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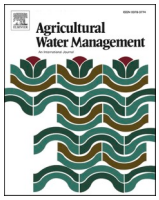

Drainage in irrigated agriculture: Bibliometric analysis for the period of 2017–2021

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ABSTRACT

Drainage is important in controlling the level of groundwater water in improving the melioration of irrigated lands in agriculture. The right choice of drainage parameters during design will allow for minimization of salt fluxes between the crop root zone and groundwater, and between drained lands and receiving water bodies. In this study, bibliometric analysis was used to identify important trends, focus areas, and regions in international irrigation and drainage research from 2017 to 2021. The data used in this analysis were taken from the online version of the Scopus database and 1492 publications met the selection criteria. Bibliometric analysis showed that all articles were published in English, with the highest publication numbers coming from the China, USA, India, Egypt, Iran, Spain and Brazil. It was revealed that 47 publications were from Central Asian countries on irrigation and drainage issue. Further information about Soviet Legacy and Current Central Asia with large areas irrigated with drainage system and with great pressure to overcome problems induced by soil salinization. To solve the above problem, existing technical conditions of drainage systems in irrigated agriculture, new technology and technical means of cleaning closed horizontal drains in the irrigation zone are necessary. Bibliometric analysis revealed that international research on irrigation and drainage would benefit from expanding scientific exchange on this topic, as well as from long-term, continuing studies and the sustainable integration of irrigation and drainage research into future agricultural and drainage system management concepts.

1. Introduction

Irrigation and drainage is very important and is becoming a basic part of well-developed agriculture and increase the quality of life, especially in the context of the 8 billion people on this planet today (De Wrachien, 2001). Insufficient rain falls have to be compensated for, to ascertain sufficient agricultural yields (Gerts et al., 2020). Irrigation using good-quality river water, groundwater and, sometimes, wastewater has been used for ages (Singh, 2018). Irrigation is often accompanied by drainage, which is the natural or artificial removal of surface and sub-surface water from a given area (Duży et al., 2017). Artificial drainage is always needed, except in cases with deep groundwater levels (Khalil et al., 2021). In most river delta regions, drainage is a must to avoid water logging (Zegeye et al., 2021). These improved soil water conditions are important for the construction of infrastructure and for good crop production (Qureshi et al., 2011). Drainage also prevents accumulation of salts in the crop root zone, which could negatively impact on crop growth and yields (Kopecký et al., 2013). The goal is to create conditions for optimal soil water management in irrigation schemes (Arifjanov et al., 2019).

Current irrigation and drainage practices generate millions of tonnes of salt, raising significant environmental concerns regarding the disposal

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and management of saline drainage water in rivers, lakes, wetlands, and lowlands within the region (Ayars et al., 2006). Drainage design must also take the irrigation system and water management practices into consideration, in order to achieve the optimum water and salt balance in the crop root zone, and also to minimize the amount of salt being mobilized and entering receiving water bodies (Dukhovny et al., 2018). Globally, improper drainage can lead to significant challenges, including waterlogging, soil salinization, and reduced crop yields. According to the Food and Agriculture Organization (FAO), over 20 % of the world's arable land is affected by drainage issues, which can severely impact agricultural outputs and food security (Erpul et al., 2019). Regional Challenges and Statistics, different regions face unique drainage challenges. For instance: **Asia**: In countries like Bangladesh and Vietnam, the prevalence of waterlogging is a major concern, affecting millions of hectares of rice paddies. The Asian Development Bank (ADB) reports that inadequate drainage infrastructure is a significant issue in these areas, exacerbating flood risks and agricultural losses (ADB, 2020). **Africa**: Sub-Saharan Africa faces problems related to both excess water and drought. In regions such as the Nile Delta and parts of the Sahel, inadequate drainage and irrigation infrastructure contribute to low agricultural productivity and increased vulnerability to climate change (World Bank, 2021). **Europe and North America**: Advanced drainage systems are in place, yet challenges remain. For example, in the Netherlands, where land reclamation and drainage are vital due to the low-lying geography, the management of excess water from rainfall and sea-level rise continues to be a significant concern (Dutch Ministry of Infrastructure and Water Management, 2022). The total area of agricultural land in the Russian Federation was 381,673 thousand hectares, of which 58 % is intended for agriculture. Land reclamation, through methods such as irrigation and drainage, plays a crucial role in ensuring higher crop yields and preventing crop loss by managing excess water effectively (Lipski, 2020). Russia faces serious challenges in managing its irrigation and drainage systems due to aging infrastructure and climate variability, and ongoing modernization efforts and technology adoption aim to improve the efficiency and sustainability of these critical agricultural support systems (Snezhko and Benin, 2021).

The Central Asian countries are among the most water-intensive economies in the world, with mean water withdrawals of 2200 m^3/y per capita and nearly 90 % of water diverted for irrigation purposes (Sehring and Diebold 2012). This can lead to problems in the future during the current water supply. About two million hectares of the irrigated land is considered to be seriously damaged by waterlogging and salinity. Most of this land is in the lower reaches of the Syr Darya and the Amu Darya Basins. Lesser degrees of salinization and waterlogging problems exist on about 1.7 million hectares of land which is also located primarily in Uzbekistan, Turkmenistan and Kazakhstan (Ochs and Smedema, 1996; Dukhovny et al., 2018). Drainage management in the developing countries is quite difficult because of the: halt to drainage development and ageing of drainage infrastructure; lack of financial support for drainage maintenance, repair and development; separation of the design and construction of drainage systems from its operation, particularly in transboundary basins and with the recent introduction of thousands of new water and land users; lack of technical capability for land reclamation and weakened efforts to create new drainage infrastructure (Kannazarova, et al., 2021; Allred and Redman, 2010; Drovovozova et al., 2021a; Khamidov et al., 2020a). Given the above challenges and issues, it is important that in the developing countries existing technical conditions of drainage systems and increase support for operating reclamation systems with closed drainage (Pogodin et al., 2020; Kannazarova, and Li, 2021). It is necessary to carry out scientifically sound and technologically advanced repair and maintenance work with the involvement of modern high-performance equipment (Usanov et al., 2019; Khamidov et al., 2020c).

Numerous reviews have been published regarding various aspects of irrigation and drainage, such as a salinity and environmental perspective, soil water movement in irrigation agriculture (Kargas et al., 2022), the salinization and drainage problems (Singh, 2020) and smart irrigation system (Azad et al., 2022), to control salinity in dryland (Steppuhn and McArthur, 2017), as well as reviews of irrigation and drainage in particular regions (De Wrachien et al., 2021), water and sanitation (Singh and Jayaram, 2022), water strategies and water-food in nexus (Salem et al., 2022) give a broad overview of the global status of irrigation and drainage and future challenges. However, no studies have been conducted to map the international scientific research output on irrigation and drainage systematically.

Bibliometric analysis is a useful tool to analyze publications in a certain research field. It is a quantitative approach to study the metadata of scientific publications in contrast to the qualitative approach of narrative scientific literature reviews, which might often be subject to bias by the researcher (Tranfield, 2003). However, bibliometric analysis might also be flawed because publication numbers do not necessarily indicate the importance of a certain research subject. But bibliometrics is a helpful method to detect research trends, whereas a narrative literature review is more suited to compiling scientific knowledge on a certain research field and to identify research deficits. Bibliometric studies in environmental science have been conducted regarding various research aspects, e.g. drainage system (Piadeh et al., 2022), irrigation in agriculture (Velasco-Muñoz et al., 2019), wastewater irrigation (Maassen, 2016), groundwater (Kannazarova et al., 2024), wastewater management (Durán-Sánchez et al., 2020), water systems (Sawassi and Khadra, 2021), water resources (Yang et al., 2022), soil water (Zhang et al., 2020), root harvester machine for agriculture food (Xaliqulov et al., 2023), marginal lands (Jumaniyazov et al., 2023), different approaches and methodologies (Nguyen et al., 2023), the usage of photocatalysis for wastewater treatment (Mohammed et al., 2023) and landslides (Khasanov et al., 2021).

The purpose of this study is to analyze hot topics and important regions of irrigation and drainage research as well as to use historical bibliometric data to gain new insights into trends and emphasis of international irrigation and drainage research. According to Scopus database period from 2017 to 2021 were more productive on irrigation and drainage related topics, therefore we decided to analyze the current period. During this period, there has been a noticeable lack of bibliometric analysis on irrigation and drainage in research articles, particularly concerning the Central Asian countries.

2. Materials and methods

In this article, we went to the selection publications on worldly knowledge from the research done. The search collects the English-language academic literature retrieved from the Scopus database for the period 2017–2021. The analysis was carried out in September 2022. A total of 1492 publications were downloaded with the keyword "Irrigation and Drainage". In the next step, articles were categorized according to year of publication. A database of all peer-reviewed papers was then created, including the year of publication, authors' names, countries, publication type, journal name, number of citations per paper, the number of citations per journal, the percentage of publications by the topic cluster name and subject area. The analysis was performed using softwares like Microsoft Excel, VOSviewer and Map chart. Fig. 1 shows the flow of the selected methodology for the research.

The reasons for our use of the methods mentioned above are related to Scopus, a well-known database that collects authoritative literature from around the world, especially on irrigation and drainage systems. English is a universal language, therefore, the literature in English is more standard and meaningful than literature in other languages.

3. Results

3.1. Trend of publications on irrigation and drainage

Overall, what stands out is that the number of published papers on a

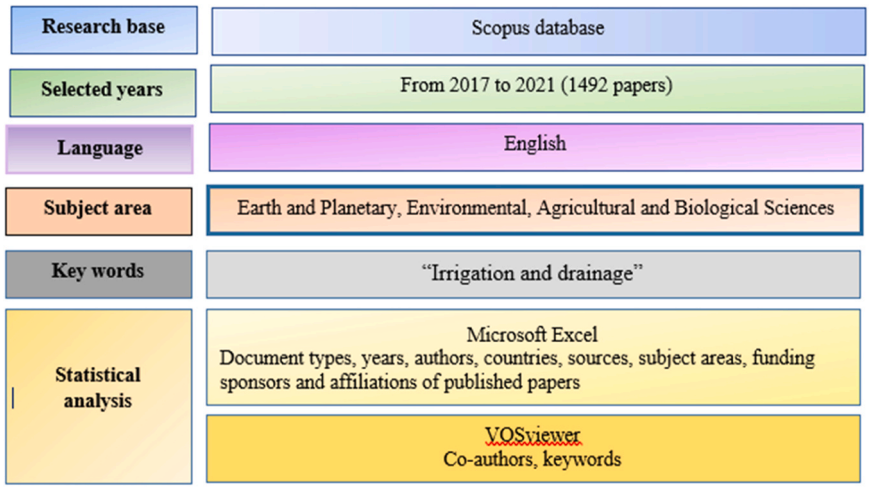

Fig. 1. Flowchart of the methodology.

particular issue studied for the first time in the world. Total of 1492 papers published between 2017 and 2021 on Irrigation and drainage issue. The number of records started to grow between 2017 and 2021 from 230 to 326 publications. Fig. 2 shows 230 (15 %) number of papers at the beginning in year 2017. From 2018 we can see the rapid increasing in the number of publications. There were 286 (19 %) and 308 (20 %) publications in 2018 and 2019. In 2020, the highest number of publications was reached during the period of analysis 342 (23 %). Almost 22 % from the total number of publications were published in 2021 (Fig. 2).

Over the past 3 years, the increase in the number of articles has been mainly observed in the IOP conference Series, Journal of Earth and Environmental Sciences, Journal of Agricultural Water Resources Management, and Journal of Irrigation and Drainage. In the main part of these articles, we observed scientific proposals about soil salinization in the deterioration of the land reclamation condition.

Furthermore, our learning shows that the largest number 1066 (72 %) of 1492 papers were research articles, followed by 273 (18 %) articles in conference proceedings, 80 (5 %) book chapters, 39 (3 %) review papers whereas there were only 2 % of other document types (e.g. Erratum 13, Note 8, Conference Review 6, Book 4, Data Paper 1, Letter 1, and Retracted 1) (Fig. 3).

3.2. Journals on irrigation and drainage

A wide variety of journals in different parts of the world are used by scholars to publish their research. The communication patterns of the scholars indicate that the total output was distributed across 149 journals published in 115 countries. Of these 15 journals published 532 (36 %) papers and remaining 64 % papers were published in other journals. Table 1 lists name of the 56 journals which published minimum 3 and higher number of papers during the abovementioned period.

The second analyzing criteria is the name of publishing country and impact factor of the top 15 journals (Table 2). Of these fifteen journals were published four from the Netherlands, three of them from UK and three from Germany, two journals in US and the other three countries have one journal each from Belgium, France, Switzerland. The average impact factor of the journals with the highest number of articles was 3.63. Among the 15 journals the *Science of the Total Environment* had the highest impact factor and the Agricultural Water Management had the highest number of publications in this field.

3.3. Authors and their affiliated country

Our research revealed that 5102 authors from 115 countries conducted research on irrigation and drainage during 2017–2021. Fig. 4

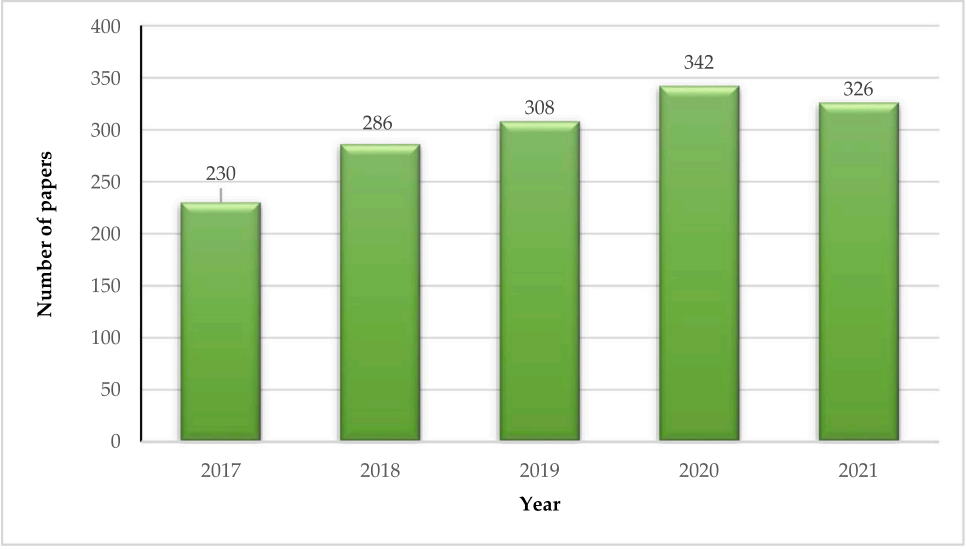

Fig. 2. Number of papers on irrigation and drainage system by the year of publication issues in the world.

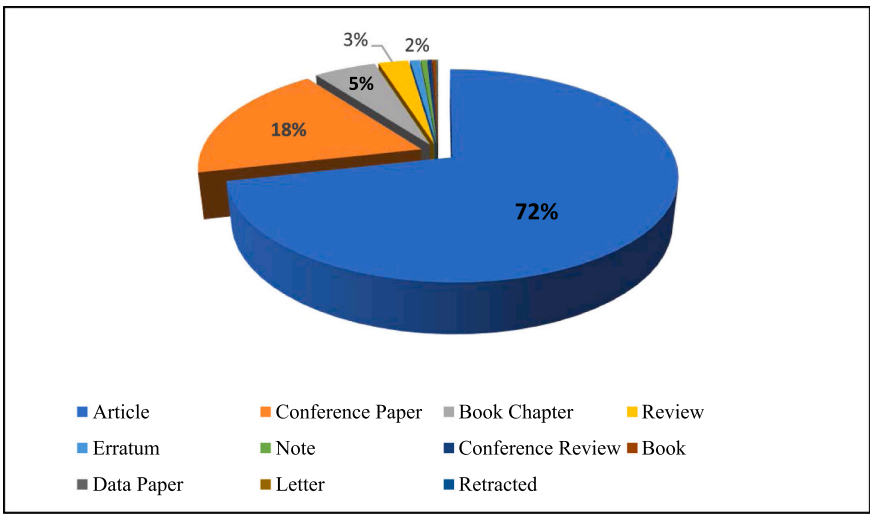

Fig. 3. Publication type on irrigation and drainage system issues in the world.

lists 12 authors who published 6 or more papers. Between them, Gheyi, H.R. reigned with 17 publications, followed by Nobre, R.G. with ten, de Lima, G.S. nine, Dias, A.S., Madramootoo, C.A. and Singh, A. with seven papers, Cui, Y., De Lima, G.S., Fernandes, P.D., Huo, Z., Jia, X. Papafotiou, M. each with six research papers. In this list of top authors coming six from Brazil, two from USA and two from China and one from Greece and one from India.

The quality of papers published by researchers determines how institutions are ranked. One hundred sixty different institutions worked in cooperation to publish 1492 papers on irrigation and drainage over the world the period of 2017–2021. Our analysis of the top 15 institutes' publications on irrigation and drainage allowed us to determine the influential and productive institutions in this field. As indicated in Fig. 5, of the 15 institutions, seven of them were from China, two were from US and Brazil, one each from Germany, Egypt, Uzbekistan and Iran. These prolific institutions contributed around 22 % of the total output. Among these, Chinese Academy of Sciences occupies the first position in record rank (38 records), followed by the Ministry of Education China (28) and Ministry of Education China (26 records).

3.4. Top countries on irrigation and drainage

Research on irrigation and drainage had been published in 115 countries around the world. Fig. 6 lists 6 most prolific countries in the field of irrigation and drainage research. Countries which published 856 research papers in last five year (2017–2021) have been considered as prolific countries. These 6 countries published more than half (57.3 %) of the total output. Among them, China dominated with (241; 16.15 %) publications, followed by the United States (226; 15.14 %) India (134; 8.98 %), Egypt (93; 6.23 %), Iran (90; 6.03 %) and Spain (72; 4.82 %).

The top ranked countries include the traditionally defined developed countries in the world. The rapid economic growth and agricultural development in PR China, USA and India resulted in an increase in agricultural and environmental research, and thus in an increase in publication numbers. This may be mainly due to the fact that these countries host a large number of highly ranked research centers and universities.

3.5. Top cited papers on irrigation and drainage

A high number of citations indicates a quality and novelty of research. Fifteen mostly cited papers on irrigation and drainage shown in the Table 3. Total of 11096 citations given to 1492 publications on irrigation and drainage for the given period. Almost 16.92 % of citations given to 15 papers from the Table 3. First 15 top cited papers are consisting of four reviews and 11 research articles. In this list of most cited papers, China has six representations, USA have two representations and Brazil, Switzerland, Turkey, Iran, Germany, Austria and Spain have one representative each.

As we have witnessed through this analysis, most of the works were published in conference series rather than peer-reviewed sources. For example, from six sources that published at least three or more articles, four conference collections contained 16 articles, as opposed to peer-reviewed journals that published nine articles. Through these conference papers, we can only see shallow results with limited factors rather than a deep analysis of their rationale. Therefore, despite the large number of papers in this conference series, they were cited more times than journal articles due to their low importance and contribution.

3.6. Top cited journals on irrigation and drainage

In 3.6 subsection we analyzed top journals which published the greatest number of papers. Taking into consideration this factor, we decided to investigate top-cited journals on irrigation and drainage. Firstly, we sorted source names alphabetically of excel extension file of 1492 documents. Then step-by-step total papers` citations are summarized by each journal. Interestingly, at the result we got updating list with potential journal names. Initial 15 journals selected and shown in Fig. 7. Almost 43.81 % (4893 citations) of total citations given to papers published in these 15 journals. As a result of the number of citations, the first ranked journal with 94 documents by publication rate emerged as the best journal (see Tables 1,2). Five journals: Science of The Total Environment, Journal of Hydrology, Irrigation and drainage, Journal of Environmental Management, Agronomy are ranked as a top cited journal (Table 2). Four journals: Horticultural, Proceedings of the National Academy of Sciences of the United States of America, Ecological Indicators and Geoderma have more citations even though they have fewer articles on irrigation and drainage issue in the world.

3.7. Top funding sponsors and cluster name on irrigation and drainage

There is a relationship between prevalence of affiliated countries and funding of large funding schemes and programs. One hundred fifty-nine different funding sponsors worked in cooperation to publish 878 papers on irrigation and drainage over the world the period of 2017–2021. Based on our analysis of the top 10 funding sponsors publications on irrigation and drainage, we were able to identify the most influential and productive institutions in the field. As indicated in Fig. 8, of the 10

Table 1
List of the journals on irrigation and drainage system by the year of publication issues in the world.

Scopus Source title	Number	Scopus Source title	Number
Agricultural Water Management	94	Irrigation Science	8
IOP Conference Series Earth and Environmental Science	74	Soil and Tillage Research	8
Irrigation and Drainage	73	Vadose Zone Journal	8
Science of The Total Environment	42	Fresenius Environmental Bulletin	7
Acta Horticulture	39	Hydrological Processes	7
Journal of Irrigation and Drainage Engineering	39	International Journal of Civil Engineering and Technology	7
Journal of Hydrology	25	Plos One	7
E3s Web of Conferences	24	Soil Research	7
Handbook of Environmental Chemistry	23	Transactions of The Asabe	7
Agronomy	19	Applied Ecology and Environmental Research	6
Environmental Earth Sciences	19	Applied Geochemistry	6
IOP Conference Series Materials Science and Engineering	19	Communications in Soil Science and Plant Analysis	6
Journal of Environmental Management	15	Ecological Indicators	6
Environmental Science and Pollution Research	14	Frontiers in Sustainable Food Systems	6
Environmental Monitoring and Assessment	13	Journal of Environmental Quality	6
Arabian Journal of Geosciences	12	Scientific Reports	6
Geoderma	12	Water Air and Soil Pollution	6
Paddy and Water Environment	11	Water Resources Development and Management	6
Revista Brasileira De Engenharia Agricola E Ambiental	11	Water Science	6
Agriculture Ecosystems and Environment	10	Advances in Intelligent Systems and Computing	5
Plant Archives	10	Agronomy Journal	5
Scientia Horticulture	10	Asian Journal of Water Environment and Pollution	5
Catena	9	Bioscience Journal	5
Lecture Notes in Civil Engineering	9	Ecological Engineering	5
Advances in Science Technology and Innovation	8	Agricultural and Forest Meteorology	4
Applied Engineering in Agriculture	8	Agriculture Switzerland	4
Computers and Electronics in Agriculture	8	Applied Water Science	4
Desalination and Water Treatment	8	Agricultural Systems	3

funding sponsors, five of them were from China, two from US and two from Brazil and last were from European Union.

There are different topic cluster names available for the subject areas given in Scopus database. Most of the papers published on irrigation and drainage issue in the world belong to 4 different topic cluster names in Fig. 9. Environmental topic cluster name covers 38 % of total publications, while Agricultural and Biological Sciences 31 %, Earth and Planetary Sciences 20 % and Engineering cluster covers 11 % of total publications.

3.8. Top co-authorships and keywords on irrigation and drainage

Co-authorship, keyword co-occurrences, citations, bibliographic coupling, and co-citation maps can be generated using VOSviewer based on bibliographic data. File formats supported include.txt, ris, and.csv

Table 2
Distribution of research output in prolific journals.

Journal	TNP (%)	Publishing country	IF
Agricultural Water Management	6,3 %	Netherlands	6.61
IOP Conference Series Earth and Environmental Science	5 %	UK	-
Irrigation and Drainage	5 %	UK	1,42
Science of The Total Environment	2,8 %	Netherlands	10,75
Acta Horticulture	2,6 %	Belgium	0,25
Journal of Irrigation and Drainage Engineering	2,6 %	US	1,34
Journal of Hydrology	1,7 %	Netherlands	6708
E3s Web of Conferences	1,6 %	France	
Handbook of Environmental Chemistry	1,5 %	Germany	3,0
Agronomy	1,3 %	Switzerland	3949
Environmental Earth Sciences	1,3 %	Germany	3119
IOP Conference Series Materials Science and Engineering	1,3 %	UK	-
Journal of Environmental Management	1,19 %	US	8.91
Environmental Science and Pollution Research	0,94 %	Germany	5190
Environmental Monitoring and Assessment	0,87 %	Netherlands	3307
Total:	**36 %**		3,63

* TNP – Total number of publications, * IF – Impact factor

from databases such as Web of Science, Scopus (Samir Kumar Jalal, 2019). The raw file was imported into VOSviewer and a map of co-authorship and keyword co-occurrences (shown in Figs. 10 and 11) were created using the software. The co-authorship analysis resulted in a network of 5102 authors. Only authors having a minimum of five publications on the topic of irrigation and drainage systems were included. There are 45 items distributed over seven clusters: cluster 1 (10 items), cluster 2 (10 items), cluster 3 (7 items), cluster 4 (5 items), cluster 5 (5 items), cluster 6 (5 items), cluster 7 (3 items).

The analysis yielded 8194 keywords. After excluding the general keywords with a low relevance score and those with low occurrence (by default, a minimum of five occurrences of a keyword is selected, to strengthen the co-occurrence results), 20 items were finally identified. Based on the total link strength, each resulting keyword is sketched in a node, creating a network map of all keywords. Fig. 11 shows the network map of the top 20 authors' keyword co-occurrence. The size of the node reflects the keyword's degree of importance.

3.9. Irrigation and drainage issue in Central Asia

In this bibliometric analysis, we selected 47 publications on Central Asia on irrigation and drainage issue. Of these, we can see thirty eight publications about Uzbekistan, six about Kazakhstan, one about Kyrgyzstan and one about Central Asian countries on irrigation and drainage study. Different authors are from ten countries such as Germany, Japan, Jordan, Sweden, Uzbekistan, Kazakhstan, Kyrgyzstan, China, Mongolia, Russian Federation. Between them, Kulmatov R reigned with five publications, followed by Abduraimova D with two, Khamidov M with two publications on irrigation and drainage issue. In the Table 4 shows ten publications on irrigation and drainage issue in CA. From the 47 papers the largest number 26 (55 %) were conference papers, followed by 18 (38 %) articles and 3 (0.6 %) book chapters. Among these 47 publications, if we pay attention to the topics of publications, such as current and future challenges of water security in central Asia (Xenarios et al., 2018), status quo and present challenges of the sustainable use and management of water and land resources in Central Asian irrigation zones (Kulmatov et al., 2018), deformation processes in open drainages (Abduraimova et al., 2021), using collector-drainage water in saline and arid irrigation areas for adaptation to climate change (Khamidov et al., 2020b).

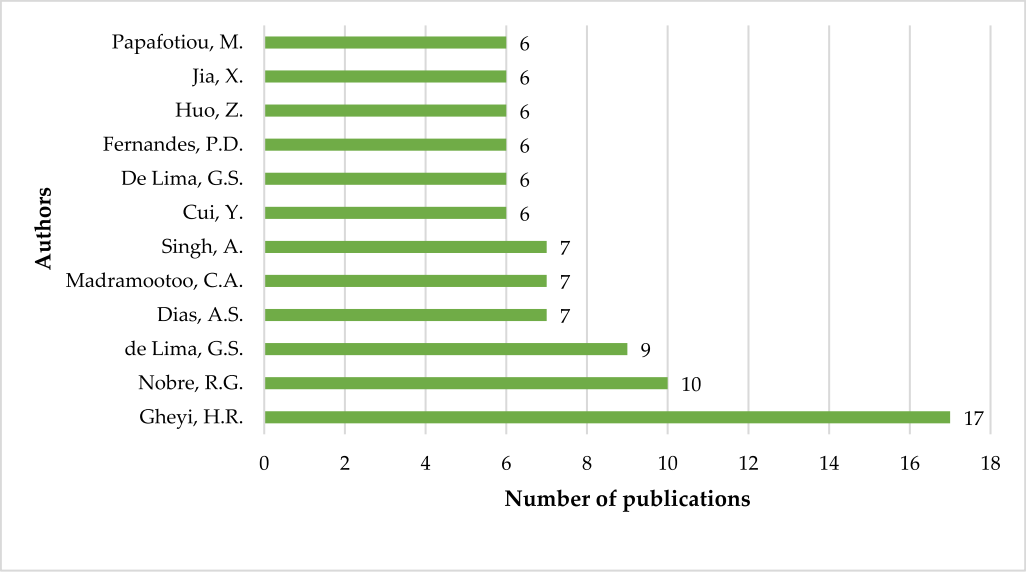

Fig. 4. List of top authors published on irrigation and drainage system issues in the world.

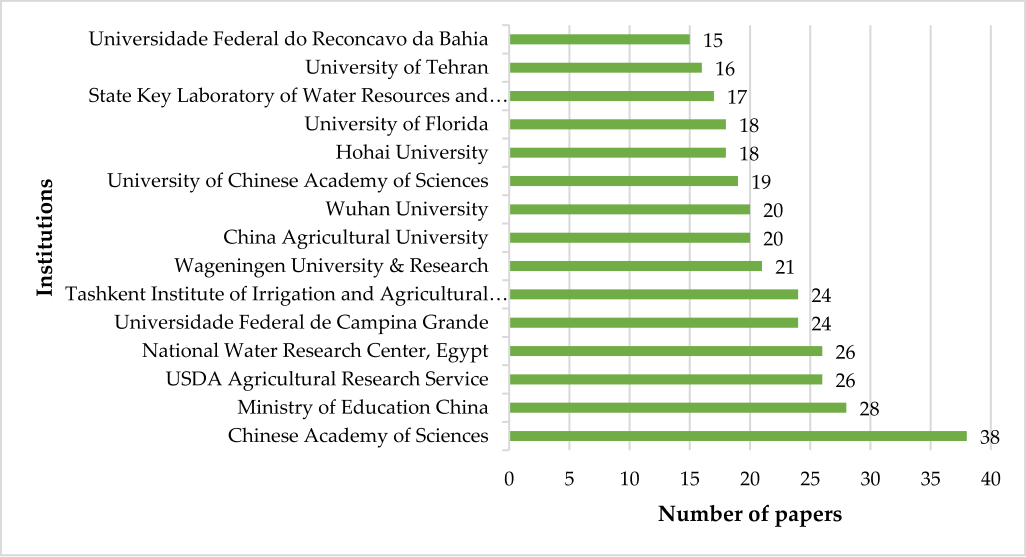

Fig. 5. List of top institutions on irrigation and drainage system issues in the world.

4. Discussion

4.1. Bibliometric analyses irrigation and drainage

Our assessment showed that around 16,15 % of China and 15.14 % of USA the reviewed publications focused on irrigation and drainage studies. From the analyses we can see that the main authors, main funding sponsors and institutions for the irrigation and drainage studies in the world are from China, from USA, from India and from Brazil. The main reason for this, the countries include the traditionally defined developed countries in the world. This might be mainly related to the fact that these countries house a large number of highly-rated research centers and universities. Although there were still no developing countries ranked in the top countries, the topic of irrigation and drainage systems is receiving more attention in Central Asia and Africa, South America and South Asia. The territories of the countries have specific soil and climatic conditions, as a result of insufficient natural drainage and a high level of groundwater mineralization, a number of territories are "primarily saline" (Gafurova and Juliev, 2021). At the same time, as a result of the irrational use of water resources and the negative impact of other anthropogenic factors, "secondary salinization" of lands is observed in some territories, the irrigated land area has a different degree of salinity (Kannazarova and Muratov, 2022; Khalil et al., 2021; Balla et al., 2014). To solve the above problem, existing technical conditions of drainage systems, new technology and technical means of cleaning closed horizontal drains in the irrigation zone. A significant part of the sown area, and almost all of it under industrial crops, is irrigated land, which is served by a powerful state irrigation system (Liu and Xu, 2022).

The quantitative analysis shows that the most prominent integrated with the context are "irrigation" with 600 documents representing 40,21 % of the total count, followed by "drainage" (301 documents), "groundwater" (200 documents), "soil salinization" (200 documents), and other water-related dimensions, such as "agriculture", "water security" and "wastewater management" (with 100, 50, and 41 documents, respectively). In these studies, it is clear that almost 60 % of the

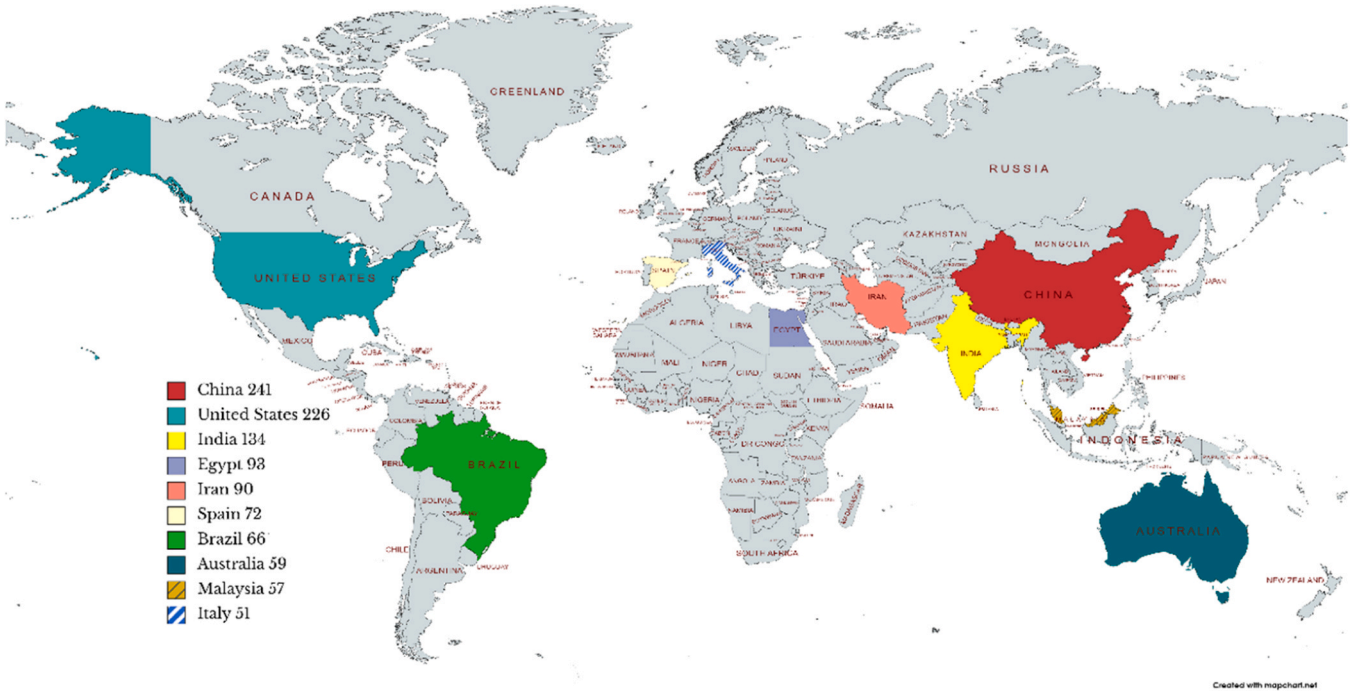

Fig. 6. List of top countries on irrigation and drainage system issues in the world.

Table 3
List of top cited publications on irrigation and drainage in the world.

No.	Title	Journal	Corresponding author	Country	PY	TC 2017–2021	Doc. type
1	Soil salinity: Effect on vegetable crop growth. Management practices to prevent and mitigate soil salinization	Horticulturae	Machado R.M.A.	Brazil	2017	509	Review
2	Freshwater salinization syndrome on a continental scale	Proceedings of the National Academy of Sciences of the United States of America	Kaushal S.S	USA	2018	243	Article
3	Increasing risks related to landslides from degrading permafrost into new lakes in de-glaciating mountain ranges	Geomorphology	Haeberli W	Switzerland	2017	140	Article
4	Monitoring soil salinity via remote sensing technology under data scarce conditions: A case study from Turkey	Ecological Indicators	Gorji T	Turkey	2017	127	Article
5	Reference evapotranspiration prediction using hybridized fuzzy model with firefly algorithm: Regional case study in Burkina Faso	Agricultural Water Management	Tao H	China	2018	100	Article
6	Land management: data availability and process understanding for global change studies	Global Change Biology	Erb K.-H.	Austria	2017	100	Review
7	Grain yield, water productivity and nitrogen use efficiency of rice under different water management and fertilizer-N inputs in South China	Agricultural Water Management	Pan J.	China	2017	93	Article
8	Bacterial, archaeal, and fungal community responses to acid mine drainage-laden pollution in a rice paddy soil ecosystem	Science of the Total Environment	Wang H	China	2018	80	Article
9	Water footprint assessment for crop production based on field measurements: A case study of irrigated paddy rice in East China	Science of the Total Environment	Xinchun C.	China	2018	78	Article
10	Uncertainty assessment of the multilayer perceptron (MLP) neural network model with implementation of the novel hybrid MLP-FFA method for prediction of biochemical oxygen demand and dissolved oxygen: a case study of Langat River	Environmental Earth Sciences	Raheli B	Iran	2017	77	Article
11	A review of soil-improving cropping systems for soil salinization	Agronomy	Cuevas J	Spain	2019	73	Review
12	Intensification of hydrological drought in California by human water management	Geophysical Research Letters	He X	USA	2017	71	Article
13	Microplastic contamination in freshwater: first observation in Lake Ulansuhai, Yellow River Basin, China	Environmental Chemistry Letters	Wang Z	China	2019	66	Article
14	Models meet data: Challenges and opportunities in implementing land management in Earth system models	Global Change Biology	Pongratz J	Germany	2018	61	Review
15	Insights into hydrological and hydrochemical processes in response to water replenishment for lakes in arid regions	Journal of Hydrology	Chen J	China	2020	60	Article

* PY – Published year, * TC – Total citation

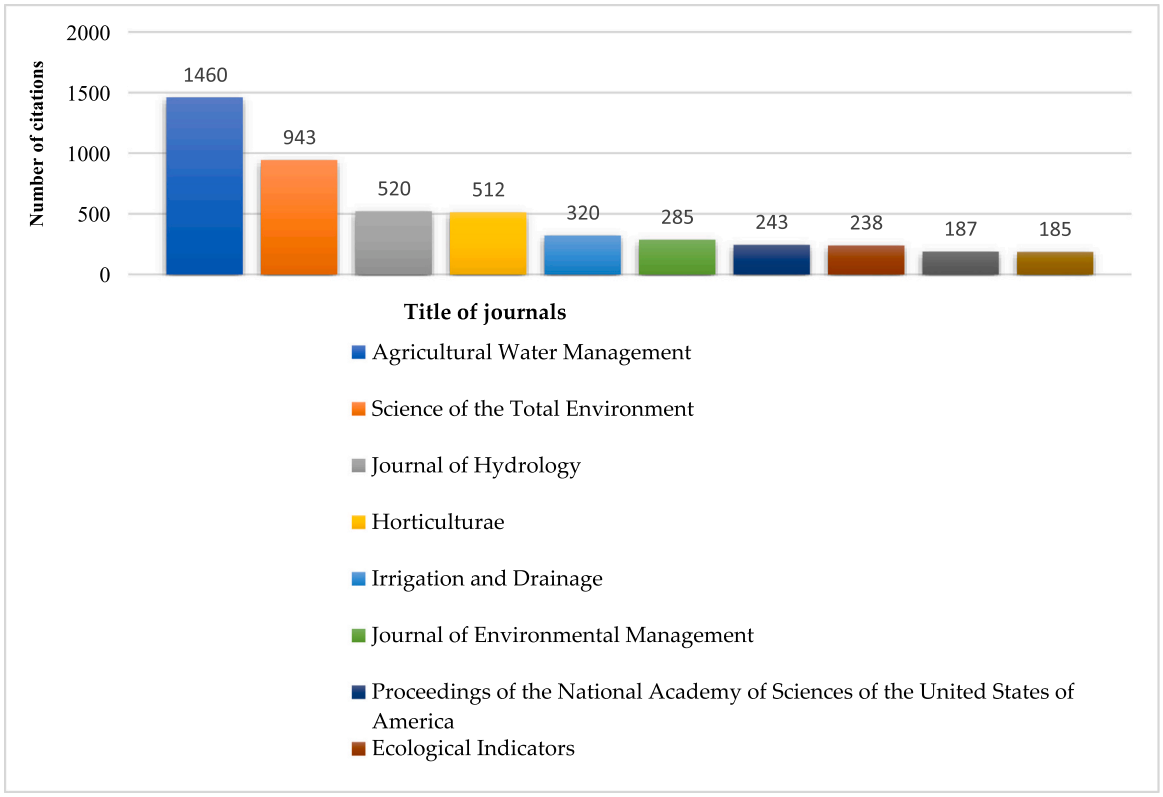

Fig. 7. Top cited journals on irrigation and drainage system issues in the world.

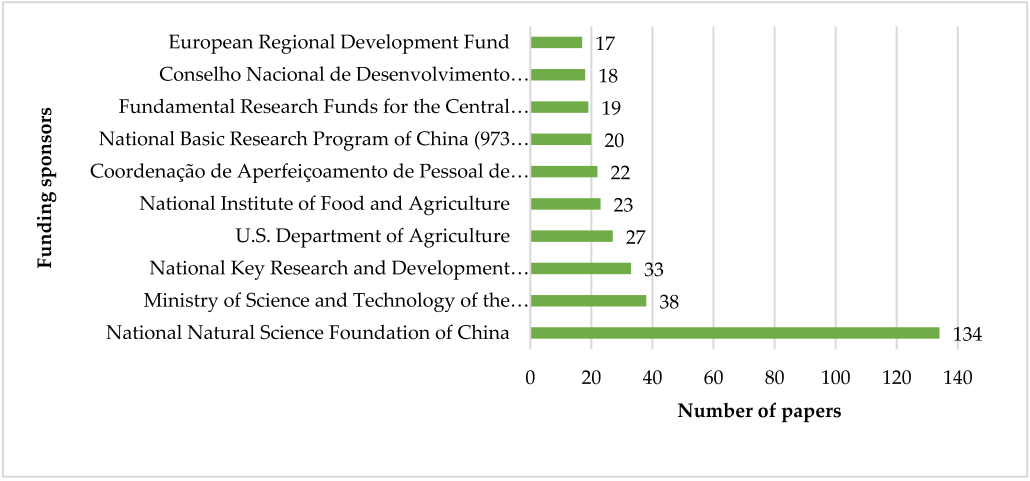

Fig. 8. List of top funding sponsors on irrigation and drainage system issues in the world.

articles are the deterioration of land reclamation in the irrigation and drainage system. In the given data, groundwater levels have risen in the following developing countries Central Asia and Africa, South America and South Asia due to lack of technical control in the drainage system (Balla et al., 2014; Ayars et al., 2006; Drovovozova et al., 2021b). If technical observations in the drainage system are not paid attention to in time when improving the melioration of irrigated lands. This will cause a lot of a irrigated land to decrease in the future.

The main disadvantage of the current period of assessment and forecasting of the volumes of flushing of closed drains in developing countries are the lack of scientifically based methods and theoretical developments that establish the dependence of the reclamation state of lands and the degree of siltation of horizontal drains of the reclamation system. When operating reclamation systems with closed drainage, it is necessary to carry out scientifically sound and technologically advanced repair and maintenance work with the involvement of modern high-performance equipment. The correct choice of the optimal parameters of the equipment when flushing the drains allows, ensures reliable, durable and high-quality operation of the closed horizontal drainage in the irrigation zone, with the lowest operating costs for the maintenance of the drainage.

4.2. *Irrigation and drainage issues worldwide*

The findings of this study provide a comprehensive overview of the global challenges and developments in irrigation and drainage over the

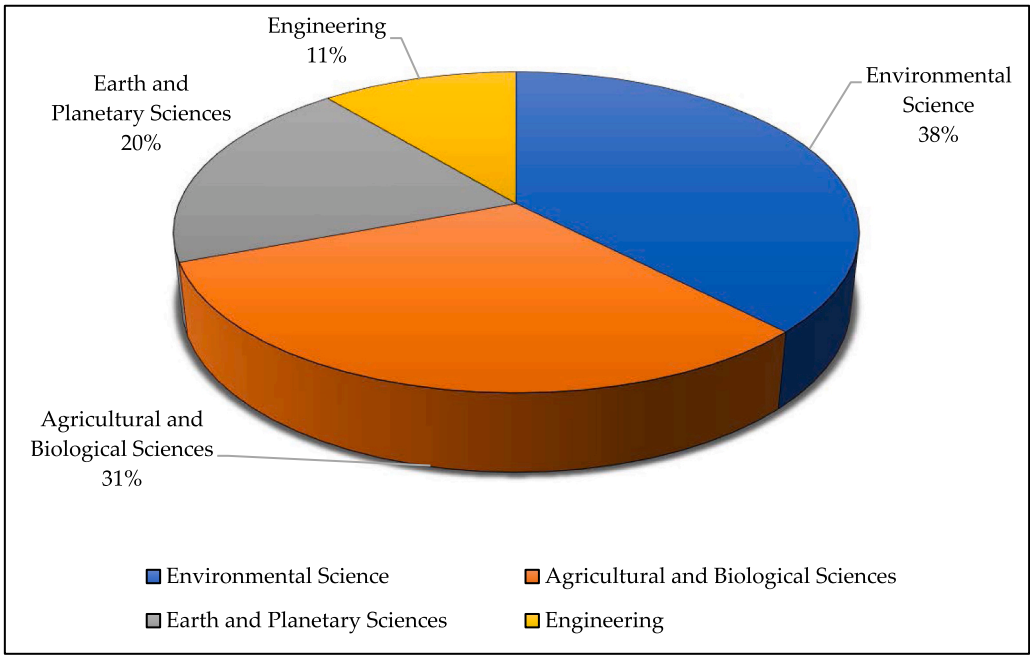

Fig. 9. Top topic cluster name on irrigation and drainage system issues in the world.

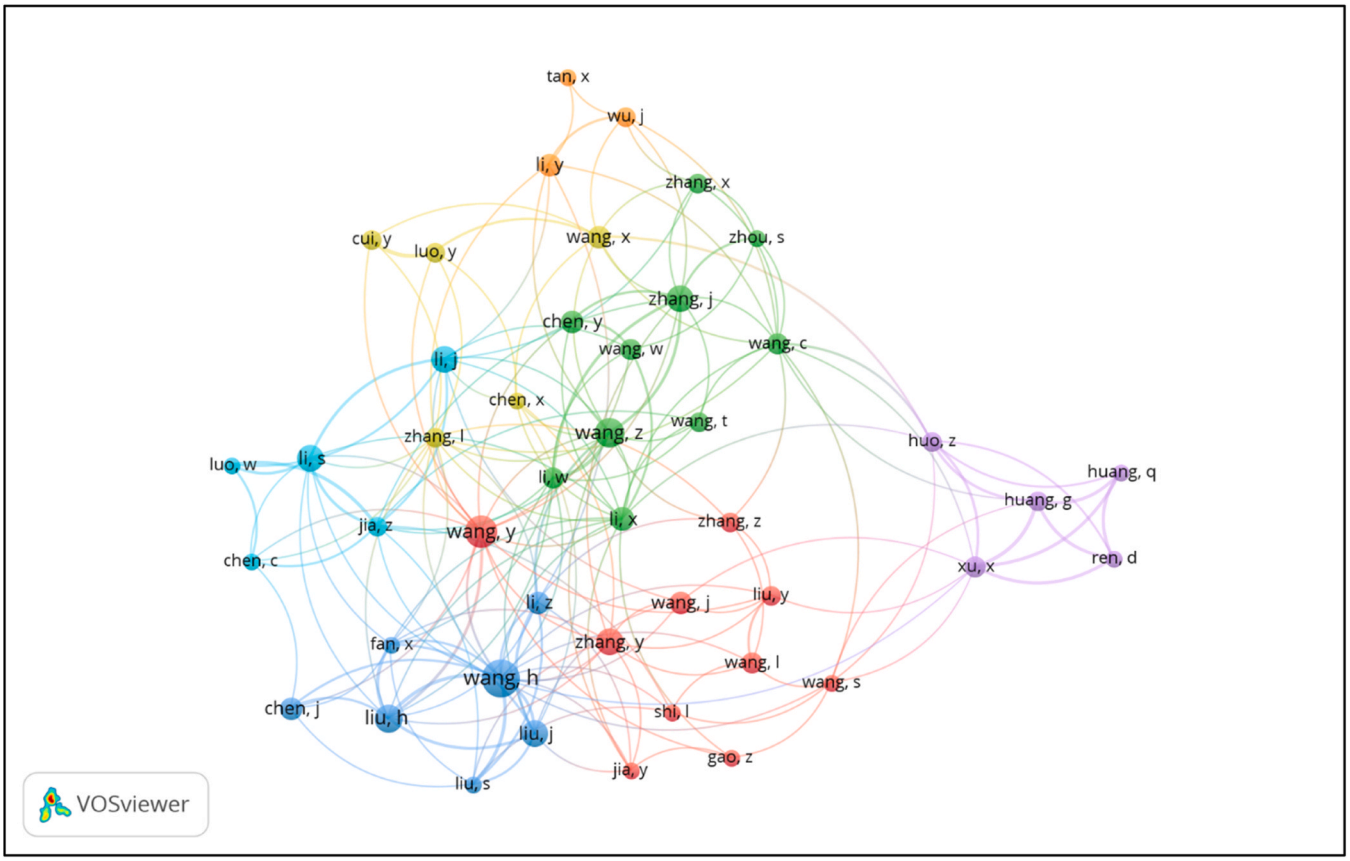

Fig. 10. Network map of top co-authorships based on the total link strength.

past five years, as reflected in the academic literature indexed in the Scopus database from 2017 to 2021. Irrigation and drainage challenges vary significantly from country to country, depending on local climate conditions, water availability, agricultural practices, infrastructure, and economic factors. Here is an overview of some of the key issues faced by different countries around the world: India faces significant irrigation and drainage problems due to its dependence on monsoon rains and the extensive use of groundwater for agriculture. Many irrigation canals and drainage systems are old and poorly maintained, leading to water losses and inefficiencies (Karegoudar et al., 2019). China's irrigation and

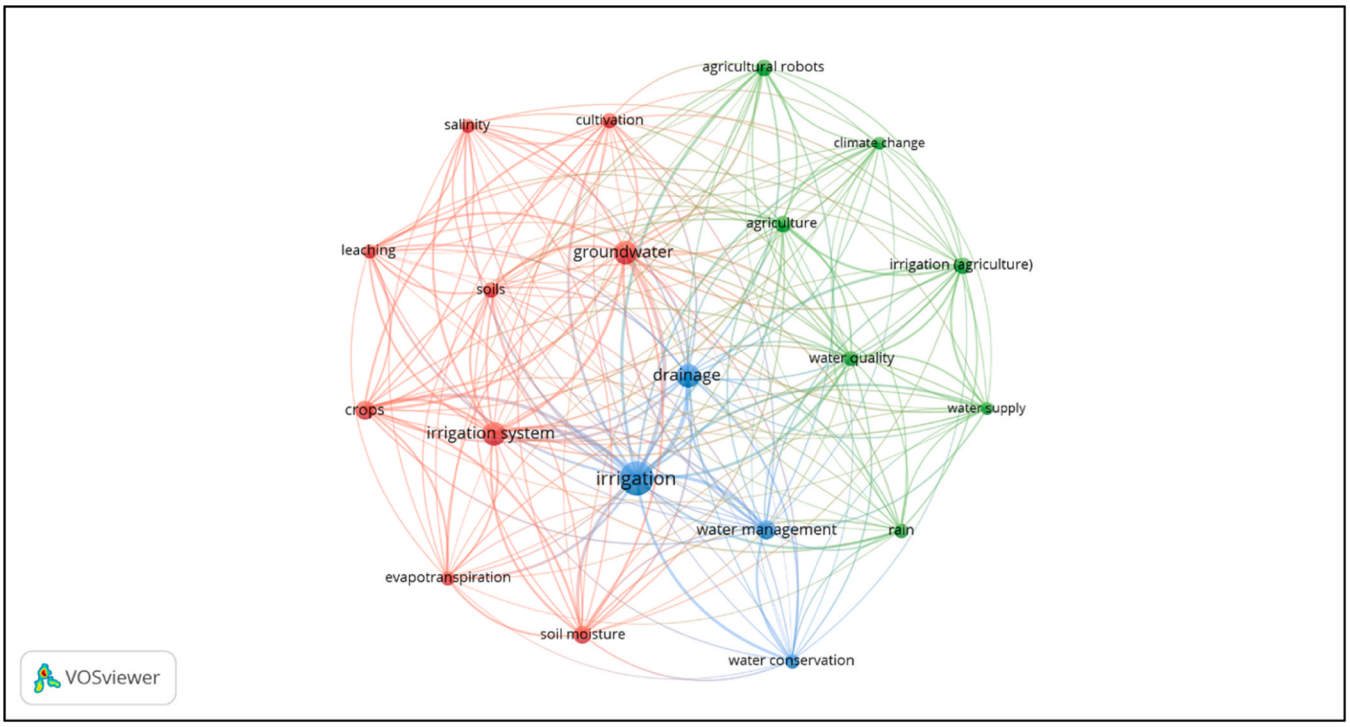

Fig. 11. Network map of top keywords based on the total link strength.

Table 4
List of publications on irrigation and drainage issue in Central Asia.

No	Title	Journal	Corresponding author	Country	PY	Doc.type
1	Assessing gaps in irrigated agricultural productivity through satellite earth observations—A case study of the Fergana Valley, Central Asia	International Journal of Applied Earth Observation and Geoinformation	Löw F.	Jordan	2017	Article
2	Climate-driven change of nitrogen retention–attenuation near irrigated fields: multi-model projections for Central Asia	Environmental Earth Sciences	Jarsjö J.	Sweden	2017	Article
3	The technology of irrigation of alfalfa by drainage-waste waters in kyzylorda region	News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences	Baishekeev A.	Kazakhstan	2017	Article
4	Controlled Subsurface Drainage as a Strategy for Improved Water Management in Irrigated Agriculture of Uzbekistan	Irrigation and Drainage	Dukhovny V.	Uzbekistan	2018	Conference Paper
5	Current and future challenges of water security in central Asia	Water Resources Development and Management	Xenarios S.	Kyrgyzstan	2018	Book Chapter
6	Status quo and present challenges of the sustainable use and management of water and land resources in Central Asian irrigation zones - The example of the Navoi region (Uzbekistan)	Quaternary International	Kulmatov R.	Uzbekistan	2018	Article
7	Understanding surface water–groundwater interactions for managing large irrigation schemes in the multi-country Fergana valley, Central Asia	Agricultural Water Management	Ibrakhimov M.	Uzbekistan	2018	Article
8	Groundwater resources	The Aral Sea Basin: Water for Sustainable Development in Central Asia	Gafurov A.	Germany	2019	Book Chapter
9	Some results of moisture and salt transfer in the initial period of plant development	International Journal of Engineering and Advanced Technology	Aliakbar K.	Uzbekistan	2019	Article
10	Application of magnetized water on the washing of salted lands under the conditions of the low village of the Amudarya River	Journal of Advanced Research in Dynamical and Control Systems	Kasimbetova S.	Uzbekistan	2020	Article

drainage challenges are driven by its large-scale agricultural production and regional disparities in water availability. In the south, frequent floods cause drainage issues, damaging crops and farmland. Industrial and agricultural pollution in key river basins (such as the Yellow River and Yangtze River) further complicates irrigation management (Li et al., 2020). In the United States, irrigation and drainage issues vary across regions, reflecting diverse climatic and agricultural conditions. States like California, Arizona, and Nevada face severe water scarcity, driven by prolonged droughts, over-allocation of water resources, and competition between agricultural, urban, and environmental needs. Many irrigation systems are outdated, causing inefficiencies and water losses (French et al., 2018). Egypt heavily relies on the Nile River for irrigation, but faces several problems related to its water management. With increasing demand for water and limited availability, Egypt is at risk of water scarcity, which affects its agricultural productivity. Irrigation practices in the Nile Delta have led to increased soil salinity, impacting crop yields. Poor drainage systems contribute to waterlogging and soil degradation, further complicating agriculture in the Nile Delta (Ashour et al., 2021).

Brazil has diverse irrigation and drainage challenges due to its varied

geography and climate. The semi-arid northeastern region faces frequent droughts, impacting irrigation. Many rural areas lack adequate irrigation and drainage infrastructure, limiting agricultural productivity (Pinhati et al., 2020).

Each country faces unique irrigation and drainage challenges shaped by its specific environmental, economic, and social conditions. Addressing these challenges requires targeted strategies that consider local contexts, along with international collaboration to share knowledge, technologies, and best practices. Sustainable water management is critical to ensuring long-term agricultural productivity and food security in these and other countries around the world.

4.3. Soviet legacy and current Central Asia in irrigation and drainage issues

As early as the 30 s of the last centuries, cotton monoculture, known as the "dictatorship of white gold", was established in Turkmenistan, Uzbekistan, and a little in Tajikistan. In the early 1960s, agricultural mechanization took place throughout the province, which enabled irrigation systems. During the Soviet era, due to the construction of many reservoirs, extensive water supply and drainage networks, and large pumping stations, priority was given to irrigated agriculture in order to meet the needs of cotton crops with high water needs. Irrigation management was partially controlled by the individual Soviet republics, but the entire process was centralized in Moscow, in the Ministry of Land Reclamation and Water Management. Consequently, after the collapse of the Soviet Union, the impact of the Syrdarya basin on water security varied depending on the facilities available in each district. Nevertheless, as the drying up and increasing salinity of the Aral Sea forced the Gorbachev government to publicly acknowledge the "Island Problem" and seek solutions, water security concerns arose throughout the region. Transboundary Irrigation Districts ceased to operate after the collapse of the Soviet Union in 1991. New administrative boundaries of water resources management were established, which made water management the competence of state bodies. A system of main drains, lateral collectors and intra-farm drains allowed for the collection and removal of excess water from irrigation and rainfall. However, this canal system alone could not maintain a stable salt balance in saturated soil in agricultural areas. Rapid implementation of new methods of drainage (vertical, horizontal, combined), creation of equipment for the construction and maintenance of drains (trenches and ditches less drainage machines, machines for cleaning drains) began in 1960 in the Hunger Steppe, where large-scale irrigation was being developed on saline lands. The Aral Sea basin is a closed drainage system encompassing about 690,000 km. The basin is primarily within five countries of the former USSR (Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan) whose rivers flow to the Aral Sea (Dukhovny, 1996).

The Table 5 shows irrigated and drained areas during Soviet and current situation in Central Asian countries. In Soviet times, it was the total area of irrigated land 7.4 mln. ha, between them reached the biggest number Uzbekistan with 4.27 mln. ha (58 %), following Turkmenistan with 1.2 mln. ha (16.3 %), Kazakhstan with 750.000 ha (10,2 %), Tadzhikistan with 570.000 ha (7.9 %) and the lowest number Kyrgyzstan with 560.000 ha (7.6 %). Also, by 1990, the area with artificial drainage in Central Asia reached 5.2 million ha. By 2021, the total area of irrigated land 10.05 mln. ha in Central Asian countries, among them Uzbekistan with 4.3 mln. ha (43 %), following Kazakhstan with 2.2 mln. ha (22 %), Turkmenistan with 1.8 mln. ha (18 %), Kyrgyzstan with 1 mln. ha (10 %) and the lowest number Tadzhikistan with 757.000 ha (7 %).

Irrigation is important to agriculture in the former Soviet Union because about 60 % of farmland is subject to potentially devastating droughts and significant water resources are available for irrigation development. In the USSR, about 20 million hectares (10 % of agricultural land) are adapted for irrigation; only India and China have more, which account for 30 % of the country's total agricultural production. Important environmental and economic problems include the problems of the Aral and Caspian Seas, land drainage and salinization, as well as groundwater pollution. Drainage has been installed on 5.2 million hectares of saline irrigated land in the Aral Sea basin, mainly in Uzbekistan.

4.4. Current Central Asia in irrigation and drainage issues

Two of the largest river systems in Central Asia, the Amu Darya and the Syr Darya, flow into the Aral Sea. Both rivers originate in the mountain ranges of the upstream countries. The Amu Darya, the larger in water volume, is formed by the Panj River on the Tajik–Afghan border and the Vakhsh River in Tajikistan and continues into Uzbekistan and Turkmenistan before emptying into the Aral Sea. The Syr Darya, which is longer, has its source in the Tien Shan Mountains in Kyrgyzstan, flows through the Ferghana Valley into Tajikistan and Uzbekistan, and ultimately empties into the Aral Sea. About 75 % of the Syr Darya runoff originates in Kyrgyzstan, while 74 % of the main flow of the Amu Darya originates in the territory of Tajikistan (Xenarios et al., 2018). The downstream countries of Uzbekistan, Kazakhstan, and Turkmenistan are poor in water resources but rich in hydrocarbon reserves. Coal, oil, and natural gas make up more than 90 % of energy consumption in Kazakhstan, Turkmenistan, and Uzbekistan (Granit et al., 2012).

Central Asia has 10.05 million ha of irrigated land, among them Uzbekistan alone has 4.3 (43 %) million ha of irrigated land. The total water consumption of the upstream countries, Kyrgyzstan and Tajikistan, amounts to only 15.6 %., and almost half of this area is affected by salinization. In Uzbekistan approximately 30,000 ha of land has drainage systems, and almost all the irrigated land is salinized (Kazievish, 2020).

Pressure on the region's water resources is expected to continue to increase. According to the World Bank, if population growth continues at the current rate of 1.5 % per year, the amount of water available per person will fall below 1700 m^3 by 2050, 1000 m^3 by 2080 and 500 m^3 by 2120; in other words, by the next century, water supply will be only a quarter of current average consumption.

The water used for irrigation evaporates and leaves salt over time, which makes the soil increasingly salty. High levels of salt make the soil unsuitable for growing most crops. In Central Asia, this problem is exacerbated by water seeping from leaky irrigation canals, use of excessive quantities of water, and poor drainage: the more water there is at surface level, the more evaporates and the more salt is left behind. All this means that more efficient use of water resources and effective cooperation will become even more important than now.

Table 5
Irrigated and drained areas in Central Asia (Dukhovny, 1996; Kannazarova, 2022).

Indicators	Uzbekistan	Kazakhstan	Tadzhikistan	Turkmenistan	Kyrgyzstan	Total
Total area of irrigated land (in 1990)	4.27 mln ha	750 000 ha	570 000 ha	1.2 mln ha	560 000 ha	7.4 mln ha
Drained area (in 1990)	3.62 mln ha	500.000 ha	330 000 ha	610 000 ha	140 000 ha	5.2 mln ha
Total area of irrigated land (in 2021)	4.3 mln ha	2.2 mln ha	757 000 ha	1.8 mln ha	1 mln ha	10.05 mln ha

5. Limitations

A limitation of this study is the reliance on a single database, Scopus, for the collection of literature over a five-year period. This method was selected to avoid potential formatting challenges that might arise when using data from multiple sources. Nevertheless, this strategy restricts the study to English-language papers available in Scopus, thereby excluding relevant literature from other databases and in different languages. Future research could address this limitation by incorporating data from a range of databases and considering literature published in multiple languages.

6. Conclusions

From the bibliometric analysis of 1492 publications, research trends, hot topics and important regions for various aspects of irrigation and drainage research were obtained. All articles were published in English, with the highest publication numbers coming from China, USA, India, Egypt, Iran, Spain and Brazil. It was revealed that most publications were from countries with large areas irrigated with drainage system and with major pressure to overcome problems induced by soil salinization. Due to the water shortage observed in recent years, the poor state of land reclamation, and the lack of timely implementation of other organizational measures, the level of water supply of several thousand hectares of irrigated land remains low, and the land area of irrigated Maintaining the reclamation state of irrigated lands in an optimal state is an integral part of the state policy to improve the welfare of the population and an essential factor in the development of agriculture land is falling from circulation every year.

Most probably, the main reasons for this research discontinuity lie in the short-period funding of research projects and thus a lack of long-term, continuing studies and of sustainable integration of irrigation and drainage research into agricultural and drainage water management concepts. These problems should be addressed in the future. Furthermore, international research on irrigation and drainage would benefit from expanding the scientific exchange on this topic, in particular between emerging and industrial countries, between the agricultural and drainage water scientific community as well as between stakeholders and scientists.

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CRediT authorship contribution statement

Fakhriddin Bekchanov: Writing – original draft, Visualization, Software, Resources. **Jilili Abuduwaili:** Funding acquisition, Project administration, Supervision, Writing – review & editing. **Mukhiddin Juliev:** Writing – review & editing, Visualization, Formal analysis. **Zulfiya Kannazarova:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation. **Ashirbek Muratov:** Writing – review & editing, Methodology.

Declaration of Competing Interest

The authors declare no conflict of interest.

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Data availability

Data will be made available on request.

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