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PESQUISA SOBRE IRRIGAÇÃO POR GOTEJAMENTO: REVISÃO ABRANGENTE DE 2016 A 2025 BASEADA NA WEB OF SCIENCE

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1 RESUMO

Melhorar os métodos de irrigação que economizam água é uma das tarefas importantes no contexto das mudanças climáticas globais. Muitas pesquisas estão sendo conduzidas nesse sentido no mundo. A irrigação por gotejamento está entre as tecnologias mais prevalentes e eficientes nesse contexto. Para obter altos rendimentos, é importante selecionar corretamente os elementos de irrigação, dependendo do tipo de cultura, das características físicas do solo e do grau de salinidade. O principal objetivo deste estudo é revisar e comparar as contribuições de países, instituições, periódicos, autores e fundações para artigos sobre o tópico selecionado. Palavras-chave serviram de base para a escrita deste artigo. Assim, este estudo preenche a lacuna analisando 976 publicações sobre gestão de recursos hídricos (2016-2025) usando o banco de dados Web of Science. Além disso, há descobertas sobre a eficácia com que os artigos adquiridos atendem aos Objetivos de Desenvolvimento Sustentável (ODS). Além disso, vários experimentos para conservação de água, fertilidade do solo e conservação de umidade, e fatores que afetam a sustentabilidade e a operação saudável dessa tecnologia são discutidos. Concluindo, pode-se dizer que os problemas relacionados à manutenção e ao uso adequado dos componentes da tecnologia de irrigação por gotejamento permanecem e precisam ser resolvidos.

Palavras-chave: economia de água, métodos de irrigação, salinidade.

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2 ABSTRACT

Improving water-saving irrigation methods is one of the important tasks under conditions of global climate change. Therefore, numerous scientific studies around the world are focused on improving irrigation efficiency and water management practices. Drip irrigation is among the most prevalent and efficient technologies in this context. High crop productivity largely depends on the proper selection of irrigation components based on crop characteristics, soil physical properties and salinity conditions. This study aims to analyze and compare the contributions of countries, institutions, journals, authors, and funding organizations within the selected research field. Keywords served as the basis for writing this article. Thus, this study fills the gap by analyzing 976 publications on water resources management (2016-2025) using the Web of Science database. Furthermore, there are findings about how effectively the acquired articles satisfy the Sustainable Development Goals (SDGs). Additionally, several experiments for water conservation, soil fertility and moisture conservation, and factors affecting the sustainability and healthy operation of this technology are discussed. In conclusion, challenges related to the maintenance and efficient use of drip irrigation system components persist and require further attention.

Keywords: water save, irrigation methods, salinity.

3 INTRODUCTION

Water shortage in arid and semi-arid regions has become an increasingly serious global challenge (Ding *et al.*, 2023). A sufficient water supply is essential for regular crop growth, consistent yields, as sustainable irrigation is a technical measure significant for the growth of crops (Yang *et al.*, 2023). However, appropriate use of water resources is an extremely huge issue. In many countries, more than 90% of freshwater resources are used in agriculture (Karandish; Šimůnek, 2019). In arid environments, water deficit and soil salinity significantly restrict the availability of water and nutrients, which in turn constrains crop yield and the long-term sustainability of agricultural production (He *et al.*, 2024; Namdarian *et al.*, 2024). In addition to irrigation, application of high-yielding seed varieties and fertilization, as well as other techniques can also consistently improve agricultural production. Currently, it is imperative to implement contemporary water-saving technologies for the irrigation of agricultural commodities and to conduct scientific research in this field due to the water scarcity that has resulted from global climate change (Isaev *et al.*, 2023). To get a high yield of agricultural crops and efficient use of water resources depends on the correct selection of irrigation equipment. This supports to correctly select of irrigation methodology elements, increase water use efficiency, maintain soil structure and evenly distribute of water applied along the length of the field. In arid regions, prolonged flood irrigation can quickly cause secondary salinization and soil compaction, which decreases soil quality and crop yields (Li *et al.*, 2021). Therefore, the implementation of advanced water-efficient irrigation technologies is critically important (drip irrigation, sprinkler irrigation, etc.) (Liang *et al.*, 2022; Tan *et al.*, 2023).

Drip irrigation is recognized as a highly efficient and widely utilized irrigation technology in modern agriculture (Faloye *et al.*, 2025). This system is characterized by the implementation of high-frequency irrigation model, while

water is supplied to the plants frequently in small amounts, which ensures to get the acceptable moisture level at the right time and minimizing deep leaks as well as significantly enhancing water use efficiency (Li *et al.*, 2024). It effectively reduces microbial surface contamination and maintains a clean soil structure, however, there are some limitations to drip irrigation's ability to improve soil because it depends on soil type, irrigation volume, and fertilizing techniques (Feng *et al.*, 2024). Furthermore, it is imperative to comprehend the mechanism of clogging of drip irrigation emitters when utilizing low-quality water sources, and to regulate the formation of clogging substances (Li *et al.*, 2019). Drip irrigation can increase crop yields while reducing water use and is more effective under saline conditions as it promotes salt leaching in the wetted soil zone around emitters, where root density is highest (Du *et al.*, 2023). So, it is seen that determining soil salinity is important when choosing an irrigation method.

One of the main problems in agriculture is soil salinization, which seriously hinders the maximum use of land resources (Chu *et al.*, 2023). This is a gradual and long-term process, and studies conducted over only a few years may be insufficient to accurately determine trends in root zone accumulation (Liu *et al.*, 2022). Over 20 percent of the world's irrigated land is made up of soils damaged by salt (Shan *et al.*, 2022). Soil salinity is very common in arid and semi-arid regions (Su *et al.*, 2024; Feng *et al.*, 2025). It has been proven that recycled water or some of the saline water can be used wisely in agriculture for irrigation, however, long-term use of such water for irrigation may lead to the accumulation of soil salt (Chen *et al.*, 2013). People usually reduce salt stress in crops by controlling water supply and irrigation (Wang *et al.*, 2022a). To mitigate soil salinity and flush excess salts from the root zone, the plant is given more water than necessary (Fujimaki; Abd El Baki, 2021). This in turn causes secondary salinization. The area of human-induced secondary salinization is increasing by 10% yearly and, at this rate, half of the world's arable land could become saline by 2050 unless better water management practices are implemented in agriculture (Wang *et al.*, 2022b). Secondary salinization refers to the formation of salt in the plough layer or on the soil surface due to rising groundwater levels and subsequent soil moisture evaporation (Guan *et al.*, 2019; Abdikairov; Juliev; Kholmurodova, 2024). Furthermore, the soil pH fluctuates in accordance with the depth, irrigation timing, and soil structure (Dragonetti *et al.*, 2020). Also, improper irrigation methods can cause soil salinization, which reduces crop yields (Yang *et al.*, 2020).

In this study, bibliometric analysis was selected as the primary method for the literature review, according to (Gronthy *et al.*, 2023) its ability to provide a wealth of bibliometric information in a concise manner. Nowadays, bibliometric methods are widely used in the study of water-saving irrigation technologies (Feng *et al.*, 2024), soil salinity (Mousavi *et al.*, 2022), water save (Zhou *et al.*, 2024).

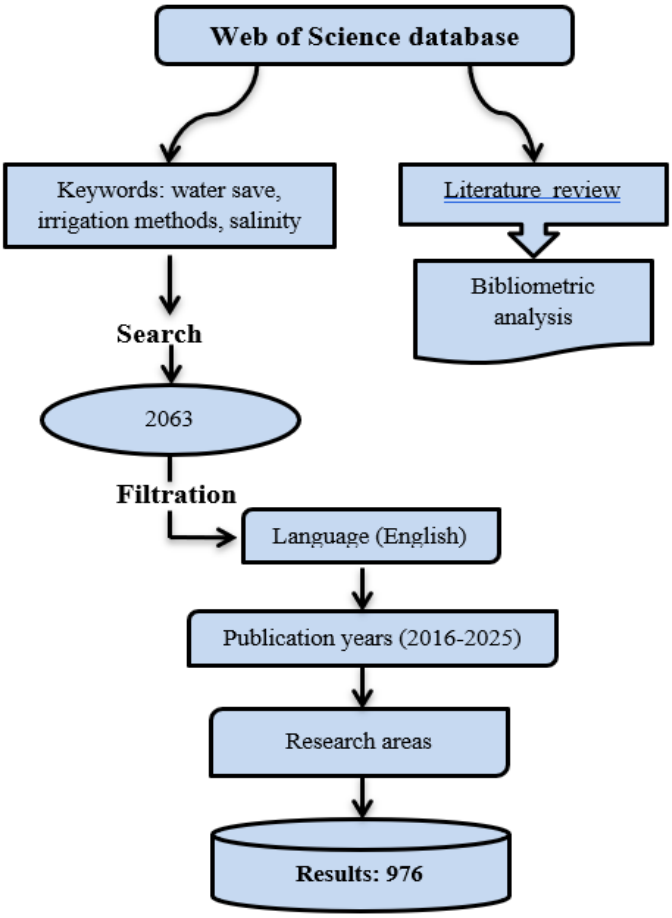
In the above context, the main objective of this study is to review the international scientific literature related to water saving technologies by applying bibliometric network analysis (Papadopoulou *et al.*, 2021). Additionally, we set out to find articles published between 2016 and 2025, the best foundations, the most active authors, and the most active countries and organizations.

4 MATERIALS AND METHODS

Scientific articles indexed in the Web of Science database were used as the primary data source for this bibliometric study. This method has many informative

aspects such as identifying research hotspots, collaboration patterns, and the evolution of knowledge within the field. Our approach begins with finding data using a framework described in Figure 1. The study on article writing was conducted in February 2025. This study used bibliometric methods to compare the most active articles published on the topic over the years, authors, countries, funding agencies, fields of study, and institutions. The methodology described in this work consists of two stages, which allows to carry out research. The keywords "water conservation", "irrigation methods", and "salinity" were selected for bibliometric analysis. Then, a filter was applied by languages, years of publication, and research areas. As a result, we had 976 articles related to topic. Additionally, MS Excel and Mapchart.com platform were used to create statistical analyses, charts, and maps.

Figure 1. Proposed methodology for bibliometric analysis.



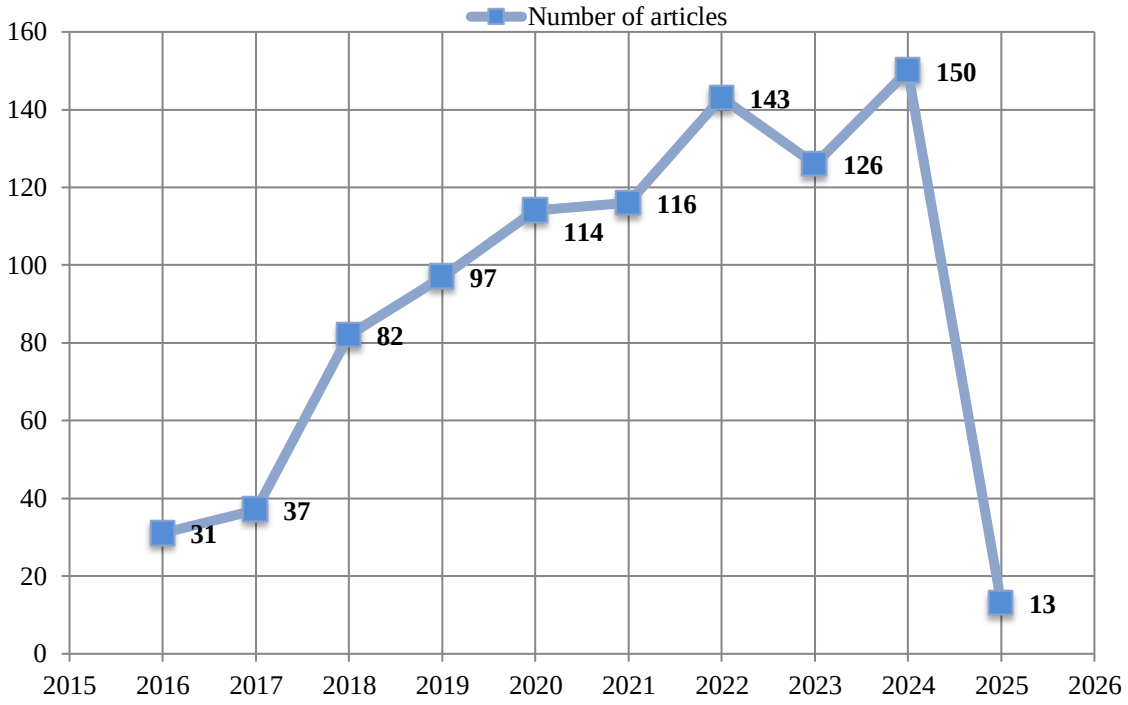
5 RESULTS

5.1 Publication trend

The number of publications is an important indicator that sheds light on the development trends of scientific research. This study found a total of 976 published papers worldwide. The research requirement for the selected topic can be seen in the Figure 2 below. It is possible to notice the steady growth of paper on the

topic over the last 10 years. Although there was a decline in 2023, it has been increasing almost every year. The number of published articles has increased dramatically, especially since 2018. The findings indicate that in the last ten years, 93% (896) of the overall articles have been published. The highest trend mark was recorded in 2024, accounting for 15% of the total articles. Considering that the study was conducted in early 2025, this year may also be a high indicator. In general, it is appears to be an increasing interest in articles on the selected topic during the research period.

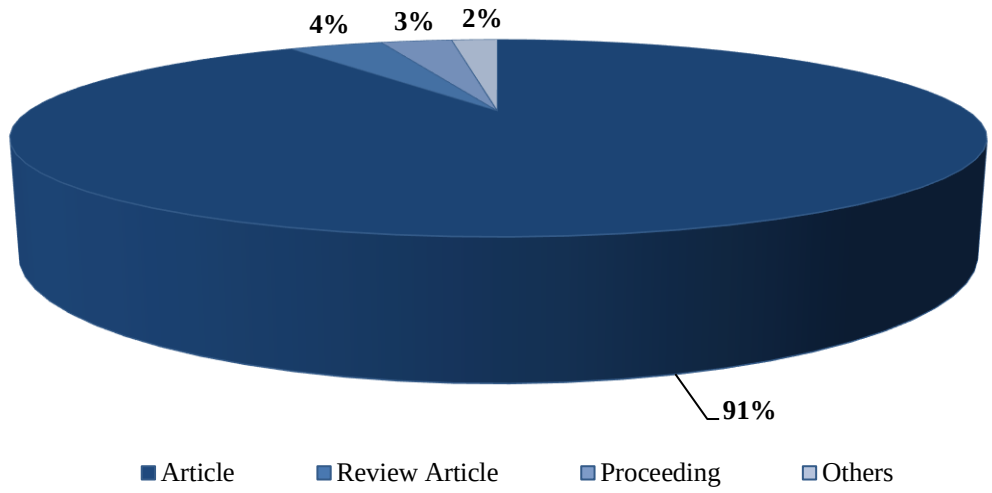
Figure 2. Published articles in 10 years.



5.2 Article types

Articles are usually divided into several types. In this study, a number of analytical methods were used to evaluate the obtained articles in more detail and are described as follows. According to data from the Web of Science core database, the articles found mainly belong to 3 different types. Figure 3 demonstrate 914 (91%) articles are scientific, followed by 41 review articles, is possible to see 31 articles belong to proceedings. The most interest of researchers is illustrated in research articles. Because when scientific articles are published in journals, many people read and cite them.

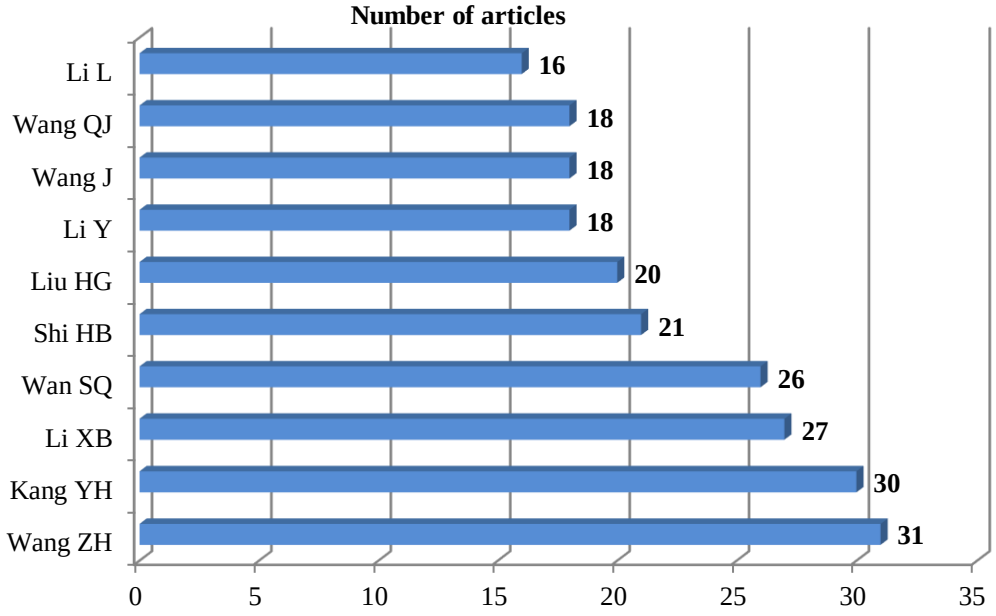
Figure 3. Document types of published.



5.3 The best authors

Recently, the number of articles written by scientists on selected topics has increased significantly. In this research we compared the 10 top-performing authors who published at least 16 articles on the issue (Figure 4). 10 authors wrote a total of 225 articles, contributed for 25% of the total. Wang ZH ranks as the most prolific author, contributing 3.1% of the total publications, followed by Kang YH's papers covered 3%, while Li XB and Wan SQ each contributed 2.7%. Shi HB and Liu HG entered the middle level of selected authors and they have almost the same result of 2.1%. The next three researchers each reported the same result, with a share of 1.8%. Although L Li has the lowest score among the 10 authors, he contributed to 1.6% of the total articles. The lowest of the top 10 selected authors was almost half the result of the highest author. It is clear from chart that topic is a relevant issue in the world today. According to the authorship results, we see that the contribution of Chinese researchers is huge.

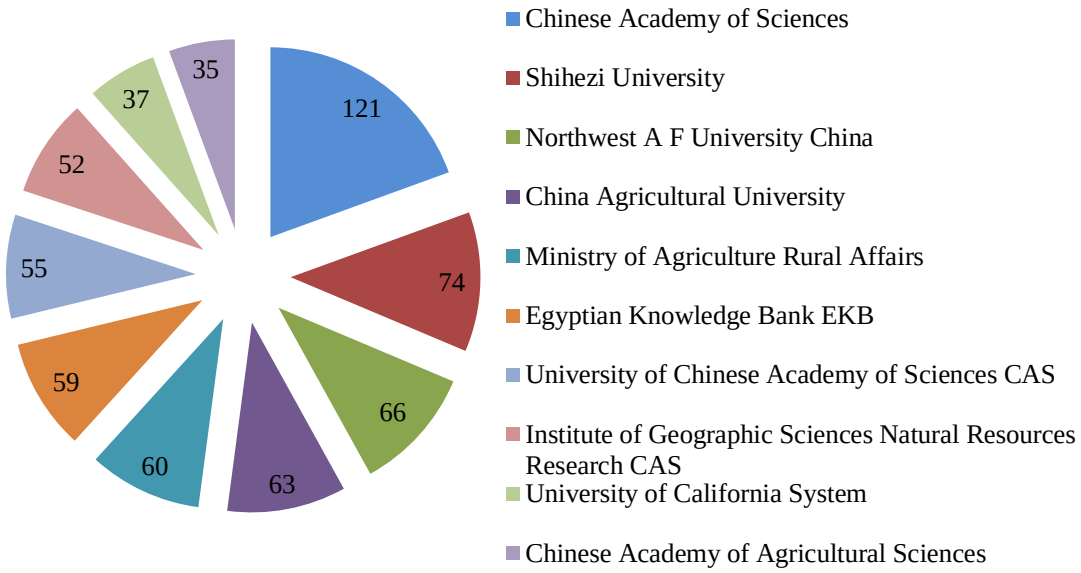
Figure 4. Articles by the top authors.



5.4 The best active organizations

Affiliations in an article show the authors' institutional connections, such as their university, research institute, or organization. During the research period, many institutions collaborated on various articles, and the top 10 organizations published 622 articles, as can be seen in the Figure 5 below. Chinese Academy of Sciences was the leader, accounting for 12% of total articles, following by Shihezi University, which has 7.5% from total papers. Next research organization was Northwest A F University China with 6.7% of share. China Agricultural University, Ministry of Agriculture Rural Affairs and Egyptian Knowledge Bank EKB have similarly results with 6.4%, 6.1%, 6%, respectively. University of Chinese Academy of Sciences CAS and Institute of Geographic Sciences Natural Resources Research CAS have similarly results with 5.5% and 5.3%, respectively. University of California System 3.8% and Chinese Academy of Agricultural Sciences 3.5% recorded a rate. The role of Chinese institutions in this diagram is enormous.

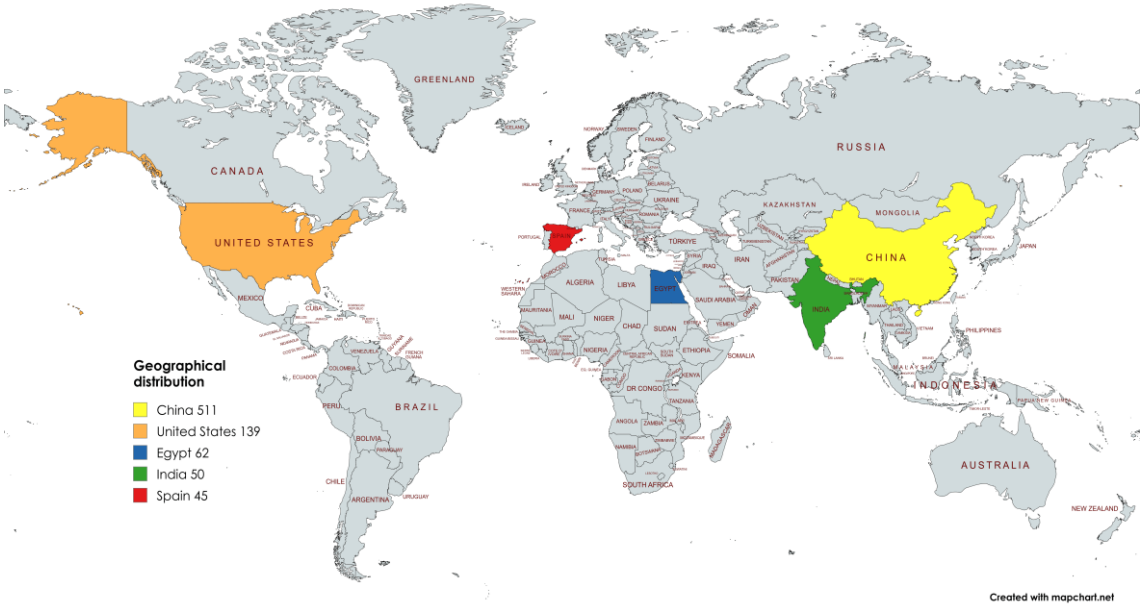
Figure 5. Top active organizations on research issue.



5.5 Top countries

We considered the relevance of chosen topic at country level. Mapchart program was applied to prepare countries distribution (Figure 6). China occupies leadership with 52% of published articles, followed by the USA with 14%. Despite being a developing country, Egypt ranked third after the United States with a score of 6%. India and Spain were next, with results of 5% and 4.6%, respectively. This trend confirms the fact that research in this field is mainly concentrated in China. It has published so many articles that even if you add up the articles from the other 4 countries in the top 5, it won't be enough. Furthermore, the significant attention and funding allocated to this issue by developed countries is one of the main factors in mitigating this problem and confirms the global nature of the issue.

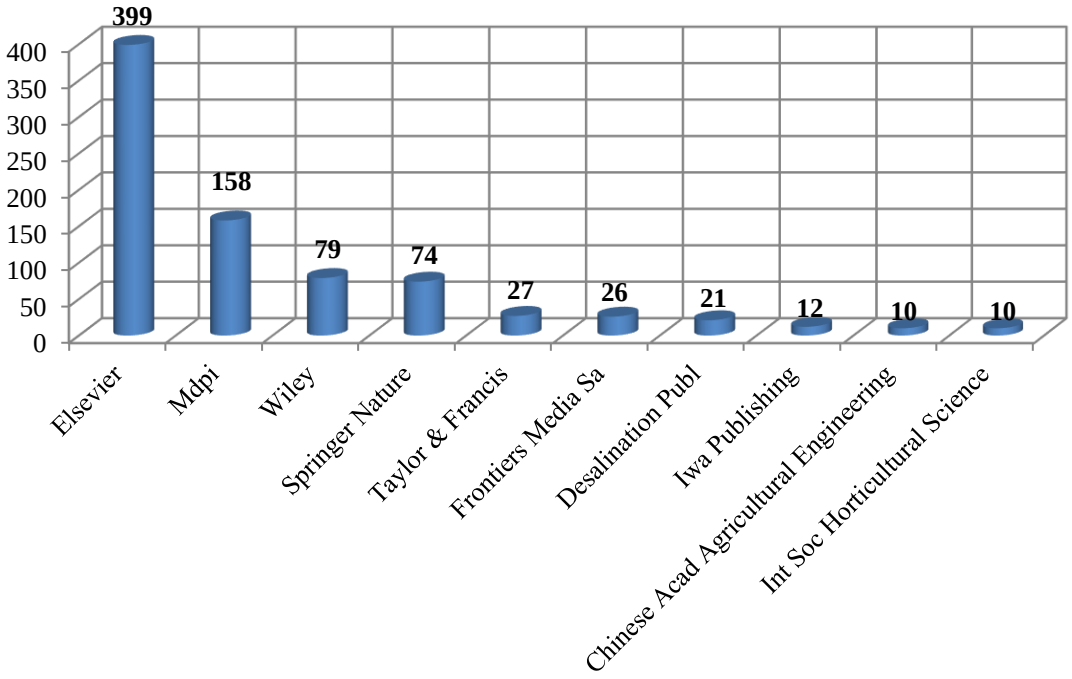
Figure 6. The most active countries.



5.6 Active publishers

Platforms are now playing a very important role in the coverage of articles. Many researchers want their articles to be published high quality journals and platforms. According to the results of the articles found on the selected topic (Figure 7), Elsevier was the most chosen with 40%, MDPI was with 16%. Wiley and Springer Nature had little difference with 8% and 7.5%, respectively. Similarly, Taylor & Francis and Frontiers Media Sa each had 3% of articles. Desalination Publ ranked slightly behind them with 2.1% papers. Next were Iwa Publishing with 1.2%, followed by Chinese Acad Agricultural Engineering and Int Soc Horticultural Science both with the same 1% result.

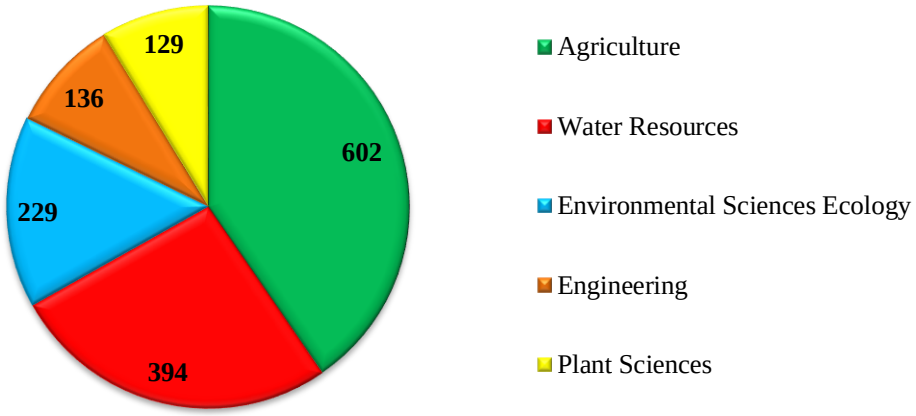
Figure 7. The most active publishers on selected topic.



5.7 Research area

Research topic is possible to be related to many subject areas which illustrated in Figure 8. However, it is worth noting that 1 article may belong to several fields at the same time. Accordingly, from the results show that Agriculture has the largest coverage with 61%. Water resources occupies the second place with 40%. The contribution of Environmental sciences ecology is almost a third of Agriculture, with 23%. Engineering came in fourth (14%) after Environmental sciences ecology, while Plant science took last place with 13%.

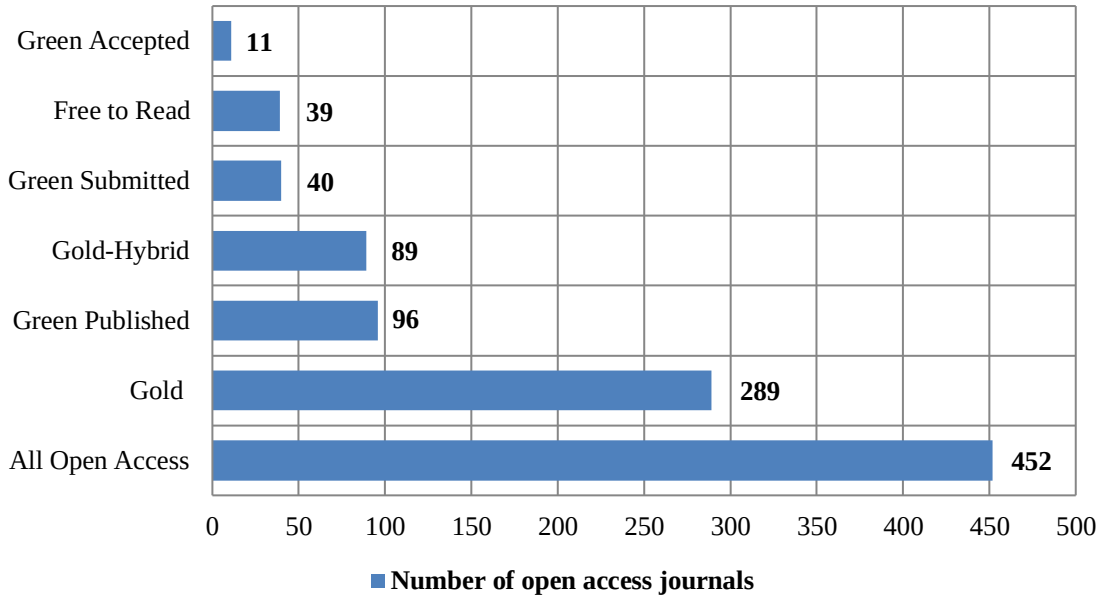
Figure 8. Analysis of subject distribution.



5.8 Accessibility of papers

Accessibility of papers mainly provides enough opportunities to readers, including citation, distribution and more. In this case, a single journal may fall into two or more categories. This is particularly common in hybrid and green open access models. For example, hybrid journals are typically subscription-based but offer open access if authors pay an additional fee. According to the results of the study, the number of All open access articles was 46.3%, and this is illustrated in Figure 9 below. Gold is in second place, with 29.6%. Green Published and Gold-Hybrid followed with very close results, at 9.8 and 9.1% respectively, while Green Submitted and Free to Read have almost the same results with 4%. Despite being at the bottom of the rankings, Green Accepted is still attracting attention. Judging by the diagram, the number of logs is greater than the total result. This suggests that many researchers and publishers are increasingly opting for open access publishing. The growing number of open access journals reflects a shift towards transparency and openness in academic research.

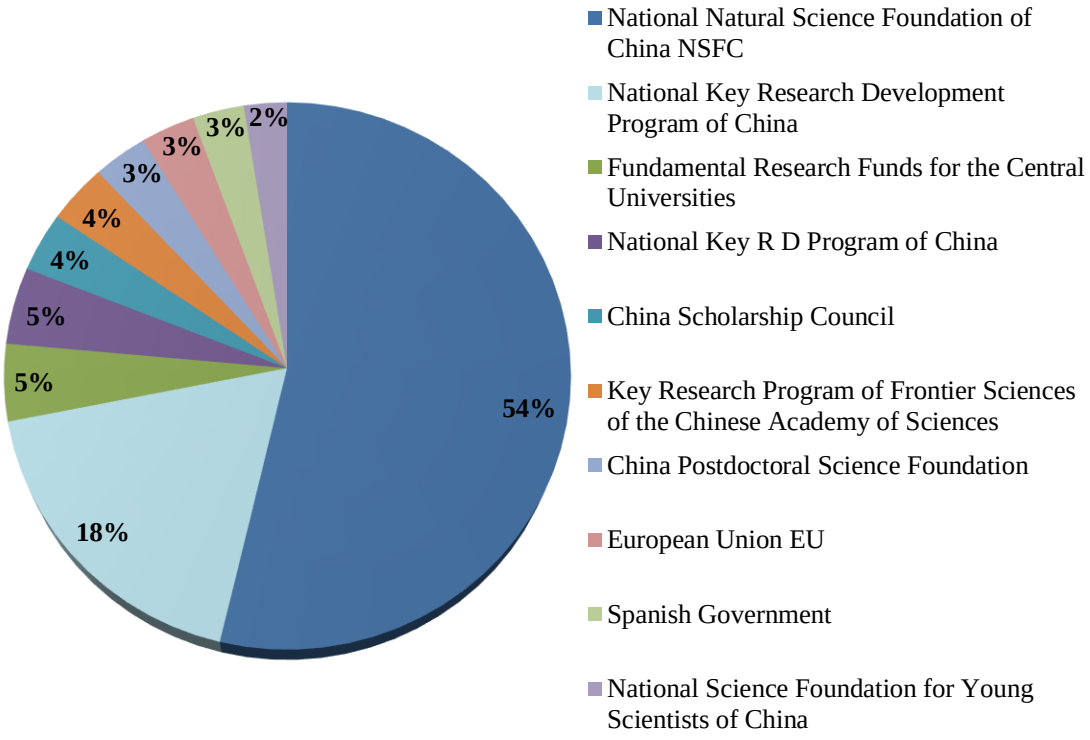
Figure 9. Open accessibility of papers.



5.9 Funding agencies

Supporting research activity is very important for the development of a country. The contribution made by foundations to published articles in science is significant. According to the results, we have shown the top 10 sponsors who financially supported the selected articles (Figure 10). The National Natural Science Foundation of China (NSFC) was leader. China's National Basic Research Development Program ranked second, sponsoring 108 articles. The fact that these two fund agencies mainly sponsored articles on the selected topic are seen in the Figure 10 below. As a results, Fundamental Research Funds for the Central Universities and National Key R D Program of China both showed the same quantity of 27 articles. Both China Scholarship Council and the Key Research Program of Frontier Sciences of the Chinese Academy of Sciences also showed the same position of 21. The China Postdoctoral Research Foundation and the European Union recorded the same results with 19 articles, while the Spanish government had 18. The National Science Foundation for Young Scientists of China contributed least with 15 articles. Among the top 10 funding agencies, Chinese sponsors contributed significantly.

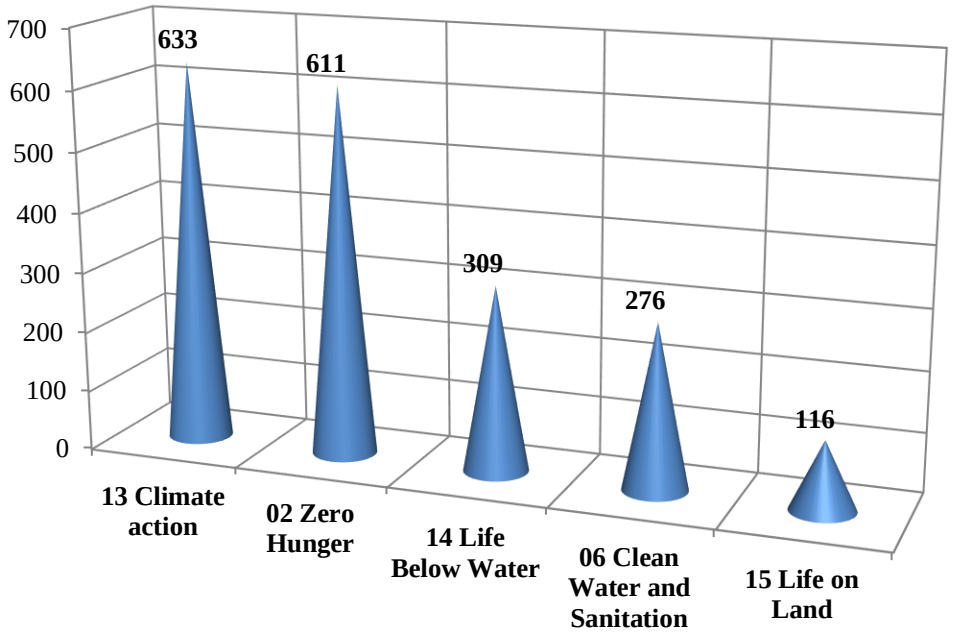
Figure 10. The best funding sponsors.



5.10 Sustainable development goals

The Sustainable Development Goals (SDG) aim to achieve peace and prosperity for people and planet, combat climate change and conserve oceans and forests, and ensure the connection between environmental, social and economic aspects (O'Dowd; Adriano; Littlemore, 2024). According to the information received, at the same time, 1 paper can correspond to several sections of the SDG. Climate change has become a significant factor influencing and negatively affecting diverse areas of human activity. SDG 13 - the importance of climate action highlights the urgency and widespread impact of climate change, and this was the top item in our results for the Sustainable Development Goals with 633 articles. SDG 02 came in second with 611 articles, while SDG 14 had half number of previous goal. Next was SDG 06 has 276 papers. Lastly, SDG 15 has only 116 articles which may indicate that deforestation, biodiversity loss, and land degradation receive comparatively in academic research (Figure 11). In general, the problem of water scarcity is a major contributor to climate change, which in turn leads to increased hunger. This can be seen from the fact that most of the articles found are relevant to SDG 13 and SDG 02.

Figure 11. The relevance of the articles to the Sustainable Development Goals.



6 DISCUSSION

This comprehensive review highlights the dynamic evolution of research interest in drip irrigation technologies between 2016 and 2025. The bibliometric trends observed in Web of Science databases clearly reflect a significant increase in publications in agricultural fields, particularly water resources management. While technological progress is promising, there are gaps in research on affordability, smallholder adoption, and long-term environmental impacts. Future research will focus on addressing these shortcomings by encouraging innovation, strengthening international collaboration, and incorporating socio-economic dimensions into technical research.

Overall, this review provides valuable insight into the potential role of drip irrigation in achieving the United Nations Sustainable Development Goals. Our results suggest that this topic is relevant only to the 5 SDGs, but we can still expand on this topic. Water scarcity first leads to climate change, and then affects productivity, which leads to increased hunger. Looking at the results in the article, we can see how large China's contribution is.

6.1 Effectiveness of water saving technologies

Agriculture has long been the basis for providing food to the population in many countries. In this regard, providing crops with sufficient water is of great importance. Water-saving technologies are really important due to climate change. Since 2018, attention and interest in water conservation in agriculture has increased significantly. Today, in solving global problems, it is advisable to eliminate water scarcity, use intensive methods in agriculture, and introduce modern water-saving irrigation technologies. Increasing water scarcity in many regions is negatively affecting human health and crop productivity and is one of the main obstacles to sustainable development worldwide. Therefore, the economical use

of available water resources is one of the main tasks facing humanity. In this regard, the effectiveness of water-saving technologies has been well documented in world experience. The use of that technologies is effective not only in water-scarce and arid regions, but also in fields with sufficient water. Because, in addition to saving water, it has the advantages of increasing productivity and reducing labor. The use of these methods has led to higher yields in humid, low-salinity zones compared to arid and high-salinity areas. Moreover, the feasibility of using film mulch to maximize water use has been confirmed by several experiments, mainly in drip irrigation (Jin *et al.*, 2018; Zribi *et al.*, 2023). Many experiments on mulching, mainly in drip irrigation, have been conducted in China and are being used in practice.

6.2 Role of drip irrigation in arid zone

According to data, drip irrigation is the most widely used type of irrigation in the world. China is among the leading countries in the production and export of drip irrigation technologies. The drip irrigation method is more effective than other water-saving technologies because it can be used even in saline soils. However, some studies show that (Sun *et al.*, 2017) the amount of drip irrigation directly affects soil salinity, as well as plant growth. In areas where surface water resources are insufficient, irrigation of crops can be carried out using groundwater. Nevertheless, it is not possible to irrigate a large area with this water. Therefore, in arid locations, little green spaces can be established using drip irrigation utilizing groundwater. It also has a positive effect on the ecology of the area.

On the other hand, although drip irrigation technology has several advantages, great importance must be attached to its proper use. In practice, farmers' level of control over new drip irrigation technologies and equipment is often insufficient, which leads to delays in maintenance of these devices and the cessation of use of the equipment. In particular, its misuse is widespread on farms where water-saving technology is just beginning to be introduced.

7 CONCLUSION

Research interest is increasing nowadays on selected topic, proved by published number of articles. According to the results of research on topics related to the selected keywords, over the past 5 years, more than 100 articles have been published annually, the number of articles published in 2018 increased by 55% compared to 2017. It was reach its peak by 2024, indicating that water scarcity is a pressing issue worldwide. Regarding the types of articles, research articles were found to be the ones that interested researchers the most. Overall, the bibliometric results show the participation of about 200 authors, where the number of articles by Chinese scientists is very high. The literature also indicates that the publications belong to the fields of “Agriculture” and “Water Resources”, which are most frequently published by the Elsevier and MDPI.

The fact that this issue is receiving attention from all continents of the world, funding from various foundations, and its relevance to various research areas indicates the relevance of the chosen topic. To sum up, we hope that the article written on the chosen topic will alleviate the problem of water scarcity and contribute to the development of science.

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