this issue. For example, Yang D. and Yang Y. et al. review the work on water cycle management under the conditions of climate change and anthropogenic changes [9]; a study by Bello A. and Zouari N. et al. considers technologies for the desalination of water resources [10]. At the same time, there are no review publications that unite and systematize knowledge about the current trends in the research development in the field of water management in the context of solving the problems of increasing the sustainability of the socio-economic development of a region. To fill this gap, we use bibliometric analysis to review the scientific papers published in recent years on water management issues. Recent studies convincingly prove that bibliometric analysis provides important information about the trends in the development of a particular scientific field [11,12]. At the same time, bibliometric analysis is not a new approach in scientific research. The discussion of bibliometric indicators began in the middle of the 20th century. With the advent of the scientific databases Scopus and Web of Science, which greatly facilitated the ability to analyze large amounts of data, as well as providing tools for such analysis, bibliometric analysis has gained high popularity in scientific research in recent years. Thus, over the past decade, more than 1000 articles using bibliometrics have been published [13]. Bibliometric methodology is used both for the analysis of various thematic areas of scientific research and for the formation of retrospectives of journals. The growing popularity of this method is explained by the demonstration of the high research effectiveness of the bibliometric methodology.

Comparing bibliometric analysis with alternative review methods—meta-analysis and theoretical commentary—researchers note a number of distinctive advantages. Meta-analysis is able to process large numbers of reports, and it concentrates on the generalization of empirical data, determining the direction and strength of the influence of relationships [14]. Meta-analysis is most often used as a tool for expanding theory, searching for studies that are closer to the chosen problem than those used in the primary search [15]. Bibliometric analysis, on the contrary, generalizes and structures certain areas of scientific research within the framework of the problem under consideration.

Theoretical comments based on systematic reviews of the literature are better suited for research of a narrow problem with a small number of articles. As a result, such reviews provide a fragmented understanding of the research subject area. In addition, this approach relies on qualitative analysis, which, as noted by MacCoun R.J., can lead to the fact that such studies "may be marred by interpretation bias from scientists from different academic circles" [16]. Unlike reviews, bibliometric analysis has a greater breadth and depth of methodology, making it possible to decipher cumulative scientific knowledge and reflecting evolutionary processes in the development of scientific research areas.

With all of the above in mind, we have determined the purpose of this article: to conduct a bibliometric review of the scientific publications related to water management issues in the context of solving the problems of increasing the sustainability of the socio-economic development of a region in order to provide a better understanding of the current research trends. This article focuses on the following research questions: What is the dynamics of the research interest in water management issues over the past 10 years and what are the priority thematic areas for research in water management? Which countries are the centers of knowledge in the field of water management? What journals publish research in this subject area? What is the level of influence of these journals?

This study makes a valuable contribution to the study of the relationship between water management processes and the sustainable development of a region. First, it highlights the thematic areas of the research and the terms that dominate them, opening up opportunities for increasing the relevance and interconnectedness of research on the problems of increasing the sustainability of development based on the rational use of water resources. Secondly, it provides a more structured view of the leading journals, research organizations and countries, reflecting their contribution to the development of this subject area.

2. Methodology

Methods of bibliometric analysis are used in this study in combination with keyword analysis. The Scopus information database for the period from 2012 to 2022 was used as the data source. This database was chosen because it provides the most comprehensive coverage of quality articles from high-ranking journals in more than 230 countries. The period for research from 2012 to 2022 was chosen due to the desire to reflect modern research trends in this subject area, given the relatively rapid obsolescence of socio-economic research.

The first step of the study was aimed at searching publications with the keyword "Water resources management" using the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) method. Search parameters were set at the "identification" step for research published over the period from 2012 to 2022, with the keyword "Water resources management": research articles, conference proceedings, book chapters. As a result, 235,681 publications were found on the ScienceDirect platform. At the "screening" step, publications were checked for compliance with the subject area of the study. The basic criterion for including a publication in the selection was that the topic of the work belonged to the subject areas of economics, econometrics and finance and business, management and accounting. This enabled us to leave 14,634 sources for further consideration. At the "eligibility check" step, publications containing research in the field of water resources management in the context of solving sustainable development problems were identified. To do this, the keyword "Sustainable development" was added to the search line and, as a result, 10,208 publications were selected for analysis.

At the second stage of the study, the analysis of selected publications was carried out in the following areas: the dynamics of the number of publications, the geography of the research, journals publishing research results in this area, the scientific significance of the research and so on.

The scientific significance of the study was determined based on the Citation Count and Field-Weighted Citation Impact.

At the third stage, we used the VOSviewer software product (Manual for VOSviewer version 1.6.17) for creating maps reflecting thematic clusters in the area of study, as well as their priority for meaningful description of the subject field of the study. The VOSviewer tool enables clustering and carrying out network analysis of bibliometric information. The maps created by the VOSviewer software product are represented by nodes, the size of which is proportional to the number of documents that they characterize. Nodes are interconnected by connections. The shorter the distance between the nodes, the closer the relationship between the studied characteristics of documents.

Metadata on publications became data sources.

3. Results

3.1. Quantitative Characteristics of the Subject Field of the Research

The dynamics of the number of publications, according to the data presented on the ScienceDirect platform, indicates a steadily growing interest in water management issues. At the same time, the share of publications considering these issues in the context of solving the problems of sustainable development of the economy in the total number of publications on water management problems increased from 65.8% in 2012 to 73.4% by 2022 (Figure 1). During the same period, these publications received a total of more than 100,000 citations with a Field-Weighted Citation Impact of 1.12.

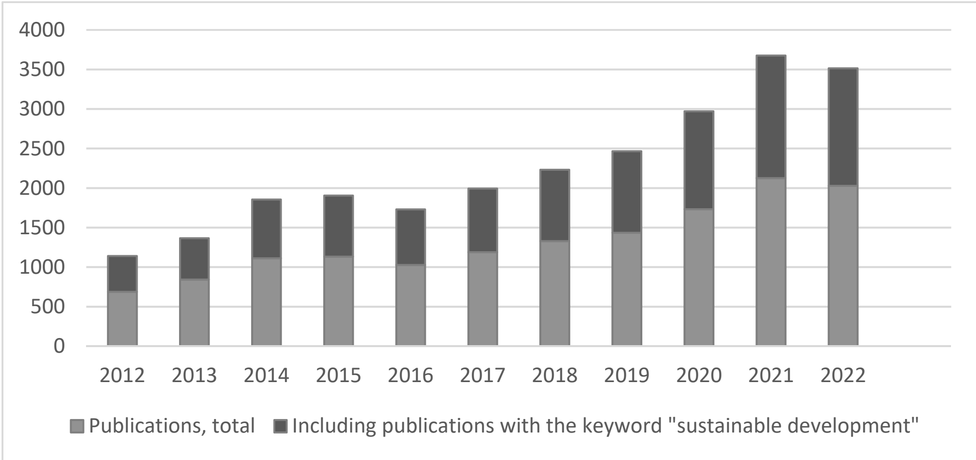

Figure 1. Annual number of publications on water management issues. Note: Compiled by the authors according to the source: https://www.sciencedirect.com (accessed on 11 October 2023).

In terms of the total number of publications throughout the study period, the United States was in the lead (Figure 2). However, starting from 2016, there can be observed an active growth in the number of publications by researchers from China.

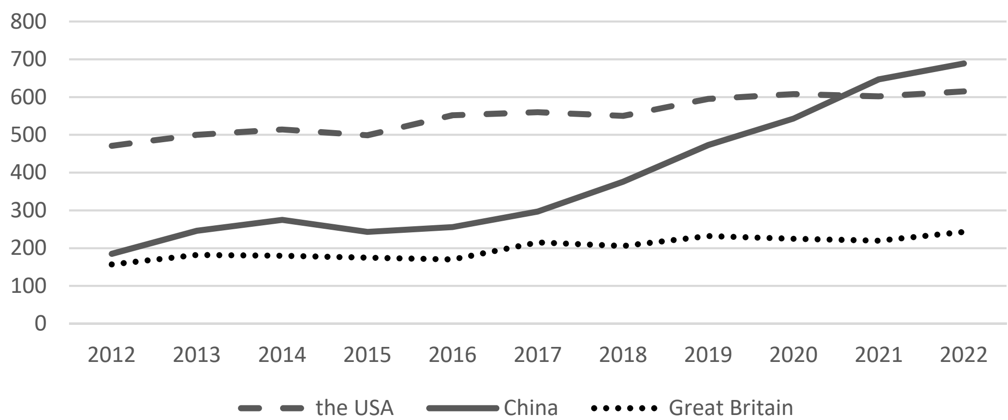

Figure 2. Data on the annual number of publications from the top 3 countries by the number of publications. Note: Compiled by the authors according to the source: https://www.scival.com (accessed on 11 October 2023).

According to the Nature Index, in fact, Chinese researchers came out on top in terms of publications in the field of Earth and environmental sciences in 2022 [17].

A determining factor in the growth of the volume of the scientific research in China is mainly public investments in the research and development field. Thus, in 2021 they reached 2.4% of GDP (2nd place in the world in terms of R&D funding) [18], which is associated with the 14 long-term goals of the country's development established by the five-year plan, which determine, among other things, tasks of dealing with environmental problems. In addition, China is constantly expanding and deepening international cooperation by opening joint laboratories and implementing scientific projects.

In the total volume of publications, the share of European authors is 34.8%, and the highest publication activity is shown for researchers from Great Britain, the Netherlands, France, Spain and Germany.

The top five universities with the largest number of publications in the studied subject area include the following: Chinese Academy of Sciences, Wageningen University of Science and Technology (the Netherlands), Development Research Institute (France); Beijing Normal University, National Institute for Agricultural Research of France and National Center for Scientific Research of France.

Among the most productive authors, researchers from the Netherlands, China and the USA predominate. A. Hoekstra (University of Twente, the Netherlands) and K. Hipel (Center for Innovation in International Management, Canada) have more than 100 publications on water management issues.

As a rule, the most productive authors also have the most scientific influence, as evidenced by the Citation Count and Field-Weighted Citation Impact. Thus, among the top 10 authors in terms of the number of publications in the field of water management, 8 have a Field-Weighted Citation Impact greater than 1, and for 3 authors it is in the range of 4–6. The total number of citations for each researcher exceeds 1000. The most-cited studies are those of Hoekstra (University of Twente, the Netherlands)—over 13,000; Wada (International Institute for Applied Systems Analysis, Laxenburg, Austria)—more than 9000; Kummu (Aalto University, Finland)—more than 6000.

The number of journals that publish research in the field of water management is quite large. At the same time, a large number of very authoritative journals from the 1st and 2nd quartiles can be highlighted. The greatest scientific productivity is associated with the publishing world of the UK and the Netherlands, as each of which has four journals from the top 10 publications with works in the studied subject area. A large number of papers are published in the IOP Conference Series: Earth and Environmental Science.

Table 1 shows the top 10 journals by the number of publications on water management issues. As can be seen from the above data, the scientific impact of articles published in these journals is quite high: the average number of citations per article is in the range from 10 to 30. It should be noted that, in general, the share of publications by European authors in the total volume of publications is quite low—34.8%. The leaders in this subject area are the countries of America, Africa and Asia, experiencing a shortage of water resources. Among European countries, the greatest publication activity is shown for Great Britain, the Netherlands, France, Spain and Germany. At the same time, the large number of scientific collaborations should be noted.

Table 1. Top 10 journals by number of publications on water management issues *.

Journal Title	Country	Quartile	Number of Publications	Citation Count
Water (Switzerland)	Switzerland	Q1	769	9999
Journal of Cleaner Production	Great Britain	Q1	397	11,539
Sustainability	Switzerland	Q1	385	4406
Water Resources Management	the Netherlands	Q1	371	8124
Science of the Total Environment	the Netherlands	Q1	316	9993
Water Policy	Great Britain	Q2	314	3354
Water International	Great Britain	Q2	287	4671
Agricultural Water Management	the Netherlands	Q1	281	6607
International Journal of Water Resources Development	Great Britain	Q1	275	4384
Journal of Hydrology	the Netherlands	Q1	251	7881

* Note: Compiled by the authors according to the sources: https://www.scimagojr.com/ and https://www.scival.com (accessed on 11 October 2023).

At the same time, a change in the share of publications in these journals over the years can be observed. From 2012–2013, publications in the "*Journal of Hydrology*", "*Water*", "*Water Resources Management*" with the promotion of the idea of the central role of water in the functioning of regional ecosystems prevailed, then, starting from 2015, the leading positions are occupied by the "*Journal of Cleaner Production*", "*Sustainability*", "*Science of the Total Environment*", which represent interdisciplinary research aimed at reaching sustainability of the development of regions and creating society based on innovation. Moreover, in 2022, the *Science of the Total Environment* journal, which presents studies of the complex interaction of the hydrosphere, anthroposphere and biosphere, became the leader in the number of publications in the field of water management aimed at sustainable development.

Another interesting fact is the increase in publications in open access journals from 12% in 2012 to 18% in 2022. Despite concerns expressed that open access journals with paid publication for authors increase the risk of dissemination of low-quality articles, studies show that "predatory" open access journals do not show significant progress in terms of their scientific impact and cannot represent a serious threat to the development of the scientific community [19].

3.2. Subject Field of the Research

In order to understand the subject field of the research opportunities in water management issues, we will analyze the relationship of keywords in scientific papers published during the study period (Figure 3), assuming that the keywords adequately reflect the content of the study.

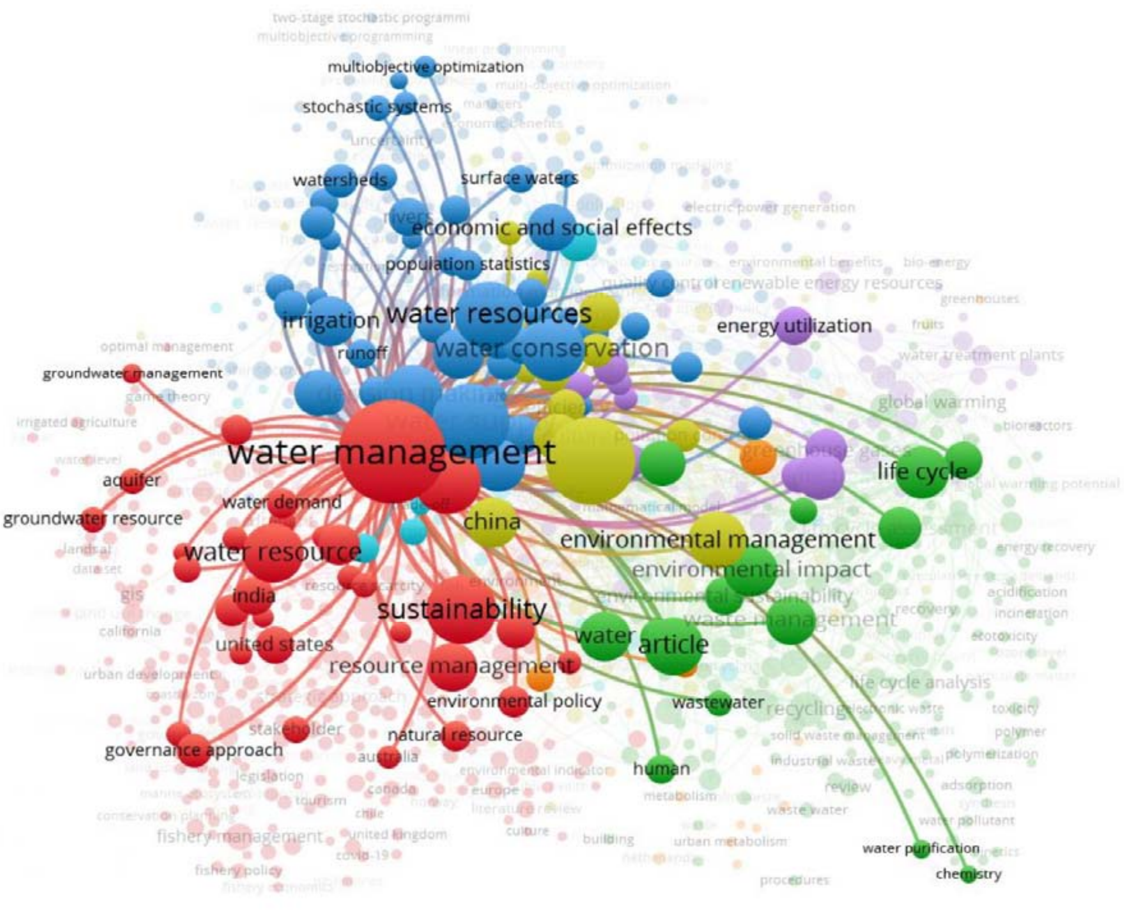

Figure 3. The relationship of keywords in publications on water management issues.

The location of keywords in different nodes reflects the relationship between the content of individual publications. Analysis of the relationship of keywords, as noted by Dorin et al., enables determination of the most popular topics among researchers and identification of the main areas of the scientific research [20].

The results of the analysis using VOSviewer tools demonstrate the presence of five thematic clusters, the priority of which is as follows: environmental management in the field of water use; decision-making methods in the field of rational use of water resources; use of water resources in circular economy business models; water management practices in different countries.

Within the framework of the first thematic cluster, the dominant direction of the research is the search for the most effective technologies, mechanisms and tools for the implementation of environmental activities as a result of environmental impacts associated with water resources. At the same time, the methodological basis of the research in recent years has been represented by the concept of "water–energy–food", based on the ideas of intersectoral multi-level management of interconnected systems of water supply, food and energy. This concept has evolved from the concept of integrated water resources management, but in its development it focuses not on the water sector but on a wide range of sectors and institutions, providing great opportunities for discovering synergies and minimizing trade-offs [21].

Researchers offer various models that optimize sustainability in the linkage of "water–energy–food" [22,23]. Optimization of this relationship is most often considered by researchers in terms of solving the problems of the water crisis in agriculture [24,25], to increase the sustainability of the development of various sectors of industry [26] and urban agglomerations [27,28]. As noted by L. Wu et al., the essence of the "water–energy–food" concept is expressed not only in the need to find compromise solutions but also in the direction of interaction that provides synergy depending on the policy being developed [24]. At the same time, P. Lalawmpuii believes that the methodology of the "water–energy–food" relationship can significantly strengthen the circular economy, opening up new opportunities for it [29].

However, as noted by D. Vargas et al., the concept of the "water–energy–food" relationship is still predominantly a theoretical construct and requires changes in intersectoral market strategies and management regimes [30]. In this regard, the need to study the issues of economic incentives for the water, energy and food sectors to implement strategic interactions is obvious.

As noted by E. Villicaña-García et al., at present, the issues of managing trade-offs are relatively well developed [31]. Most often, the main task of developing such compromise scenarios is related to balancing the interests of various sectoral and regional consumers of water resources. To meet the various and often conflicting requirements for the quality and volume of water resources necessary for the implementation of efficient production and economic activities on the part of various actors, researchers suggest using optimization models for the rational distribution of water resources, taking into account their multi-purpose nature [32]. At the same time, the behavioral aspects of the parties involved in the interaction and the modeling of their relationship remain an understudied topic.

Within the framework of the second thematic cluster, the studies are related to: (a) the use of modern innovative technologies for solving various management tasks in the field of improving the efficiency of water management; (b) the assessment of the effectiveness of the use of water resources and the analysis of the risks of inefficient water management.

Thus, Fu G., Jin Y. et al. consider the possibilities of using artificial intelligence in managing urban water resources [33]. P. Vandôme et al. explore the possibilities of improving the efficiency of water management in agriculture based on the use of digital technologies in irrigation systems [34]. In the article written by Li X., Luo J. et al., it is proposed to use the model of digital twins to solve the problems of increasing the environmental sustainability of cities by reducing the level of their waterlogging [35]. At the same time, researchers note that, compared to other industries, the level of innovation in the field of water management is rather low, since this sector is characterized by a high level of uncertainty in the relationship between innovation and water problems [36,37].

There are also a number of studies related to assessing the effectiveness of water resources use and determining risks of inefficient water management [38,39]. In evaluating the effectiveness of water management, researchers either focus on one component of sustainable development or consider the balance of socio-economic and environmental benefits. As Tang Y., Zhou Q. et al. note, constant auditing of water resources assets and drawing up their balance on this basis are important for ensuring the water security of a country and a region [40]. From the point of view of ensuring economic sustainability, the GRP water intensity indicator is most often used as a criterion for the effectiveness of water management [41,42]. From the standpoint of balancing economic efficiency and social equality, researchers propose to use the indicator of the magnitude of economic benefits per unit of wastewater emission [43].

Among the obstacles to the effective management of water resources, researchers often highlight the lack of proper systems for monitoring and controlling the state of water resources. To solve this problem, scientists propose the use of modern digital technologies that provide synergy of machine learning methods and statistical and dynamic models. In particular, the study of Xu H., Berres A. et al. reviews the applications of visual computing for water management [2] and the study of Phan Th., Bertone E., Stewart, R. focuses on applications of system dynamics [3].

However, despite the fact that in recent years the number of articles on the possibility of using digital technologies in water management systems has increased significantly, there is a lack of research in the scientific community based on primary data from the analysis of the effects of digitalization in terms of creating prerequisites for increasing sustainability and regional development. Therefore, this area needs further study.

The third thematic cluster is related to the study of the possibility of using water resources in the business models of the circular economy. The possibilities of reducing the water intensity of GRP are most often considered by researchers when substantiating the feasibility of using closed-loop business models to increase the sustainability of regional development [44,45]. To a greater extent, the possibilities of treated wastewater reuse are considered in relation to solving the problems of increasing the sustainability of regional agriculture functioning [46–48] and the urban sector [49]. The recommendations contained in scientific articles are aimed at overcoming a significant number of organizational, economic, technical and social barriers that is necessary for the implementation of business models for water reuse. In particular, Mihai F.-C., Minea I., Ulman S.-R. draw attention to the fact that circular economy initiatives related to water management should be interrelated with solving the problems of improving the water supply infrastructure [50]. Breitenmoser L., Quesada G. et al. emphasize the importance of cooperation between individual water management bodies in different regions [51].

It is expected that the transition to a circular economy in the water sector will solve many problems of increasing the sustainability of the development of regional economies. However, despite the potentially significant opportunities for the implementation of circular business models in the water sector, there is a clear need to study the possibility of their application in certain sectors of the economy, taking into account the existing industry and regional specifics. As noted by Koseoglu-Imer D., Oral H. et al., the biggest problem of reusing purified water is related to the existing geographic differences, reflected in different treatment standards, rules for use in certain sectors of the economy and so on [52].

Finally, the fourth thematic cluster includes publications that reflect the problems of water management in individual countries in the context of their sustainable development challenges. It is important to note here that the priority research topics are determined by: (1) the level of water supply of the country and its regions and, accordingly, the issues of rational water use that they face, (2) the level of socio-economic development of the country, which determines the possibility of solving the problems of improving the efficiency of resources. Accordingly, researchers in densely populated and semi-arid countries of Africa, Asia and Latin America pay much attention to the issues of increasing the sustainability of urban water supply by overcoming infrastructural and administrative barriers [53–57] and tasks of solving food security problems on the basis of efficient irrigation and water saving [58–61].

It is also typical for developing countries to consider various aspects of the functioning of the water market. At the same time, the solution to the problems of increasing sustainability is often considered within the framework of fair pricing in the water market [62–65].

The most pressing issue for the most-developed countries is the use of modern digital technologies (artificial intelligence, big data, digital twins, etc.) in water management systems [66–69].

It should be noted that, regardless of the range of problems being solved, almost all modern research is based on the concept of "water–energy–food", which once again emphasizes that the modern vector of the research in the field of water management for sustainable development is associated with the consideration of issues of building effective intersectoral interactions.

4. Discussion

The review of bibliographic sources in the field of water management in the subject area of economics, econometrics and finance and business, management and accounting showed that despite the identification of several thematic areas, in recent years, scientific research within all of them has been carried out within the framework of the concept of "water–energy–food". However, there are no significant geographic differences in the perception of water management issues aimed at improving development sustainability. This enables us to say that, regardless of the socio-economic problems existing in each region, the key tasks of improving the efficiency of water resources management, which have the highest priority, are: the implementation of circular business models for the use of water resources (environmental perspective); development of a competitive market for water resources (economic perspective); increasing the availability of water resources (social perspective). Therefore, the authors are in favor of uniting the efforts of different countries in relation to solving the problems of effective management of water resources.

From the point of view of scientific influence, the highest citation rates and popularity are for publications related to the study of the following issues: assessment of the water footprint—the volume of water consumption by individual industries and areas of activity; forecasting the impact of various factors (climatic, socio-economic, etc.) on the water security of countries and regions. Along with this, publications on the problems of fair pricing in the water market have a high level of popularity (Table 2).

Table 2. Topics of publications on water management issues with the highest indicators of scientific impact *.

Subject	Number of Publications	Field-Weighted Citation Impact	Prominence Percentile
Production and consumer water footprint	5039	1.63	99.8
Water market, pricing for water resources	1117	1.08	92.8
Hydropower	1019	1.02	96.9
Political ecology	878	1.67	92.2
Water resources and climate change	482	1.18	88.3
Water security	420	1.03	89.1

* Note: Compiled by the authors according to the sources: https://www.scimagojr.com/ and https://www.scival.com (accessed on 11 October 2023).

The results of this study demonstrate that the popularity of water management issues is growing in the world scientific space. The centers of knowledge that form the vector of the scientific research are the USA and the Netherlands, but in recent years, the work of Chinese scientists has become increasingly important. However, despite the change in the geographical landscape of the research towards China, its long-term leadership in the field of the research on the issues of water management aimed at sustainable development seems doubtful. As S. Baker notes, in recent years, China has become more and more confident in the independent training of researchers without the help of Western universities [70]. According to new guidelines from China's Ministry of Education, researchers must publish at least 1/3 of articles in representative Chinese journals. As a result, a decrease in the flow of articles to international journals is expected, as well as a decrease in the level of international cooperation, signs of which have been already noted by researchers [71].

5. Conclusions

The results of this study demonstrate that bibliometric analysis allows us to assess the current state of the studied subject area.

In particular, it can be stated that the problem of improving the efficiency of water management aimed at achieving the goals of sustainable development is a popular topic of scientific research. This can be clearly explained by the policy of increasing Earth health implemented by many countries. From the point of view of the geography of the study, they most often focus on regions with water scarcity.

The articles that were selected for this study belong to the subject areas of economics, econometrics and finance and business, management and accounting.

The results of this study showed that the problems of environmental management in the field of water use, decision-making methods in the field of rational use of water resources and issues of using water resources in the business models of the circular economy have become the priority areas of research in recent years. At the same time, the concept of the relationship between water, energy and food, which prevails in the research methodology, enables focus not only on the need for finding a compromise but also identifying the synergistic effects of intersectoral interaction.

Despite the change in the number of publications in favor of free access journals of the publishing world in a number of European and Asian countries, high-ranking journals from Great Britain and the Netherlands still show the highest scientific productivity. At the same time, there is an increase in the activity of research of Chinese scientists in the study of water management issues aimed at increasing the sustainability of regional development, which is the result of the country's long-term policy in the field of scientific development.

It is noted by the authors that the potential for the development of research in the field of water management in the context of solving the problems of sustainable development of regions is associated with the search for the possibility of revealing the synergy of intersectoral interactions, taking into account their industry and regional specifics. It is also necessary to obtain empirical knowledge about the effects arising from the implementation of new approaches to water management, using new technologies and business models.

The main limitation of our research is that the information base for the analysis was Scopus data, which presents mainly the works of English-speaking authors. This database does not reflect studies published in other languages. Therefore, of course, in order to obtain a more accurate idea of how world science in the field of water management is developing it is necessary to study in more detail the data provided by other scientific databases. Therefore, further research by the authors will continue in this direction.

Author Contributions: Conceptualization, I.V.M., O.C. and Z.M.; methodology, I.V.M. and O.C.; software, I.V.M., O.C. and Z.M.; formal analysis, I.V.M., O.C. and Z.M.; investigation, O.C. and Z.M.; resources, Z.M.; data curation, I.V.M., O.C. and Z.M.; writing—original draft preparation, I.V.M., O.C. and Z.M.; writing—review and editing, O.C. and Z.M.; visualization, O.C.; supervision, I.V.M., O.C. and Z.M.; project administration, I.V.M., O.C. and Z.M.; funding acquisition, Z.M. All authors have read and agreed to the published version of the manuscript.

Funding: The publication was prepared as part of the State Assignment of the Southern Scientific Centre of the Russian Academy of Sciences, project "Strategic vectors of development of the social and economic complex of South of Russia, taking into account regional resilience (economic and demographic aspects)", state registration No. 122020100349-6.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Gribova, E.V. Environmentally sustainable management of water resources. *Natl. Interests Priorities Saf.* **2015**, *2*, 22–35.
2. Xu, H.; Berres, A.; Liu, Y.; Allen-Dumas, M.R.; Sanyal, J. An overview of visualization and visual analytics applications in water resources management. *Environ. Model. Softw.* **2022**, *153*, 105396. [CrossRef]
3. Phan, T.D.; Bertone, E.; Stewart, R.A. Critical review of system dynamics modelling applications for water resources planning and management. *Clean. Environ. Syst.* **2021**, *2*, 100031. [CrossRef]
4. Hernández-Cruz, A.; Sandoval-Solís, S.; Mendoza-Espinosa, L.G. An overview of modeling efforts of water resources in Mexico: Challenges and opportunities. *Environ. Sci. Policy* **2022**, *136*, 510–519. [CrossRef]
5. Yang, X.; Sun, B.; Lei, S.; Li, F.; Qu, Y. A bibliometric analysis and review of water resources carrying capacity using rené descartes's discourse theory. *Front. Earth Sci.* **2022**, *10*, 970582. [CrossRef]
6. Bennett, A.; Demaine, J.; Dorea, C.; Cassivi, A. A bibliometric analysis of global research on drinking water and health in low- and lower-middle-income countries. *J. Water Health* **2023**, *21*, 417–438. [CrossRef]
7. Ahmed, M.E.; Zafar, A.M.; Hamouda, M.A.; Hassan, A.A.; Arimbrathodi, S. Biodesalination Research Trends: A Bibliometric Analysis and Recent Developments. *Sustainability* **2022**, *15*, 16. [CrossRef]
8. Nikitaeva, A.Y.; Chernova, O.A.; Dolgova, O.I. Conceptualization for Decision-Making on Circular Economy Development in the Russian Black Sea Regions. *Reg. Econ. South Russ.* **2022**, *10*, 62–175. [CrossRef]
9. Yang, D.; Yang, Y.; Xia, J. Hydrological cycle and water resources in a changing world: A review. *Geogr. Sustain.* **2021**, *2*, 115–122. [CrossRef]
10. Bello, A.S.; Zouari, N.; Da'Ana, D.A.; Hahladakis, J.N.; Al-Ghouti, M.A. An overview of brine management: Emerging desalination technologies, life cycle assessment, and metal recovery methodologies. *J. Environ. Manag.* **2021**, *288*, 112358. [CrossRef]
11. Rana, I.A. Disaster and climate change resilience: A bibliometric analysis. *Int. J. Disaster Risk Reduct.* **2020**, *50*, 101839. [CrossRef]
12. Kim, B.J.; Jeong, S.; Chung, J.-B. Research trends in vulnerability studies from 2000 to 2019: Findings from a bibliometric analysis. *Int. J. Disaster Risk Reduct.* **2021**, *56*, 102141. [CrossRef]
13. Donthu, N.; Kumar, S.; Mukherjee, D.; Pandey, N.; Lim, W.M. How to conduct a bibliometric analysis: An overview and guidelines. *J. Bus. Res.* **2021**, *133*, 285–296. [CrossRef]
14. Junni, P.; Sarala, R.M.; Taras, V.; Tarba, S.Y. Organizational Ambidexterity and Performance: A Meta-Analysis. *Acad. Manag. Perspect.* **2013**, *27*, 299–312. [CrossRef]
15. Combs, J.G.; Ketchen, J.K., Jr.; Crook, T.R.; Roth, P.L. Assessing Cumulative Evidence within 'Macro' Research: Why Meta-Analysis Should be Preferred Over Vote Counting. *J. Manag. Stud.* **2011**, *48*, 178–197. [CrossRef]
16. MacCoun, R.J. Biases in the interpretation and use of research results. *Annu. Rev. Psychol.* **1998**, *49*, 259–287. [CrossRef]
17. Tables: Countries/Territories—Earth & Environmental Sciences. Available online: https://www.nature.com/nature-index/annual-tables/2023/country/earth-and-environmental/all (accessed on 11 October 2023).
18. National Bureau of Statistics of China. Available online: http://www.stats.gov.cn/enGliSH/ (accessed on 15 September 2017).
19. Chernova, O. The effect of Open Access on scientometric indicators of Russian economic journals. *Upravlenets* **2022**, *13*, 69–82. [CrossRef]
20. Maier, D.; Maier, A.; Aşchilean, I.; Anastasiu, L.; Gavriş, O. The Relationship between Innovation and Sustainability: A Bibliometric Review of the Literature. *Sustainability* **2020**, *12*, 4083. [CrossRef]
21. Hülsmann, S.; Sušnik, J.; Rinke, K.; Langan, S.; van Wijk, D.; Janssen, A.B.; Mooij, W.M. Integrated modelling and management of water resources: The ecosystem perspective on the nexus approach. *Curr. Opin. Environ. Sustain.* **2019**, *40*, 14–20. [CrossRef]
22. Núñez-López, J.M.; Rubio-Castro, E.; Ponce-Ortega, J.M. Optimizing resilience at water-energy-food nexus. *Comput. Chem. Eng.* **2022**, *160*, 107710. [CrossRef]
23. Mansour, F.; Al-Hindi, M.; Najm, M.A.; Yassine, A. Multi-objective optimization for comprehensive water, energy, food nexus modeling. *Sustain. Prod. Consum.* **2023**, *38*, 295–311. [CrossRef]
24. Wu, L.; Elshorbagy, A.; Helgason, W. Assessment of agricultural adaptations to climate change from a water-energy-food nexus perspective. *Agric. Water Manag.* **2023**, *284*, 108343. [CrossRef]
25. Zolghadr-Asli, B.; McIntyre, N.; Djordjevic, S.; Farmani, R.; Pagliero, L. The sustainability of desalination as a remedy to the water crisis in the agriculture sector: An analysis from the climate-water-energy-food nexus perspective. *Agric. Water Manag.* **2023**, *286*, 108407. [CrossRef]
26. Navarro-Ramírez, V.; Ramírez-Hernandez, J.; Gil-Samaniego, M.; Rodríguez-Burgueño, J.E. Methodological frameworks to assess sustainable water resources management in industry: A review. *Ecol. Indic.* **2020**, *119*, 106819. [CrossRef]
27. Huang, D.; Wen, F.; Li, G.; Wang, Y. Coupled development of the urban water-energy-food nexus: A systematic analysis of two megacities in China's Beijing-Tianjin-Hebei area. *J. Clean. Prod.* **2023**, *419*, 138051. [CrossRef]

28. Ding, T.; Fang, L.; Chen, J.; Ji, J.; Fang, Z. Exploring the relationship between water-energy-food nexus sustainability and multiple ecosystem services at the urban agglomeration scale. *Sustain. Prod. Consum.* **2023**, *35*, 184–200. [CrossRef]
29. Lalawmpuii; Rai, P.K. Role of water-energy-food nexus in environmental management and climate action. *Energy Nexus* **2023**, *11*, 100230. [CrossRef]
30. Vargas, D.C.M.; Hoyos, C.d.P.Q.; Manrique, O.L.H. The water-energy-food nexus in biodiversity conservation: A systematic review around sustainability transitions of agricultural systems. *Heliyon* **2023**, *9*, e17016. [CrossRef]
31. Villicaña-García, E.; Cansino-Loeza, B.; Ponce-Ortega, J.M. Applying the "matching law" optimization approach to promote the sustainable use of resources in the water-energy-food nexus. *Sustain. Prod. Consum.* 2023, *in press*. [CrossRef]
32. He, Y.; Tu, Y.; Liu, J.; Shi, H.; Lev, B. Quartet trade-off for regional water resources allocation optimization with multiple water sources: A decentralized bi-level multi-objective model under hybrid uncertainty. *J. Hydrol.* **2023**, *619*, 129341. [CrossRef]
33. Fu, G.; Jin, Y.; Sun, S.; Yuan, Z.; Butler, D. The role of deep learning in urban water management: A critical review. *Water Res.* **2022**, *223*, 118973. [CrossRef]
34. Vandôme, P.; Leauthaud, C.; Moinard, S.; Sainlez, O.; Mekki, I.; Zairi, A.; Belaud, G. Making technological innovations accessible to agricultural water management: Design of a low-cost wireless sensor network for drip irrigation monitoring in Tunisia. *Smart Agric. Technol.* **2023**, *4*, 100227. [CrossRef]
35. Li, X.; Luo, J.; Li, Y.; Wang, W.; Hong, W.; Liu, M.; Li, X.; Lv, Z. Application of effective water-energy management based on digital twins technology in sustainable cities construction. *Sustain. Cities Soc.* **2022**, *87*, 104241. [CrossRef]
36. O'callaghan, P.; Adapa, L.M.; Buisman, C. How can innovation theories be applied to water technology innovation? *J. Clean. Prod.* **2021**, *276*, 122910. [CrossRef]
37. Wehn, U.; Vallejo, B.; Seijger, C.; Tlhagale, M.; Amorsi, N.; Sossou, S.K.; Genthe, B.; Onema, J.M.K. Strengthening the knowledge base to face the impacts of climate change on water resources in Africa: A social innovation perspective. *Environ. Sci. Policy* **2021**, *116*, 292–300. [CrossRef]
38. Mitrofanova, I.; Chernova, O.; Pyankova, S.; Kleitman, E. Environmental and Economic Risks in Estimating Investment Potential of Coastal Areas of the South of Russia. *Int. J. Qual. Res.* **2021**, *15*, 961–976. [CrossRef]
39. Chen, X.; Zheng, Y.; Xu, B.; Wang, L.; Han, F.; Zhang, C. Balancing competing interests in the Mekong River Basin via the operation of cascade hydropower reservoirs in China: Insights from system modeling. *J. Clean. Prod.* **2020**, *254*, 119967. [CrossRef]
40. Tang, Y.; Zhou, Q.; Jiao, J.-L. Evaluating water ecological achievements of leading cadres in Anhui, China: Based on water resources balance sheet and pressure-state-response model. *J. Clean. Prod.* **2020**, *269*, 122284. [CrossRef]
41. Matveeva, L.G.; Chernova, O.A.; Kosolapova, N.A.; Kosolapov, A.E. Assessment Of Water Resources Use Efficiency Based on the Russian Federation's Gross Regional Product Water Intensity Indicator. *Reg. Stat.* **2018**, *8*, 154–169. [CrossRef]
42. Kosolapov, A.; Matveeva, L.; Chernova, O.; Kosolapova, N. Efficiency of water resource use in economics of the north Caucasus mountain territories. *Sustain. Dev. Mt. Territ.* **2018**, *10–11*, 48–62. [CrossRef]
43. Yuan, M.; Chen, X.; Liu, G.; Ren, H. Coordinated allocation of water resources and wastewater emission permits based on multi-objective optimization model: From the perspective of conflict between equity and economic benefits. *J. Clean. Prod.* **2022**, *372*, 133733. [CrossRef]
44. Kosolapova, N.; Matveeva, L.; Nikitaeva, A.; Chernova, O. The drivers of the circular economy: Theory vs. practice. *Terra Econ.* **2023**, *21*, 68–83. [CrossRef]
45. Mannina, G.; Gulhan, H.; Ni, B.-J. Water reuse from wastewater treatment: The transition towards circular economy in the water sector. *Bioresour. Technol.* **2022**, *363*, 127951. [CrossRef] [PubMed]
46. Ofori, S.; Puškáčová, A.; Růžičková, I.; Wanner, J. Treated wastewater reuse for irrigation: Pros and cons. *Sci. Total Environ.* **2021**, *760*, 144026. [CrossRef]
47. Ricart, S.; Rico, A.M. Assessing technical and social driving factors of water reuse in agriculture: A review on risks, regulation and the yuck factor. *Agric. Water Manag.* **2019**, *217*, 426–439. [CrossRef]
48. Dziedzic, M.; Gomes, P.R.; Angilella, M.; El Asli, A.; Berger, P.; Charmier, A.J.; Chen, Y.-C.; Dasanayake, R.; Dziedzic, R.; Ferro, F.; et al. International circular economy strategies and their impacts on agricultural water use. *Clean. Eng. Technol.* **2022**, *8*, 100504. [CrossRef]
49. Hernández-Chover, V.; Castellet-Viciano, L.; Bellver-Domingo, Á.; Hernández-Sancho, F. The Potential of Digitalization to Promote a Circular Economy in the Water Sector. *Water* **2022**, *14*, 3722. [CrossRef]
50. Mihai, F.-C.; Minea, I.; Ulman, S.-R. *Chapter 8—Water Resources Preservation through Circular Economy: The Case of Romania*; Zamparas, M.G., Kyriakopoulos, G.L., Eds.; Water Management and Circular Economy; Elsevier: Amsterdam, The Netherlands, 2023; pp. 143–176. [CrossRef]
51. Breitenmoser, L.; Quesada, G.C.; Anshuman, N.; Bassi, N.; Dkhar, N.B.; Phukan, M.; Kumar, S.; Babu, A.N.; Kierstein, A.; Campling, P.; et al. Perceived drivers and barriers in the governance of wastewater treatment and reuse in India: Insights from a two-round Delphi study. *Resour. Conserv. Recycl.* **2022**, *182*, 106285. [CrossRef]
52. Koseoglu-Imer, D.Y.; Oral, H.V.; Calheiros, C.S.C.; Krzeminski, P.; Güçlü, S.; Pereira, S.A.; Surmacz-Górska, J.; Plaza, E.; Samaras, P.; Binder, P.M.; et al. Current challenges and future perspectives for the full circular economy of water in European countries. *J. Environ. Manag.* **2023**, *345*, 118627. [CrossRef]
53. Burt, Z.; Ercümen, A.; Billava, N.; Ray, I. From intermittent to continuous service: Costs, benefits, equity and sustainability of water system reforms in Hubli-Dharwad, India. *World Dev.* **2018**, *109*, 121–133. [CrossRef]

54. Wang, Z.; Lin, L.; Zhang, B.; Xu, H.; Xue, J.; Fu, Y.; Zeng, Y.; Li, F. Sustainable urban development based on an adaptive cycle model: A coupled social and ecological land use development model. *Ecol. Indic.* **2023**, *154*, 110666. [CrossRef]
55. Tan, S.; Yao, L. Managing and optimizing urban water supply system for sustainable development: Perspectives from water-energy-carbon nexus. *Sustain. Prod. Consum.* **2023**, *37*, 39–52. [CrossRef]
56. Abubakari, M.; Ibrahim, A.-S.; Dosu, B.; Mahama, M. Sustaining the urban commons in Ghana through decentralized planning. *Heliyon* **2023**, *9*, e15895. [CrossRef] [PubMed]
57. Zhou, C.; Gong, M.; Xu, Z.; Qu, S. Urban scaling patterns for sustainable development goals related to water, energy, infrastructure, and society in China. *Resour. Conserv. Recycl.* **2022**, *185*, 106443. [CrossRef]
58. Fishman, R.; Giné, X.; Jacoby, H.G. Efficient irrigation and water conservation: Evidence from South India. *J. Dev. Econ.* **2023**, *162*, 103051. [CrossRef]
59. Zhang, Y.; Li, Y.; Sun, J.; Huang, G. Optimizing water resources allocation and soil salinity control for supporting agricultural and environmental sustainable development in Central Asia. *Sci. Total. Environ.* **2020**, *704*, 135281. [CrossRef]
60. Kotir, J.H.; Smith, C.; Brown, G.; Marshall, N.; Johnstone, R. A system dynamics simulation model for sustainable water resources management and agricultural development in the Volta River Basin, Ghana. *Sci. Total. Environ.* **2016**, *573*, 444–457. [CrossRef]
61. Feng, T.; Liu, B.; Ren, H.; Yang, J.; Zhou, Z. Optimized model for coordinated development of regional sustainable agriculture based on water–energy–land–carbon nexus system: A case study of Sichuan Province. *Energy Convers. Manag.* **2023**, *291*, 117261. [CrossRef]
62. Matveeva, L.G.; Southern Federal University; Chernova, O.A.; Kosolapova, N.A. The Federal Water Resources Agency Pricing Problems in the Competitive Environment of Water-Economic Complex in the Region. *Zhurnal Econ. Teor.* **2020**, *17*, 424–432. [CrossRef]
63. Bajaj, A.; Singh, S.; Nayak, D. Impact of water markets on equity and efficiency in irrigation water use: A systematic review and meta-analysis. *Agric. Water Manag.* **2022**, *259*, 107182. [CrossRef]
64. Nouri, A.; Saghafian, B.; Bazargan-Lari, M.R.; Delavar, M. Local water market development based on multi-agent based simulation approach. *Groundw. Sustain. Dev.* **2022**, *19*, 100826. [CrossRef]
65. Tu, Y.; Shi, H.; Zhou, X.; Lev, B. Optimal trade-off of integrated river basin water resources allocation considering water market: A bi-level multi-objective model with conditional value-at-risk constraints. *Comput. Ind. Eng.* **2022**, *169*, 108160. [CrossRef]
66. Stein, U.; Bueb, B.; Knieper, C.; Tröltzsch, J.; Vidaurre, R.; Favero, F. The diagnostic water governance tool − supporting cross-sectoral cooperation and coordination in water resources management. *Environ. Sci. Policy* **2023**, *140*, 111–121. [CrossRef]
67. Wu, Z.Y.; Chew, A.; Meng, X.; Cai, J.; Pok, J.; Kalfarisi, R.; Lai, K.C.; Hew, S.F.; Wong, J.J. High Fidelity Digital Twin-Based Anomaly Detection and Localization for Smart Water Grid Operation Management. *Sustain. Cities Soc.* **2023**, *91*, 104446. [CrossRef]
68. Chang, F.-J.; Wang, K.-W. A systematical water allocation scheme for drought mitigation. *J. Hydrol.* **2013**, *507*, 124–133. [CrossRef]
69. Goap, A.; Sharma, D.; Shukla, A.K.; Krishna, C.R. An IoT based smart irrigation management system using Machine learning and open source technologies. *Comput. Electron. Agric.* **2018**, *155*, 41–49. [CrossRef]
70. Baker, S. China sees renewed surge in natural sciences. *Nature* **2023**, *620*, S1. [CrossRef]
71. Woolston, C. What China's leading position in natural sciences means for global research. *Nature* **2023**, *620*, S2–S5. [CrossRef]