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Reference Evapotranspiration Modeling Using Artificial Intelligence-Based Approaches: A Bibliometric Analysis

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ABSTRACT

A bibliometric analysis was performed over the period 1992–2023, to pinpoint important trends, emphasis, and geographic distribution of international reference evapotranspiration (ETo) modeling research using intelligence-based approaches. Data was mined from the databases of the online version of Web of Science. The data was analyzed using the Excel program, and the bibliometric mapping was performed using the VOSviewer software. A total of 1148 articles met the required criteria. The findings indicated that the number of articles had increased rapidly over the past five years and that English was the prevalent language (99.5%). Researchers in 99 countries have published in this field of research. China ranked first with 356 articles (31.0%), followed by the United States of America with 193 articles (16.8%). Egypt and Saudi Arabia are two of the top 15 countries in the world. These articles were published in 289 journals; the Journal of Hydrology was the most productive journal (95 articles, 8.3%), followed by Computers and Electronics in Agriculture (67, 5.8%). The most productive author is Kisi Ozgur from Turkey (68 articles, 4.2%). Taking into account all the institutions working on ETo modeling (1555 institutions), the Chinese Academy of Science was ranked first (80 articles, 7.0%), followed by the Egyptian Knowledge Bank (55 articles, 4.8%). Artificial neural networks and machine learning were the most commonly used intelligence-based approaches for ETo modeling. Reinforcement learning was the least popular technique for ETo modeling, which could be due to its complexity and data requirements.

INTRODUCTION

The reference evapotranspiration (ETo) is defined as "the rate of evapotranspiration from a hypothetical reference crop with an assumed crop height (12 cm), a fixed crop surface resistance (70 s m^{-1}), and albedo (0.23), closely resembling the evapotranspiration from an extensive surface of green grass cover of uniform height, actively growing, and completely shading the ground with adequate water" (Smith, *et al.*, 1997). The computation of crop evapotranspiration (ETc) is based on an accurate estimation of reference evapotranspiration (Priestley & Taylor, 1982; Allen, *et al.*, 1998; Ozkan, *et al.*, 2011). Crop evapotranspiration (ETc) can be calculated using the crop coefficient (Kc) multiplied by ETo, as described in Allen *et al.* (1998). The calculation of ETc leads to an accurate estimation of crop water requirements and, finally, better irrigation management at field scales (Cavero, *et al.*, 2000; Ines, *et al.*, 2023).

Several methods can be used for modeling and estimating reference evapotranspiration (Jensen, *et al.*, 1990). The majority of these methods use climatic data and empirical equations based on air temperature, solar radiation, mass transfer, or a combination based on physical processes (Yassin, *et al.*, 2016). Evapotranspiration depends on the interaction between climatic parameters as well as the type and growth stage of the crop (Kumar, *et al.*, 2002). Jensen *et al.* (1990) affirm that the combination of energy balance and aerodynamic equations "provides the most accurate results as a result of their foundation in physics and basis on rational relationships." The Food and Agricultural Organization of the United Nations (FAO) adopted the FAO Penman-Monteith method (FAO-PM) as the standard for ETo estimation (Allen, *et al.*, 1998). Other models were also formulated and adopted to estimate ETo, such as the temperature-based FAO Balney-Criddle model (Thongkao, *et al.*, 2022; Kwakye, 2023), the equation of Hargreaves (Hargreaves & Samani, 1985), and the radiation-based model developed by Benzarti and Riou (1982).

During the last two decades, new artificial intelligence-based approaches (AI) were used in several fields of research (Kisi, 2006). AI-based approaches are effective tools for modeling nonlinear processes, as they require few inputs (Sudheer, *et al.*, 2003). Many studies on AI-based approaches for predicting ETo have been carried out during the last two decades (Kumar, *et al.*, 2002; Huo, *et al.*, 2012; Sudheer, *et al.*, 2003; Trajkovic, *et al.*, 2003). These researchers found satisfactory results, even better than those obtained from the FAO-PM conventional method. Kumar *et al.* (2002) estimated ETo using artificial neural networks (ANN) and found better results when compared to the conventional method of FAO-PM. The same findings were obtained by Huo *et al.* (2012) when using ANN to forecast ETo using 50 years of meteorological data in north-west China. Sudheer *et al.* (2003) estimated ETo as a function of the average air temperature only.

Bibliometric analysis is a powerful statistical tool for

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examining any kind of publication, such as articles, books, proceedings papers, etc. (Liang, *et al.*, 2017). The bibliometric study is a very interesting tool that helps researchers assess current trends in research activities and take advantage of international collaboration opportunities (Arfaoui, *et al.*, 2019). It is a quantitative approach to monitoring advances in scientific publications (Tranfield, *et al.*, 2003). A qualitative approach could also be used to assess trends in narrative scientific literature reviews. This technique of analysis could be subject to bias on the part of the researcher (Tranfield, *et al.*, 2003). Bibliometric assessment approaches are the relevant tools to describe and draw temporal tendencies and upgrades in relation to the WoS categories, journals, and international collaborations among authors, as well as the geographical distribution of publications in terms of author affiliation and their citations (Sawassi & Khadra, 2021).

The objective of this study is to perform a bibliometric analysis to identify the current research field of ETo prediction using AI-based approaches over the period 1992–2023. It provides a comprehensive overview of the existing literature in this specific field, allowing readers to grasp the current state of the-art and identify key contributors and trends. It enables readers to assess the growth and impact of research in this domain, highlighting areas of interest and potential research gaps. Overall, this bibliometric analysis serves as a valuable tool for both academics and practitioners seeking to gain deeper insights into ETo prediction techniques and the broader research landscape.

MATERIALS AND METHODS

Data Collection

The bibliometric analysis of ETo modeling using AI-based approaches was performed using the Web of Science (WoS) databases published online. The data gathered in this article was mined in January 2024. We made the query on the WoS using the following terms of research: TITLE-ABS-KEY "Artificial neural network" OR "ANN " OR "Neural network" OR "Machine learning" OR "Support vector machines" OR "Genetic algorithms" OR "Decision trees" OR "Deep learning" OR "Neuro Fuzzy" OR "Reinforcement learning") AND TITLE-ABS-KEY "Prediction" OR "Estimation" OR "Forecasting" OR "Modelling") AND TITLE-ABS-KEY "Reference evapotranspiration" OR "ETo" OR "ET0" OR "Maximum evapotranspiration" OR "Potential evapotranspiration" OR "Evapotranspiration"). The obtained data was refined by excluding reviews, proceeding papers, book chapters, editorial material, meeting abstracts, and letters. We then manually checked the results for accuracy and relevance to the topic search. The mined data included the following information: authors, titles, year of publication, keywords, subject categories, journals, organizations, and the number of citations for each article.

Bibliometric Analysis

A bibliometric analysis is a statistical method used to identify, organize, and analyze the main components within a specific research field (Zhang, *et al.*, 2017). The bibliometric method has been widely used in biology, energy, engineering, medicine, and management areas (Velasco-Muñoz, *et al.*, 2018). Hereby, statistical and mathematical methods are involved to represent, through mapping techniques, bibliographic information available on databases, and identify trends in a specific field of research (Zhou, *et al.*, 2014). These tools allow us to identify collaboration relationships between involved agents (Yarime, *et al.*, 2010). Bibliometric approaches include co-occurrence analysis, co-citation, and bibliographic coupling (Van Eck & Waltman, 2019).

The minded data regarding ETo modeling using AI-based approaches were analyzed with respect to document types, language and index of publications, categories, country, evolution over the years, most productive authors and institutions, source and references, terms, and keywords. Additionally, data visualization was performed using VOSviewer software for bibliometric mapping to create reference, keyword, and term graphs (Van Eck & Waltman, 2019). This tool uses bibliometric database files to build a scientific network of the elements mentioned above.

RESULTS AND DISCUSSION

General Trends and WoS Categories

During the 32-year study period (from 1992 to 2023), a total of 1148 articles dealing with ETo modeling using AI-based approaches were obtained. Most of the articles were published in English (1142 articles, 99.5%); the remaining 6 articles were published in Spanish. Table 1 lists the top 10 WoS categories in relation to ETo modeling using AI-based approaches. The top five WoS categories included water resources (465 articles; 40.5%), environmental sciences (310 articles; 27.0%), geosciences multidisciplinary (227 articles; 19.8%), engineering civil (185 articles; 16.1%), and agronomy (148 articles; 12.9%). We should say that one publication can be mentioned in more than one category. This shows the interdisciplinary nature of the research field of ETO prediction techniques. The modeling of ETo involves various disciplines such as hydrology, climatology, agronomy, engineering, and environmental sciences.

The choice of categories may be influenced by the practical applications and implications of ETo modeling. Water resources, being the top category with 40.5% of articles, reflect the importance of ETo prediction in managing and allocating water resources efficiently. Environmental sciences, geosciences, and engineering civil categories are also prominent, indicating the relevance of ETo prediction in environmental impact assessments, climate change studies, and engineering projects related to water management and infrastructure development. The inclusion of the agronomy category highlights the significance of ETo prediction in agricultural practices, such as irrigation scheduling and crop water requirements. Furthermore, the distribution

Table 1: Top 10 WoS categories for ETo modeling using AI-based approaches

Rank	WoS categories	Article number	Ratio of 1148 (%)
1	Water Resources	465	40.5
2	Environmental Sciences	310	27.0
3	Geosciences Multidisciplinary	227	19.8
4	Engineering Civil	185	16.1
5	Agronomy	148	12.9
6	Meteorology Atmospheric Sciences	129	11.2
7	Computer Science Interdisciplinary Applications	106	9.2
8	Remote Sensing	87	7.6
9	Agriculture Multidisciplinary	86	7.5
10	Imaging Science Photographic Technology	77	6.7

of publications across categories may be influenced by the availability of funding, research interests, and priorities within different scientific communities. Funding agencies and research institutions may prioritize certain categories, leading to a higher concentration of publications in those areas. Additionally, researchers' interests and expertise in specific fields can guide their choice of category for publication, aligning with their primary research areas or collaborations.

Evolution Over the Time

The time evolution of the number of articles related to ETo modeling using AI-based approaches is displayed in Figure 1. The histograms represent the annual publications from 1992, and the curve simulates the growth pattern of global articles. This figure indicates that research on ETo modeling using AI-based approaches is a relatively old field of research that started nearly three decades ago. Indeed, the first publication in this line of research was published in 1992. However, the evolution of the number of articles during the first fourteen years (from 1992 to 2005) was quite slow, with an average production of 1.7 articles per year. During this period, only 1.4% of the total number of articles were published.

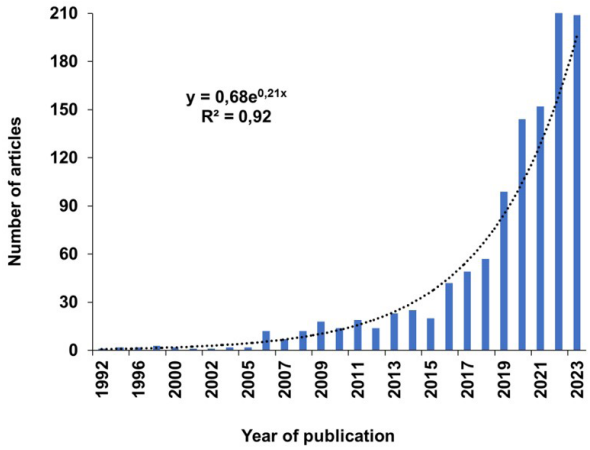

Figure 1: Number of articles published per year for the query over the period 1992-2023. (Web of Science search in January 2024).

The slow evolution of the number of articles during the first nine years (1992–2005) can be attributed to several factors. Firstly, the field of prediction of ETo using AI-based approaches is relatively new and emerging during that time. As a result, there may have been limited research interest and a smaller pool of researchers actively working on this specific topic. Additionally, the complexity of the subject matter and the reliance on advanced computational techniques such as ANN might have posed challenges for researchers. Developing accurate prediction models and conducting thorough analyses using these methods requires specialized knowledge and expertise. The limited availability of resources, data, and computational tools during that period could have further hindered the pace of research and article production.

Figure 1 shows a significant increase in the number of articles over the last five years. The number of published articles has improved in recent years, demonstrating that ETo modeling studies using AI-based approaches are attracting increasing attention from scientists. Indeed, from 2019 to 2023, 820 articles were published (71.4% of total published papers), with an average production of 164 articles per year, practically 100 times superior to the first fourteen years. The number of articles per year displayed exponential growth, as shown in Figure 1 (R2 = 0.92). This finding verifies that the research field of ETo modeling using AI-based approaches is starting to attract interesting scientific researchers around the world. The significant increase in the number of publications over the last five years can be attributed to several factors, such as advancements in technology, recognition of the importance of accurate ETo prediction, and improved accessibility and exchange of research findings. Firstly, advancements in technology and computing power have made AI more accessible and efficient for research purposes. As a result, scientists have been able to utilize AI-based models more effectively in predicting ETo. Furthermore, the growing recognition of the importance of accurate ETo prediction for various fields, such as agriculture, hydrology, and climate studies, has likely fueled the increased attention from researchers. The ability to effectively estimate ETo using AI-based models can have

significant implications for water resource management, irrigation planning, and climate change assessments. In addition, the sharing and dissemination of knowledge and research findings have become more accessible and efficient with the advent of digital platforms and open-access journals. This has facilitated greater collaboration and information exchange among researchers globally, leading to a broader range of perspectives and insights on the prediction of ETo using AI-based approaches.

Country Analysis

The country analysis showed that 99 countries contributed to the 1148 articles related to ETo modeling using AI-based approaches. Only 46 countries met the minimum requirements of five articles. Table 2 summarizes the top 10 most productive countries, publishing 110.2% of all publications (150.2%). Articles whose authors belong to different countries were counted as complete publications for each country rather than as fractional publications. The results of this analysis reveal a significant concentration of publications primarily originating from the People's Republic of China. With a share of 31.0% of the total publications and 9313 citations, China clearly takes the lead in this research domain. China's dominance in this research domain can be attributed to several factors. Firstly, China possesses vast agricultural areas and a diverse climate, making it a favorable ground for using ETo prediction models. Additionally, China has made substantial investments in scientific and technological research over the past decades, which undoubtedly contributed to the growth of research in this field.

Among the countries included in the classification,

Table 2: Top 10 most productive countries. Number of citations and total link strength are also showed

Rank	Country	Article number	Ratio of 1148 (%)	Citations	Total link strength
1	China	356	31.0	9313	278
2	USA	193	16.8	5082	283
3	Iran	189	16.5	3795	163
4	India	130	11.3	3432	145
5	Turkey	86	7.5	3998	64
6	Canada	70	6.1	2044	135
7	Australia	65	5.7	1773	89
8	Egypt	56	4.9	766	154
9	Germany	56	4.9	1341	39
10	Spain	54	4.7	839	129

Egypt stands out as a notable MENA contributor to the field of ETo modeling using AI-based approaches. With 56 publications, accounting for 4.9% of the total publications, and 766 citations. Egypt is also a country characterized by diverse climatic conditions and significant agricultural activity, which may explain the particular interest of Egyptian researchers in studying reference evapotranspiration. Moreover, Egypt has developed expertise in the field of environmental sciences, as reflected by the significant number of publications and citations. Tunisia is one of the MENA countries that is facing serious problems with respect to water resources, especially with climate change. Therefore, an accurate estimation of reference evapotranspiration could enhance irrigation water requirements at the field and district scales.

Figure 2 represents the network map of the top 20 countries by co-authorship based on the total link strength. The co-authorship country analysis revealed 99 countries, but only 46 met the selection criteria of a minimum of five published articles related to the studied topic. The data drawn in Figure 2 represents the "total link strength" for co-authorships between researchers from various countries. In this co-authorship network, each country's "total link strength" signifies the cumulative strength of collaborations with researchers from other countries. The countries are ranked based on their respective "total link strength" values. At the forefront of the rankings, we find Iran, showcasing an impressive "total link strength" of 283. This high value indicates that Iranian researchers actively collaborate with their peers from around the world, making valuable contributions to the global research landscape. Close behind, the People's Republic of China holds the second position with a "total link strength" of 278. As a major player in scientific research, China's researchers engage in robust co-authorship relationships with colleagues worldwide, fostering a strong international research network. The USA takes the third spot with a "total link strength" of 163. While the USA is renowned for its research output, the "total link strength" suggests that a significant portion of collaborations might be concentrated within the country itself, resulting in a slightly lower international co-authorship impact compared to Iran and China. Egypt secures fourth place, boasting a "total link strength" of 154. Egyptian researchers actively participate in global research collaborations, contributing substantially to the advancement of knowledge.

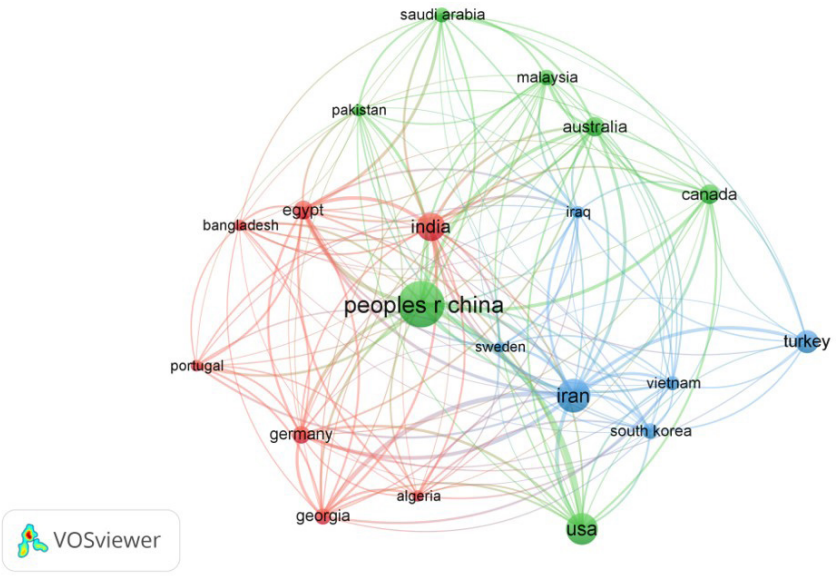

Figure 2: Network map of top 20 countries by co-authorship based on the total link strength

Co-Authorship Analysis

The 1148 published articles were produced by a total of 6781 authors. Only authors with a minimum of five publications on the topic of ETo modeling using AI-based approaches were included. Therefore, the number of authors was reduced to 109. Figure 3 represents the top 10 most productive authors. The analysis reveals a diverse group of researchers who have made significant contributions to the domain. At the forefront of this research area is Kisi Ozgur with an outstanding 68 articles (4.2% of total publications, 3079 citations), followed by Cui Ningbo with 28 articles (1.7% of total publications, 919 citations).

Figure 4 illustrates the network map of co-authorship, showing twelve clusters of authors. This map reflects the level of consistency of collaboration between authors within their cluster and among other clusters. With a remarkable total link strength of 74 and the highest number of citations (3519), Kisi, Ozgur emerges as the most influential and well-connected author in the network. Their extensive collaboration and significant number of citations indicate their leadership and impact in the field. Followed by Cui Ningbo, who holds the second position with a total link strength of 90 and 1195 citations. Their strong connections and substantial citation count highlight their prominent role in co-authorships and contributions to the literature.

The analysis shows that high total link strength, indicating strong co-authorship connections, does not always directly correlate with citation count, which measures the impact and visibility of a researcher's work. Some authors with lower link strength exhibit higher citation counts, suggesting that their individual research contributions have attracted significant attention and recognition. Overall, the network map illustrates a dynamic and collaborative research community, with authors contributing to the field's advancement through both strong collaborations and impactful individual research outputs. These findings can guide researchers and institutions in identifying key collaborators and influential researchers in the field of interest.

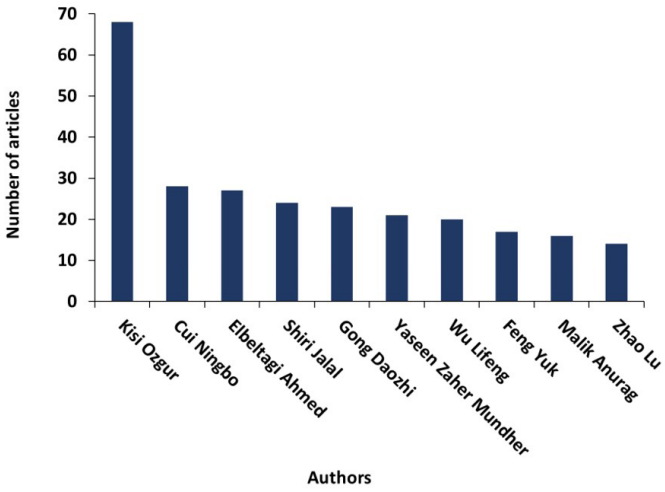

Figure 3: Top 10 most productive authors in terms of ETo modeling using AI-based approaches over the period 1992-2023

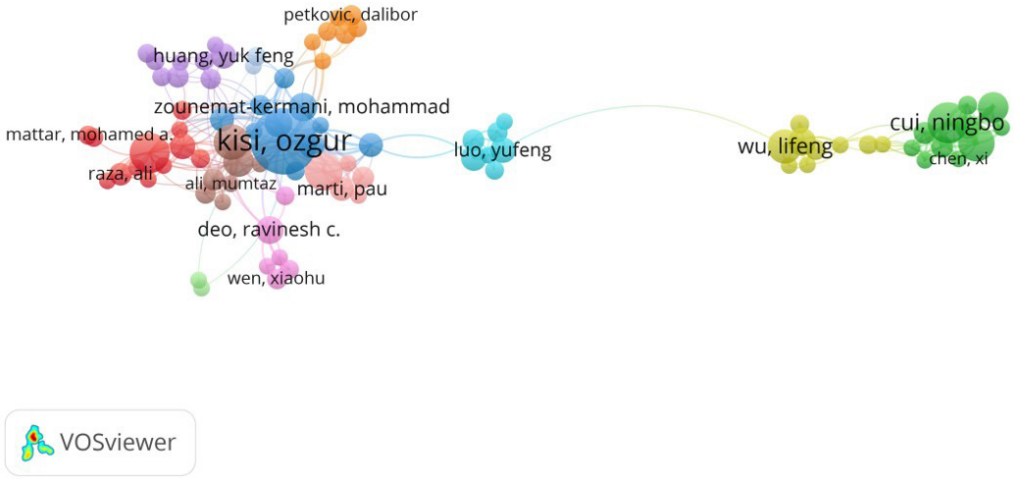

Figure 4: Network map of co-authorships based on the total link strength

Institution Citation Analysis

The citation analysis of institutions resulted in a network of 1555 organizations working on ETo modeling using AI-based approaches. Only 103 institutions met the selection criteria of a minimum of five documents published by an organization. Figure 5 shows the top 10 ranked institutions for the period 1992–2023. The results showed that the Chinese Academy of Sciences (CAS) emerges as the leading institution with an impressive 80 publications (7.0% of total publications, 1966 citations). As one of the most prestigious research institutions in China, CAS's significant output underscores its strong commitment to research in the field of ETo modeling using AI-based approaches. Followed by the University of Tabriz with 48 articles (4.2% of total publications, 1180 citations), this Iranian university has demonstrated a substantial research output in the area. Overall, the list highlights the active engagement of various institutions worldwide in the study of reference evapotranspiration using artificial neural networks. The contributions of these institutions have collectively advanced the understanding of this field and have implications for various domains, including agriculture, water management, and climate studies.

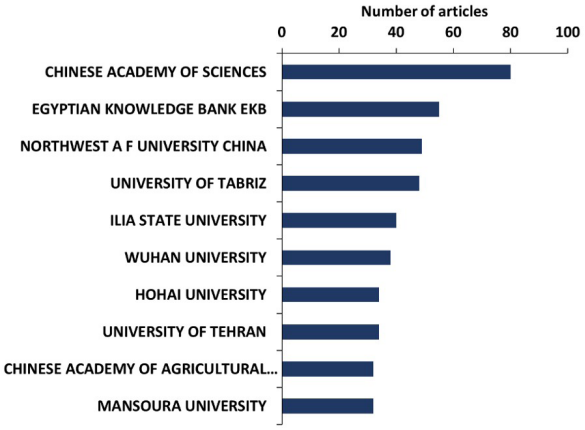

Figure 5: Top 10 most productive institutions in ETo modeling using AI-based approaches for the period 1992-2023

Figure 6 represents the network map of the citation analysis of institutions based on the total link strength, which reflects the level of consistency of collaboration between institutions. The institutions collaboration produced five clusters, with collaboration within the same cluster and with the other clusters.

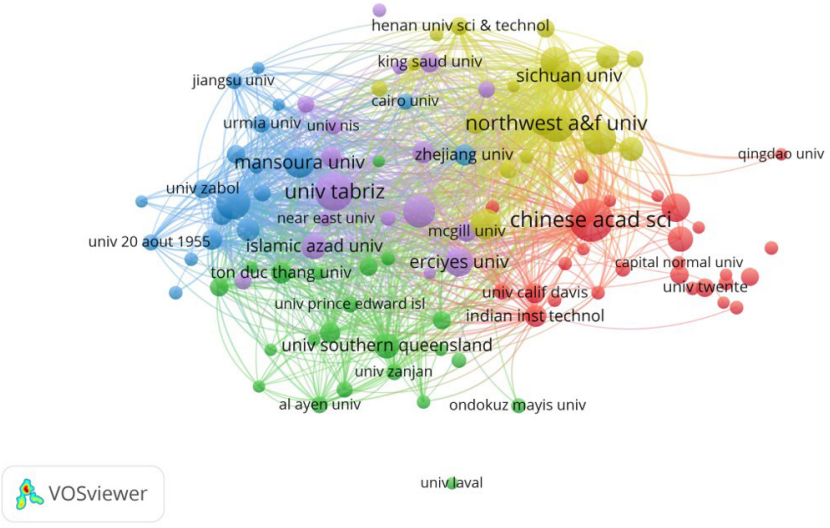

Figure 6: Network map of institutions based on total link strength

Sources Analysis

The bibliometric analysis revealed that 1148 articles were published in 289 journals between 1992 and 2023. Only 47 journals meet the selection criteria of a minimum of five documents published by a journal. Figure 7 represents the top 10 scientific journals that have published articles. In the first place, we have the Journal of Hydrology with 95 articles (8.3% of publications, 2889 citations). The Journal of Hydrology is a highly influential journal in the field of hydrology and water resources. Its focus on reference evapotranspiration research indicates the journal's significance in this area. Followed by Computers and Electronics in Agriculture with 67 publications (5.8% of publications, 2789 citations), this journal emphasizes the application of computers and electronics in various agricultural aspects, including evapotranspiration studies. In third place, we found the Journal of Agricultural Water Management with 62 publications (5.4% of publications, 2662 citations). Agricultural Water Management is a prominent journal that addresses various aspects of water use in agriculture, including the management of evapotranspiration.

The analysis shows that researchers publish studies on ETo modeling using AI-based approaches in various journals, reflecting the interdisciplinary nature of the topic. This research is disseminated in key fields such as hydrology, water resources management, agriculture, meteorology, and remote sensing. These journals play a crucial role in disseminating knowledge, fostering collaboration, and driving advancements in the study of reference evapotranspiration and its applications in various fields. Figure 8 represents the network map of the citation analysis of journals based on the total link strength, which reflects that the topic of ETo modeling using AI-based approaches has been undertaken by journals of different disciplines.

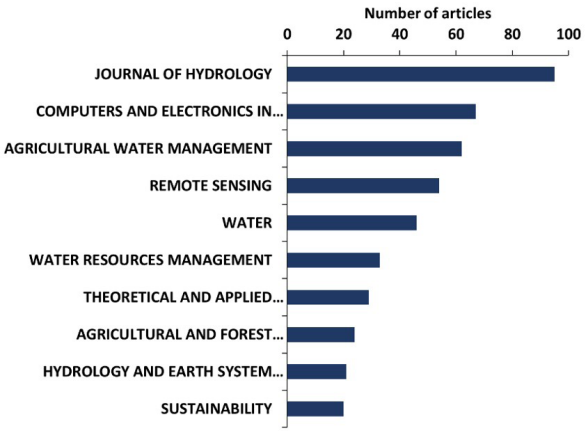

Figure 7: Top 10 journals that published articles related to ETo modeling using AI-based approaches for the period 1992-2023

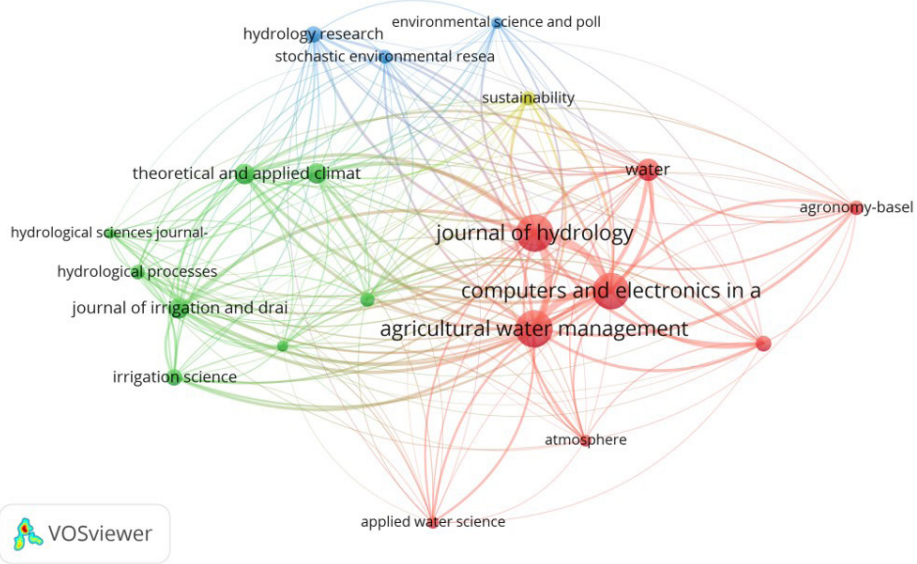

Figure 8: Network map of top 20 cited journals based on the total link strength

Keywords Analysis

The analysis of keywords yielded a total of 2353 keywords used by authors. After excluding those with low occurrences (a minimum of five occurrences of a keyword to be selected) and those with low relevance, 133 items were finally identified. Figure 9 shows the network map of the top 20 most frequently used keywords by authors. Three clusters with different colors were used to group the keywords. As we can see, the analysis indicates that the field of ETo modeling using AI-based approaches heavily relies on machine learning techniques, especially artificial neural networks and support vector machines.

The identified keywords, namely "irrigation," "climate change" "spei" "drought" "soil moisture" "reference evapotranspiration" "prediction" and "forecasting" are interconnected in the context of water resource management and agricultural sustainability. Climate change impacts precipitation patterns and temperature regimes, leading to increased drought occurrences and variability. Accurate prediction and forecasting of reference

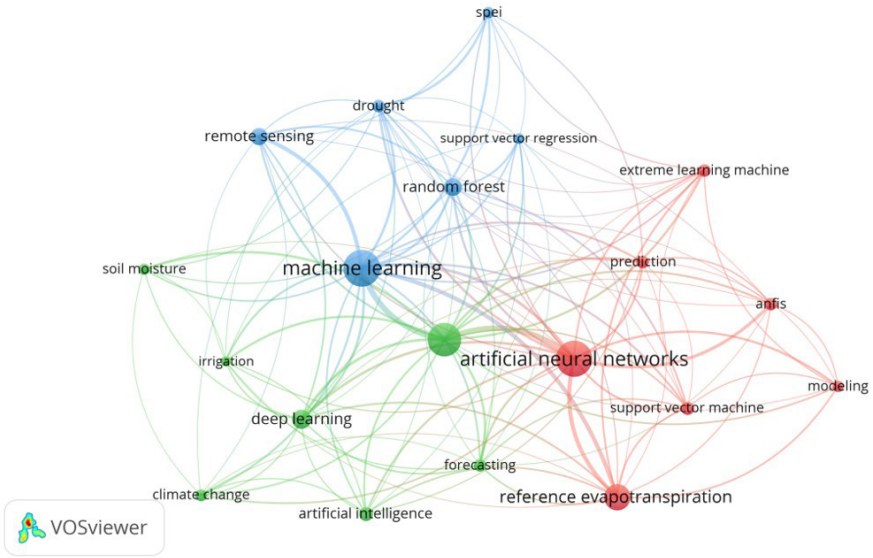

Figure 9: Co-occurrence network map of the top 20 most used keywords during the 1992-2023 period of analysis

evapotranspiration become crucial for efficient irrigation practices, as it serves as a fundamental measure of water loss from well-watered reference crops under standard conditions. Monitoring soil moisture levels is essential to understand the water requirements of crops and optimize irrigation strategies. Additionally, incorporating predictive AI-based techniques enables the forecasting of future reference evapotranspiration values, aiding in proactive water management and irrigation decision-making. The Standardized Precipitation Evapotranspiration Index (SPEI) provides a comprehensive assessment of drought severity, incorporating both precipitation and evapotranspiration factors. By considering the relationships among these keywords, policymakers and researchers can develop effective strategies to mitigate the impacts of climate change on irrigation systems, optimize water usage, enhance agricultural resilience, and make informed decisions based on accurate reference evapotranspiration prediction and forecasting.

Analysis of the Most AI-Based ETo Modeling Approaches

Figure 10 represents the results of the analysis of the most commonly used AI-based ETo modeling techniques. The results show that artificial neural networks (ANNs) are by far the most popular approach, accounting for 65.9% of the analysed articles. Machine learning (ML) is the second most popular approach, with 26.5% of the articles. Neuro Fuzzy (NF) is one of the most AI-based techniques used for ETo modeling, accounting for 3.0% of total published articles. Deep learning (DL) is the fourth most popular approach, with 2.1% of the articles. Genetic algorithms (GA) and support vector machines (SVMs) are the least popular approaches, with 1.3% and 1.1% of the articles, respectively.

The popularity of ANNs for ETo modeling is likely due to their ability to learn complex relationships between input and output data. Training ANNs on large datasets of weather and climate data enables them to learn how these factors affect ETo. This allows ANNs to generate more accurate ETo estimates than traditional methods, which are based on simple mathematical equations. ML is another powerful approach for ETo modeling. ML algorithms learn from data without requiring explicit programming. This makes them well-suited for ETo modeling, which is a complex problem with many interacting factors. The other AI approaches shown in Figure 10 are less popular for ETo modeling. Neural Fuzzy (NF) is a type of machine learning algorithm that is specifically designed for modeling natural systems. Deep learning (DL) is a type of machine learning that uses artificial neural networks with multiple layers. One can use genetic algorithms (GA) as an optimization algorithm to find the best parameters for an ETo model. Support vector machines (SVMs) can perform classification or regression tasks as they are a type of machine learning algorithm.

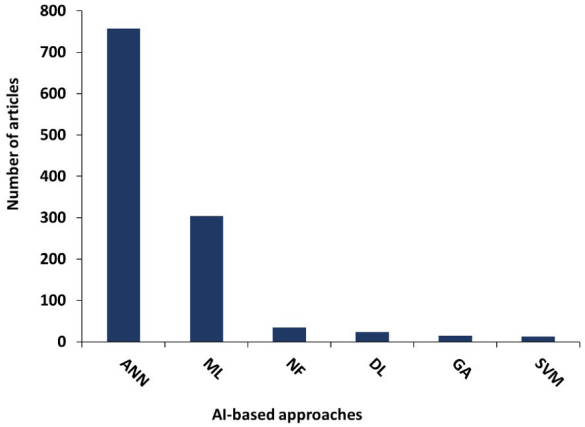

Figure 10: Distribution of AI-based ETo modeling techniques. (Web of Science search in January 2024).

CONCLUSIONS

Based on the analysis of 1148 research articles on AI-based ETo modeling techniques published on WoS from 1992 to 2023, we can draw the following conclusions:

• This field of research encompasses diverse disciplines such as hydrology, climatology, agronomy, engineering, and environmental sciences;

• The significant increase in the number of articles published in the past five years demonstrates the growing interest and attention from scientists in utilizing AI-based approaches for ETo modeling, driven by advancements in technology, recognition of the importance of accurate ETo prediction, and improved accessibility and exchange of research findings;

• China was found to be the dominant country in terms of both publication quantity and citation impact, followed by Egypt as a notable contributor in the MENA region, while the co-authorship network demonstrated active international collaborations with Iran, China, and the USA;

• The Chinese Academy of Sciences and the University of Tabriz were found to be the leading institutions in terms of research output and impact in the field of ETo modeling using AI-based approaches;

• Agriculture, Water Management and Computers and Electronics in Agriculture were the most productive and cited journals;

• The modeling of ETo using AI-based approaches was found to be very significant for irrigation and hydrology purposes;

• The results of this study suggest that ANNs are the most promising approach for ETo modeling. However, other AI approaches may also be useful in certain cases.

In summary, the study highlights the interdisciplinary nature, global interest, and potential of AI-based approaches, particularly artificial neural networks, for ETo modeling, emphasizing the importance of collaboration, technological advancements, and accurate ETo prediction for irrigation and hydrology purposes.

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