Artificial Intelligence in Water Conservation : A Meta-Analysis Study

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Abstract

In present times, the protection of the environment and the conservation of natural resources have emerged as the areas that need immediate attention for the survival and sustenance of the human population. One of the most prominent technological advancements is the surge of artificial intelligence (AI) in various fields. Research efforts to apply AI in water conservation (WC) have been made in multiple domains of study. This study involved a bibliographic analysis of such available documents in the combined field of AI and its application in WC. The analysis was performed using the two major databases of research literature: Web of Science and Scopus. Classification of the information was presented based on comprehensive research available, and then a screening was performed to find the open-access documents on the subject. Leading institutions and countries, most cited research works, leading authors, and the journals that contributed to this literature were presented through the analysis. We used VoS viewer and MS Power BI software for the keyword analysis and identification of contributing countries. The analysis of documents of the past two decades from 2000 – 2020 is presented in the study.

Keywords : **artificial intelligence, bibliometric analysis, meta-analysis, technology applications, water management**

JEL Classification Codes : O330, M150, Q250

Paper Submission Date : May 5, 2021 ; Paper sent back for Revision : March 1, 2022 ; Paper Acceptance Date : March 10, 2022; Paper Published Online : March 15, 2022

Artificial intelligence (AI) and its application in various fields have been on a fast growth trajectory. They have gained laces in the shoes, and devices *Alphago* and *Siri* stand as living examples of these developments. AI has also been distinctly classified based on the social, cognitive, or emotional intelligence it presents in its functioning (Haenlien & Kaplan, 2019). Today, the AI is still considered weak AI, as it can only perform the designated tasks, such as performing voice and facial recognition, searching on the internet, or driving cars. The general AI is perhaps outperforming humans in specific ways, such as defeating humans in a chess game or cracking some mathematical problems (Lu et al., 2018).

The emergence of AI can be attributed to its ability to improvise certain daily functions by using algorithms (Johnson et al., 2018). Its applications have been rising in hitherto unexplored fields of application (Kaur & Khanna, 2016). It explains the power of the AI to perform both routine and extraordinary tasks, thus

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DOI : https://doi.org/10.17010/pijom/2022/v15i3/160407

extending its application to extensive fields. Both machine learning and AI are becoming subjects of deep interest in the field of natural and engineering sciences (Palkovits & Palkovits, 2019).

The rapid increase in production and consumption has placed environmental issues at the forefront of society. There is a speedy increase in modern technology like AI in many areas of the environment. One of the significant components connected with climate change is water resources. In the last few decades, there has been a rise in studies based on AI and other algorithms that have been progressively deployed to manage and conserve water resources (Sharma & Gundraniya, 2020).

Several regions in the world have been witnessing droughts since the beginning of the new century, and the water supply has been severely affected in many areas globally. It is expected that due to anthropogenic reasons, there will be an intensified threat of droughts in many places (Diffenbaugh et al., 2015). Studies have highlighted the plight of farming communities that face acute shortages of water resources (Kalra & Mishra, 2014; Khosla, 2012). Water scarcity and droughts have also been identified as the greatest global threats (Shivdas & Chandrasekhar, 2016). These droughts have caused a reduction in per-capita availability of water in economically poor regions (Moglia et al., 2018). The developed nations have also not remained unaffected by this situation. According to the study of Brelsford and Abbott (2017), many cities in the United States and Canada have been seeing a steady drop in the per-capita disposal of water. This phenomenon is quite widespread, and water scarcity has not left any region untouched. Almost all major cities in Australia witnessed a decline in per-capita availability of water in the range of 5% to 48% during the five years of 2004 to 2009 (Rutherfurd & Finlayson, 2011). There has been a sharp fall and continued irregular water supply in South Africa, resulting in a widespread public movement to control this prevailing situation (Onyenankeya et al., 2018).

According to the study by De Clercq et al. (2018), the availability of potable water in China has declined. The same study also indicated that the reduced water supply in Botswana and South Africa is presenting an alarming position. The resulting environmental losses have raised questions on the sustainability of planet Earth (Saarangapani & Sripathi, 2015). Such an alarming situation of water scarcity across the globe demands the establishment of water conservation efforts. An effective means could be developing water conservation models, which can be reliable and effective in overcoming long-term water insecurity (Moglia et al., 2018). The water conservation models using AI could answer this alarming situation.

Background and Rationale of the Study

The innovation in AI has indicated that there is a possibility of developing applications using AI to support the integrated management of water. Several studies have also established the likelihood of developing models based on an algorithm to help develop decision-making and management systems to conserve water resources (Sharma & Gundraniya, 2020).

There are also indications that AI can be successfully deployed in many fields of conservation of natural resources, including weather forecasting (Thornton et al., 2000), land irrigation (Calvo et al., 2009; Raju & Kumar 2006), and water conservation (Manu & Thalla, 2017). The study of AI by Al Aani et al. (2019) has specifically outlined the means through which the use of AI can enhance water conservation efforts. There are several tools and techniques available in AI, such as artificial neural networks (ANNs), genetic algorithms (GAs), and particle swarm optimization (PSO), which can be productively used in the field of water management, conservation, and treatment (Fan et al., 2018).

There is a vast deployment of technology in a varied set of mobile applications, which also are connected to AI (Chakraborty et al., 2021; Chakraborty, 2021; Siddiqui & Siddiqui, 2021). AI tools are becoming widespread and have advanced knowledge in multiple domains. The technology used through the utilization of AI has built capabilities in machines and various fields for the well-being of humans. The growth of AI in medical sciences, pharmacology, and robotics has improved human life and reduced human efforts. However, the survival of human beings is mainly dependent on critical natural resources such as air and water; hence, their conservation is of vital significance for the existence of the human race.

As a domain of knowledge, AI is considered by both industry and academia as a potential source to transform the future due to its applicability across diverse fields. Environmental science and environmental conservation and management are no exception (Deka & Chandramouli, 2009). This research aims to provide a bibliometric analysis of the two terms in this context, AI and WC. This study will enable collating the research articles and other publications combined based on these two terms. The bibliometric analysis will make use of the databases for the determination of trends and contributions from different research fields with a focus on the two identified themes.

This research aims to provide updated and classified information about the literature associated with the two terms. In order to meet this objective, a survey of global literature was performed, followed by a systematic analysis of the data collected from the databases. In order to develop a more profound appreciation of the varied literature, the analysis of various dimensions is presented, such as the country-wise data, subject areas of research, growth in published research over two decades, and the journals that have made substantial publications in these areas. This type of synthesis of information has been established to serve the scholarships in a specific field (Tripathi et al., 2020). The focal point of this research is to provide a bird's eye view of the research that has happened over 20 years.

The research initially captures the unprecedented number of studies that have contributed to AI and WC and then further classifies them through a series of screening procedures and captures the variations in the two specific domains. A synthesis is provided based on commonalities and differentiations in the published research. This research does not aim to present a detailed survey of the literature, but to provide an integrated record of the various disciplines that have contributed to the development of literature in the combined domain of AI and WC. The consolidated information will not only help in assimilating the knowledge domains, but it will also encourage the potential researchers in these domains, providing a direction for future research. This study will enhance the growth in AI in the context of WC and provide an impetus for further growth of literature.

Meta-Analysis

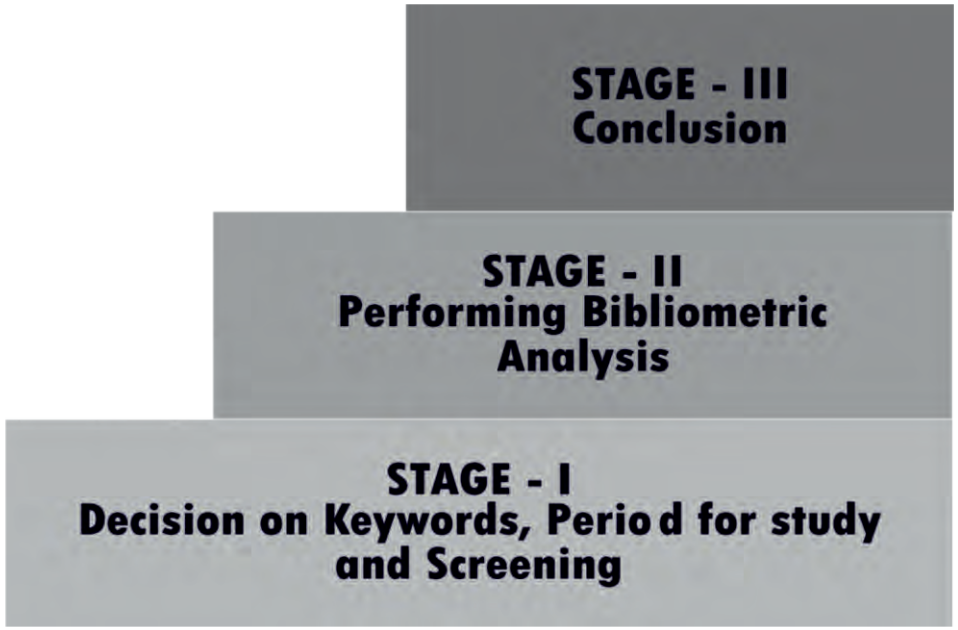
Researchers have widely benefitted from the digital databases of published research works. This mass of scientific knowledge has acted as an enabler of bibliometric methods and techniques. As a technique of analysis of the knowledge databases, bibliometric methods serve to present the information about literature on any subject area. This information helps trace the development of literature in a specific field over a specified period and present quantitative facts in an organized and classified manner. This method is like digging into data mines and extracting selected information on particular subjects. This research is also an effort to provide an organized set of information about research using a combination of AI and WC. The study is done in three different stages, as illustrated in Figure 1. It uses the two most prominent digital databases, Web of Science and Scopus, to aggregate the published documents and then presents them through different classifications. The collected data are analyzed using spreadsheets and graphical illustration tools.

The Results of the Meta - Analysis

Phase I : Research

Looking into the importance of water conservation, it is imperative to identify and understand water conservation methods. Artificial intelligence is one such method. It has become more interesting to understand the trend of

Figure 1. ***Stage-Wise Process of the Study***



academic research undertaken in the last 20 years. This research study comprises three phases. The first phase is further divided into two sections. Section one, "Identification," involves recognizing the documents that qualify for the research using the identified keywords. It is followed by suitably analyzing these documents for the study. The second section, "Screening," is where the documents that have free access and thus that can be referred to for analysis are identified for the bibliometric analysis. These two steps of Stage One are explained below in detail with the help of tables and graphs.

Section A : Identification

Section A of Stage One involves the identification of databases. The databases selected for the study are Web of Science and Scopus. Additionally, relevant keywords were chosen and kept standardized while searching in both databases. The search is done to preserve the uniformity and thus reliability of the results. The identified keywords and the time zone used for the study are as stated in Table 1.

The data extracted from the two selected databases show a vast difference in numbers. Scopus has 300 documents, while Web of Science has 81 documents, as shown in Table 2. In terms of numbers, this lead could be because Scopus is the database owned by Elsevier, which gathers data from a more significant number of other databases compared to the Web of Science.

It is evident from the extracted data that articles dominate the documents in the case of Web of Science and

Table 1. ***Keywords and Period of Analysis***

Keyword	Time Period
Artificial Intelligence	2000 – 2020
Water Conservation	

Table 2. *Total Results of Research on Web of Science and Scopus*

Research Carried on 24.10.2020	
Source of Research	**Total Results**
Web of Science	81
Scopus	300

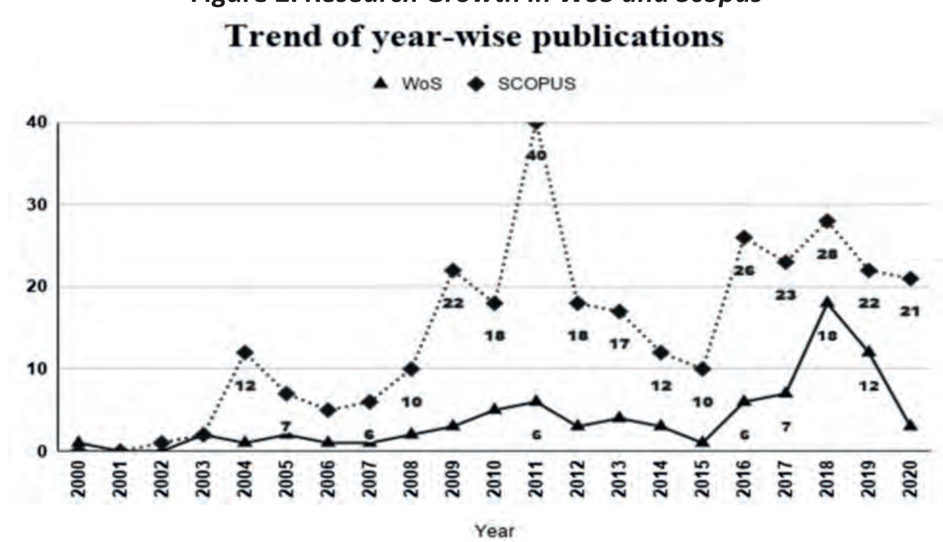
contribute 97.53% of all documents, followed by editorials, which are comparably very low, barely contributing 7.41%. In the case of Scopus, 50.33% of the documents are conference papers followed by an almost equal contribution of articles, that is, 46.33% of the total number of documents. The other types of documents are reviews, book chapters, and conference reviews, and their quantities are depicted in Table 3.

Since its inception, AI has captured the interest of researchers, and in the period considered in the study concerning AI and WC, that is, from 2000 onwards, the research has seen a steady rise. However, a sudden upsurge is noticed during 2011 to the extent of 120%. The following developments can explain this rise during this period. The technology giants started investing substantially in artificial intelligence (Mhlanga, 2020). These investments led to the availability of funds; thus, research and publications received impetus during this phase. The surge in

Table 3. *Document Distribution in WoS and Scopus*

WoS			Scopus		
Document Types	**Records**	**% Contribution**	**Document Types**	**Records**	**% Contribution**
Article	79	97.53	Conference Paper	151	50.33
Editorial	1	7.41	Article	139	46.33
Review	1	2.47	Review	7	2.33
		1.24	Book	1	0.33
		1.24	Book Chapter	1	0.33
		1.24	Conference Review	1	0.33

Figure 2. *Research Growth in WoS and Scopus*



this period can also be ascribed to technological developments that aroused interest in AI (Figure 2). During this year, the term Industry 4.0 was coined in the Hannover Messe 2011, where the industry's transformation utilizing software and technology was mooted (Rüßmann et al., 2015). Hence, AI-related research witnessed a sudden spurt in the year 2011.

Section B : Screening

For in-depth analysis of the documents, it is essential to refer to the complete documents. It is only possible if the data available to us is open access. Hence, in Section Two, the data with restrictions were excluded from the identified data of Section One via the process of screening for both Web of Science and Scopus databases. Due to this step, data from both databases were significantly condensed to 21 items from WoS and 34 items from Scopus, as shown in Table 4.

Table 4. ***Subject Area Filter on Scopus and WoS***

WoS Research Area (Domain)	Scopus Research Area (Domain)
Environmental Sciences Ecology	Environmental Science
Biodiversity Conservation	Agricultural and Biological Sciences
Water Resources	Biochemistry, Genetics, and Molecular Biology
Mathematics	Social Sciences
Agriculture	Earth and Planetary Sciences
Computer Science	Engineering
Geochemistry Geophysics	Computer Science
Science Technology – Other Topics	Decision Sciences
Physical Sciences – Other Topics	Chemistry
Communication	Physics and Astronomy
Geography	Chemical Engineering
Remote Sensing	Materials Science
Energy Fuels	Multidisciplinary
Forestry	
Business Economics	
Geology	
Information Science Library Science	
Marine Freshwater Biology	
Mathematical Computational Biology	
Meteorology Atmospheric Sciences	
Oceanography	
Physical Geography	
Telecommunications	
Automation Control Systems	
Engineering	

Phase II : Analysis Phase

After assessing all the documents of the databases, the analysis phase offers the outcomes of the assessments. The complete data analysis is divided into various subcategories. With a brief outline of the selected documents, each of these subcategories has been discussed one by one.

Most Cited Documents

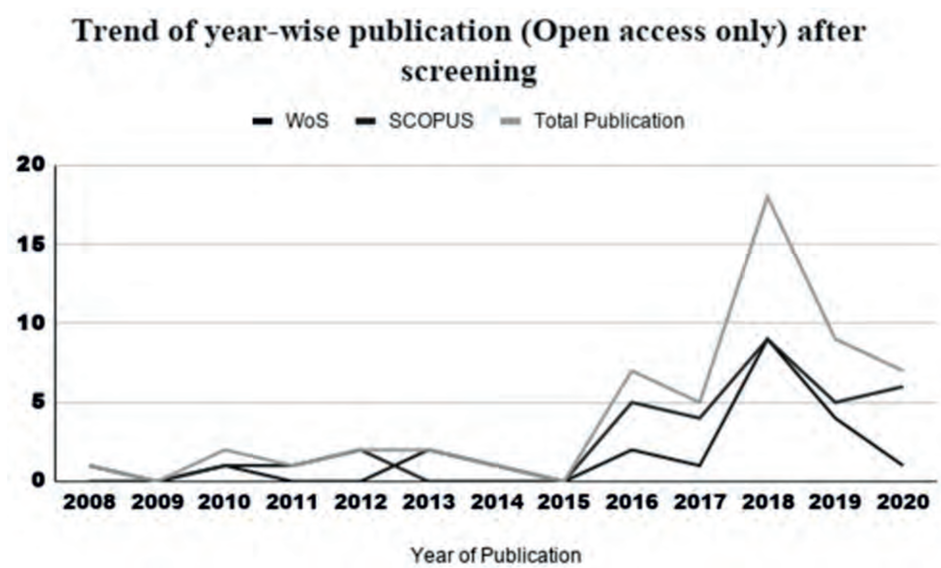
This section lists the most cited documents in WoS and Scopus. The list is organized by author, database, title, year, and citation in WoS or Scopus, as per the research source. The paper authored by Bagstad et al. in 2014 from Web of Science has the highest citation count of 121 citations. This article includes an analysis of five ecosystem services and spatial dynamics, and their effects can be understood from this article. As compared to the studies merely deliberating the facility of theoretical service, a thorough foundation for economic valuation and policy applications can be delivered by this article. This article received an unprecedented number of citations and is, therefore, one of the most productive articles of all.

This article is followed by the study of Granata et al. (2016), with less than half citations. This article compares rainfall-runoff modeling between a support vector machine-based approach and the EPA's stormwater management model. This article has received 55 citations since 2016 and is the second most productive article in terms of citations.

Publications by Years

Figure 3 illustrates the open-access publications as estimated after the screening. These publications demonstrate a different picture in comparison to those in Figure 2. This phenomenon can be explained as the restricted publications were removed from the total publications, and the data reflects only open-access documents. The dip in the research during 2015 conforms to the trend shown in Figure 2 and the rise noticed in 2018. The substantial rise noticed in 2018 is attributed to the noticeable implementation of AI systems in water conservation and allied

Figure 3. ***Year-Wise Publications***



fields such as agriculture, biodiversity, and environmental science and technology. In so far as the decline in the year 2020 is concerned, the studies have again noticed a decline, but as the results have been captured during the middle of October, the figure does not represent the entire year of 2020.

Authors as Collaborators

The data available for extraction from the databases also provide the authors who have formed collaborations for their research. The number of co-authors in the related publications was analyzed to demonstrate the extent of collaborative work being done in AI and WC. As illustrated in Figure 4, the analysis yielded that 95% (50) of studies were done in collaboration, whereas the highest 18% (10) of the published research works were performed with five co-authors. Around 62% (34) of the research was done with the collaboration of four or more co-authors, and it was also noticed that one publication has 14 co-authors. Eighty percent (44) of the studies were published with a range of two to six co-authors. This indicates that collaborating authors are doing the vast majority of the research work in this field.

Analysis of Research Areas

As indicated in the trends of year-wise publications, most studies have taken place after 2011–12, as Industry 4.0 was conceived and propagated during this period. The research areas indicate the spread of subject areas that have contributed to the research in AI and WC. As displayed in Table 5, there are a total of 11 domains that have made research contributions, out of which a maximum contribution of 9% has been made by environmental sciences ecology in the WoS ; whereas, the same field has made a dominant contribution of 6% in the Scopus database; hence, this subject area leads the contribution. The domain of biodiversity conservation is the next contributor, with 6% of published research. Agricultural and biological sciences, biochemistry, genetics, and molecular biology class have contributed 5% each. An equal contribution (5%) has also been made by water resources and mathematics, which indicates the application of cross-domain knowledge in AI and WC. Agricultural and

Figure 4. ***Collaborative Authors***

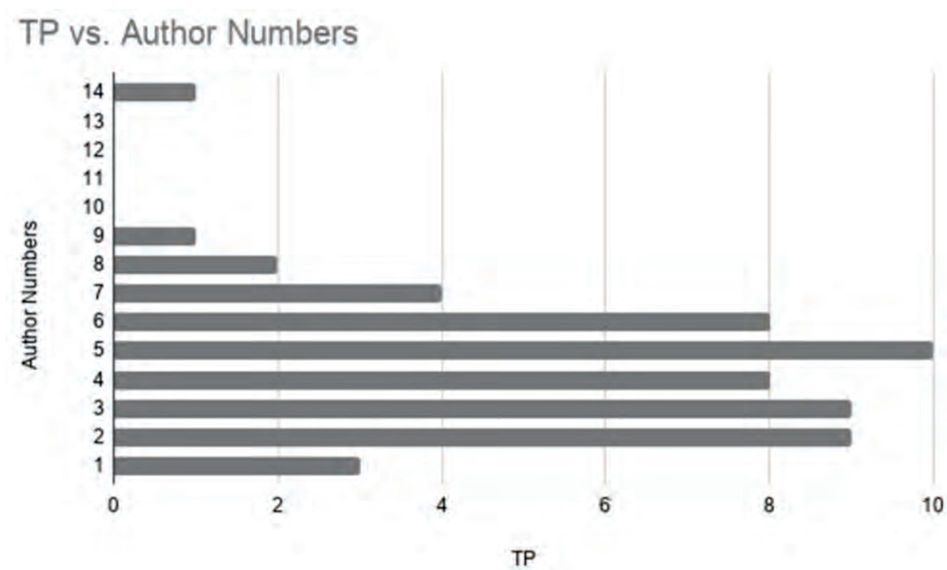


Table 5. *Domain-Wise List of Contribution*

S. No.	Domain	Database	Percentage
1	Environmental Sciences Ecology	WoS	9%
2	Biodiversity Conservation	WoS	6%
3	Environmental Science	Scopus	6%
4	Agricultural and Biological Sciences	Scopus	5%
5	Biochemistry, Genetics, and Molecular Biology	Scopus	5%
6	Water Resources	WoS	5%
7	Mathematics	WoS	5%
8	Social Sciences	Scopus	4%
9	Agriculture	WoS	4%
10	Computer Science	WoS	4%
11	Geochemistry Geophysics	WoS	4%

biological sciences and biochemistry, genetics, and molecular biology contribute 5% each. A surprising contribution of 4% is made by the social sciences field, which is equal to agriculture, geochemistry and geophysics, and computer science. A look across domains indicates a transversal element in the published research, thus making these two themes widely researched across numerous disciplines.

Analysis of Top Source Journals

In this section, the top five journals have been extracted. In the current study, 24 journals published 41 articles. Nineteen out of 24 journals published only one article related to the topic. The contribution of the rest of the five journals is given in Table 6.

As illustrated in Figure 5, *Water Switzerland* is the top journal in the Scopus database, with 22% of the publications. The exceptionally high concentration of articles in this journal, as compared to the other journals, makes it the most productive journal of all. The top journal of Web of Science is known as *Water.* This journal contributed 12% and followed after *Water Switzerland*. *Remote Sensing* occupies the third position by contributing 10%. These three journals are followed by *ISPRS International Journal of Geo-Information* and *Journal of the American Water Resources Association*, with 5% each.

Country Analysis

The analysis performed to identify the leading nations that have given particular emphasis to research in the

Table 6. *Top Five Journals*

Journal Title	Articles	Database	Percentage
Water Switzerland	9	Scopus	22
Water	5	WoS	12
Remote Sensing	4	WoS	10
ISPRS International Journal of Geo Information	2	WoS	5
Journal of the American Water Resources Association	2	Scopus	5

Figure 5. *Most Productive Journals*

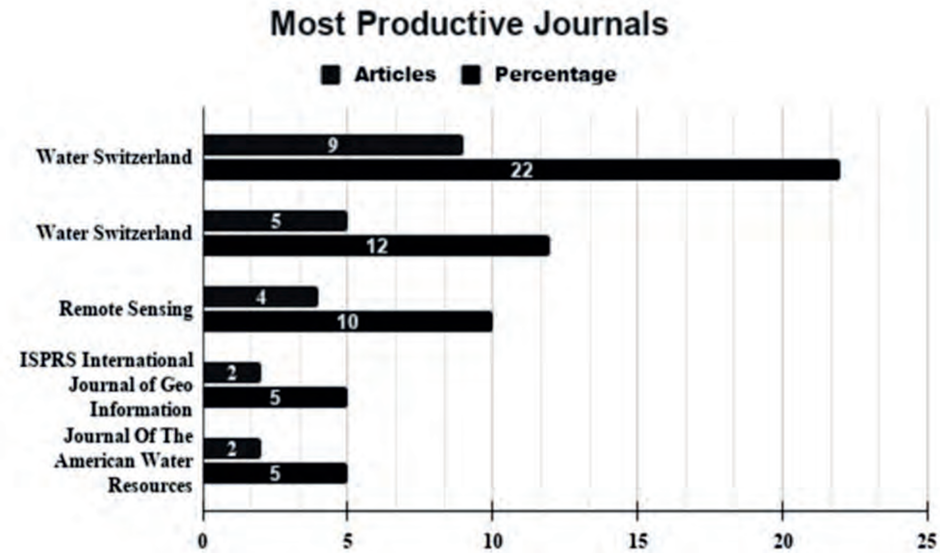


Table 7. ***Contribution of the Top Five Countries***

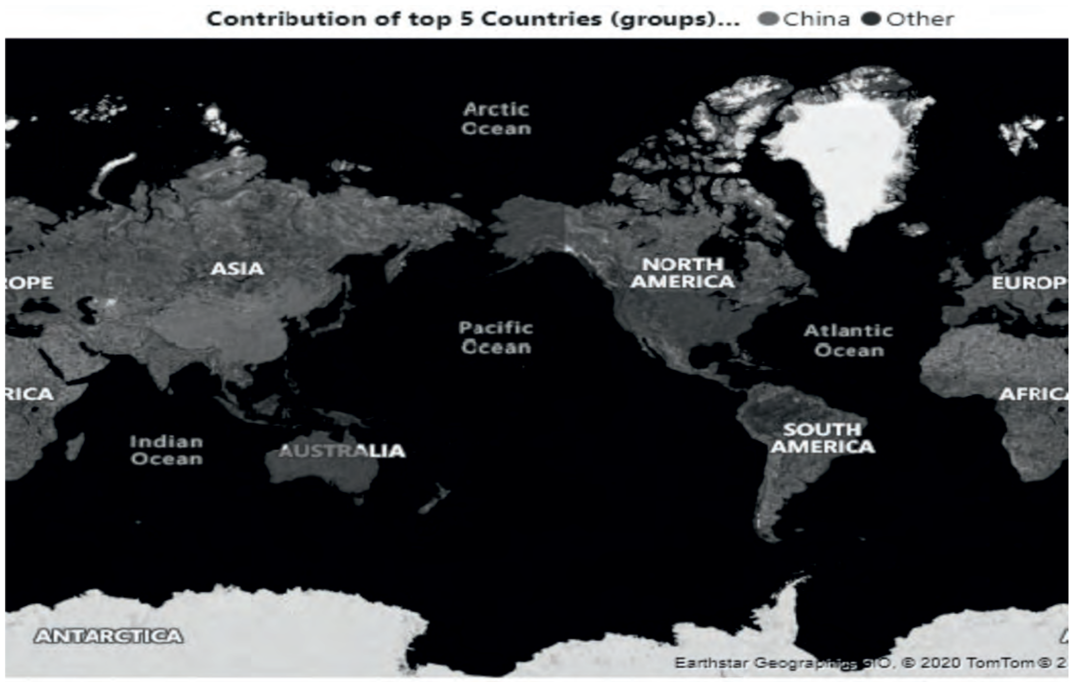
Country	Publications	%
China	22	41%
United States	19	35%
Spain	6	11%
Italy	4	7%
Australia	3	6%

domains of AI and WC yielded that the data on this parameter is skewed towards China and the United States. These two nations jointly produced 76% (41) research publications; China leads with a contribution of 41%, and the United States has a share of 35%. Spain and Italy are the two European nations in the top five nations globally and contributed 11% and 7%, respectively, to the published research. With China being the frontrunner and the highest contributor to the field, as explained in the study by Zhang et al. (2019), there is a sharp increase in the recruitment of AI professionals in China, as there is enormous support for the local industries working in the field of AI. On the other hand, China has, in general, seen a sudden spurt in AI-related research after 2015; in fact, the number of publications in AI was around 200; whereas, it increased to 4,504 publications in 2018, a 34-fold leap compared to the publication in 2010 (Zhang et al., 2020). These results are demonstrated in Table 7 and mapped in Figure 6.

Affiliation Analysis

The WoS and Scopus database analysis produces the results of the institutions to which the authors are affiliated. This information is critical to understanding the institutions that are making contributions to AI and WC. After analyzing the data, it is observed that for a total of 117 publications, there are 107 different institutions to which the

Figure 6. *Top Five Contributing Countries*

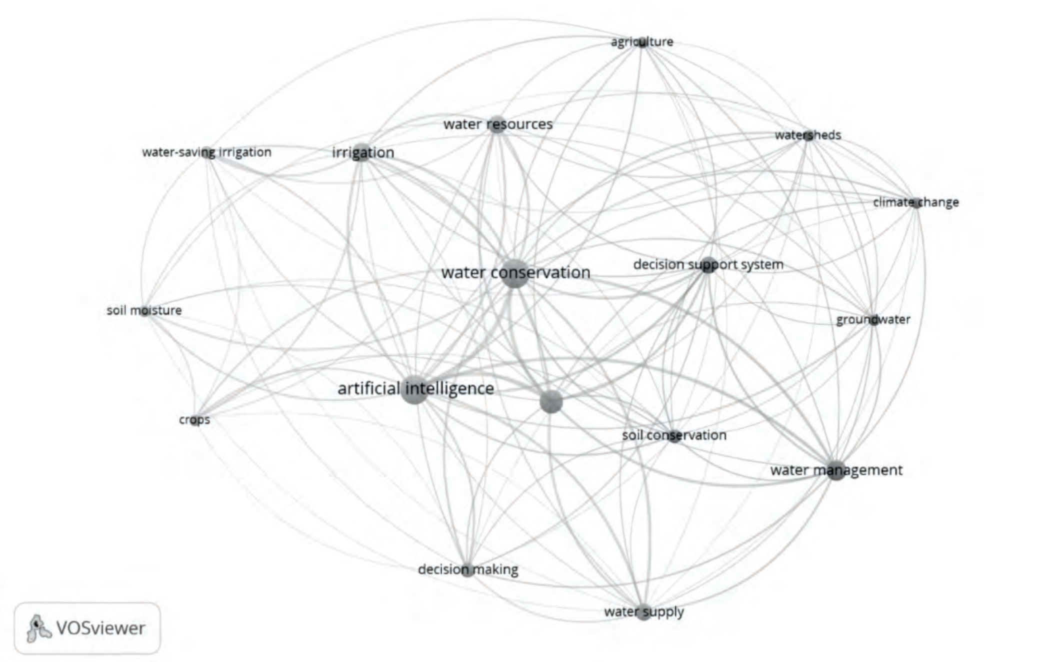


authors are affiliated. There could be multiple affiliations to the same institutions, and for each article, multiple authors may have multiple affiliations. This analysis provides an insight into the names of the institutions that make significant contributions to the development of the literature in a specific area. The University of Vermont is the frontrunner with 5% (6) of the published research articles. All other institutions identified to be amongst the top seven institutions have the same contribution at 2%. In this dimension of the most productive institutions, Chinese institutions also lead, with four institutions making it to the list, while three institutions from the United States complete the list of the top seven most productive institutions in the world. None of the European institutions are present in the list of the top seven institutions in the world. Table 8 demonstrates the most productive institutes and their respective contributions.

Table 8. ***Most Productive Institutes***

Institute	Articles	Database	Percentage Contribution
University of Vermont	6	WoS	5
Pennsylvania State University	2	Scopus	2
Zhejiang University	2	Scopus	2
China Agricultural University	2	Scopus	2
Texas A&M University	2	Scopus	2
Northwest A&F University	2	Scopus	2
Ministry of Agriculture, People's Republic of China	2	Scopus	2

Figure 7. *Keywords Cluster Analysis*



Author Keyword Analysis and Hot Research Areas

Keyword extraction is a concept for explaining the discussed concept of words other than title words to illustrate the extension of the subject (Garfield, 1990). To assess the expansion of the subject, author keywords have been used in several bibliometric studies (Mao et al., 2010).

For measuring hotspots in research related to artificial intelligence and water conservation, author keywords have been used in the current study. Artificial intelligence, water conservation, water resources, and water management are keywords with maximum concentration. They can be the top keywords used in the research related to the topic.

As displayed in Figure 7, the keywords form three clusters. Cluster 1 has seven items: agriculture, climate change, decision support system, groundwater, soil conservation, water management, and watershed. Cluster 2 also has seven items: artificial intelligence, crops, irrigation, soil moisture, water conservation, water resources, and water-saving irrigation. The last cluster is Cluster 3, with three items: decision making, decision support systems, and water supply.

Discussion

The research analysis presents a comprehensive view of the subject of AI and WC when probed in the Scopus and WoS databases. The broad areas in which the studies have been traced and extracted from the databases reflect the interest these subjects have invoked over 20 years. Over two decades, researchers have contributed to building a body of knowledge. The quantity of documents in this emerging field indicates immense potential for the next generation of researchers to carry the mantle. It is imperative to mention that this study includes WoS and Scopus as the two databases for the study, and the coverage is of studies in the context of those documents that were open access. The papers provide the direction and the areas in which future researchers can explore the knowledge. The information about the number of institutions that have contributed to the documents also indicates the appeal of these two ideas. The emergence of the themes in expansive subject areas ranging from social science to computer science, environmental science, and agricultural science makes AI and WC fields traverse a broad spectrum of domains and subjects. The leading institutions and countries contributing to the documents also indicate the advancement of knowledge in the world's leading economy in these domains.

Implications

Theoretical Implications

The research in the field of AI and its applications to WC has been contributed by authors of diverse backgrounds ranging from environmental sciences to life sciences, from social sciences to technology, and from mathematics to agricultural sciences. This study has accentuated the diversity in the theoretical exploration in this field, thus providing a basis for authors across diverse domains to gain an interdisciplinary perspective. The study further identifies the top-cited articles and institutions that contribute to this field, which can help future researchers ascertain the distinguishing works and help stimulate the theoretical advancement of knowledge.

Practical Implications

The applications of AI have been increasing in diverse fields and present enormous potential for growth and advancement. From this analysis, we conclusively illustrate that this field has the capacity to travel on a higher growth trajectory for better conservation of water resources. The professionals in the field of water conservation can explore the usage of AI and can further bolster their conservation efforts. This study has further identified the nations which have increased focus in this field of study. Other nations and agencies of the world can provide backing to this knowledge domain and improve their standing of research contribution in the identified research areas. This study has also composed a methodological approach for performing the meta-analysis, and other scholars can adopt this structured procedure to present analysis across different academic fields. The policy level influence of this research is from the perspective of improving the studies by identifying opportunities on different aspects of water conservation and water management, which can help the conservation efforts of the government departments responsible for water conservation and related activities.

Conclusion

This study delves into the two critical terms of artificial intelligence and water conservation and explores the related research literature that combines these two. Exploring knowledge in any specific domain is a tedious task for the researchers, and collecting relevant and updated documents has its challenges. This study, therefore, undertakes the task of systematically collecting the data and providing valuable insights on the relevant documents available on two of the prominent databases. The search and analysis of the data in this research are carried out using the accepted analysis methods equitably to present the status of research in AI and WC for the research community's use.

The analysis of 381 documents on AI in the WC context, gathered from the WoS and Scopus databases, demonstrates that the documents carry scientific value for the researchers. The expression: artificial intelligence first appeared in the year 1956. After that, there was not much focus on this area in water conservation, as research continued to be lacking until 2010, when the researchers started to probe the applications of AI in WC. The research publications peaked in 2018 and have since been declining. The highest number of publications has been reached in China (41%) followed by the United States (35%). The journal that has published the highest number of scientific publications in this specific area is *Water Switzerland* (22%) followed by *Water* (12%). The University of Vermont has emerged as the institution that has made the highest contribution (5%). The research article by Bagstad et al. (2014) is the most cited, with 121 citations. Environmental sciences have contributed most scientific research in this area (9%).

The research provides a comprehensive overview of the research documents and other relevant information that can be used as the starting point for academic research and provides direction for future studies. The study used papers that are available in the open access and presented the information that covers a vast majority of documents on the subject. Researchers engaged in similar areas may explore the possibility of including more databases to extend the study's coverage. The study of two decades covers a significant portion of the developments happening in AI and WC, which could be termed as the period of the genesis of these two critical domains of study.

Limitations of the Study and Scope for Future Research

Even though this study has made a significant contribution to the current body of knowledge in the field, yet it holds certain limitations. The first limitation concerns the data sources used in this study, as it included Scopus and Web of Science databases only. Future researchers can use additional databases such as IEEE Xplore and ERIC to further expand the search and improve the number of articles studied. The second limitation is that we probed the highly cited works by authors without discriminating the direct influence of the authors' work in the field. This may have introduced a bias in the understanding, and future researchers may remove this bias by analyzing the direct influences of works by individual authors. The third element which limits the findings of this study concerns the self-citation in the analysis; although, it does not have any bearing on the outcomes, yet future studies can remove this limitation and present an analysis by further refining the self-cited works of the contributing authors.

Authors' Contribution

Dr. Aaliyah Siddiqui, Dr. Mujahid Siddiqui, Dr. Nirzar Kulkarni together conceptualized the research. The data for the study were jointly collected by all the authors. Dr. Aaliyah Siddiqui performed the data analysis using the software. The draft manuscript was written by Dr. Mujahid Siddiqui and Dr. Nirzar Kulkarni. All three authors did the editing of the final manuscript. The final proofreading for correction of references was done by Dr. Nirzar Kulkarni, while the final draft was completed by Dr. Mujahid Siddiqui and Dr. Aaliyah Siddiqui.

Conflict of Interest

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

Funding Acknowledgement

The authors received no financial support for the research, authorship, and/or for the publication of this article.

References

Al Aani, S., Bonny, T., Hasan, S. W., & Hilal, N. (2019). Can machine language and artificial intelligence revolutionize process automation for water treatment and desalination? *Desalination, 458*, 84–96. https://doi.org/10.1016/j.desal.2019.02.005

Bagstad, K. J., Villa, F., Batker, D., Harrison-Cox, J., Voigt, B., & Johnson, G. W. (2014). From theoretical to actual ecosystem services: Mapping beneficiaries and spatial flows in ecosystem service assessments. *Ecology and Society, 19*(2), 64. https://www.jstor.org/stable/26269567

Brelsford, C., & Abbott, J. K. (2017). Growing into water conservation? Decomposing the drivers of reduced water consumption in Las Vegas, NV. *Ecological Economics, 133*, 99–110. https://doi.org/10.1016/j.ecolecon.2016.10.012

Calvo, I., Sánchez, R., & Carreras, B. A. (2009). Fractional lévy motion through path integrals. *Journal of Physics A: Mathematical and Theoretical, 42*(5), 055003. https://doi.org/10.1088/1751-8113/42/5/055003

Chakraborty, D. (2021). Factors influencing passengers' purchase intention towards app-cab services in metro cities of India: A study on smartphone users. *Indian Journal of Marketing, 51*(1), 41–54. https://doi.org/10.17010/10.17010/ijom/2021/v51/i1/156933

Chakraborty, D., Siddiqui, A., & Siddiqui, M. (2021). Factors associated with the adoption of health apps : Evidence from emerging economies. *Journal of Electronic Commerce in Organizations, 19*(4), 20–39. https://doi.org/10.4018/JECO.2021100102

De Clercq, D., Smith, K., Chou, B., Gonzalez, A., Kothapalle, R., Li, C., Dong, X., Liu, S., & Wen, Z. (2018). Identification of urban drinking water supply patterns across 627 cities in China based on supervised and unsupervised statistical learning. *Journal of Environmental Management, 223,* 658–667. https://doi.org/10.1016/j.jenvman.2018.06.073

Deka, P. C., & Chandramouli, V. (2009). Fuzzy neural network modeling of reservoir operation. *Journal of Water Resources Planning and Management, 135*(1), 5–12. https://doi.org/10.1061/(ASCE)0733-9496(2009)135:1(5)

Diffenbaugh, N. S., Swain, D. L., & Touma, D. (2015). Anthropogenic warming has increased drought risk in California. *Proceedings of the National Academy of Sciences, 112*(13), 3931–3936. https://doi.org/10.1073/pnas.1422385112

Fan, M., Hu, J., Cao, R., Ruan, W., & Wei, X. (2018). A review on experimental design for pollutants removal in water treatment with the aid of artificial intelligence. *Chemosphere, 200,* 330–343. https://doi.org/10.1016/j.chemosphere.2018.02.111

Garfield, E. (1990). Key words plus-ISI's breakthrough retrieval method. 1. Expanding your searching power on current-contents on diskette. *Current Contents, 32*, 5 – 9.

Granata, F., Gargano, R., & De Marinis, G. (2016). Support vector regression for rainfall-runoff modeling in urban drainage: A comparison with the EPA's storm water management model. *Water, 8*(3), 69. https://doi.org/10.3390/w8030069

Haenlein, M., & Kaplan, A. (2019). A brief history of artificial intelligence: On the past, present, and future of artificial intelligence. *California Management Review, 61*(4), 5–14. https://doi.org/10.1177/0008125619864925

Johnson, K. W., Torres Soto, J., Glicksberg, B. S., Shameer, K., Miotto, R., Ali, M., Ashley, E., & Dudley, J. T. (2018). Artificial intelligence in cardiology. *Journal of the American College of Cardiology, 71*(23), 2668–2679. https://doi.org/10.1016/j.jacc.2018.03.521

Kalra, B. S., & Mishra, A. K. (2014). Integrating social and business case approaches to implement watershed development projects in India. *Prabandhan: Indian Journal of Management, 7*(5), 47–52. https://doi.org/10.17010/pijom/2014/v7i5/59322

Kaur, R., & Khanna, A. (2016). A literature review on evolving earnings management techniques. *Prabandhan: Indian Journal of Management, 9*(1), 21 – 28. https://doi.org/10.17010/pijom/2016/v9i1/85733

Khosla, R. (2012). Production efficiency of the selected agro industries in Punjab. *Prabandhan: Indian Journal of Management, 5*(2), 21 – 26. https://doi.org/10.17010/pijom/2012/v5i2/60129

Lu, H., Li, Y., Chen, M., Kim, H., & Serikawa, S. (2018). Brain intelligence: Go beyond artificial intelligence. *Mobile Networks and Applications, 23*(2), 368 – 375. https://doi.org/10.1007/s11036-017-0932-8

Manu, D. S., & Thalla, A. K. (2017). Artificial intelligence models for predicting the performance of biological wastewater treatment plant in the removal of Kjeldahl Nitrogen from wastewater. *Applied Water Science, 7,* 3783 – 3791. https://doi.org/10.1007/s13201-017-0526-4

Mao, N., Wang, M. - H., & Ho, Y. - S. (2010). A bibliometric study of the trend in articles related to risk assessment published in *Science Citation Index*. *Human and Ecological Risk Assessment, 16*(4), 801–824. https://doi.org/10.1080/10807039.2010.501248

Mhlanga, D. (2020). Industry 4.0 in finance: The impact of artificial intelligence (AI) on digital financial inclusion. *International Journal of Financial Studies, 8*(3), 45. https://doi.org/10.3390/ijfs8030045

Moglia, M., Cook, S., & Tapsuwan, S. (2018). Promoting water conservation: Where to from here? *Water, 10*(11), 1510. https://doi.org/10.3390/w10111510

Onyenankeya, K., Caldwell, M., & Okoh, A. I. (2018). Sustainable water use and the nexus of behavioural intentions: The case of four South African communities. *Water and Environment Journal, 32*(2), 285–291. https://doi.org/10.1111/wej.12326

Palkovits, R., & Palkovits, S. (2019). Using artificial intelligence to forecast water oxidation catalysts. *ACS Catalysis, 9*(9), 8383 – 8387. https://doi.org/10.1021/acscatal.9b01985

Raju, K. S., & Kumar, D. N. (2006). Ranking irrigation planning alternatives using data envelopment analysis. *Water Resources Management, 20*(4), 553 – 566. https://doi.org/10.1007/s11269-006-3090-5

Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., & Harnisch, M. (2015). Industry 4.0: The future of productivity and growth in manufacturing industries. *Boston Consulting Group, 9*(1), 54 – 89.

Rutherfurd, I., & Finlayson, B. (2011). Whither Australia: Will availability of water constrain the growth of Australia's population? *Geographical Research, 49*(3), 301–316. https://doi.org/10.1111/j.1745-5871.2011.00707.x

Saarangapani, B., & Sripathi, K. (2015). Environmental degradation in India - Dimensions and concerns: A review. *Prabandhan: Indian Journal of Management, 8*(4), 51 – 62. https://doi.org/10.17010/pijom/2015/v8i4/63821

Sharma, R., & Gundraniya, V. (2020). Artificial intelligence towards water conservation: Approaches, challenges, and opportunities. In, *Artificial intelligence and machine learning applications in civil, mechanical, and industrial engineering* (pp. 141–151). IGI Global. https://doi.org/ 10.4018/978-1-7998-0301-0.ch008

Shivdas, A. P., & Chandrasekhar, J. (2016). Sustainability through frugal innovations: An application of Indian spiritual wisdom. *Prabandhan: Indian Journal of Management, 9*(5), 7–23. https://doi.org/10.17010/pijom/2016/v9i5/92567

Siddiqui, A., & Siddiqui, M. (2021). Buy my trust, before I buy your food – Consumers' insights for online food delivery platforms during the COVID-19 pandemic. *Indian Journal of Marketing, 51*(12), 26–40. https://doi.org/10.17010/ijom/2021/v51/i12/167218

Thornton, P. E., Hasenauer, H., & White, M. A. (2000). Simultaneous estimation of daily solar radiation and humidity from observed temperature and precipitation: An application over complex terrain in Austria. *Agricultural and Forest Meteorology, 104*(4), 255–271. https://doi.org/10.1016/S0168-1923(00)00170-2

Tripathi, A., Bagga, T., & Aggarwal, R. K. (2020). Strategic impact of business intelligence: A review of literature. *Prabandhan: Indian Journal of Management, 13*(3), 35–48. https://doi.org/10.17010/pijom/2020/v13i3/151175

Zhang, X., Zhang, S., Liu, J., Cai, L., & Wang, J. (2019). Artificial intelligence recruitment analysis. In, Y. Liu, L. Wang, L. Zhao, & Z. Yu (eds.), *Advances in natural computation, fuzzy systems and knowledge discovery. ICNC-FSKD 2019. Advances in intelligent systems and computing* (Vol. 1075). Springer, Cham. https://doi.org/10.1007/978-3-030-32591-6_46

Zhang, W., Li, L., & Liu, J. (2020). The visualization analysis of artificial intelligence research in recent 10 years in China. In, *IOP Conference Series: Materials Science and Engineering* (Vol. 806, No. 1, p. 012033). IOP Publishing. https://doi.org/10.1088/1757-899X/806/1/012033

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