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Review article

Bibliometric Mapping of Research on Water Availability in Central Asia

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Abstract

Water resources in Central Asia are primarily derived from the glaciers of the Tian Shan and Pamir Mountains, which have been significantly impacted by global climate change. The formation and consumption of these resources are not in balance due to the demands of energy production and agriculture. This review investigates the water availability issue in Central Asia using a bibliometric approach, analyzing 299 final published papers indexed in Scopus. The analysis focuses on publication trends and types, active researchers and institutions, funding sponsors, subject areas, leading journals and countries, keywords, and international cooperations. Research interest in water availability in Central Asia has increased gradually since 2010, with its results primarily published as research articles. Geographical distribution indicates that both advanced and developing countries contribute to the research field. Germany and China are leaders in partnership collaboration. Lamers J.P.A. is recognized as the most active researcher, while the Chinese Academy of Sciences holds a leadership position among organizations. Additionally, the National Natural Science Foundation of China ranks at the top, which supports the most research. Research topic is integrated mainly in Environmental Sciences and Water Switzerland is positioning as the best journal. “Water availability”, “Climate change,” and “Central Asia” are described as the most popular keywords.

Keywords: water; research; availability; Scopus; database.

1. Introduction

Water is a valuable natural resource, and our actions immediately jeopardize its supply (Alifujiang *et al.*, 2017). It is the most troubling, limited, and disputable resource of nature on any territorial level (Amiraslani & Dragovich, 2023). A lack of water resources is one of the most pressing ecological issues confronting humanity today (Ren *et al.*, 2021). Usually, freshwater resources are categorized as a combination of surface water (77%), return flow (14%), and groundwater (9%) (Kahinda & Boroto, 2009). Water resources of Central Asian countries are supported by cross-border rivers, which are crucial to the economy of the states (Didovets *et al.*, 2021). With its semi-arid to dry arid climatic conditions, the region is an iconic instance of an area that heavily relies on mountain water sources (Duethmann *et al.*, 2016). Water governance and water accessibility are critical components of environmental and socioeconomic systems everywhere (Nkosi *et al.*, 2021). The issue of regional water resource distribution is complicated, dynamic, and multi-objective (Ma *et al.*, 2022). Today, an increasing number of scientists are focusing on water resource management in the conditions of climate change for sustainable development of water management, while climate change heightens the possibility of water deficit (Salokhiddinov *et al.*, 2020; S. Zhang *et al.*, 2023). According to Zhao et al. (2022), the latest research has analyzed water resources in Central Asia (Chen & Yuan, 2016; Deng & Chen, 2017) with the focus on water availability.

Water availability is inextricably tied to the broader idea of water sustainability in water management (Salehie *et al.*, 2022). Currently, variable climate and human activity have drastically changed water availability in the world, leading to water shortage, which is a significant concern for people in semi-arid and arid regions, especially (Bekchanov *et al.*, 2016). Central Asian countries are among the regions most impacted by limited water resources, characterized by annual rainfall of less than 250 mm, which restricts inputs to food security and economic and social growth (Abou Zaki *et al.*, 2022; Aleksandrova *et al.*, 2014; Mirzaqobulov *et al.*, 2024). The resources of water in Central Asian republics are distributed inequitably, with 90% of all resources concentrated in Kyrgyzstan and Tajikistan, while Uzbekistan and Kazakhstan account for the most significant consumption (Aktymbayeva *et al.*, 2021). Water resource management is a pressing concern in Central Asia, particularly when considering the arid environment and the predicted implications of climate change (Casale *et al.*, 2020). Decreased river discharge and anticipated upstream infrastructure expansions both pose possible concerns to water for irrigation availability in Central Asia's downstream countries (Bekchanov & Lamers, 2016), as densely inhabited and irrigated areas rely heavily on water from glaciers and snow. Globally, 15-20% of glaciers are

expected to melt by 2030, and if it is not replenished, the water in Central Asia's rivers would be severely decreased, exacerbating the water scarcity issue (Chathuranika *et al.,* 2022). Karthe *et al.* (2017) assure that scientific foundations are becoming more essential in water management in Central Asia.

Water resources in Central Asia are usually formed and provided by mountain glaciers of the Tien Shan and Pamir (Apel *et al.,* 2018). These are the two primary mountain systems in Central Asia, located north of the Karakoram and Hindu Kush (Barandun & Pohl, 2023). Gafurov *et al.* (2022) and (2024) refer to them as "water towers" of Central Asia. All the major streams in the region, including Amu Darya, Syr Darya, and Ili, come from these mountains (Apel *et al.,* 2019). The snow melt in these mountains determines the availability of water in Central Asia throughout the summer. Carey *et al.* (2014) mention that climate change-induced glacier shrinking is projected to end in reduced and inconsistent stream flow in glacier-fed basins across the world. Continuous loss of glaciers on the abovementioned mountains is expected to have significant effects on the amount of fresh water in Central Asia (Barandun *et al.,* 2021). According to Casassa *et al.* (2009), mountain glaciers provide freshwater to downstream valley communities that rely significantly on meltwater. The unpredictability of water supply due to changing environmental conditions provides an important reason for political friction and produces an intricate constellation of future dangers, affecting several sectors such as irrigation, energy generation, and agriculture (Barandun *et al.,* 2018). Bekchanov *et al.* (2015) consider that inefficient water governance institutions are the leading cause of intersectoral and interstate water distribution conflicts, as well as a lack of incentives to improve water usage efficiency. Climate change's impact on the accessibility of water supplies may exacerbate these conflicts (Bocchiola *et al.,* 2017). To efficiently use and manage water resources, the construction of a water management system involving the accessibility of dams for purposes of water resource management has been considerably developed in Central Asian countries (Bazarov *et al.,* 2020). Central Asia's water resources are usually divided into two categories: surface water and groundwater, with groundwater contributing 10%-15% of the total (Bekturganov *et al.,* 2016).

Bibliometric analysis is a unique approach to investigating academic papers in a specific research area. It discovers cognitive frameworks and logical links through examining the outcomes of papers, researchers, states, publishers, and institutions. This study aimed to review the most relevant investigations into water availability in Central Asian countries. Similar research by Claro et al. (2024) for Mediterranean countries under climate change can be found, but such studies in the Central Asian countries are lacking. In addition, bibliometrics has made significant contributions to academic areas such as drainage in agriculture (Kannazarova et al., 2024), groundwater (Kannazarova *et al.,* 2024), soil erosion (Juliev *et al.,* 2024), marginal lands (Jumaniyazov *et al.,* 2023), landslides (Khasanov *et al.,* 2021), and soil salinity modeling (Abdikairov *et al.,* 2024).

The main objective of this bibliometric review is to investigate and analyze published papers on water availability in Central Asia between 1979-2024 years from Scopus database with the focus on active researchers, notable countries, leading institutions, prominent journals, major publication types, main funding sponsors, relevant subject areas, years, proper keywords and countries collaboration network. At the end of the research, all hypotheses were confirmed by the results received.

2. Research Methods

The Scopus database is one of the primary bibliometric sources that embraces more articles (Ansorge, 2024). Documents from this database are usually provided with DOI (Digital Object Identifier) numbers, which are comparable to those found in other databases. According to Chadegani *et al.* (2013), it is the greatest searchable citation and summary resource for exploring research, continuously widened and upgraded. Even though it was founded in 2004 (Vieira & Gomes, 2009), this database is a worthy competitor to WoS and other platforms. Therefore, the Scopus database was selected as a source for this research. The analysis performed in this work was based on documents through the following flowchart, as described in Figure 1. There was a language limitation in the search, focusing on the English and Russian languages. The search was performed on November 28, 2024, and contained 299 final published works. There were no restrictions on the research interval, and the identified results were from 1979 to 2024.

A bibliometric analysis is meant to quantify published research on a particular topic, outlining what currently exists and tendencies for future research. It provides academics and governmental organizations with a framework for conducting investigations and drawing conclusions. In this research, identified publications were evaluated by: (1) publication period, (2) subject field, (3) authors, (4) geographic locations, (5) document type, (6) funding supporters, (7) journals, (8)

researcher affiliations, (9) publication citations, (10) keyword analyses, (11) countries collaboration. All of the bibliographic data and quotations from these papers were downloaded and transferred to VOS viewer, which was made by VanEck and Waltman (2023), to undergo further bibliometric analysis. VOS viewer program (v.1.6.19, 2023) may obtain and evaluate the meaning of publication titles, abstracts, and keywords, correlate them with bibliographic statistics, and produce bubble visualizations to display the results. Additionally, it is an essential tool for analyzing countries' contributions as well as research topics (Ullah *et al.*, 2022). Moreover, Microsoft Excel was applied to analyze and assess the information presented at this stage owing to its flexibility. Additionally, we provided this research using a variety of tools and formats, including CSV files, RIS, and Map Charts.

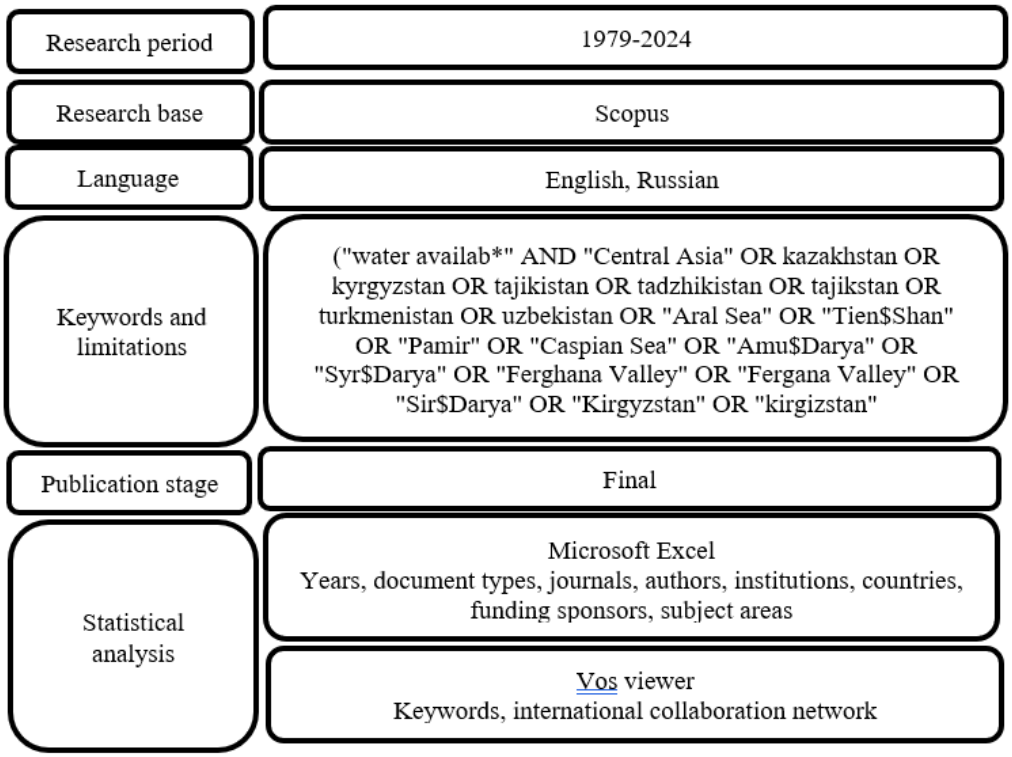

Figure 1. Methodology Flowchart for the Research.

3. Results

3.1. General Literature Trends

Water, as a main component of the life system, is discussed among researchers every time. Identification of scientific production trends in water availability research enables us to understand better and accept the current status and direction of the research.

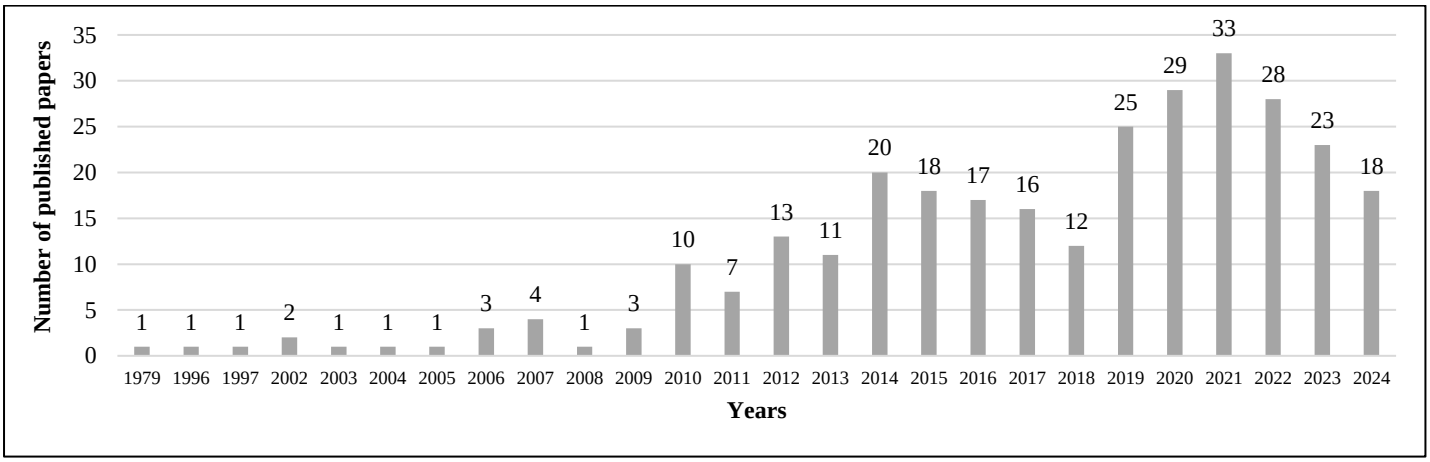

Figure 2. Yearly scientific trend.

The findings illustrated in Figure 2 can be divided into two stages: the 1979-2009 period, which accounts for 6.4% of papers, and the 2010-2024 period, which contributes 93.6% to research

activity. An increasing number of publications from 2010 is strongly connected with global climate change, which promotes water scarcity in arid and semi-arid regions of the world. It is possible to include the Central Asian water deficit of 2001 and 2008. The most productive year for water availability research was 2021, when more than 11% of scientific research articles were produced.

3.2. Publication types on water availability

An assessment of publication types on water availability was performed to better understand how researchers prefer to publish their results. According to results, 80.2% of articles were distributed as research papers, followed by conference papers 7.4%, book chapters 6%, review articles 4.4% and others 2% (Figure 3). The results suggest that lots of scholars favour publishing their results in journals, compared to conference proceedings. This choice is often influenced by a desire to make their research more public and recognized within scientific circles.

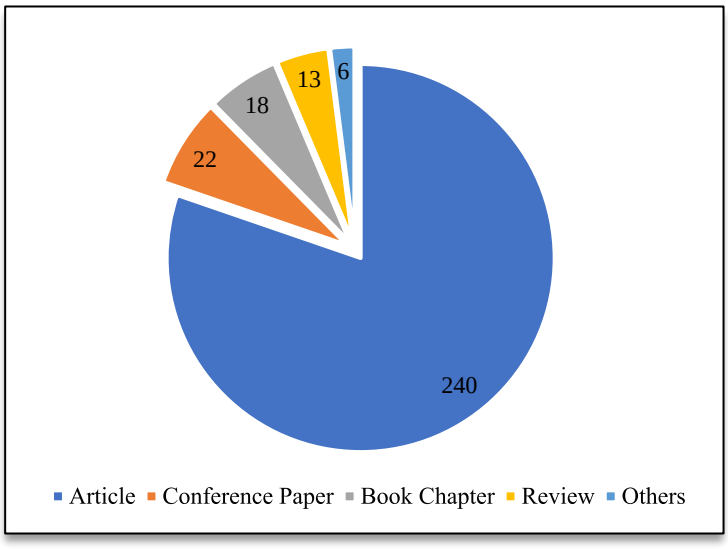

Figure 3. Publication type distribution.

3.3. Influential authors

The top ten researchers who have produced the most notable publications on this topic, as shown in Figure 4, offer an excellent overview of contributors who have made significant contributions to the literature. Lamers, J.P.A., is the most productive author with a 5.7% share of total publications, followed by Bekchanov, M., and Gafurov, A., with 2.7% and 2.3% shares of total published papers, respectively. Furthermore, the next six influencers on water availability research contributed each 2% to the total number of research articles. Last but not least, Chen Y developed five research papers and contributed 1.6% to the research topic. The role of scholars in water availability research is evident in both advanced and developing states, indicating a global interest in the aforementioned issue.

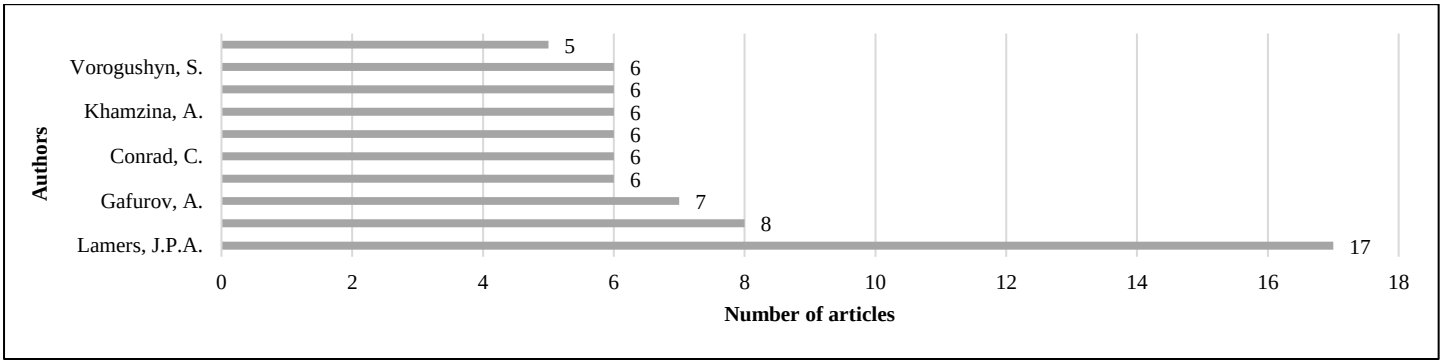

Figure 4. Most productive authors.

3.4. Active institutions

The role of organizations is valuable for the development of the research area. A total of 160 institutions worldwide participated in water availability research during the 1979-2024 period. As a result of the investigation, the top 10 institutions are shown in Figure 5 with at least 11

publications. The number of articles from selected institutions is 203, with almost 68% of the contributions made to all research papers. Chinese institutions held the leadership position, followed by German research organizations with 6 and 4, respectively. It is worth mentioning that the Chinese Academy of Sciences' contribution is enormous, with 17%. The most active German research organization is Zentrum für Entwicklungsforschung, sharing 7% of water availability research. Chinese institutions' leadership is proven by the greatest interest in water availability in Central Asia research, since the geographical location of countries may negatively affect both economic and social conditions of the country.

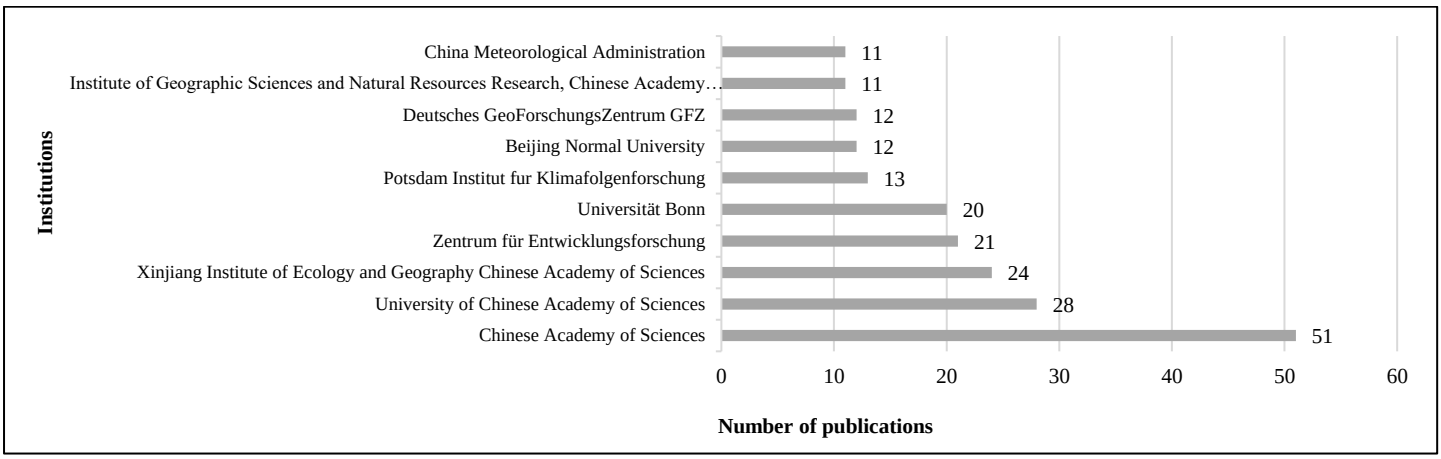

Figure 5. Contribution of research to water availability research.

3.5. Funding sponsors for water availability research

Any scientific research activity needs both financial and technical support for publishing. Financial support of research papers is a critical component of scientific knowledge development. Following funding analyses, a total of 159 financial supporters worldwide were identified, with 299 research papers published on water availability during the research period. Figure 6 illustrates the most active funding sponsors, which supported 62% of total publications on water availability. National Natural Science Foundation of China is mentioned as a remarkable supporter, with 18.7% share, followed by Chinese Academy of Sciences and Bundesministerium für Bildung und Forschung, which encouraged 12.3% and 7.7% of total research articles, respectively. In comparison, the contribution of others may vary between 1.7% and 5.7%. Of the ten identified financing donors, four were from China, two were from the European Union and Germany, and one was from Kazakhstan, and one was an internationally recognized organization based in France. Financial support of academic research is a crucial mechanism for scientific progress. In the case of National Natural Science Foundation of China financial support, it must provide original innovation and lead to sustainability. Additionally, it promotes international exchange and collaboration.

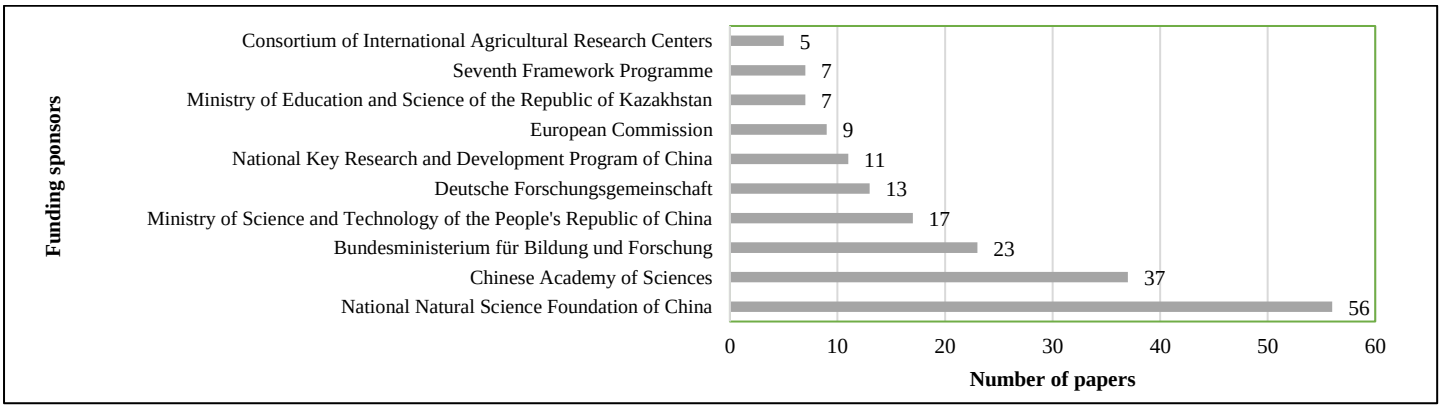

Figure 6. Top funding sponsors for water availability research.

3.6. Key Subject Areas for Water Availability Issue

Identification of research belonging to a certain area is an essential driver for the development of the field. Figure 7 highlights the top five research fields with the most presented publications on water availability. According to the results, water availability articles are indicated in all subject areas, which exceeds the total number of publications from the database, because an investigation could be catalogued in more than one area. It is noteworthy that Environmental Science leads with

186 articles, followed by Earth and Planetary Science with 119 publications. Additionally, water availability research was included in Agricultural and Biological Sciences, Social Sciences, and Biochemistry, Genetics and Molecular Biology, where the total number of published papers equals 97, 54, and 25, respectively.

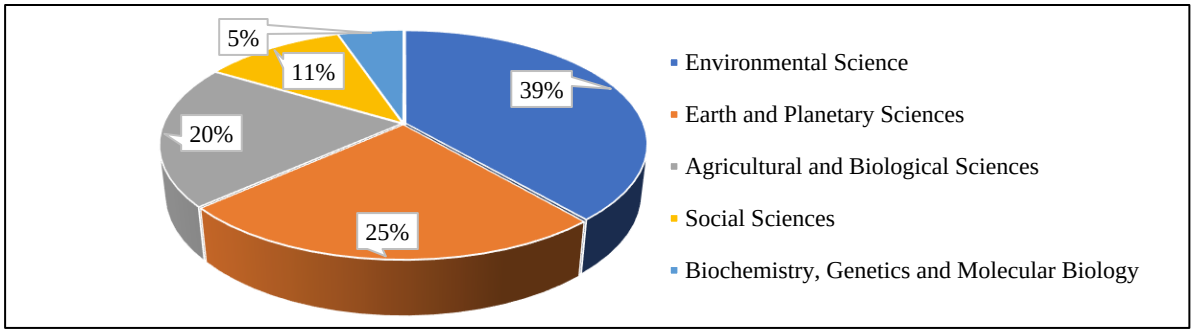

Figure 7. Top subject areas of water availability research.

3.7. Source publications of the literature

The number of papers published by journals identifies the efficiency of the source. A total of 148 journals participated in publishing 299 articles on water availability research. Out of 148 journals, 10 were selected for further analysis, each containing at least four articles. The contribution of these journals, shown in Figure 8, is enormous to the research field and accounts for a 28% share of the total published papers. Water Switzerland is the most influential journal in water availability research, with a 6.4% share, followed by Science of the Total Environment with 5% contribution and Agricultural Water Management, which published 3.4% of total articles. At the same time, Environmental Research Letter, IOP Conference Series Earth and Environmental Science, and Journal of Hydrology printed 2.4% of papers each. The next priority is given to Environmental Earth Sciences, which demonstrated a 2.2% share, as well as Cryosphere, Plos One, and Sustainability Switzerland, which have only 1.3%.

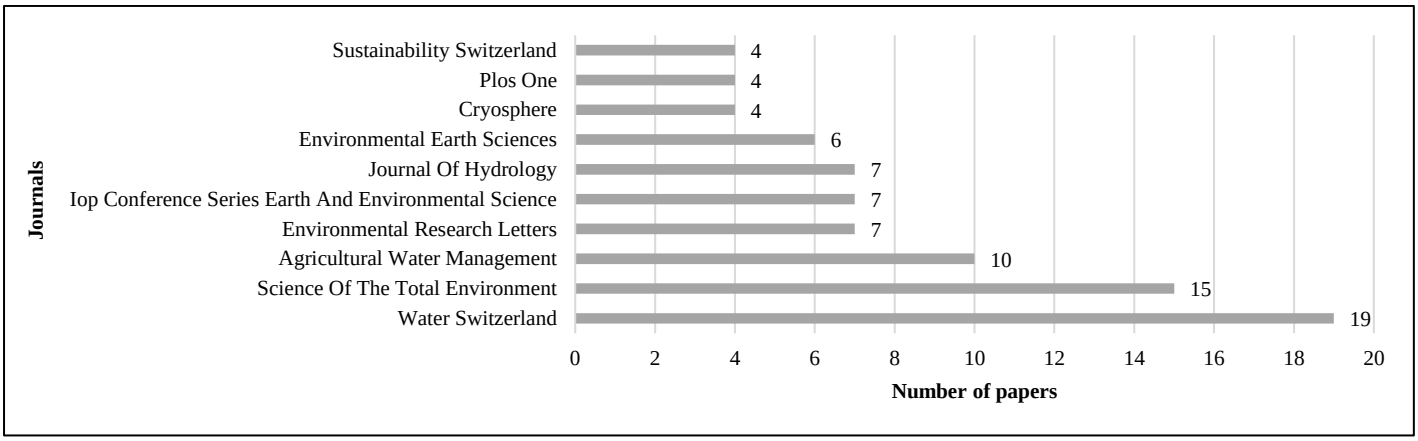

Figure 8. Top journals on water availability research.

3.8. Geographical distribution of water availability research

Academic papers based on a country's publications are an effective tool to evaluate scientific research potential. To analyze countries' impact on water availability, the Mapchart online platform was applied to assess the most active states on the above-mentioned issue, which is illustrated in Figure 9. A total of 45 countries participated between 1979 and 2024 to investigate water availability issues. Germany leads other countries with 102 published papers, followed by China and Kazakhstan, which have 84 and 43 research articles on water availability, respectively. Germany's leadership in water availability research in Central Asia is vindicated by international development programs supported by German Technical Cooperation, which establishes projects promoting water-efficient use due to its shortage in the region. There is a significant research interest in Kazakhstan and Uzbekistan regarding water availability issues, given their location in Central Asia. The total number of analyzed papers outperforms the 299 research articles received from the Scopus database, as the researchers' geographical locations could be identified in more than one area. As a result of countries' contributions, it is possible to present that the water availability challenge deserves attention from both advanced and developing states.

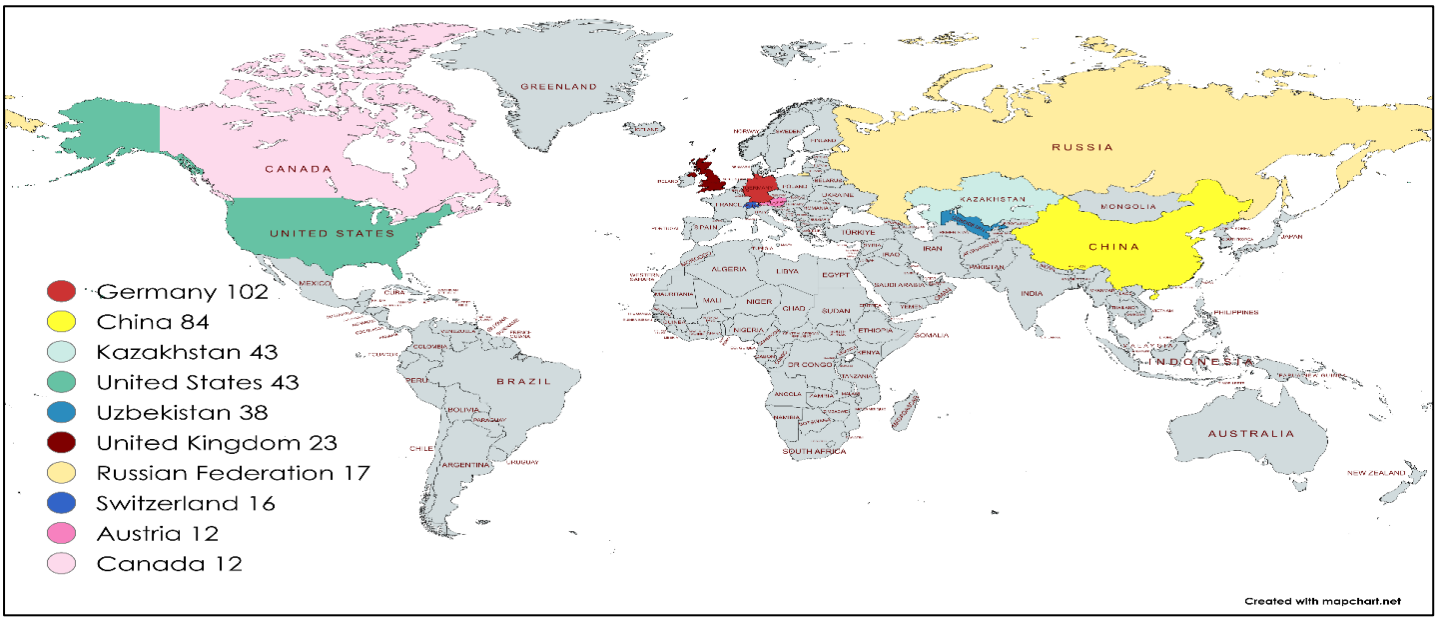

Figure 9. Top countries in water availability research.

3.9. Most Cited Documents

Citation analyses provide a unique opportunity to evaluate the most frequently referenced papers on the subject of water availability. Additionally, it is an effective tool for analyzing the fundamental logical framework for a research topic. 272 papers received a total of 11303 citations during the research period. Table 1 visually illustrates the top 10 most cited publications, including titles, years, journals, number of citations, publishers, and types of articles. According to the results, the 10 selected articles accounted for 35% of the total citations. Additionally, the shortlist included two reviews and eight research papers. “Sensitivity of global terrestrial ecosystems to climate variability,” published by Nature, holds the top position with 966 citations. The most cited papers, spanning the 1997-2022 period, demonstrate the topic's relevance over the last 25 years.

Table 1. Top most-cited publications.

Title of publication	Year	Journal	Citations	Publishers	Publication Type
Sensitivity of global terrestrial ecosystems to climate variability	2016	Nature	966	Nature Publishing Group	Article
Constraints and potentials of future irrigation water availability on agricultural production under climate change	2014	Proceedings of the National Academy of Sciences of the United States of America	805	PubMed	Article
Climate change impacts on glaciers and runoff in the Tien Shan (Central Asia)	2012	Nature Climate Change	750	Nature Publishing Group	Review
The climatic cyclicity in semiarid-arid central Asia over the past 500,000 years	2012	Geophysical Research Letters	367	Blackwell Publishing Ltd	Article
Neoproterozoic to Paleozoic long-lived accretionary orogeny in the northern Tarim Craton	2014	Tectonics	263	American Geophysical Union	Article
Meeting the water requirements of an expanding world population	1997	Philosophical Transactions of the Royal Society B: Biological Sciences	198	Royal Society	Article
Climate change threatens terrestrial water storage over the Tibetan Plateau	2022	Nature Climate Change	182	Nature Research	Article
Asia's glaciers are a regionally important buffer against drought	2017	Nature	163	Nature Publishing Group	Article
Recent climate and hydrological changes in a mountain–basin system in Xinjiang, China	2022	Earth-Sciences Reviews	159	Elsevier B.V.	Review
Mechanisms of resilience in common-pool resource management systems: An agent-based model of water use in a river basin	2007	Ecology and Society	142	The Resilience Alliance	Article

3.10. Keyword analyses

The frequency of keyword co-occurrence is a commonly regarded trustworthy metric for strengthening the link and relationship between publications. To determine the authors' area of focus, we must first visualize the network produced by the co-occurrence of authors' keywords. A total of 2937 keywords from 299 publications participated in the research. Figure 10 indicates the most applied keywords with a minimum of five appearances of a term. The final network consists of 203 nodes and 5 clusters. During the research period, the most often used keywords were water availability (154 times), climate change (106 times), Central Asia (104 times), water supply (71 times), and water management (63 times). This data visualization highlights the most significant and often recurring terms in water availability research, allowing for a better understanding of connections and trends.

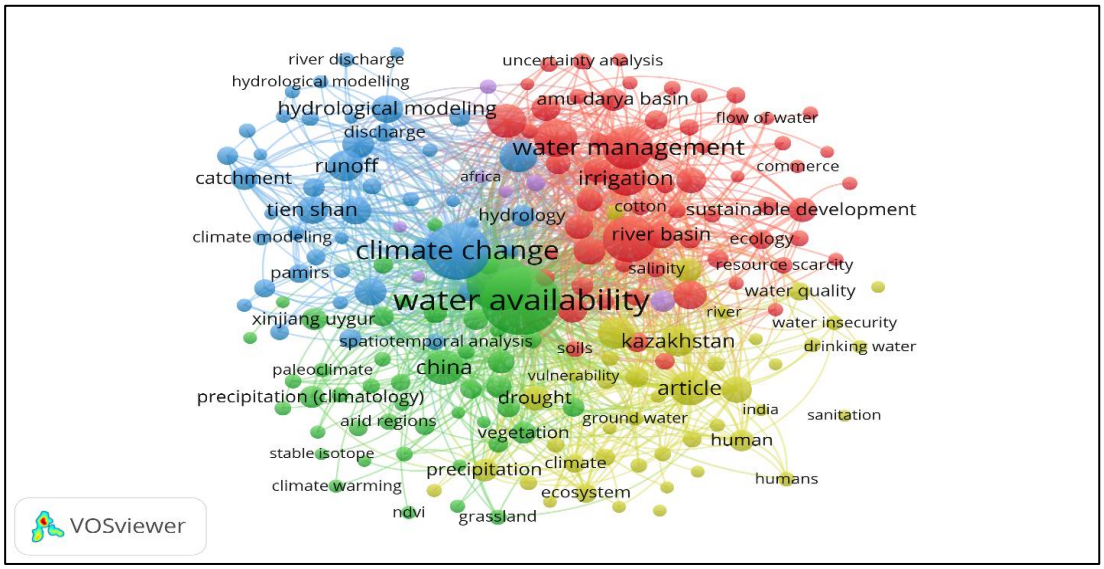

Figure 10. Network map of top keywords based on occurrences.

3.11. Contribution by countries

International collaboration is a key component of current research activity, allowing the interchange of information and skills. Figure 11 demonstrates cooperation among the states included in this investigation via a bibliometric map created by Vos viewer. A significant scientific partnership can be discovered, shown in six categories displayed through various shades. Germany holds the top position with 137 collaborations, followed by China and the United States, which have 74 and 63 collaborations, respectively. Also, they lead in terms of overall citations by country with 4834, 4081, and 2922 citations, respectively. It is essential to recognize the contributions of developing states, such as Uzbekistan and Kazakhstan, to collaboration in water availability research.

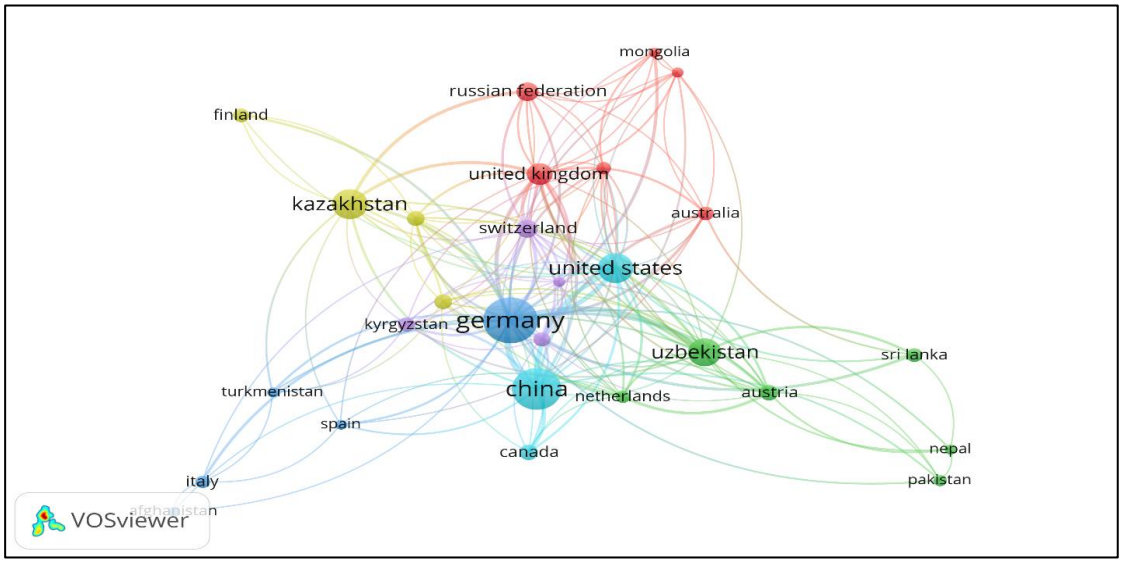

Figure 11. International co-authorship network.

4. Discussion

4.1. Climate change impact on water availability

Climate change is imperiling the hydrological cycle in the world, causing floods, droughts, over-exploitation of water resources, pollution, and ecosystem degradation, where over two billion people live in areas with high water stress (Z *et al.*, 2020). According to Yao *et al.* (2021) Climate change poses a significant threat to Central Asia's water cycle. Currently, water resources in Central Asian countries face challenges due to climate impacts, which negatively influence the amount of mountain glaciers in the Tian Shan and Pamir Mountain systems, as demonstrated by Li *et al.* (2017). Xu *et al.* (2019) suppose that glacier meltwater is a major source of water for populations and hydro-economies in semi-arid and arid regions including Central Asia. In the past few years, climate change has had a substantial influence on precipitation levels in Central Asia, resulting in a decrease in surface water formation (Zhang *et al.*, 2021). According to Zheng *et al.*, (2021) , there has been considerable warming at a rate of 0.34 ◦C/decade over the last 50 years in the Central Asian mountains, which is three times faster than the global average. Field experiments provided by Zhang *et al.* (2022) prove that summertime droughts result from winters with low snowfall in this region, which focuses on a quick analysis of the influence of cryospheric variations on the availability of water. Additionally, Zonn *et al.* (2020) promoted the idea that water scarcity had become an important issue in many Central Asian states. Zhang *et al.* (2020) stated that only 24.4% of water resources in Central Asia are possible to use by humans, where numerous transnational streams negatively impact this amount of water.

4.2. Water scarcity and management

In dry regions, including Central Asia, water is essential for controlling biological processes (G.-Q. Xu *et al.*, 2011). The sustainable management of water must be a major policy in the aforementioned region, given that scarcity has dominated for the last two decades. The water scarcity problem in Central Asia resulted from both the Aral Sea's shrinking and environmental changes, requiring effective integrated management of surface and groundwater systems, which must be done immediately (Zhai *et al.*, 2022). Water resources are used for both hydropower generation in Kyrgyzstan and Tajikistan and irrigation purposes in Uzbekistan, Turkmenistan, and Kazakhstan, which is called upstream and downstream demands in Central Asia, respectively (Zeng *et al.*, 2017). Water consumption for agriculture and energy generation has become a source of disagreement between downstream and upstream nations in Central Asia (Zakeri *et al.*, 2022). Effective water management and supply are provided if upstream requests are met by supplying necessary electricity to Kyrgyzstan and Tajikistan during the winter period, while these countries cover the summer irrigation demands of downstream locations. Additionally, one of the most appropriate solutions for water scarcity in the downstream is the practice of building water reservoirs and dams. Zupankhan *et al.* (2018) mentioned Kazakhstan as the first Central Asian country that created essential conditions for implementing integrated water resource management (IWRM). It promotes sustainable local collaboration on water management in Central Asia, including the construction of regulatory water management rules according to globally orientated water law. Based on the results of this research, water availability in Central Asia is becoming an insurmountable challenge, destroying both political and geographical balance in the region. Satisfaction of demands for electricity and agriculture in the region is liable to enlarge the debate, which requires revision of both international and local laws. One of the most appropriate solutions to this challenge is sustainable exploitation of water resources, which requires smart agriculture with drip irrigation and energy production by alternative sources. Strong collaboration among states in Central Asia, including cooperation and mutual understanding, is considered an alternative solution to the problem.

4. Conclusion

Nowadays, water availability is becoming an essential challenge for the Central Asian region, where water scarcity is deeply felt. This investigation aims to analyze publications on water availability in Central Asia from the Scopus database by the bibliometric method, where total research interest has increased drastically since 2010 and achieved a maximum level in 2021 which proved by number of published articles requiring more attention to water resources management in Central Asia due to its transboundary distribution for both agriculture and energy production. Research articles dominated the publication types, with Lamers J.P.A. identified as a leading researcher, followed by Bekchanov, M., and Gafurov, A. Given the water availability issue's critical importance to the Central Asia scientific community, the region must prioritize future research to meet sustainability requirements. The most active organizations are mainly from China, which validates its leadership in the financial support of research on water availability in Central Asia.

Stronger and deeper collaboration is needed for future water research with Chinese organizations for Central Asian academician companies. This research identified Environmental and Earth and Planetary Sciences as the top subject areas for water availability research due to their multidisciplinary nature. One of the European journals, "Water Switzerland," published more articles than others during the research period, and Germany, a European country, occupies the leadership for article production, followed by China and Kazakhstan.

The active contribution of European countries and publishers encourages locals to be more loyal, as they possess sufficient financial and technical resources for collaboration. The most cited document, "Sensitivity of global terrestrial ecosystems to climate variability," with 966 citations, was published in 2016. In terms of country collaboration, Germany's leadership demonstrates its commitment to supporting the region in achieving sustainability. These results can be considered for water management policies in Central Asian countries. One of the most appropriate explanations is the worldwide scientific and public attention to water availability research in Central Asia. Since developed states are ready to support activities directed to efficient water management by implementation of projects with technical and financial support to achieve sustainability in the region, Central Asian countries must immediately start discussion and collaboration in order to avoid migration, which covers more than 100 million people.

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Author Contributions

Conceptualization: Salokhiddinov, A., Juliev, M.; **methodology:** Juliev, M., Abdikairov, B.; **investigation:** Mirzaqobulov , J., Khakimova, P., Khomidov, A.; **writing—original draft preparation:** Abdikairov, B., Juliev, M.; **writing—review and editing:** Salokhiddinov, A.; **visualization:** Mirzaqobulov , J., Khakimova, P., Khomidov, A. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

All authors declare that they have no conflicts of interest.

Data availability

The author confirms that all data generated or analysed during this study are included in this article.

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