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Research article

Agricultural drought research knowledge graph reasoning by using VOSviewer

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ABSTRACT

Drought seriously affects agricultural systems and food security. While previous researchers have explored the causes, monitoring, and impacts of drought on agriculture, no systematic investigations into the development of agriculture drought (AD) and its relationships with related knowledge have been conducted. This study assessed existing publications, particularly those conducted between 2020 and 2023. Systematic analysis was carried out using VOSviewer software and the Web of Science (WoS) database. These findings reveal a rising trend in the literature, with a recent acceleration. A total of 7416 articles on AD were identified, with contributions from 6935 institutions across 166 countries. China leads with 1833 publications, followed by the USA with 1278. There are 457 journals publishing AD studies, with the top five being sustainability, frontiers in plant science, agricultural water management, water, and agronomy-basel. The most frequently used keywords reflecting the current significant research direction in the AD field include climate change, yield, variability, impact, growth, and adaptation. The study also highlights four research hotspots and four future research directions. This bibliometric analysis provides a novel guide for agricultural drought research.

1. Introduction

Global warming, as a backdrop, has caused the world's surface temperature in the twenty-first century (2001–2020) to increase by 0.99 °C compared to that in the period of 1850–1900. This has led to an increase in the frequency and intensity of extreme weather and climate events [1,2]. Among these events, drought is one of the most severe natural disasters and results from an imbalance between precipitation and evaporation, leading to continuous water shortages. Droughts have become increasingly common in recent decades and have had significant negative impacts on agricultural production, ecological environments, social livelihoods, and global food security [3–5].

Droughts are classified into four categories: meteorological, socioeconomic, agricultural and hydrological [6,7]. Agricultural drought entails a shortage of available water for plant growth. Drought includes various drought indices, e.g. PDSI (Palmer drought severity index), PHDI(Palmer hydrological drought index), SPI(Standardized precipitation index), SPEI(Standardized precipitation evapotranspiration index), which also includes the drought index derived from remote sensing image of VCI(Vegetation condition index), TCI(Temperature condition index), PDI(Perpendicular drought index), MPDI(Modified PDI), TMVID(Temperature microwave vegetation index) [8–10].

Drought is a natural disaster with the broadest global impact and the most substantial agricultural losses. Severe drought conditions

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occur in nearly half of the world's countries [11,12]. In recent years, numerous regions worldwide have experienced frequent and severe droughts, causing economic losses totaling hundreds of billions of dollars annually [13]. Globally, drought related fatalities account for 59.8% of all deaths caused by natural disasters, with particularly high occurrences in Africa, North America, East Asia, and Australia [14]. For instance, the United States experienced extensive economic losses due to drought, ranging from 6 to 8 billion US dollars annually, reaching a peak of 40 billion US dollars in 1988. In the latter half of 2018, California recorded a record-breaking number of forest fires, resulting in 85 deaths and 249 individuals reported as missing in November alone. This marked the highest number of forest fires in nearly a century in the United States [15–17]. Furthermore, the severe drought in 2018 significantly impacted agriculture in the western and southwestern United States and played a pivotal role in the California "Century Fire" outbreak [18]. Drought has caused damage of $250 billion and nearly 3000 fatalities between 1980 and 2020, making it the costliest natural disaster and the second deadliest in the United States [19].

During the latter half of the 20th century, prolonged severe drought in North Africa had a profound impact on more than 20 countries. In 1984, drought in Ethiopia alone resulted in nearly a million deaths and a 40% reduction in livestock consumption. Between 1968 and 1973, scarce precipitation led to a 6-year drought in parts of the Sahara Desert, causing the desert to expand more than 500 km southward and affecting several African countries, resulting in approximately 10,000 deaths and substantial losses. Even the Amazon basin, known for its abundant precipitation, experienced unprecedented large-scale extreme droughts in 2005 and 2010, leading to a significant reduction in green vegetation and substantial effects on the global carbon cycle [20–22].

China also experiences frequent and severe droughts annually affecting approximately 22.32 million hectares of farmland. Drought is the most economically damaging natural disaster in the country and accounts for more than 15% of all losses from natural disasters. China loses 5 million tons of grain each year due to drought. From the 1950s to the 1980s, drought-related food losses constituted 50% of the national food loss [23,24]. In 2000, northern and northeastern China experienced severe spring and summer droughts, affecting 40.54 million hectares of crops and resulting in 26.78 million hectares of damage, the highest recorded since 1961. Grain production decreased by 59.96 million tons, accounting for 13.0% of total grain production [25]. From September 2019 to March 2010, Southwest China, including Yunnan, Guizhou, Guangxi, and Chongqing, endured extreme droughts of unprecedented magnitude. These severe droughts affected 77.15 million people and 6.11 million hectares of crops and caused economic losses totaling 48.44 billion yuan [26].

Despite the extensive impact of AD on food security, there has been a noticeable absence of comprehensive scientific inquiries into its management. Therefore, this paper employs bibliometric analysis to review numerous global studies on AD, providing an overview of its global outputs related to AD, climate change, and food security and ascertaining its current research direction. Bibliometric analysis, a quantitative review technique, employs data mining, statistics, and mathematics to uncover emerging trends within specific research areas. It has become increasingly popular and has been applied to various research topics [27,28].

Bibliometric analysis is an effective tool for objectively studying the status quo and reflecting the development of a scientific field. Quantitative analysis was conducted based on the information available in posted records, including journal, publication date, author, institution, affiliated country, and keyword [29,30]. However, it seems very difficult to manually extract information and systematically analyze the research status in a field because a large number of publications were published after several years of development. Therefore, it is essential to use reliable analytical tools. Recently, VoSviewer and CiteSpace have been widely used in diverse academic research fields [31]. Bibliometric analysis has become a hot study topic and a commonly used method for analyzing developmental trends. However, facing the explosive and complex growth of scientific and technological information, the challenge is how to comprehensively and accurately obtain information and effectively and quickly extract information while balancing the depth and breadth of research [32].

This study conducted an analysis of annual publication numbers, journal distributions, publication institution distributions, high-frequency keywords, keyword co-occurrence clustering, and timeline visualization analysis. This study comprehensively examined and organized the research results related to global AD. This analysis has aided researchers in understanding the current status, trends, and hotspots in the AD field. In this study, based on academic articles related to AD from the Web of Science core collection during 2000–2023, VOSviewer software was used to comprehensively utilize bibliometric and visual analysis methods to study the development process and structural relationships of agricultural drought research in a visual way. From diverse, multiple time scales, and dynamic perspective, we analyze the knowledge foundation, research hotspots, and frontiers of agricultural drought research, predict future research directions, and clarify the evolutionary path and development trend of agricultural drought research.

2. Materials and methods

2.1. Source database

The bibliometric approach has been employed to discern statistical patterns in bibliography studies across various research fields over time. The data used in this study were sourced from the WoS Core Collection database and included more than 12,000 authoritative and high-impact academic journals in fields ranging from natural sciences, engineering technology, biomedicine, social sciences, arts, humanities, etc., dating back to 1900 [33,34]. The WoS Core Collection database compiles references cited in papers and generates a unique citation index based on cited authors, sources, and publication age, serving as a valuable window into the research achievements of world-renowned scholars.

The present study defined suitable keywords for the search after reviewing highly cited literature on AD research. The search terms included the title, abstract, and keywords as follows: TS = ("agriculture" & "drought"). The study period spanned from 2020 to 2023. The search was executed separately for "drought" and "agriculture", and the document type was restricted to "article" and "review". Following the utilization of Endnote X9 software, 3096 articles remained, while 8512 non-research articles and non-agricultural meteorological drought articles were excluded. Ultimately, 7416 articles meeting the criteria were included in the analysis. These 7416 articles, spanning from 2000 to 2023, were further examined to assess the current state and key areas of international research on AD.

2.2. Research tools

VOSviewer software, developed by the Centre for Science and Technology Studies at Leiden University in the Netherlands, was employed. This software facilitates the creation of visual bibliometric knowledge maps based on network data, enables the analysis of literature keywords, subject words, authors, and more, and offers text mining capabilities [35–37]. In this study, VOSviewer visualization software was used to analyze and present the knowledge context within the field of domestic agrometeorological drought research.

2.3. Methods

Statistical analysis was also conducted to examine the annual number of bibliographies, journal distribution, and publishing institution distribution. Abstracts of bibliographies were preprocessed to reduce abbreviations and merge synonyms.

The collated catalog data were input into VOSviewer 1.6.14 software, and keywords were extracted. The frequency of keywords was tallied and ranked in descending order, with high-frequency keywords identified using a threshold of 10 occurrences. Co-occurrence cluster visualization analysis of high-frequency keywords was performed. In the keyword co-occurrence clustering graph, each circular node represents a keyword, with the node's size indicating its frequency of occurrence. Lines signify co-occurrence relationships between two keywords, with line thickness and length correlating with the strength of the relationship. The node color indicates the cluster to which a keyword belongs. Additionally, a keyword occurrence timeline analysis was conducted for high-frequency keywords, where different colors represent different years of keyword occurrence. Bluer node colors indicate earlier keyword appearances, while yellower node colors denote higher emergence degrees. The keyword co-occurrence timeline map illustrates the evolution of research topics in the AD field over time, providing insights into the latest progress and development trends.

3. Results and discussions

3.1. Trend analysis of the number of publications

The number of papers published on AD has shown an increasing trend and can be divided into three stages. In the first period (2000–2006), there were relatively few papers on this subject, averaging 45 publications per year. In the second stage (2007–2015), the annual number of papers on ADs exhibited consistent growth, averaging 187 papers per year. The third stage (2016-present) marked rapid development, with an average of 629 papers per year, surpassing 1000 papers by 2022, reaching 1096 papers. As of August 6, 2023, 571 papers were published (Fig. 1). The recent surge in AD papers is primarily attributable to the increasing focus on research related to the escalating impact of global warming-induced drought events on agriculture.

3.2. Periodical distribution

VOSviewer software was used to analyze the WoS data. The "bibliographic coupling" method was used to analyze the "Sources" project, with the "Minimum number of documents of an organization" set to 1, yielding 1124 results. The analysis revealed that 7416 AD literature studies were published in 1124 journals, with 60 journals each publishing more than 20 AD articles. Journals with more than 100 publications included Sustainability (N = 195 articles, comprising 2.63% of the total articles), Frontiers in Plant Science (N = 168, 2.26%), and Agricultural Water Management (N = 166, 2.23 %). Additional noteworthy journals include Water (N = 143, 1.93%), Agronomy-Basel (N = 129, 1.74%), Science of the Total Environment (N = 124, 1.67%), Remote Sensing (N = 103, 1.39%), and Plants-Basel (N = 103, 1.39%), as shown in Table 1.

The distribution of periodicals can be categorized into three clusters. Cluster 1 includes Sustainability, Agricultural Systems,

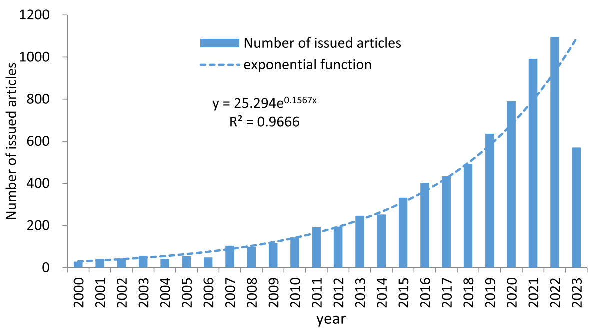

Fig. 1. Trend of annual publications on AD since 2000 (up to August 6, 2023).

Agricultural Water Management, Agriculture, Ecosystem and Environment, Agroforestry Systems, and Agronomy for Sustainable Development, among others (184 journals, depicted in pink). Cluster 2 included Agronomy-Basel, Frontiers in Plant Science, Plants-Basel, and Plant Science, among others (182 journals, shown in green). Cluster 3 comprises Science of the Total Environment, Remote Sensing, Remote Sensing Letters, Remote Sensing of Environment, and Journal of Hydrology, among others (108 journals, depicted in blue) (Fig. 2).

3.3. Distribution of research institutions

VOSviewer software was used to analyze the WoS data. The “co-authorship” method was employed to analyze the “Organizations” project, with the “minimum number of documents of an organization” set to 10, resulting in 382 results. A “number of authors to be selected” threshold of 68 was used to construct a knowledge graph network depicting cooperative relationships among research institutions in the field of AD. In this network, each circle represents a research institution, with the circle size corresponding to the number of documents produced by that institution. The connecting lines represent collaborative relationships with other institutions, with the line frequency indicating the degree of cooperation. Different colors signify distinct clusters of relationships.

There are four clusters identified in the network. Cluster 1 included the Chinese Academy of Sciences, the Chinese Academy of Agricultural Sciences, and the Chinese Meteorological Administration, which primarily consisted of Chinese institutions (depicted in yellow). Cluster 2 includes the USDA, the US Geological Survey, Colorado State University, and the University of California, Davis, predominantly representing American institutions (in green). Cluster 3 includes the University of Sydney, the University of Western Australia, and others, mainly from Oceania (in blue). Cluster 4 included the University of Oxford, the Swiss Federal Institute of Technology, Islamic Azad University, Wageningen University, and others, with a presence primarily in Europe and Asia (in red) (Fig. 3).

A total of 6935 institutions were involved in AD research, with 22.3% of these institutions publishing only one article and 11.6% publishing five articles. Moreover, a mere 5.2% of institutions have published more than 10 papers, while 1.9% have published more than 20 papers. Among the top institutions contributing to AD research are the Chinese Academy of Sciences (N = 309, 4.46%), the University of Chinese Academy of Sciences (N = 120, 1.73%), the United States Department of Agriculture (N = 87, 1.25%), the University of California: Davis (N = 84, 1.21%), Beijing Normal University (N = 76, 1.09%), and the Chinese Agriculture University (N = 74, 1.06%). Notably, Texas State University (N = 68, 0.98%), the Chinese Academy of Agriculture Science (N = 67, 0.96%), Nanjing University of Information Science and Technology (N = 66, 0.95%), and the US Geological Survey (N = 65, 0.93%) also rank among the top 10 institutions contributing to AD research (Table 2).

3.4. Distribution of research countries

The utilization of VOSviewer software in analyzing WoS data using the “co-authorship” method for the “Countries” project, with a “Minimum number of documents of an organization” set to 1, yielded 382 results. By setting the “number of authors to be selected” threshold to 68, a knowledge graph network representing cooperative relationships among research institutions in the field of AD was created (Fig. 4).

A total of 166 countries participated in AD research. The United States leads in the number of published papers, contributing 1833 papers (24.71% of total papers), followed by China with 1278 papers (17.23% of total papers) and Germany with 486 papers (6.55% of total papers). The top 20 countries are detailed in Table 3. Notably, 113 countries have published more than 5 AD papers, 95 countries

Table 1
The top 20 journals for publication in AD.

Rank	Sources	Articles	Total link strengthen
1	Sustainability	195	26
2	Frontiers in Plant Science	168	27
3	Agricultural Water Management	166	28
4	Water	143	29
5	Agronomy-Basel	129	30
6	Science of Total Environment	124	31
7	Remote Sensing	103	32
8	Plants-Basel	103	33
9	Environmental Research Letters	99	34
10	Journal of Hydrology	91	35
11	Climate Change	91	36
12	Theoretical & Applied Climatology	80	37
13	Natural Hazards	78	38
14	Regional Environmental Change	68	39
15	PLOS ONE	68	40
16	Agricultural & Forest Meteorology	66	41
17	Agricultural Systems	60	42
18	Scientific Reports	58	43
19	Water Resources Research	58	44
20	Agriculture-Basel	54	45

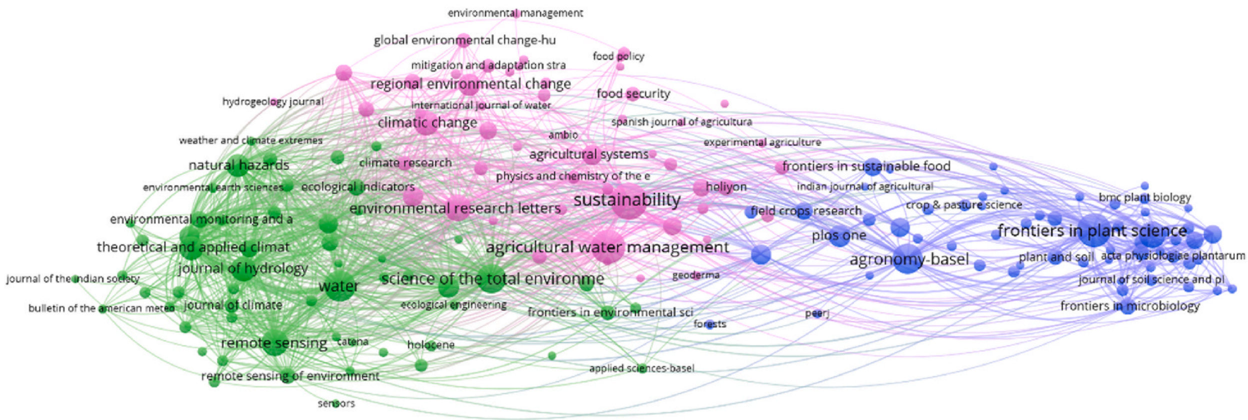

Fig. 2. Co-occurrence map of the journals.

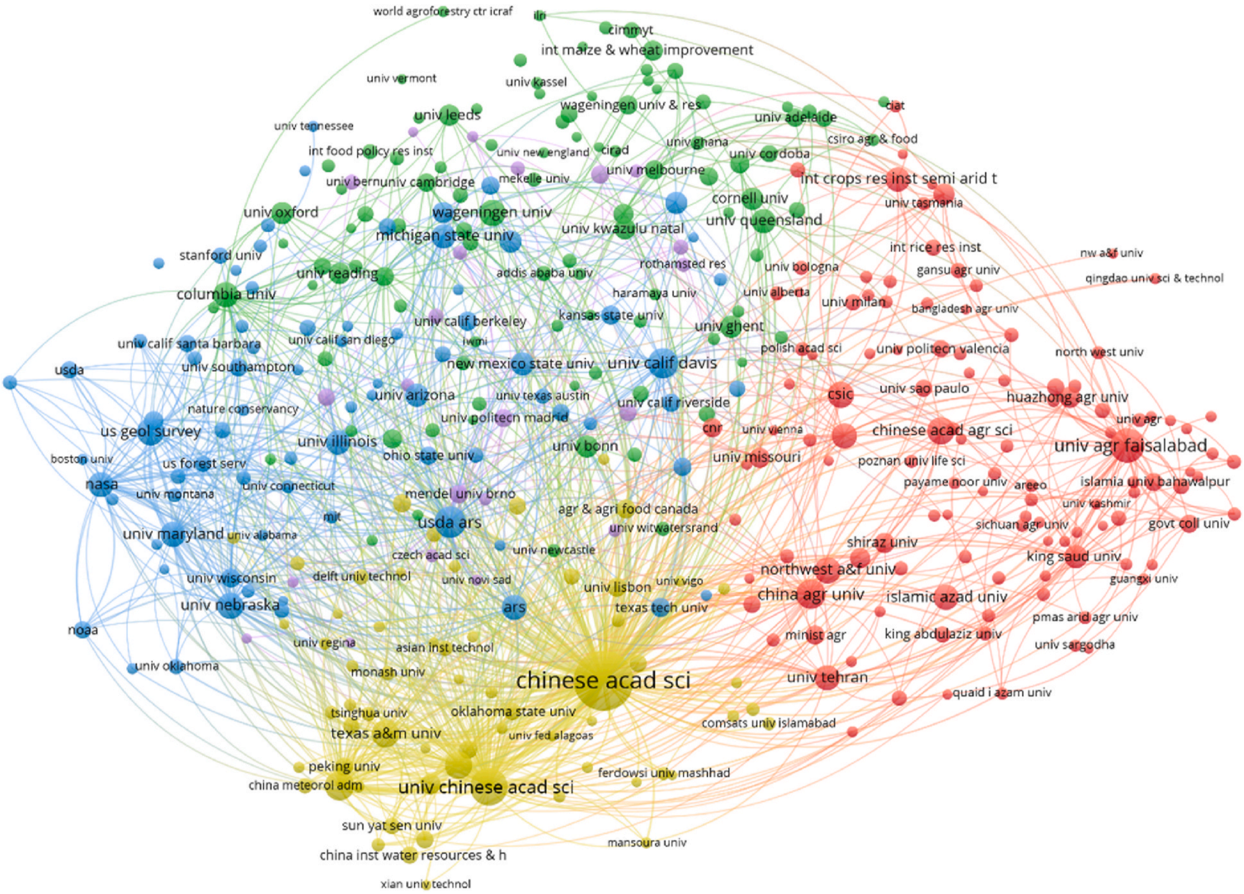

Fig. 3. Cooperative knowledge map of AD literature institutions from 2000 to 2023.

have published more than 10 AD papers, and 77 countries have published more than 20 AD papers.

3.5. Keyword analysis

Keywords in the literature play a vital role in indexing content and providing a concise summary of core paper content. The logical combination of keywords effectively represents the subject matter of the paper.

Table 2
The top 20 institutes contributing to AD research.

Rank	Organization	Documents	Total link strength
1	Chinese Academy of Sciences	*309*	280
2	University of Chinese Academy of Sciences	120	168
3	University of Agriculture, Faisalabad	104	85
4	United States Department of Agriculture	87	85
5	University of California, Davis	84	78
6	Beijing Normal University	76	71
7	China Agricultural University	74	88
8	Texas State University	*68*	62
9	Chinese Academy of Agricultural Sciences	67	53
10	Nanjing University of Information Science and Technology	66	47
11	US Geological Survey	65	66
12	University of Nebraska	62	64
13	Wageningen University	61	51
14	Northwest Agriculture and Forestry University	61	41
15	University of Florida	*58*	*68*
16	Agricultural Research Service	*58*	*57*
17	University of Tehran	*58*	*21*
18	Columbia University	*56*	*71*
19	University of Maryland	*55*	*90*
20	University of Illinois	*54*	*46*

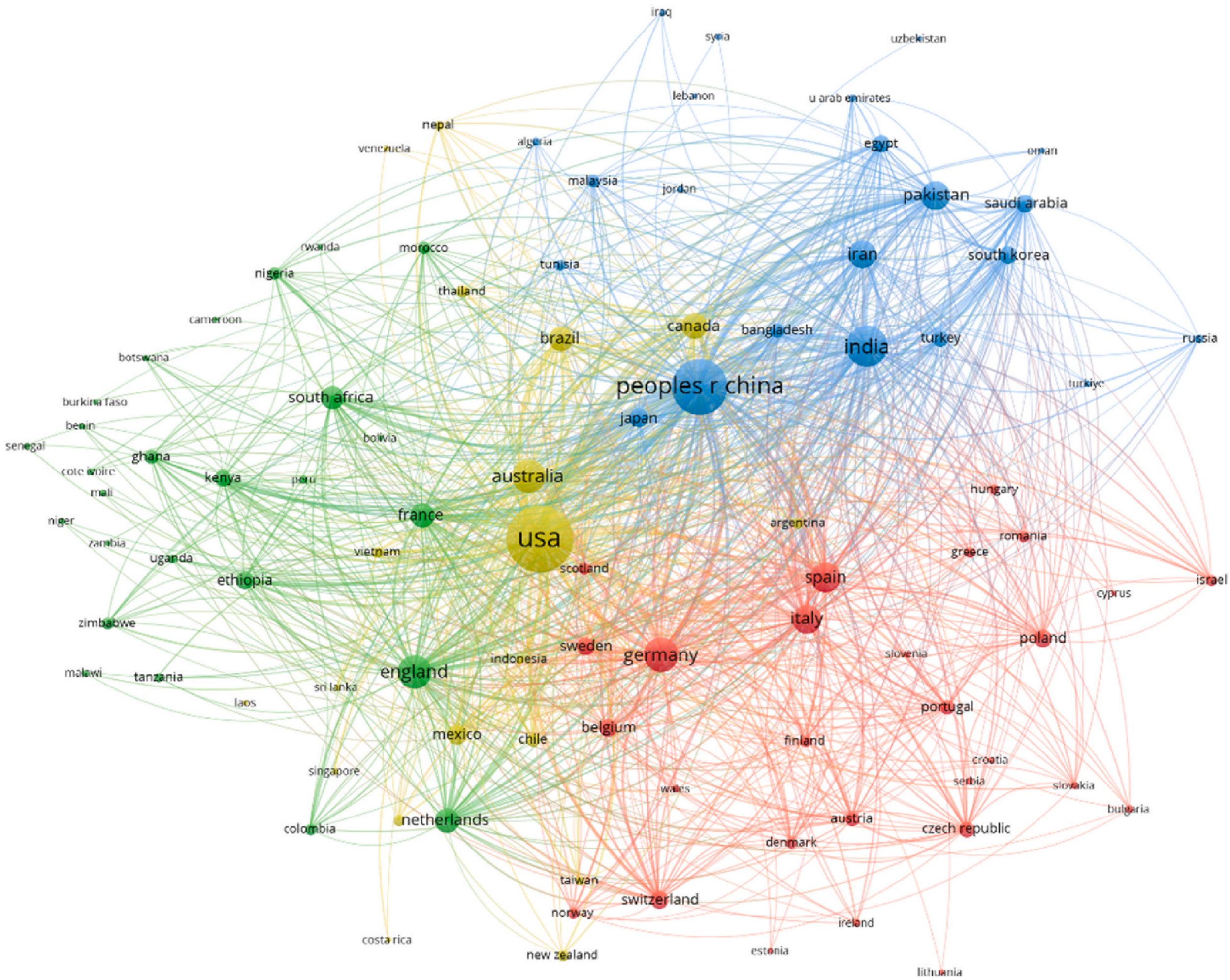

Fig. 4. Cooperative knowledge map of the AD Literature Country from 2000 to 2023.

Table 3
The top 20 countries that contributed to AD research.

Rank	country	documents	Total link strength
1	USA	1833	820
2	China	1278	582
3	Germany	486	338
4	England	445	336
5	India	706	271
6	Australia	452	266
7	Pakistan	345	232
8	Spain	364	207
9	Italy	350	206
10	Netherlands	244	190
11	France	255	176
12	Canada	264	160
13	Iran	333	136
14	Brazil	247	122
15	South Africa	227	119
16	Austria	94	257
17	Egypt	125	255
18	Kenya	118	253
19	Brazil	247	233
20	Czech Republic	101	226

3.5.1. *High-frequency keyword analysis*

Out of a total of 25,021 keywords, 1205 keywords appear with a frequency of ≥10 times, while 561 keywords appear with a frequency of ≥20 times, and 218 keywords appear with a frequency of ≥50 times. The top 10 most common keywords were related to drought (N = 2,255, accounting for 9.01% of the total), climate change (N = 1,716, 7.09%), agriculture (N = 1,349, 5.39%), yield (N = 671, 2.68%), growth (N = 657, 2.63%), variability (N = 656, 2.62%), impact (N = 594, 2.37%), drought stress (N = 590, 2.36%), adaptation (N = 548, 2.19%), and precipitation (N = 512, 2.04%), and temperature (N = 491, 1.96%). The top 20 high-frequency keywords according to frequency are shown in Table 4. The frequency ranking of the same high-frequency keyword may be inconsistent with its correlation strength value ranking.

3.5.2. *Keyword co-occurrence cluster analysis*

VOSviewer software was used to conduct keyword co-occurrence cluster analysis for keywords with a frequency of ≥10, leading to the generation of four clusters, each represented by a distinct color signifying a research hotspot (Fig. 5).

(1) The green cluster area highlights drought stress as the primary research focus in the AD field. This research investigated crop growth, yield, responses to drought, photosynthesis, leaf surface gas exchange, sustainable agriculture, abiotic stress, etc. The physiological effects and responses to drought stress, including effects on crop yield, leaf growth, leaf area, tillage systems, and

Table 4
The top 20 keywords with the highest frequency of occurrence.

Rank	Keywords	Documents	Total link strength
1	drought	2255	26
2	climate change	1716	27
3	agriculture	1349	28
4	yield	671	29
5	variability	656	30
6	growth	657	31
7	impact	594	32
8	adaptation	548	33
9	temperature	491	35
10	precipitation	512	36
11	management	503	37
12	responses	386	38
13	tolerance	369	39
14	irrigation	413	40
15	wheat	346	41
16	water	436	42
17	vulnerability	341	43
18	stress	359	44
19	maize	334	45
20	food security	327	46

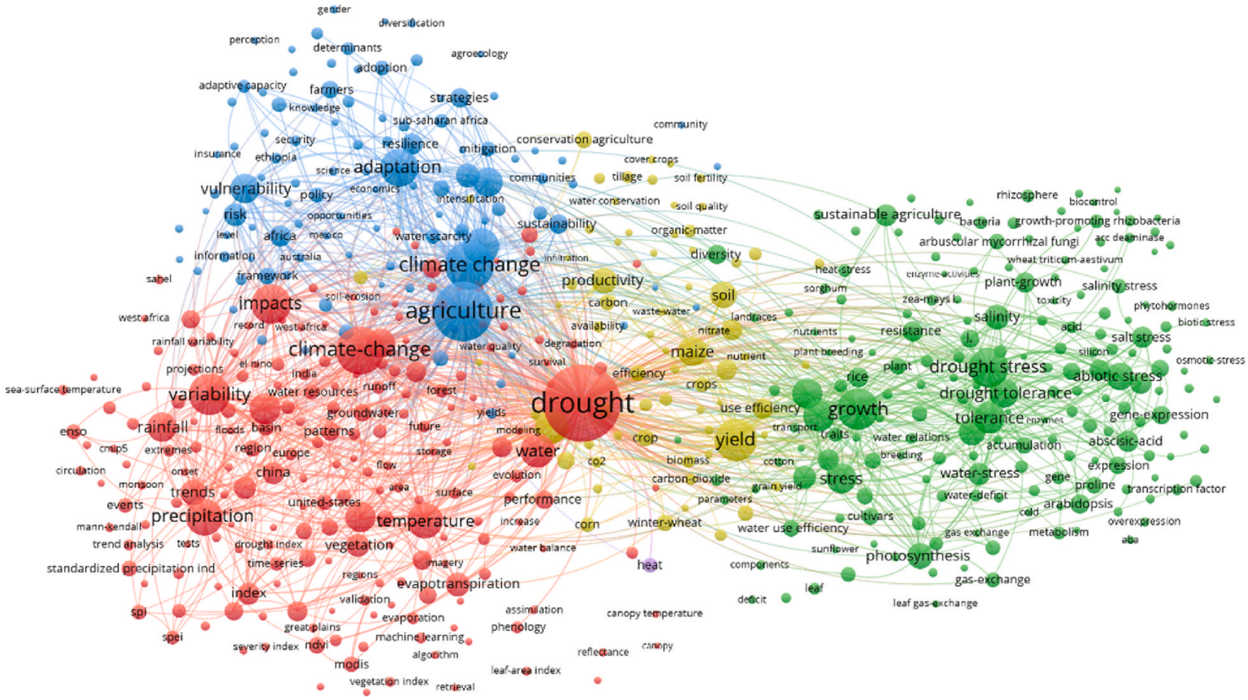

Fig. 5. Knowledge map of literature keywords co-occurring worldwide in the AD field from 2000 to 2023.

planting structures, were explored. Additionally, advanced technologies such as remote sensing and geographic information systems are utilized for drought monitoring, enhancing precision in monitoring.

(2) The red cluster area highlights the second research focus in the AD field, which revolves around the influencing factors of drought. This research investigated climate change, temperature, precipitation, variability, evapotranspiration, soil moisture,

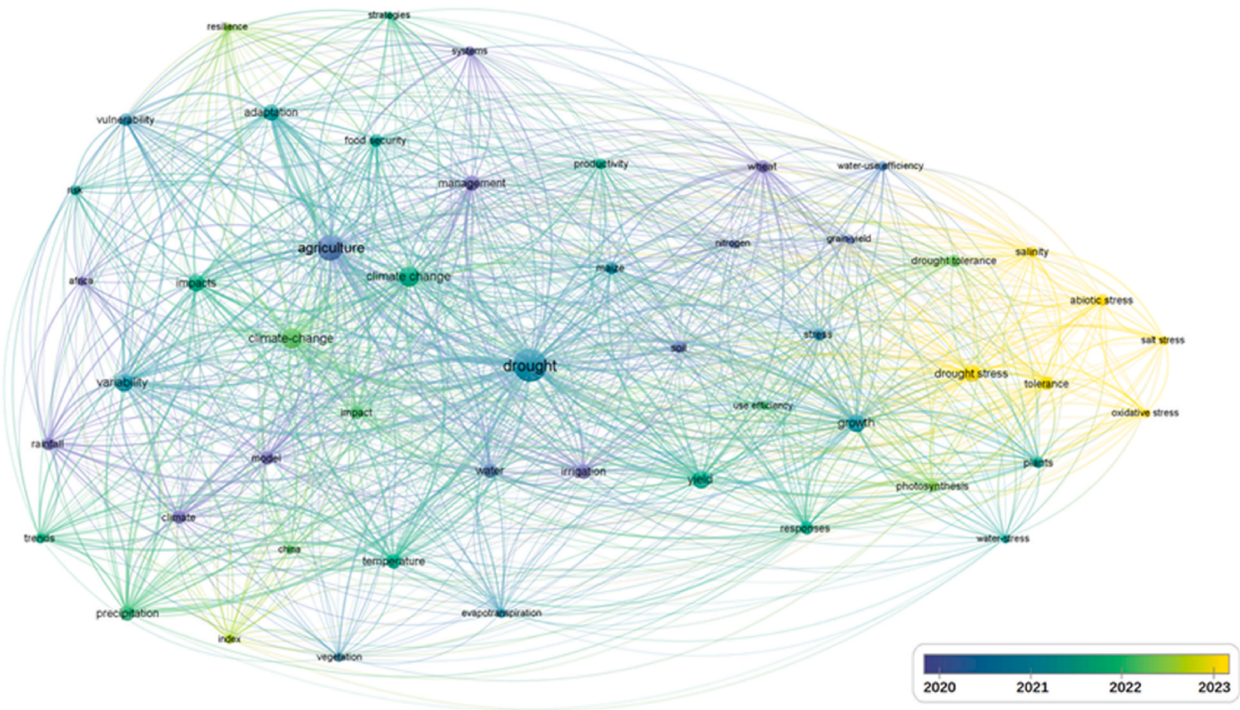

Fig. 6. Timeline visualization of co-occurring keywords in the AD field worldwide from 2000 to 2023.

drought impact, extreme events, ENSO (El Niño–Southern Oscillation), monsoons, and more. The study examined the causes of drought, the characterization of meteorological drought, drought indices (SPI, SPEI), the causes of high temperature and low rainfall, and the influence of El Niño and La Niña phenomena on drought occurrence, particularly in regions such as Africa and China.

(3) The blue cluster area draws attention to the third research focus in agrometeorological drought, which centers on agricultural impacts and adaptability. This research explores agricultural interactions with climate change, vulnerability to agricultural impacts, crop hazards, drought risk, agricultural yields, crop insurance, food security, capacity, challenges, climate adaptation, and decision-making. The study investigated the impact of drought on agriculture, agricultural responses to drought, and strategies for agricultural adaptation to drought.

(4) The yellow cluster area signifies another research focus within agrometeorological drought, focusing on the impact of drought on different crops and their yields. Research in this cluster examines productivity; rice, maize, wheat, potato, and grassland production; modeling; simulation; microclimate; soil water content; and the soil environment. This study investigated the effects of drought on the yields of various crops utilizing crop models to simulate agricultural responses to drought and the parametric environments simulated by these models.

3.5.3. Keyword co-occurrence timeline analysis

VOSviewer software was used to analyze the timeline of keyword co-occurrence for keywords with a frequency of ≥50. The results revealed the following trends. In the early stages of AD research, the primary focus was on drought monitoring indicators and methods, including the SPI, SPEI, PDSI, and other drought indicators. These investigations considered the adaptability of computer models to regional conditions and the impacts of climate factors such as precipitation, temperature, evapotranspiration, high temperatures, and soil moisture on drought. In recent years, research has shifted toward examining the impact of drought on agricultural yields. This involves quantitatively assessing the effects on different crop yields through the use of crop models. Additionally, there is growing interest in understanding the impact of climate change on agricultural drought. Research in this area has explored agricultural adaptation to climate change and management strategies to cope with agricultural drought (Fig. 6).

3.6. Hotspot analysis

Research hotspot analysis relies on keyword co-occurrence clustering graphs. The main research topics in this field can be summarized into four aspects.

(1) Drought monitoring indicators and regional adaptability

Drought indicators form the foundation of drought monitoring and assessment. Extensive research has focused on these indicators and methods. Drought indices include various measures, such as the percentage of precipitation anomalies, standardized precipitation indices, humidity, and Palmer drought indices. Moreover, with advancements in technology, including remote sensing and artificial intelligence (AI), new indicators, such as the vegetation health index, Palmer Crop Moisture Index, relative humidity, reservoir storage capacity, groundwater levels, and soil humidity, have emerged [38,39]. Regional and climatic adaptability are critical factors in the development of drought monitoring indicators and methods.

(2) The impact mechanism of climate change on drought

A comprehensive understanding of drought patterns is crucial for predicting and addressing drought risks. The IPCC has highlighted the likelihood of sustained droughts worldwide under the backdrop of climate change. Global warming has led to more frequent and intense droughts and heatwaves, affecting agricultural production and food security [40,41]. Understanding the impacts of climate change on drought conditions is essential, particularly in vulnerable regions.

(3) The impact of drought on crop yield

While overall agricultural productivity has increased globally, climate change has hampered this growth over the past 50 years, especially in mid- and low-latitude regions [42]. Drought has significantly contributed to this impact, with droughts and extreme heat reducing cereal production by 9–10% [43,44]. Research on drought risk has evolved beyond traditional single-factor assessments, developing into an interdisciplinary field that integrates climate, geography, hydrology, society, and economics. This comprehensive research involves numerous disciplines. Quantitatively assessing the impact of drought on crop yield using crop models is a crucial research direction.

(4) Agriculture adapting to climate change and extreme events

Research on drought risk includes exploring which social groups are most vulnerable to drought impacts. Due to their ecological fragility and poverty, developing countries are more vulnerable to climate change adverse effects than developed countries are [45]. Identifying and adopting suitable adaptation technologies is a pressing issue. Establishing a system for dynamic monitoring, quantitative impact assessment, forecasting, warning, and information dissemination of extreme climate events, as well as improving farmland infrastructure to respond to droughts and rainstorms, is essential.

3.7. Future research directions

Through keyword co-occurrence timeline analysis, recent trends in AD research over the past four years have emerged.

(1) Research drought monitoring and climate change impact

Advanced technologies, such as remote sensing techniques, provide information on changes in agricultural land use, paddy field identification, and climate change impacts on food production estimates. The use of technologies such as remote sensing and geographical information systems, coupled with modeling and simulation, represents a significant future research direction. Remote sensing drought monitoring, characterized by high spatiotemporal resolution and wide coverage, has become a new research method [46,47]. In the future, droughts are likely to be more frequent, severe, and prolonged unless greenhouse gas emissions are reduced aggressively [48].

(2) Research on the mechanism of drought formation

Drought occurrence and development result from the synergistic effects of factors such as monsoons, sea surface temperatures, plateau heat dynamics, local land–atmosphere interactions, and human activities. Understanding the formation and development mechanisms of drought requires a multifaceted approach that goes beyond analyzing single factors. The relationships between temperature, precipitation, evaporation, and humidity are complex and nonlinear. Future research should collect data from various sources and dimensions to quantitatively study drought formation mechanisms.

(3) Research on the chain transmission process of droughts

Although there are many studies on short-chain disaster systems, there is a lack of research on the complex and lengthy chain transmission mechanisms of droughts. Future research should focus on identifying, analyzing, and quantifying the formation patterns of drought and clarifying strategies for breaking the drought cycle. Quantitative assessments of disaster mechanisms and transmission processes through systemic dynamic evolution models, grain yield models, probability models, and remote sensing are needed.

(4) The region of interest has developed mainly in Asia and Africa

Research on AD has developed mainly in Asian regions, including China, India, the Philippines, Thailand, the USA, Australia, and the Netherlands. These areas are largely consistent with major grain crop planting regions. Scholars should consider collaboration with authors worldwide to advance AD research [49]. Asia accounts for 67% of global agricultural production. Despite increased food production in Asia from 1990 to 2014 [50–52], the projected negative impacts of climate-related risks on agriculture and food security will outweigh the expected benefits. These risks will escalate as global warming exceeds 1.5 °C above preindustrial levels, with varied impacts across the Asian continent [53].

4. Conclusions

This paper examined the current state and trends of AD research based on the performance analysis of 7416 retrieved articles from the WoS database. There was an increasing trend from 2000 to 2023, and 6935 institutions in 166 countries engaged in AD research. China leads with 1833 publications, followed by the USA with 1278. There are 457 journals publishing AD studies, with the top five being sustainability, frontiers in plant science, agricultural water management, water, and agronomy-basel. The five most common keywords include climate change, yield, variability, impact, growth, and adaptation. It also highlights four research hotspots and four future research directions.

Visualization analysis can systematically, intuitively and clearly display the research topics and categories of a certain discipline. First, a preliminary analysis of the development trends in AD research was conducted considering dimensions such as development trends, disciplinary categories, countries, and research institutions. Second, it investigates the analysis of the knowledge foundation, identifies knowledge topics, and traces the evolutionary path within the field of AD research over the past two decades. This exploration also uncovers the evolutionary path and future development trends of AD research, providing a valuable reference and foundation for further AD-related research. The limitation lies in the influence of the literature data sources and the inability to conduct an in-depth analysis of the underlying mechanisms involved. This bibliometric analysis has the potential to guide future research directions, fostering networking and collaboration among researchers worldwide by analyzing the most prominent articles, scholars, institutions, and countries contributing the highest number of articles.

Data availability statement

Data will be made available.

CRediT authorship contribution statement

Fengjin Xiao: Writing – review & editing, Writing – original draft, Project administration, Methodology, Funding acquisition, Conceptualization. **Liu Qiufeng:** Software, Investigation, Data curation. **Qin Yun:** Software, Resources, Formal analysis. **Huang Dapeng:** Validation, Supervision. **Liao Yaoming:** Visualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e27696.

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