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Research hotspot and trend of plant water use in karst: Based on a bibliometric analysis from 1984 to 2022

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A B S T R A C T

Research on the ecohydrological processes of terrestrial plants is a frontier field comprising ecology, hydrology and global change research, yielding the key theoretical foundations of ecohydrology. In karst areas, due to its unique geological background, the karst landscape is strongly developed, with high bedrock exposure, high permeability, fragmented soils, shallow soils, and high spatial heterogeneity, resulting in very limited water storage for plant uptake and growth in rock fissures and shallow soils. Therefore, water conditions are an important ecological factor influencing plant growth. To comprehensively understand the current progress and development trends in plant water use research focusing on karst areas, this paper uses the VOSviewer software to analyze the literature on plant water use in karst areas between 1984 and 2022. The results showed that: (1) Research on plant water use in karst areas has developed rapidly worldwide, and the number of relevant studies in the literature have increased year by year, which together means that it is attracting more and more attention. (2) The investigation of plant water sources, geological background of karst areas, seasonal arid tropical climates, the relationship between δ^{13}C values and plant water use efficiency, karst plant water use in karst savannas and subtropical areas, and ecosystems under climate change yields the knowledge base in this field. (3) Most studies in this area focus on the division of water sources of plants in karst areas, the methods of studying the water use sources of plants, and the water use strategies and efficiency of plants. (4) Future research will focus on how plant water use in karst areas is influenced by Earth’s critical zones, climate change, and ecohydrological separation. These studies will provide a key scientific basis for guiding ecological restoration and promoting sustainable development in karst areas.

1. Introduction

The utilization and regulation of water by terrestrial plants have always been a core focus of ecohydrology research (Li ZK et al., 2022; Wang GX et al., 2021). Plant water source refers to the water required for plants to maintain normal growth and physiological activities and affects the distribution of plant populations; it usually includes rainfall, condensation, soil water, surface water, and groundwater (Ehleringer JR and Dawson TE, 1992; Nie YP et al., 2011; Song LN et al., 2016). The concept of plant water use efficiency is used to describe the relationship between plant growth and water consumption, reflecting the carbon and water cycles along the soil-plant-atmosphere continuum (De Deurwaerder HPT et al., 2020). Plant water use in different seasons reflects the hydrological and environmental characteristics of ecosystems in karst areas, contributing to ecosystem stability (Wang R et al., 2020). Comprehending the sources, strategies, and efficiency of plant water use can enhance understanding of soil-vegetation-atmosphere hydrological processes, as well as facilitate ecological management and plant adaptation to

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climate change.

Karst is a widely distributed landform formed by soluble rocks (carbonate, sulfate, halite, etc.), accounting for 15% of the world's land area (Jiang ZC et al., 2014). Due to its unique geological background, the karst landscape is strongly developed with high bedrock exposure, high permeability, fragmented soils, shallow soils, and high spatial heterogeneity, resulting in very limited water storage for plant uptake and growth in rock fissures and shallow soils (Jiang NN et al., 2022; Jiang ZC et al., 2014; Shi PT et al., 2019). This has resulted in a spatial distribution pattern of soil and water resources characterized by segregating soil resources in higher elevations and water resources in lower elevations. Previous studies on the supply sources of nutrient elements, photosynthesis and transpiration, and root systems have indirectly shown that the sources of water uptake by karst plants are multitudinous (Feng ZZ et al., 2008; Huang YQ et al., 2009). Using stable isotope technology to study plant water in karst areas has significantly advanced knowledge in this field (Shi XY et al., 2022). The study of plant water sources in karst areas is currently increasing interest to researchers. Several studies have shown that plant water sources in karst areas are related to season, plant type, the depth of water table burial, and rock outcrop (Deng Y et al., 2020; Liu J et al., 2019; Nie YP et al., 2011, 2012; Wang XX et al., 2020). Rose KL et al. (2003) found that water stored in granite bedrock was an essential and necessary source of water for plants in shallow soils in karst areas, helping them to survive in the dry season. Querejeta JI et al. (2007) found that water in the soil-rock interface at 2–3 m was an important source for evergreens in shallow soils in karst areas during the dry season. In the areas where the bedrock comprises dolomite or impure carbonate rock, the bedrock weathering layer yields an important source of water for plants in the dry season (Rong L et al., 2012). In contrast, the plants growing on hard and pure tuffs in rocky desertification areas rely on fractured soil water as an important source, while pore water, fractured water, or pipe water are their main sources in the dry season (Cao KF et al., 2014). The enrichment of groundwater in karst areas is mainly controlled by aqueous medium, stratigraphic lithology, and geological structure, resulting in limited surface runoff (Hylander K and Dynesius M, 2006; Liu W et al., 2014). While previous research in this area is extensive, there remains a scarcity of literature on bibliometric analyses pertaining to vegetation water use in karst areas (Li PJ et al., 2008; Li SG et al., 2007).

Bibliometrics is a quantitative evaluation method that involves constructing a data matrix based on the external characteristics of literature, analyzing a large amount of literature data through statistical methods, and visualizing the relationships between information units or groups to study distribution characteristics, quantitative relationships, and change patterns in literature (Zhu J and Hua WJ, 2017). It is mainly used to study academic research, using objective and quantitative measures to reflect the overall layout, hotspots, frontier dynamics and development trends of a specific discipline or field through mathematical and statistical methods (Gaede J and Rowlands IH, 2018; Zou X et al., 2018). Zhao YL et al. (2021) analyzed karst research from a bibliometric perspective, in which authors, countries, journals, and disciplines of karst research were considered, and showed that stable isotopes and karst hydrology have been the focus of research in recent years. Sohel MSI et al. (2019) analyzed research on woody plant water sources from the past three decades from a bibliometric perspective and discussed the research directions and development trends of woody plant water sources in the context of global warming. Some researchers have discussed the directions and development trends of studies on water resources used by woody plants in the context of global warming, but have not addressed the analysis of plant water use in karst areas. Aleixandre Tudo JL et al. (2019) examined the trends in the research on global water use efficiency, and Wang J et al. (2022) examined the trends in research on heat tracer-based sap flow methods.

Based on the core database of Web of Science (WoS) and using the VOSviewer software, this paper considers the number of publications, the major countries and research institutions, leading scholars, subject categories, and keyword clusters in the field of plant water use in karst areas over the past 40 years (1984–2022). This study aims to (1) identify the developmental lineage and leading journals in the field; (2) identify the most productive authors, countries, and institutions; and (3) summarize the knowledge base, research hotspots, and research trends in the context of plant water research in karst areas.

This study analyzed 40 years of research on plant water use in karst areas. In Section 1, this study presents the most important findings on the topic and specifies the goals of this study. In Section 2, this study explains how the goals of this study were achieved via the three phases of data processing and use methodology (source and topic selection, processing software, and data analysis and visualization). In Section 3, the results of the data analysis are presented, which consist mainly of analyses of the numbers and sources of publications, the patterns of collaboration, and the most salient knowledge areas. Section 4 presents a discussion of future research trends on the topic. Section 5 presents the main conclusions and findings of this study.

2. Materials and methods

The methodology includes three phases (Fig. 1): (1) Data source and topic selection; (2) data processing software; (3) data analysis and visualization.

2.1. Data source and topic selection

The Web of Science Core Collection database (WoS) is one of the most widely used for bibliometric analyses. It has one of the oldest and most comprehensive citation indexes and includes a useful analysis tool (Wang Q and Waltman L, 2016; Zhu JW and Liu WS, 2020). Compared with other databases, WoS may not contain the largest number of

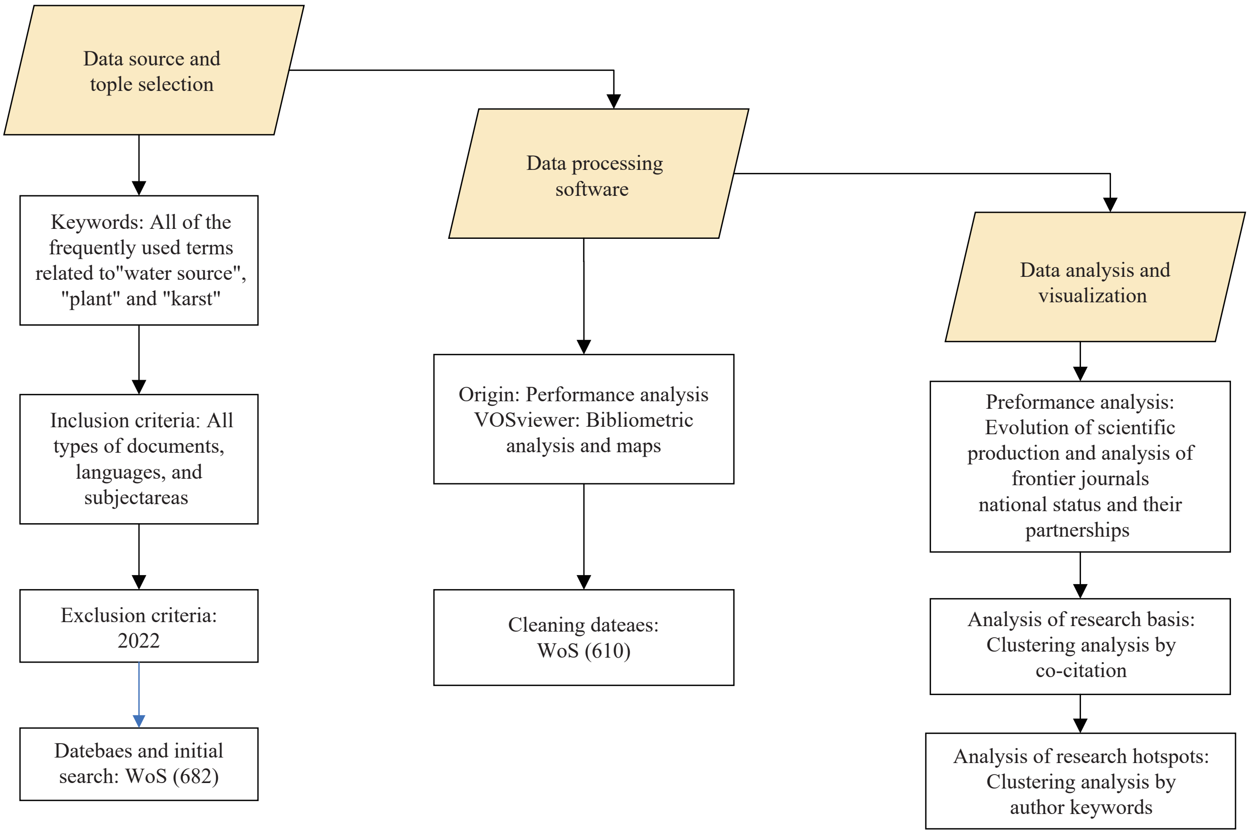

Fig. 1. Method steps and summary process.

journals in all fields, but it has a sufficient quantity of high-quality literature, and all relevant trends are appropriately reflected within (AlRyalat SAS et al., 2019; Badia G, 2018). The data cited in research papers were collected from the WoS, with the themes of “plant water source” and “biological” being selected, covering the period from 1984 to 2022.

The term “plant water use in karst area” consists of three elements (i.e., plant, water use, and karst). To ensure that all aspects are fully represented in the keyword search, this study included three search strings, as follows: TS=(vegetation OR plant OR plants OR forest OR tree OR trees OR plant OR planted OR reforest OR afforest OR “mixed plantation” OR agroforest OR grassland OR grass OR turf OR meadow OR shrubs OR bush OR coppice) AND TS=(“water source” OR “water use” OR “water efficiency” OR ecohydrology OR “plant ecophysiology”) AND TS=(carbonate OR limestone OR dolomite OR dolostone OR karst OR karstic NOT “Picea abies Karst” NOT “Picea abies (L.) Karst”). The keywords were chosen based on previous literature reviews on similar topics, the authors’ own research experience, and the views of experts from this field (Sohel MSI et al., 2019). The plant-related content yielded by the terms “ecohydrology” and “plant ecophysiology” will contain information on plant water use (Urli M et al., 2013).

From the WoS databases, this study collected and then stored journal articles (conference papers, books, and chapters of books excluded) related to the defined search terms with an open starting time to include as many publications as possible up to December 2022. The initial search attempts identified 682 titles. The search results were stored in plain text files to preserve all the essential information, such as the papers titles, authors names and affiliations, abstracts, keywords and references.

The titles and abstracts were reviewed by applying inclusion and exclusion criteria. Each publication was then carefully reviewed to ensure relevance to plant water use, and a total of 610 publications were retained for scientometric analysis.

2.2. Data processing software

The WoS search resulted in a database of 610 documents exported in txt. file format, and the downloaded information was related to authors, abstracts, keywords, references, and bibliographic information. Origin (Moberly JG et al., 2018) and VOSviewer (Gaviria-Marin M et al., 2019; Gaviria-Marin M et al., 2018; Pan XL et al., 2018) are the software programs utilized for data analysis.

2.3. Data analysis and visualization

This study used the VOSviewer analysis software package to analyze the current status and hotspots of plant water use research in karst areas. Additionally, Origin2021 was used to analyze the overall posting trends and numbers of high-frequency keywords (Rabbani MRA et al., 2021; Sohel MSI et al., 2019). The paper analyzed the number of publications, as well as the keywords, citations, journal of publication, authors, countries, and institutions of each article. Using this data, the study identified research trends and leading journals, undertook keyword co-occurrence analysis and co-citation analysis, and derived author, country, and institutional cooperation networks relating to plant water use in karst regions. The following approaches were used:

(i) Bradford's law, which is used to rank journals in decreasing order according to the number of papers published in a specialty field, then is divided into a core region and several successive regions, each of which contains an equal number of papers. The number of scientific and technical journals in a certain period of time is arranged in decreasing order, then the journals in the discipline can be divided into core, relevant and non-relevant areas, and the number of relevant papers in each area is equal. In this way, the number of journals in the core, related, and non-related areas is into a $1{:}a{:}a^2$ proportional relationship (Nicolaisen J and Hjorland B, 2007; Sudhier KG, 2010; Venable GT et al., 2016).

(ii) Collaboration network analysis is used to evaluate the most productive countries, institutions, and authors (the number of publications in each country and publications of each major institution), as well as interaction networks over a period of time (Yu DJ et al., 2021). The national collaboration networks and institutional collaboration networks were constructed in VOSviewer, which provides a better graphical layout. An author collaboration network was also derived to analyze collaborations among researchers (Klavans R and Boyack KW, 2017; Merigo JM et al., 2018).

(iii) Literature co-citation analysis is based on the fact that, in the context of scientific metrology, the cited literature forms the research frontier and the knowledge base of a field (Hota PK et al., 2020; Trujillo CM and Long TM, 2018). Literature co-citation analyses are based on statistics concerning the number of studies cited at the same time by one or more papers to perform network and cluster analyses, and thus assess the knowledge base of the specific topic represented by these papers (Hou JH et al., 2018; Shiau WL et al., 2017).

(iv) Keyword co-occurrence analysis involves counting the number of pairs of keywords cited in the same document, which then gourds network and cluster analyses of these words, and this reveals the structure of the knowledge base and research frontier of a given topic (Chen KH et al., 2019; Donthu N et al., 2020). Keywords in academic publications are natural language words that outline the main concepts of a document (Benita F, 2021; Caputo A et al., 2021; Guan JC and Liu N, 2016). Keywords condense and express the author's opinion, making them an important bibliometric indicator. In the process of analyzing the keywords, those that are synonymous, consistently present in singular and plural forms, or expressed in different wordings were combined, e.g., soils and soil, water-use efficiency and water use efficiency, trees, and plants, CO_2 and carbon-dioxide, etc., due to the possible inconsistencies of the expressions used between authors.

3. Results

3.1. Research development history

3.1.1. Temporal and spatial distribution of articles

The change in the number of academic papers in a certain discipline is an important indicator of the development trends of the research field, and also reflects the changing scope of the knowledge in this discipline (Zou X et al., 2018). By plotting the number of papers over time and performing multivariate statistical analysis, it is possible to understand the level of research and future trends in a certain field (Benita F, 2021). To derive an accurate and clear understanding of the international literature on plant water sources, the annual distribution of the literature on plant water use in karst area and the publication trends were plotted (Fig. 2a). The number of academic papers published from 1984 to 2022 is divided into three phases:

(i) Constant phase (1984–1991). As can be seen from Fig. 2b, from 1984 to 1991, few relevant studies were published in this field, with a maximum of two papers published per year, indicating that a complete body of literature had not yet been

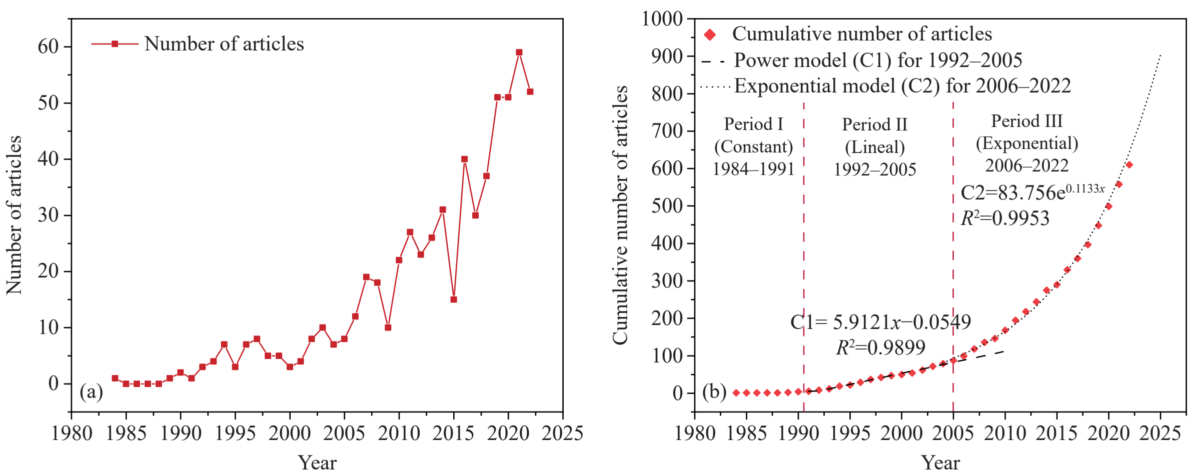

Fig. 2. Annual distribution and publication trends of the literature on vegetation moisture sources in Web of Science. a–number of articles from 1984 to 2022; b–relationship between the cumulative number of articles and the year published from 1984 to 2022.

developed. Rambal S (1984) published the earliest paper on water use by plants in karst areas in Oecologia. In this study, the root uptake pattern of *Quercus coccifera* growing on limestone was calculated by monitoring soil water, surface runoff, and water balance (Freersmith PH and Dobson MC, 1989).

(ii) Linear growth phase (1992–2005). The relevant literature base started to increase substantially in this phase, with an average increase of about six articles per year, and it can be seen that the field of research on plant water sources in karst areas was initially formed in this period. During this phase, carbon isotopes were introduced into the study methodology of plant water efficiency in karst areas, and the introduction of isotopes and hydrogen led to faster growth in the literature in this field. The main themes of this period were plant stomata, water potential, and plant water use efficiency.

(iii) Exponential growth phase (2006–2022). The rate of scientific production was evaluated using Price's law, which measures the growth of research in the study area, and it can be found that exponential growth in this period (Andreo-Martinez P et al., 2020; Borden W, 2006). This showed that the field underwent a phase of rapid development. The entire rate of production of the study area was estimated, and a growth model was generated, indicating the interest of the academic community. The use of hydrogen and oxygen isotopes in studying of water sources in karst areas and the importance of researching global climate change and plant ecohydrological processes have led to increased research on plant water use in karst areas (Leite PAM et al., 2020; Muangsong C et al., 2020). The most cited publications included Flexas' article on climate change and water use efficiency, cited 139 times (Flexas J et al., 2016), and Ding and Nie's article on water uptake depth and drought vulnerability, cited 43 times (Ding YL et al., 2021).This period of increasing research implies rapid development and has yielded various key topics in the current research.

3.1.2. Frontier journals with articles

Academic journals are the main carriers of relevant data. Highly cited international journals can show the main research topics in a specific field over time. An analysis of 610 articles revealed 289 main source journals. Using Bradford's law (the law of literature dispersion), the authors identified 21 core journals out of 419 (Table 1). The ratio of the number of journals between the three districts is 21∶79∶216, and the core effect is obvious.

Table 2 shows the top 10 journals with the highest number of publications. In terms of the number of published articles, the Journal of Hydrology contains the most literature on plant water use in karst areas, followed by Tree Physiology and Environmental Earth Sciences. Overall, the journals on plant water research in karst areas are multidisciplinary and address mainly hydrology, plant physiology, environmental ecology, etc.

3.1.3. Distribution of national status and their partnerships

The analysis of research countries aims to determine the international distribution of research efforts focusing on the

Table 1. Discrete distribution table of the literature on vegetation water use sources in karst areas.

Partition	Number of journals	Percentage of the total number of journals	Paper volume	Proportion out of the total number of papers	Average density of articles
Core interval	21	6.44%	218	33.38%	10.38
Related interval	79	24.23%	209	32.01%	2.74
Discrete interval	216	69.33%	226	35.61%	1

Notes: Percentage of the total number of journals=Partition number of journals/total number of journals; Proportion out of the total number of papers= Papers volume/total number of papers; Average density of articles=Papers volume/Number of journals.

Table 2. Main information from the top 10 most relevant resources regarding karst plant water sources.

No.	Journal	IF	Nation	ND	Main publication topics
1	Journal of Hydrology	6.731	USA	26	Ecology of environmental sciences, including identification of plant water sources, response to engineering construction, methods for determining plant water sources
2	Tree Physiology	5.121	England	18	Plant physiology, including physiological characteristics of plants and vegetation water use efficiency, carbon isotope information of tree annual rings
3	Environmental Earth Sciences	3.152	Germany	16	Environmental science ecology, including plant water use strategies and water source division among trees
4	Hydrological Processes	4.117	USA	12	Water resources and botany, including plant water uptake processes and isotopic analysis
5	Science of the Total Environment	10.237	Netherlands	12	Geology and plant ecology, including plant water use in critical zones of the Earth and plant water use response to climate extremes and vegetation restoration
6	Ecohydrology	3.369	USA	12	Environmental science ecology, including plant water discriminations and plant water allocation
7	New Phytologist	10.768	England	11	Plant science, including primarily the effects of climate change on water sources and water use efficiency
8	Plant and Soil	5.44	Germany	11	Agricultural and plant sciences, including seasonal patterns of plant water use, water sources and nutrient relationships
9	Oecologia	3.645	Germany	10	Ecosystem science, including primarily the effects of revegetation on plant water sources and water use efficiency
10	Forests	3.292	Switzerland	10	Plant physiology, including plant physiological responses to drought and water adaptation strategies

Note: Impact factor recorded on 27 April 2023.

sources of plant water use and the general state of the scientific collaboration between countries. Fig. 3 shows that 70 countries have participated in this research area, indicating its global reach. Table 3 lists the top 10 countries with the highest number of academic publications, totaling 400 publications and representing 70% of the overall output.

The United States pioneered research on plant water use in karst areas, with a primary focus on tropical America, mainly in Mexico and Brazil, as well as in Florida (Cavender-Bares J et al., 2004; Perez-Garcia EA and Meave JA, 2004; Perez-Garcia EA et al., 2009; Trejo-Torres JC and Ackerman JD, 2002). According to Fig. 3, China accounts for almost a quarter of the total published literature and has the greatest density. China conducts relevant studies the most frequently and is currently the highest producer of karst areas. China has the most extensive karst landscape in the world, providing a good research background for Chinese experts and scholars (Geekiyanage N et al., 2019). In addition, China has the world’s largest population, research staff, and institutions. The water use of subtropical plants is a main area of study in China. There is also a significant collaboration between China and the United States, mainly focusing on the responses of plant water sources to climate change and extreme climates such as drought.

3.2. Research basis analysis

When two papers reference the same source, they established a literature coupling relationship, with the strength of this relationship being directly proportional to the total number of references they cite. The knowledge bases of studies on plant water use in karst areas can be classified into two distinct categories: (1) Foundational texts from the early stages of research, and (2) documents with high co-citation frequencies (Kessler MM, 1963). By conducting a thorough analysis of document co-citations, researchers can efficiently and effectively identify most significant knowledge bases within the field of study by considering the total number of references cited. Furthermore, the relevance and developmental processes of the documents can also be analyzed (Zou X et al., 2018).

Stronger coupling between papers, leads to closer similarity in the research topic, discipline and professionalism. Literature coupling analysis can identify highly relevant and frequently cited papers, helping to efficiently locate fundamental knowledge in a research area. Fig. 4 categorizes the knowledge network into six clusters based on clustering density using VOSviewer’s default method.

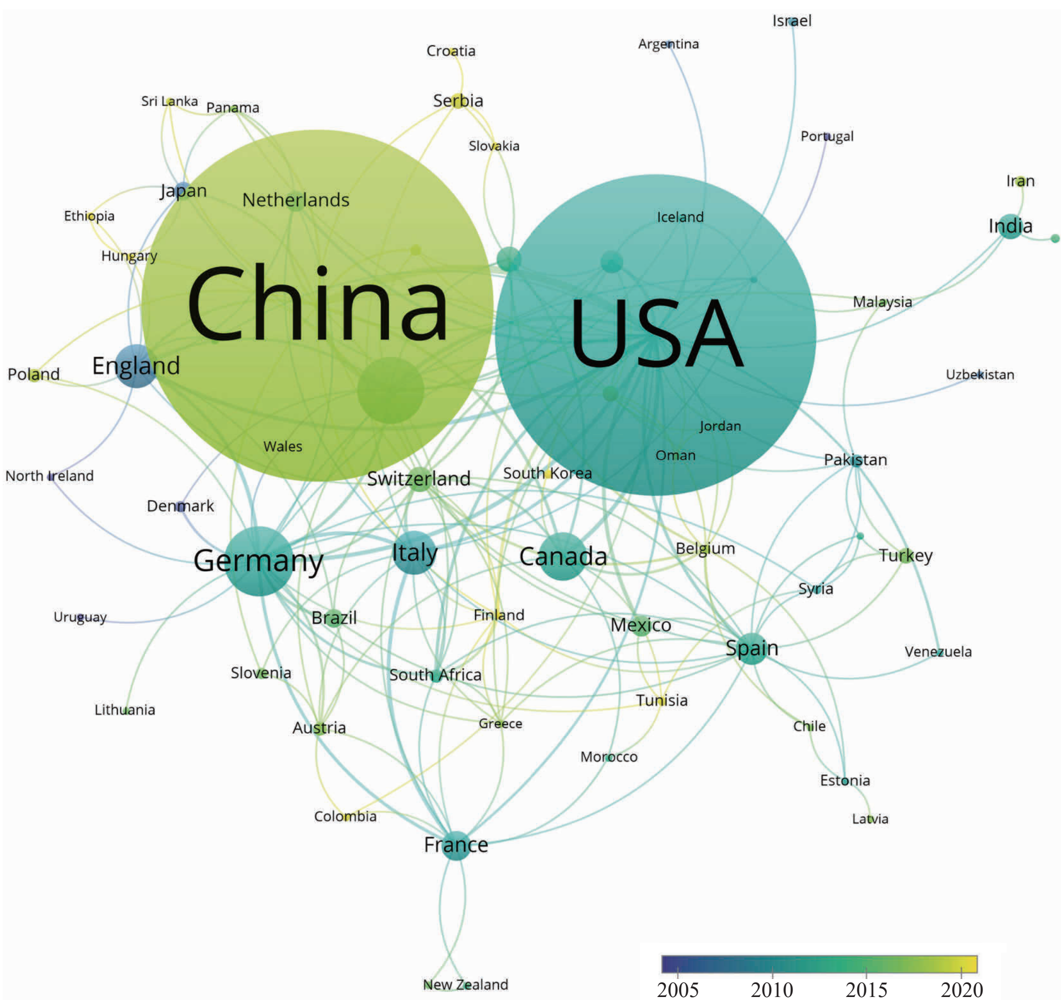

Fig. 3. Distribution of countries and cooperative relationships outlined in WoS.

3.2.1. Application of stable isotopes technique in plant water use studies

The purple cluster in Fig. 4 focuses on research about water sources of karst savanna plants, with a key article being “Water uptake by plants: Perspectives from stable isotope composition” by Ehleringer JR and Dawsonin TE (1992) in Plant, Cell and Environment. This article has 126 citations and a total link strength of 419, indicating its importance in the co-citation network. Ehleringer JR and Dawson TE (1992) summarized the relationship between the isotopic variation in water sources, deep water use by mature trees and soil water in summer, and water use efficiency in plants in arid areas. They claimed that stable isotopes could reveal plant water sources, competitive interactions between species, water use efficiency, plant performance and landscape hydrology. This approach can also assess the effects of droughts and floods.

Table 3. Number of articles co-published by countries in WoS.

No.	Nation	Region	ND	Percentage	Number of collaborations
1	China	Asia	176	27.71%	43
2	USA	North America	144	22.68%	81
3	Germany	Europe	36	5.67%	43
4	Australia	Oceania	30	4.72%	27
5	Canada	North America	23	3.62%	28
6	England	Europe	23	3.62%	23
7	Italy	Europe	19	2.99%	22
8	France	Europe	16	2.52%	21
9	India	Asia	15	2.36%	19
10	Spain	Europe	14	2.21%	21

3.2.2. Correlation between $\delta^{13}C$ value and plant water use efficiency

The orange cluster represents the literature on the correlation between the carbon isotope resolution ($\delta^{13}C$) and water use efficiency of plants. Within this cluster, the most cited article is “On the Rela-tionship between Carbon Isotope Discrimination and the Intercellular Carbon Diox-ide Concentration in Leaves” by Farquhar GD et al. (1982), published in the Australian journal Plant Physiology. This paper has garnered 96 citations and a total link strength of 179. This study posits a potential correlation between the ^{13}C isotope ratio and intracellular CO_2 concentration in plant leaves, and formulates an equation that quantitatively represents the relationship between $\delta^{13}C$ and the intracellular CO_2 concentration radio in leaves.

3.2.3. Geological environmental background of karst

The yellow cluster in Fig. 4 focuses on how the geoenvironmental context affects vegetation water sources in karst areas. A key paper is “Rocky Desertification in Southwest China: Impacts, causes, and Restoration” by Jiang ZC et al. (2014). This paper has 19 citations and a total link strength of 345, discussing the transition of karst areas from vegetation-covered to exposed bedrock. Rocky desertification is widespread in karst areas like Belize, Guatemala, Mexico, North America, Israel in the Middle East, and East and Southeast Asia. Jiang ZC et al. (2014) discussed this phenomenon in China, Europe, and globally, highlighting the geological conditions that contribute to it. This paper suggests that rocky desertification not only harms vegetation, but also hinders the growth of pioneer plants due to insufficient water

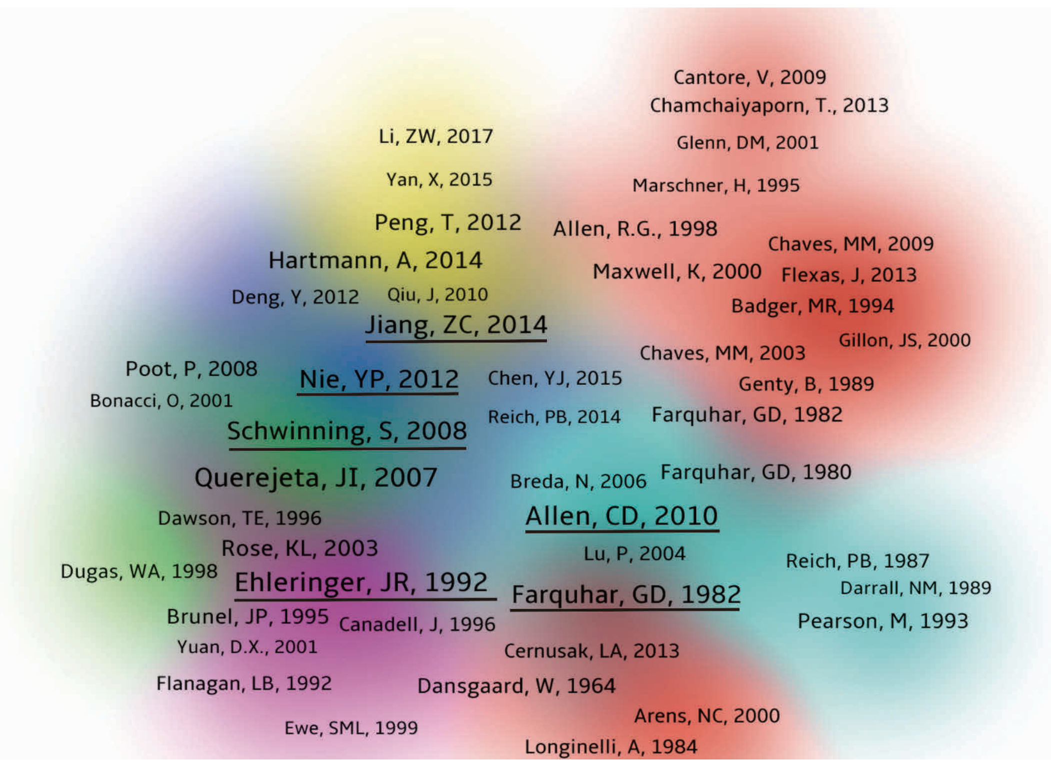

Fig. 4. Cluster density view of document co-citation network.

supply caused by the thin soil layer. In these conditions, plants must reach underground rivers for water by extending roots through cracks in rocks. This accelerates the infiltration of precipitation into groundwater, affecting water availability for plants and the isotopic value of water sources.

3.2.4. Water sources of karst plants in savanna

The green cluster in Fig. 4 focuses on literature about water sources for karst savanna plants. The most cited paper in this group is "The water relations of two evergreen tree species in a karst" by Schwinning S (2008) in Oecologia Savanna, with 27 citations, and a total link strength of 505. The paper addresses the role of karst savannah plants in hydrological processes, and discusses the relationship between stem water and potential water sources of *Texas live oakQuercus fusiformis* and *Ashe juniper Juniperus ashei*. The findings indicated that during the rainy season, the two species primarily absorbed residual water from surface evaporation, whereas in the dry season, they predominantly utilized water from the deep soil. This study has led to the formulation of a new hypothesis, suggesting that a decrease in water potential resulting from root system absorption may disrupt the flow path between the rooted and rootless portions of the surface karst.

3.2.5. Water sources of karst vegetation in subtropical regions

The blue cluster in Fig. 4 focuses on water sources of plants in subtropical regions, with a key study being "Water source utilization by woody plants growing on dolomite outcrops and nearby soils during dry seasons in karst region of Southwest China" by Nie YP et al. (2012) in the Journal of Hydrology with 137 citations, and a total link strength of 381. Nie YP et al. (2012) examined how plants on continuous and isolated dolomite in subtropical karst areas of southwest China obtain water during the dry season. They found that plants on continuous dolomite rely on stored rainwater early in the dry season, and deep saturated zone water later on, while plants on isolated limestone use recent rains. Trees in the study region adapt to changing water availability by using shallow soil water in the early dry season and deep water from nearby dolomite outcrops in the late dry season, which helps them to maintain transpiration demand and improve water storage capacity.

3.2.6. Sources of water use of ecosystem vegetation under climate change

The cyan clusters focus on studies about vegetation water sources in ecosystems impacted by climate change. The most cited study in this cluster is "A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests" by Allen CD et al. (2010) in Forest Ecology and Management. It has 12 citations and a total link strength of 95, summarizing changes in forests due to climate change. According to the study, rising temperatures cause water stress in plants, leading to increased plant mortality. To understand how future climate change will affect forest systems, the authors need to analyze how plants respond to water stress. However, there are few studies on how plants regulate water potential and absorb water in changing climates.

3.3. Analysis of research hotspots

Keyword co-occurrence analysis is a common method of metrology used in the literature. Its purpose is to clearly show the co-occurrence relationships of key words used in the international research on plant water use in karst areas. A visualization is shown in Fig. 5.

3.3.1. Selection of water sources for plants in karst areas

The purple cluster is the "water source" group; here, the six terms ecohydrology, stable isotopes, precipitation, runoff and soil water are particularly prominent. This cluster includes nine keywords with a total of 135 occurrences. Plant water sources in karst areas may be affected by seasonal changes, vegetation types, groundwater levels and rock outcrops (Geekiyanage N et al., 2019). In the rainy season, plants predominantly rely on rainwater, soil water and surface karst water for their water supply (Stubbington R et al., 2019). Shrubs typically utilize broad but shallow root systems to extract water from the soil, as opposed to developing deep roots that penetrate rock crevices. When the frequency of rock fissures is relatively high (20%–50%), the water in surface areas of karst zones is also an important source for shallow-rooted plants (Liu CN et al., 2021). In the dry season, when soil water and surface karst water are quickly depleted, deep-rooted plants shift their reliance to groundwater, such as arboreal water. Conversely, shallow-rooted plants can only rely on the most recent precipitation (Nardini A et al., 2021). The use of groundwater by deep-rooted plants is also affected by the depth of the groundwater. Studies have shown that (1) plants with a groundwater level that fluctuates between 4 m and 10 m mainly use soil water in the rainy season and rock water in the dry season (Deng Y et al., 2020), and that (2) plants with a groundwater level fluctuating between 0 and 1 m exploit rock water in both seasons, while plants with a groundwater range of 2–3 m use soil water in both seasons. In southwest China, plants growing on outcrops of dolomite mainly use the rainwater stored in shallow fissures in the rainy season, and then use the most recent rain in the dry season. Deciduous plants growing on limestone outcrops mainly use deep water in the dry season and a mixture of rain and deep water in the rainy season, while evergreen plants rely mainly on deep water in both the rainy and dry seasons (Nie YP et al., 2012).

3.3.2. Water use determination method for plants in karst areas

The red cluster concerns the "water source methods" group, highlighting the terms groundwater, oxygen isotopes and carbon isotope discrimination. This cluster includes eight papers with a total of 62 occurrences. The study of plant water sources in karst areas has its peculiarities due to the shallow

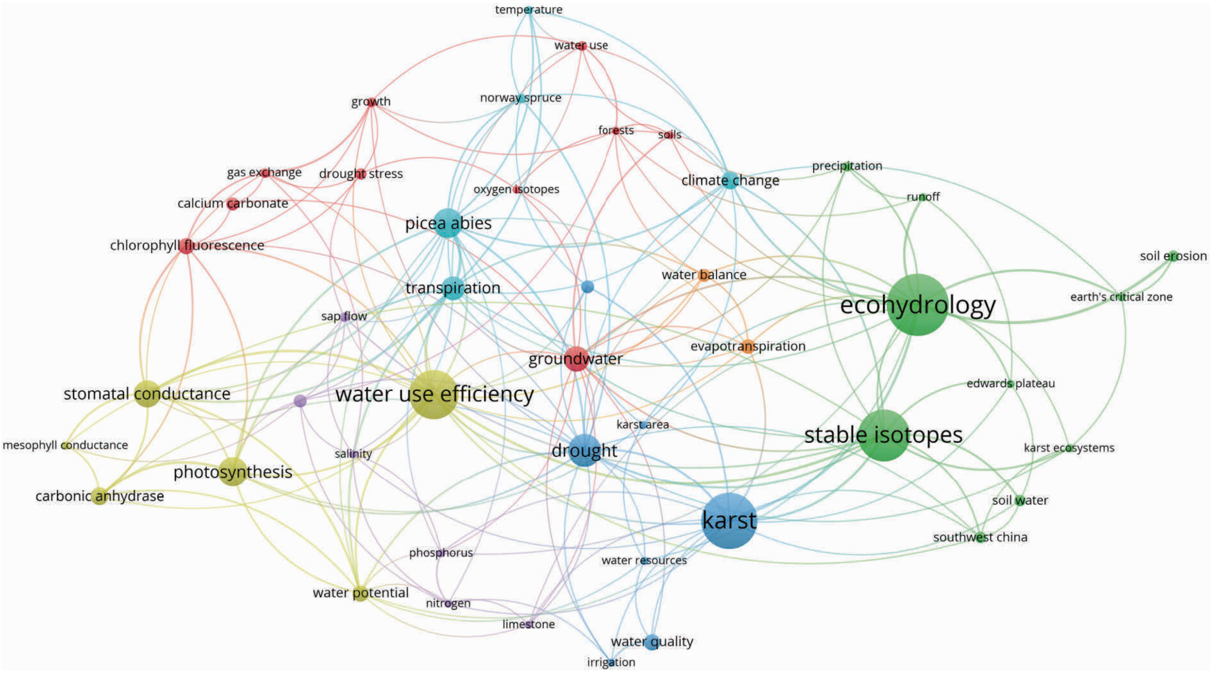

Fig. 5. Co-occurrence distribution map of WoS keywords.

soil in karsts. Nie YP et al. (2010,2017) have summarized the four most commonly used methods in recent years to analyze plant water sources in shallow soils: Plant water sources based on plant root growth and distribution characteristics (Brunel JP et al., 1995; Isaac ME et al., 2014), changes in the water present at various levels belowground (Dai Y et al., 2015; Moore JW and Semmens BX, 2008; Parnell AC et al., 2010; Phillips DL and Gregg JW, 2003), and changes in plant water indicators and the use of hydrogen and oxygen isotopes for the analysis of plant water sources (Zeng XM et al., 2021). The root excavation method is very destructive, but the direct correlation method cannot determine the proportions of the individual sources (Asbjornsen HD et al., 2007; Zwieniecki MA and Newton M, 1995). The dynamic monitoring method is only suitable for areas with high levels of weathering, while the isotope method can effectively determine the proportion of uptake of each water source (Brunel JP et al., 1997; Dawson TE and Ehleringer JR, 1993; Peng XD et al., 2019; Wang ZQ et al., 1995).

Due to the developed and complex networks of plant roots in karst areas, determining the types of plant water sources, collecting samples of the various potential water sources, and illustrating the complex water sources used by plants are the three greatest difficulties encountered in karst areas. Researchers usually use the "rainwater substitution method" and the "spring water substitution method" to address these challenges, in addition to utilizing indoor simulations to analyze the hydrogen and oxygen isotopes of rock water (Ding Y et al., 2018; Nie YP et al., 2011). Recently, a growing body of literature identified isotopic deviations that were caused by cryogenic vacuum extraction. Jiang NN et al. (2022) summarized the application of an isotope-based method that involves cryogenic vacuum extraction, emphasizing the necessity for adaptation to the unique characteristics of karst areas.

3.3.3. Water use strategies and efficiency of plants in karst areas

The yellow cluster represents "water use efficiency" with a focus on key terms such as water use efficiency, stomatal conductance, photosynthesis and water potential are particularly prominent. This cluster consists of five items with a total of 79 occurrences. The water use efficiency of plants in karsts can be directly related to specific factors, such as growth dynamics, plants' ability to adapt to their environment, responses to environmental stress and the coordination between carbon assimilation and water consumption. Plant water use strategies are analyzed mainly via studies of leaves and whorls, with leaves being used mainly for short sequences and whorls for long sequences (Du H et al., 2023). Using a short sequence of analyses, Van de Water PK et al. (2002) conducted the first study of plant water use efficiency using the δ^{13}C karst zone of leaves. The study revealed the relationship between δ^{13}C and elevation, slope and precipitation in the southwestern USA, with plants showing increased water use efficiency with increased elevation and slope and decreased precipitation. Karst plants of different bedrocks also have different water use efficiencies. For example, plants growing on dolomite showed higher average daily transpiration rates than those in limestone areas, but lower average daily photosynthetic rates and water use efficiencies (Nie YP et al., 2014). Plants growing in different habitats in a karst area show different adaptations. Plants growing in shallow soils in karst areas have notably thinner and slightly more curved roots, while plants growing in loose rocky soils and exposed rocks have thinner but more strongly curved roots, which suggests that plants in different habitats can potentially improve their water use efficiency via increasing root curvature (Ding YL et al., 2021; Qin XJ et al., 2022). Under high Karst Ca and Mg stress, water use efficiency of herbaceous plants is more sensitive to Ca stress, while that of woody plants is more sensitive to Mg stress (Xia AT and Wu YY, 2022).

In a long-sequence analysis of plant water use efficiency, Petrucco L et al. (2017) investigated the causes of the decline in black pine using δ^{13}C and δ^{18}O values in trees' annual rings and concluded that declining trees adopt a more conservative water use strategy under drought stress, leading to lower water use efficiency. However, such studies are less common in karst areas.

3.3.4. Climate change and transpiration

The cyan cluster is indicative of the process of "transpiration", with a focus on the interconnected concepts of transpiration, climate change and temperature. This cluster encompasses eight items, totaling 73 occurrences. Drought identified as the primary environmental constraint on plant growth in karst areas, with deep-rootedness playing a crucial role in plant survival in water-limited ecosystems. Under conditions of drought stress, the net photosynthetic rate (Pn), stomatal conductance (Gs), transpiration rate (Tr) and intercellular CO_2 concentration (Ci) of plants decline (Wang M et al., 2021). As drought stress continues, different plants adopt different strategies of response. Evergreen plants adopt drought-tolerance strategies, while deciduous plants adopt avoidance strategies (Liu CC et al., 2011). Isohydrogenic species tend to regulate their water potential within a strict narrow range by gradually closing their stomata, while more hydrogenic species keep their stomata open, allowing their water potential to drop sharply as water availability decreases (McDowell NG et al., 2019; Tardieu F and Simonneau T, 1998).

3.3.5. Alkaline stress and water use

The green cluster represents is indicative of the process of "alkaline stress", with a focus on key terms such as water stress and sap flow, which are particularly prominent. This cluster consists of five items with a total of 28 occurrences. Studies of biological salt stress mechanisms and plant responses to high salinity using simple salt stress (NaCl only) have been a hot topic for two decades (Chen Z et al., 2007; Hansen JK et al., 1998; Teobaldelli M et al., 2004; Vanhoorn JW et al., 1993). Many studies have demonstrated the presence of alkali stress compared to salt stress. Salinity stress has been shown to have detrimental effects on plant growth and development across various aspects (Chen Z et al., 2007; Perez-Garcia EA et al., 2009; Siddiqui MH et al., 2014). The primary factor contributing to soil salinity damage in plants is the elevated concentration of salt ions surrounding the roots, leading to increased osmotic pressure and subsequent physiological drought. This condition hinders water absorption by the roots and triggers various toxic effects (Adame MF et al., 2014; Zheng CC et al., 2019). However, under alkaline stress, the water use efficiency of plants increased with salinity (Medina-Calderon JH et al., 2021; Zeng Y et al., 2020).

3.3.6. Irrigation and water use

The blue cluster, which is indicative of "irrigation", prominently features the terms drought, irrigation, and water resources, with a total of 40 occurrences across four items. The research within this cluster examines the effects of different various irrigation practices on plant water use, plant water status, and agricultural product quality during periods of high temperature. Allen et al. (2010) suggest that extreme heat can negatively affect yields, but advancements in irrigation systems and techniques can mitigate the adverse effects of drought and enhance agricultural product quality.

4. Discussion

In recent years, there has been an upward trend in the quantity of literature focusing on plant water sources. However, concerning institutional cooperation and author cooperation analyses, taking China as an example, inter-institutional cooperation is mainly centered on institutions with deep links and proximity. Cooperation between authors is also mainly seen within the group. The cooperation between research groups is still relatively underdeveloped, and large-scale, vertical and international research cooperation has not generally emerged (Ignacio Querejeta J et al., 2006; Nilsen P, 1995). Because of this limitation, most of the research has been limited to local geographical units, such as a depression, a lake, a salt marsh, or a forest, and has not been extended to a large spatial scale (Fan B et al., 2022; Romic D et al., 2020; Savi T et al., 2018).

In constructing the WoS keyword time overlay network diagram (Fig. 6), the keywords filtered out were climatic change, Earth's critical zone, variability, groundwater recharge, ecohydrology, and diffusion conductance. Therefore, this study determined the topic of future research: plant water use at community and spatial scales, and the response of plant water sources to the critical zones of the Earth, the "two water world", and climate change.

Grime developed a maximum growth rate theory in terms of plant traits and the effects of competition, suggesting that competition is primarily a reflection of resource capture capacity and that the competitive winner will be the species with the greatest nutrient tissue growth rate (Davis MA et al., 2000). Fornara DA and Tilman D (2008) established the minimum resource demand theory from the perspective of population traits and competitive responses. Resource demand refers to a species' capacity to reduce a resource to a lower level of tolerance. He posits the species with the lowest resource requirements will be the winners. Researchers found that inter-specific competition leads to the differentiation of plant resource utilization, mainly in the form of complementary differentiated utilization of shallow and deep soil water by plants (Wu J et al., 2020; Wu JE et al., 2022; Zeng HH et al., 2022). The shallow soils of karst areas can impose strong resource constraints on plants and different

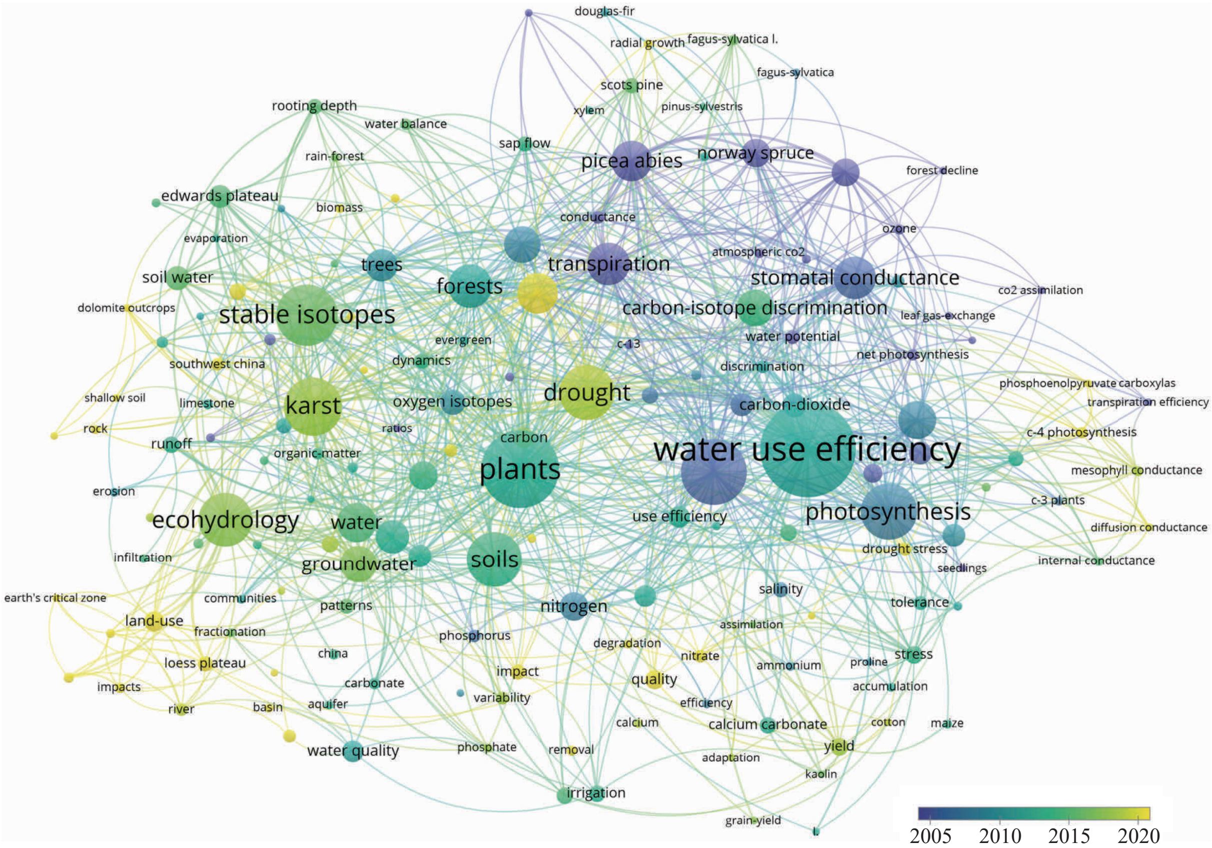

Fig. 6. Time overlay network map of WoS keywords.

resource acquisition strategies are adopted by different populations (Adams RE and West JB, 2022). However, the relationship between plant inter-species relationships, water use strategies and community structure is unclear in the unique geological context of karst (lack of water and soil , and underdeveloped root system). Observations suggest that global mean temperatures will increase by 0.3°C to 4.8°C by the end of the 21st century (Tollefson J, 2022). Forest productivity and adaptation to climate change are heavily dependent on how plants respond to water levels in warm and dry climates, and species diversity, ecosystem structure and forest composition will also be highly influenced by water availability (Malhi Y et al., 2009). Water availability and its impact on forest productivity is becoming an increasingly important issue. The Earth’s critical zone is an dynamic geoscientific system that generally ranges from the tree canopy to deep groundwater. Plant water use is an important component of the functionality of the Earth’s critical zone, suggesting that the latter can be understood via the former. In the Earth’s critical zone , how plant-water systems respond to climate change, such as warming and droughts, is still a matter of debate (Saurer M et al., 2014). Studies of plant water uptake are key to elucidating ecosystem function, and concern a critical component of the global water cycle (Isdell RE et al., 2020; Sternberg LDL and Swart PK, 1987). Studying plant water use in the context of global warming can provide useful information on the potential impacts on efficient water use, forest productivity and ecosystem function.

With the development of isotope analysis technology, studies on plant water utilization have been elaborated. Recent studies have shown that the water seeping into the soil after rain in some areas gives rise to ecohydrological separation (Brooks JR et al., 2010). The phenomenon of ecohydrological separation refers to the separation of bound water from free water after the infiltration of rainfall into soil. Bound water can be directly used by plants, while free water flows freely and supplements runoff; the two types belong to independent reservoirs, and are thus together known as the “two-water world” (Miguez-Macho G and Fan Y, 2021). However, the response of the hydrological system to climate change leaves considerable uncertainty regarding the evolution of forest land water availability in the future (Goldsmith GR et al., 2022; Liu R et al., 2018). Predicting the future groundwater trends and dynamic changes affecting plant water use, as well as plant health and function in different communities, also requires linking water availability to initial patterns of plant water use (Leonelli G et al., 2014; Ye H et al., 2018).

5. Conclusion

This study focuses on studying the development process and evolution of plant water use sources and efficiency in karst areas from 1984 to 2022 from three aspects including overall development trend, main research forces at different stages, and research themes. Over the span of roughly thirty years, significant achievements have been made, particularly in the fields of (1) advancements in plant water source investigation using stable isotope methodologies; (2) the identification of adaptations in plants living in karst regions to withstand challenging water conditions; (3) the clarification of the effects of climate change on plant water use efficiency and ecosystem functionality; and (4) the observation of diverse water acquisition and utilization strategies among different plant species in karst environments. However, there are still many studies that need pay more attention: (1) The functional response of water use in karst areas to the features of the Earth's critical zone; (2) the impact of climate change on plant water use in karst areas; and (3) the phenomenon of ecohydrological separation in karst areas. These studies will serve as a critical scientific foundation for informing ecological restoration efforts in karst areas and advancing regional sustainable development, representing important avenues for future research.

CRediT authorship contribution statement:

Conceptualization: De-gen Zhu and Hui Yang; methodology: De-gen Zhu, Jing Ning and Hui Yang; software: Jing Ning, Meng-xia Zhou, Jun-bing Pu and Hui Yang; resources; De-gen Zhu and Hui Yang; data curation: De-gen Zhu, Jing Ning and Hui Yang; original draft preparation: De-gen Zhu, Jing Ning and Hui Yang; review and editing: De-gen Zhu, Jing Ning, Hui Yang, Jun-bing Pu, Jian-hua Cao, Meng-xia Zhou, Mitja Prelovšek and Nataša Ravbar; visualization: De-gen Zhu, Jing Ning, and Hui Yang; supervision: Hui Yang, Jun-bing Pu, and Jian-hua Cao; project administration: Hui Yang and Jun-bing Pu; funding acquisition: Hui Yang, Jun-bing Pu and Jian-hua Cao. All authors have read and agreed to the published version of the manuscript.

Declaration of competing interest

The authors declare no conflicts of interest.

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References

Adame MF, Teutli C, Santini NS, Caamal JP, Zaldivar-Jimenez A, Hernandez R, Herrera-Silveira JA. 2014. Root biomass and production of mangroves surrounding a karstic oligotrophic coastal lagoon. Wetlands, 34, 479–488. doi: 10.1007/s13157-014-0514-5.

Adams RE, West JB. 2022. Functional groups mask inter- and intraspecific variation in water use strategies in a seasonally dry tropical forest. Front Water, 4, 13. doi: 10.3389/frwa.2022.950346.

Aleixandre-Tudo JL, Castello-Cogollos L, Aleixandre JL, Aleixandre-Benavent R. 2019. Emerging topics in scientific research on global water-use efficiency. Journal of Agricultural Science, 157, 480–492. doi: 10.1017/s0021859619000789.

Allen CD, Macalady AK, Chenchouni H, Bachelet D, McDowell N, Vennetier M, Kitzberger T, Rigling A, Breshears DD, Hogg EH, Gonzalez P, Fensham R, Zhang Z, Castro J, Demidova N, Lim JH, Allard G, Running SW, Semerci A, Cobb N. 2010. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. Forest Ecology and Management, 259, 660–684. doi: 10.1016/j.foreco.2009.09.001.

AlRyalat SAS, Malkawi LW, Momani SM. 2019. Comparing bibliometric analysis using PubMed, Scopus, and Web of Science Databases. Journal of Visualized Experiments, 152. doi: 10.3791/58494.

Andreo-Martinez P, Ortiz-Martinez VM, Garcia-Martinez N, de los Rios AP, Hernandez-Fernandez FJ, Quesada-Medina J. 2020. Production of biodiesel under supercritical conditions: State of the art and bibliometric analysis. Applied Energy, 264, 16. doi: 10.1016/j.apenergy.2020.114753.

Asbjornsen HD, Mora G, Helmers MJ. 2007. Variation in water uptake dynamics among contrasting agricultural and native plant communities in the Midwestern US. Agriculture Ecosystems & Environment, 121, 343–356. doi: 10.1016/j.agee.2006.11.009.

Badia G. 2018. Identifying "best bets" for searching in chemical engineering Comparing database content and performance for information retrieval. Journal of Documentation, 74, 80–98. doi: 10.1108/jd-09-2016-0112.

Benita F. 2021. Human mobility behavior in COVID-19, A systematic literature review and bibliometric analysis. Sustainable Cities and Society, 70, 16. doi: 10.1016/j.scs.2021.102916.

Borden W. 2006. New York: Columbia University Press. Psychoanalytic Social Work, 13, 67–76. doi: 10.1300/J032v13n02_05.

Brooks JR, Barnard HR, Coulombe R, McDonnell JJ. 2010 Ecohydrologic separation of water between trees and streams in a Mediterranean climate. Nature Geoscience, 3, 100–104. doi: 10.1038/ngeo722.

Brunel JP, Walker GR, Dighton JC, Monteny B. 1997. Use of stable isotopes of water to determine the origin of water used by the vegetation and to partition evapotranspiration. A case study from HAPEX-Sahel. Journal of Hydrology, 188, 466–481. 10.1016/S0022-1694(96.03188-5.

Brunel JP, Walker GR, Kennettsmith AK. 1995. Field validation of isotopic procedures for determining sources of water used by plants in a semiarid environment. Journal of Hydrology, 167, 351–368. 10.1016/0022-1694(94.02575-v.

Cao KF, Fu P, Chen YJ, Jiang YJ, Zhu SD. 2014. Implications of the Ecophysiological Adaptation of Plants on Tropical Karst Habitats for the Ecological Restoration of Desertified Rocky Lands in Southern China. Scientia Sinica Vitae, 44, 238–247 (in Chinese with English). doi: 10.1360/052013-234.

Caputo A, Pizzi S, Pellegrini MM, Dabic M. 2021. Digitalization and business models: Where are we going? A science map of the field. Journal of Business Research, 123, 489–501. doi: 10.1016/j.jbusres.2020.09.053.

Cavender-Bares J, Kitajima K, Bazzaz FA. 2004. Multiple trait associations in relation to habitat differentiation among 17 Floridian oak species. Ecological Monographs, 74, 635–662. doi: 10.1890/03-4007.

Chen KH, Zhang Y, Fu XL. 2019. International research collaboration: An emerging domain of innovation studies? Research Policy, 48, 149-168. doi: 10.1016/j.respol.2018.08.005.

Chen Z, Cuin TA, Zhou M, Twomey A, Naidu BP, Shiabala S. 2007. Compatible solute accumulation and stress-mitigating effects in barley genotypes contrasting in their salt tolerance. Journal of Experimental Botany, 58, 4245–4255. doi: 10.1093/jxb/erm284.

Dai Y, Zheng XJ, Tang LS, Li Y. 2015. Stable oxygen isotopes reveal distinct water use patterns of two Haloxylon species in the Gurbantonggut Desert. Plant and Soil, 389, 73–87. doi: 10.1007/s11104-014-2342-z.

Davis MA, Grime JP, Thompson K. 2000. Fluctuating resources in plant communities: a general theory of invasibility. Journal of Ecology, 88, 528–534. doi: 10.1046/j.1365-2745.2000.00473.x.

Dawson TE, Ehleringer JR. 1993. Isotopic enrichment of water in the woody tissues of plants - implications for plant water source, water-uptake, and other studies which use the stable isotopic composition of cellulose. Geochimica Et Cosmochimica Acta, 57, 3487–3492. doi: 10.1016/0016-7037(93)90554-A.

De Deurwaerder HPT, Visser MD, Detto M, Boeckx P, Meunier F, Kuehnhammer K, Magh R-K, Marshall JD, Wang LX, Zhao LJ, Verbeeck H. 2020. Causes and consequences of pronounced variation in the isotope composition of plant xylem water. Biogeosciences, 17, 4853–4870. doi: 10.5194/bg-17-4853-2020.

Deng Y, Ke J, Wu S, Jiang GH, Jiang ZC, Zhu AJ. 2020. Responses of plant water uptake to groundwater depth in limestone outcrops. Journal of Hydrology, 590. doi: 10.1016/j.jhydrol.2020.125377.

Ding Y, Nie YP, Schwinning S, Chen HS, Yang J, Zhang W, Wang K. 2018. A novel approach for estimating groundwater use by plants in rock-dominated habitats. Journal of Hydrology, 565, 760–769. doi: 10.1016/j.jhydrol.2018.08.033.

Ding YL, Nie YP, Chen HS, Wang KL, Querejeta JI. 2021. Water uptake depth is coordinated with leaf water potential, water-use efficiency and drought vulnerability in karst vegetation. New Phytologist, 229, 1339–1353. doi: 10.1111/nph.16971.

Donthu N, Kumar S, Pattnaik D. 2020. Forty-five years of Journal of Business Research: A bibliometric analysis. Journal of business research, 109, 1–14. doi: 10.1016/j.jbusres.2019.10.039.

Du H, Fu W, Song TQ, Zeng FP, Wang KL, Chen HS, Liu MX. 2023. Water-use efficiency in a humid karstic forest in southwestern China: Interactive responses to the environmental drivers. Journal of Hydrology, 617, 12. doi: 10.1016/j.jhydrol.2022.128973.

Ehleringer JR, Dawson TE. 1992. Water-uptake by plants - perspectives from stable isotope composition. Plant Cell and Environment, 15, 1073–1082. doi: 10.1111/j.1365-3040.1992.tb01657.x.

Fan B, Liu ZQ, Xiong KN, Li Y, Li KP, Yu X. 2022. Influence of Environmental Factors on the Sap Flow Activity of the Golden Pear in the Growth Period of Karst Area in Southern China. Water, 14. doi: 10.3390/w14111707.

Farquhar GD, Oleary MH, Berry JA. 1982. On the Relationship between Carbon Isotope Discrimination and the Inter-Cellular Carbon-dioxide Concentration in Leaves. Australian Journal of Plant Physiology, 9, 121–137. doi: 10.1071/pp9820121.

Feng ZZ, Qing HY, Kun LIX, Ling MO, Fei JJ, Yeming YOU. 2008. Features of Quercus glauca sap flow and its relationship to environmental factors in karst terrain. Carsologica Sinica, 27, 228–234 (in Chinese with English). doi: 10.3969/j.issn.1001-4810.2008.03.006.

Flexas J, Diaz-Espejo A, Conesa MA, Coopman RE, Douthe C, Gago J, Galle A, Galmes J, Medrano H, Ribas-Carbo M, Tomas M, Niinemets U. 2016. Mesophyll conductance to CO2 and Rubisco as targets for improving intrinsic water use efficiency in C-3 plants. Plant Cell and Environment, 39, 965–982. doi: 10.1111/pce.12622.

Fornara DA, Tilman D. 2008. Plant functional composition influences rates of soil carbon and nitrogen accumulation. Journal of Ecology, 96, 314–322. doi: 10.1111/j.1365-2745.2007.01345.x.

Freersmith PH, Dobson MC. 1989. Ozone flux to picea-sitchensis (bong) carr and picea-abies (l) karst during short episodes and the effects of these on transpiration and photosynthesis. Environmental Pollution, 59, 161–176. doi: 10.1016/0269-7491(89)90103-6.

Gaede J, Rowlands IH. 2018. Visualizing social acceptance research A bibliometric review of the social acceptance literature for energy technology and fuels. Energy Research & Social Science, 40, 142–158. doi: 10.1016/j.erss.2017.12.006.

Gaviria-Marin M, Merigo JM, Baier-Fuentes H. 2019. Knowledge management: A global examination based on bibliometric analysis. Technological Forecasting and Social Change, 140, 194–220. doi: 10.1016/j.techfore.2018.07.006.

Gaviria-Marin M, Merigo JM, Popa S. 2018. Twenty years of the Journal of Knowledge Management: A bibliometric analysis. Journal of Knowledge Management, 22, 1655–1687. doi: 10.1108/jkm-10-2017-0497.

Geekiyanage N, Goodale UM, Cao K, Kitajima K. 2019. Plant ecology of tropical and subtropical karst ecosystems. Biotropica, 51, 626–640. doi: 10.1111/btp.12696.

Goldsmith GR, Allen ST, Braun S, Siegwolf RTW, Kirchner JW. 2022. Climatic Influences on Summer Use of Winter Precipitation by Trees. Geophysical Research Letters, 49. doi: 10.1029/2022gl098323.

Guan JC, Liu N. 2016. Exploitative and exploratory innovations in knowledge network and collaboration network: A patent analysis in the technological field of nano-energy. Research policy, 45, 97–112. doi: 10.1016/j.respol.2015.08.002.

Hansen JK, Saxe H, Raebild A, Nielsen CN, Simonsen JP, Larsen JB, Wellendorf H. 1998. Decline and physiological response to foliar-deposited salt in Norway spruce genotypes: a comparative analysis. Canadian Journal of Forest Research, 28, 1879–1889. doi: 10.1139/cjfr-28-12-1879.

Hota PK, Subramanian B, Narayanamurthy G. 2020. Mapping the Intellectual Structure of Social Entrepreneurship Research: A Citation/Co-citation Analysis. Journal of Business Ethics, 166, 89–114. doi: 10.1007/s10551-019-04129-4.

Hou JH, Yang XC, Chen CM. 2018. Emerging trends and new developments in information science: a document co-citation analysis. 2009–2016. Scientometrics, 115, 869–892. doi: 10.1007/s11192-018-2695-9

Huang YQ, Zhang ZF, He C-x, Zhao p, Yuan W-Y, Jiao J-f, You Y-m. 2009. Seasonal variation of Cyclobalanopsis glauca whole-tree transpiration in karst region. Chinese Journal of Applied Ecology, 20, 256–264 (in Chinese with English).

Hylander K, Dynesius M. 2006. Causes of the large variation in bryophyte species richness and composition among boreal streamside forests. Journal of Vegetation Science, 17, 333–346. doi: 10.1111/j.1654-1103.2006.tb02453.x.

Ignacio Querejeta J, Estrada-Medina H, Allen MF, Jimenez-Osornio JJ, Ruenes R. 2006. Utilization of bedrock water by Brosimum alicastrum trees growing on shallow soil atop limestone in a dry tropical climate. Plant and Soil, 287, 187–197. doi: 10.1007/s11104-006-9065-8.

Isaac ME, Anglaaere LCN, Borden K, Adu-Bredu S. 2014. Intraspecific root plasticity in agroforestry systems across edaphic conditions. Agriculture Ecosystems & Environment, 185, 16–23. doi: 10.1016/j.agee.2013.12.004.

Isdell RE, Bilkovic DM, Hershner C. 2020. Large Projected Population Loss of a Salt Marsh Bivalve (Geukensia demissa) from Sea Level Rise. Wetlands, 40, 1729–1738. doi: 10.1007/s13157-020-01384-4.

Jiang NN, Wang ZC, Ma XY, Liu WN, Chen HS, Nie YP. 2022. Isotopic deviations of water extracted from carbonate soil by cryogenic vacuum extraction: implication for root water uptake analysis. Plant and Soil, 475, 79–89. doi: 10.1007/s11104-022-05455-9.

Jiang ZC, Lian YQ, Qin XQ. 2014. Rocky desertification in Southwest China: Impacts, causes, and restoration. Earth-Science Reviews, 132,

1–12. doi: 10.1016/j.earscirev.2014.01.005.
Kessler MM. 1963. Bibliographic coupling between scientific papers. American Documentation, 14, 10–25. doi: 10.1002/asi.5090140103.
Klavans R, Boyack KW. 2017. Which Type of Citation Analysis Generates the Most Accurate Taxonomy of Scientific and Technical Knowledge? Journal of the Association for Information Science and Technology, 68, 984–998. doi: 10.1002/asi.23734.
Leite PAM, Wilcox BP, McInnes KJ. 2020. Woody plant encroachment enhances soil infiltrability of a semiarid karst savanna. Environmental Research Communications, 2. doi: 10.1088/2515-7620/abc92f.
Leonelli G, Pelfini M, Panseri S, Battipaglia G, Vezzola L, Giorgi A. 2014. Tree-ring stable isotopes, growth disturbances and needles volatile organic compounds as environmental stress indicators at the debris covered miage glacier (monte bianco massif, european alps). Geografia Fisica e Dinamica Quaternaria, 37, 101–111. doi: 10.4461/gfdq.2014.37.09.
Li PJ, Liu WJ, Wang PY, Li JT. 2008. Plant water use strategies in a limestone tropical seasonal moist rainforest in Xishuangbanna, SW China. Acta Botanica Yunnanica, 30, 496–504 (in Chinese with English).
Li SG, Romero Saltos H, Tsujimura M, Sugimoto A, Sasaki L, Davaa G, Oyunbaatar D. 2007. Plant water sources in the cold semiarid ecosystem of the upper Kherlen River catchment in Mongolia: A stable isotope approach. Journal of Hydrology, 333, 109–117. doi: 10.1016/j.jhydrol.2006.07.020.
Li ZK, Li XY, Zhou S, Yang XF, Fu YS, Miao CY, Wang S, Zhang GH, Wu XC, Yang C, Deng Y. 2022. A comprehensive review on coupled processes and mechanisms of soil-vegetation-hydrology, and recent research advances. Science China Earth Sciences, 65, 2083–2114. doi: 10.1007/s11430-021-9990-5.
Liu CC, Liu YG, Guo K, Li GQ, Zheng YR, Yu LF, Yang R. 2011. Comparative ecophysiological responses to drought of two shrub and four tree species from karst habitats of southwestern China. Trees, 25, 537–549. doi: 10.1007/s00468-010-0533-7.
Liu CN, Huang Y, Wu F, Liu WJ, Ning YQ, Huang ZR, Tang SQ, Liang Y. 2021. Plant adaptability in karst regions. Journal of Plant Research, 134, 889–906. doi: 10.1007/s10265-021-01330-3.
Liu J, Shen L, Wang Z, Duan S, Wu W, Peng X, Wu C, Jiang Y. 2019. Response of plants water uptake patterns to tunnels excavation based on stable isotopes in a karst trough valley. Journal of Hydrology, 571, 485–493. doi: 10.1016/j.jhydrol.2019.01.073.
Liu R, Wang Y, Li C, Ma J, Li Y. 2018. Partitioning water source and sinking process of a groundwater-dependent desert plant community. Plant and Soil, 430, 73–85. doi: 10.1007/s11104-018-3714-6.
Liu W, Li P, Duan W, Liu W. 2014. Dry-season water utilization by trees growing on thin karst soils in a seasonal tropical rainforest of Xishuangbanna, Southwest China. Ecohydrology, 7, 927–935. doi: 10.1002/eco.1419.
Malhi Y, Aragao LEOC, Galbraith D, Huntingford C, Fisher R, Zelazowski P, Sitch S, McSweeney C, Meir P. 2009. Exploring the likelihood and mechanism of a climate-change-induced dieback of the Amazon rainforest. Proceedings of the National Academy of Sciences of the United States of America, 106, 20610–20615. doi: 10.1073/pnas.0804619106.
McDowell NG, Grossiord C, Adams HD, Pinzon-Navarro S, Mackay DS, Breshears DD, Allen CD, Borrego I, Dickman LT, Collins A, Gaylord M, McBranch N, Pockman WT, Vilagrosa A, Aukema B, Goodsman D, Xu C. 2019. Mechanisms of a coniferous woodland persistence under drought and heat. Environmental Research Letters, 14, 045014. doi: 10.1088/1748-9326/ab0921.
Medina-Calderon JH, Mancera-Pineda JE, Castaneda-Moya E, Rivera-Monroy VH. 2021. Hydroperiod and Salinity Interactions Control Mangrove Root Dynamics in a Karstic Oceanic Island in the Caribbean Sea (San Andres, Colombia). Frontiers in Marine Science, 7, 19. doi: 10.3389/fmars.2020.598132.
Merigo JM, Pedrycz W, Weber R, de la Sotta C. 2018. Fifty years of Information Sciences: A bibliometric overview. Information Sciences, 432, 245–268. doi: 10.1016/j.ins.2017.11.054.
Miguez-Macho G, Fan Y. 2021. Spatiotemporal origin of soil water taken up by vegetation. Nature, 598, 624–628. doi: 10.1038/s41586-021-03958-6.
Moberly JG, Bernards MT, Waynant KV. 2018. Key features and updates for origin 2018. Journal of cheminformatics, 10, 2. doi: 10.1186/s13321-018-0259-x.
Moore JW, Semmens BX. 2008. Incorporating uncertainty and prior information into stable isotope mixing models. Ecology Letters, 11, 470–480. doi: 10.1111/j.1461-0248.2008.01163.x.
Muangsong C, Pumijumnong N, Cai B, Buajan S, Lei G, Wang F, Li M, Payomrat P. 2020. Effect of changes in precipitation amounts and moisture sources on interand intra-annual stable oxygen isotope ratios (delta O-18. of teak trees from northern Thailand. Agricultural and Forest Meteorology, 281. doi: 10.1016/j.agrformet.2019.107820.
Nardini A, Petruzzellis F, Marusig D, Tomasella M, Natale S, Altobelli A, Calligaris C, Floriddia G, Cucchi F, Forte E, Zini L. 2021. Water “on the rocks” : A summer drink for thirsty trees? New Phytologist, 229, 199–212. doi: 10.1111/nph.16859.
Nicolaisen J, Hjorland B. 2007. Practical potentials of Bradford’s law: a critical examination of the received view. Journal of documentation, 63, 359–377. doi: 10.1108/00220410710743298.
Nie YP, Chen HS, Wang KL. 2010. Methods for determining plant water source in thin soil region: A review. Chinese Journal of Applied Ecology, 21, 2427–2433. doi: 10.13287/j.1001-9332.2010.0320.
Nie YP, Chen HS, Wang KL. 2011. Seasonal variation of water sources for plants growing on continuous rock outcrops in limestone area of Southwest China. Chinese Journal of Plant Ecology, 35, 1029–1037. doi: 10.3724/sp.J.1258.2011.01029.
Nie YP, Chen HS, Wang KL, Ding YL. 2014. Rooting characteristics of two widely distributed woody plant species growing in different karst habitats of southwest China. Plant Ecology, 215, 1099–1109. doi: 10.1007/s11258-014-0369-0.
Nie YP, Chen HS, Wang KL, Susanne S. 2017. Challenges and probable solutions for using stable isotope techniques to identify plant water sources in karst regions: A review. Chinese Journal of Applied Ecology, 28, 2361–2368. doi: 10.13287/j.1001-9332.201707.017.
Nie YP, Chen HS, Wang KL, Yang J. 2012. Water source utilization by woody plants growing on dolomite outcrops and nearby soils during dry seasons in karst region of Southwest China. Journal of Hydrology, 420, 264–274. doi: 10.1016/j.jhydrol.2011.12.011.
Nilsen P. 1995. Effect of nitrogen on drought strain and nutrient uptake in Norway spruce Picea abies (L.) Karst.) trees. Plant and Soil, 172, 73–85. doi: 10.1007/bf00020861.
Pan XL, Yan EJ, Cui M, Hua WN. 2018. Examining the usage, citation, and diffusion patterns of bibliometric mapping software: A comparative study of three tools. Journal of informetrics, 12, 481–493. doi: 10.1016/j.joi.2018.03.005.
Parnell AC, Inger R, Bearhop S, Jackson AL. 2010. Source Partitioning Using Stable Isotopes: Coping with Too Much Variation. Plos One, 5. doi: 10.1371/journal.pone.0009672.
Peng XD, Dai QH, Ding GJ, Shi DM, Li CL. 2019. The role of soil water retention functions of near-surface fissures with different vegetation types in a rocky desertification area. Plant and Soil, 441, 587–599. doi: 10.1007/s11104-019-04147-1.
Perez-Garcia EA, Meave JA. 2004. Heterogeneity of xerophytic vegetation of limestone outcrops in a tropical deciduous forest region in southern Mexico. Plant Ecology, 175, 147–163. doi: 10.1007/s11258-005-4841-8.
Perez-Garcia EA, Sevilha AC, Meave JA, Scariot A. 2009. Floristic

differentiation in limestone outcrops of southern mexico and central brazil: A beta diversity approach. Boletín de la Sociedad Botánica de México, 84, 45–58.

Petrucco L, Nardini A, von Arx G, Saurer M, Cherubini P. 2017. Isotope signals and anatomical features in tree rings suggest a role for hydraulic strategies in diffuse drought-induced die-back of Pinus nigra. Tree Physiology, 37, 523–535. doi: 10.1093/treephys/tpx031.

Phillips DL, Gregg JW. 2003. Source partitioning using stable isotopes: coping with too many sources. Oecologia, 136, 261–269. doi: 10.1007/s00442-003-1218-3.

Qin XJ, Xing DK, Wu YY, Wang WX, Li MQ, Solangi K. 2022. Diurnal Variation in Transport and Use of Intracellular Leaf Water and Related Photosynthesis in Three Karst Plants. Agronomy, 12, 13. doi: 10.3390/agronomy12112758.

Querejeta JI, Estrada-Medina H, Allen MF, Jimenez-Osornio JJ. 2007. Water source partitioning among trees growing on shallow karst soils in a seasonally dry tropical climate. Oecologia, 152, 26–36. doi: 10.1007/s00442-006-0629-3.

Rabbani MRA, Bashar A, Atif M, Jreisat A, Zulfikar Z, Naseem Y, Ieee. 2021. Text mining and visual analytics in research: Exploring the innovative tools. In 2021 international conference on decision aid sciences and application (DASA), 1087–1091.

Rambal S. 1984. Water-Balance and Pattern of Root Water-Uptake by A Quercus-Coccifera L Evergreen Scrub. Oecologia, 62, 18–25. doi: 10.1007/bf00377367.

Romic D, Kontic JK, Preiner D, Romic M, Lazarevic B, Maletic E, Ondrasek G, Andabaka Z, Begic HB, Kovacic MB, Filipovic L, Husnjak S, Markovic Z, Stupic D, Tomaz I, Zovko M. 2020. Performance of grapevine grown on reclaimed Mediterranean karst land: Appearance and duration of high temperature events and effects of irrigation. Agricultural Water Management, 236. doi: 10.1016/j.agwat.2020.106166.

Rong L, Wang SJ, Yu GS, Deng XQ, Ran JC. 2012. Stable Isotope Analysis of Water Sources of Four Woody Species in the Libo Karst Forest. Scientia Silvae Sinicae, 48, 14–22 (in Chinese with English).

Rose KL, Graham RC, Parker DR. 2003. Water source utilization by Pinus jeffreyi and Arctostaphylos patula on thin soils over bedrock. Oecologia, 134, 46–54. doi: 10.1007/s00442-002-1084-4.

Saurer M, Spahni R, Frank DC, Joos F, Leuenberger M, Loader NJ, McCarroll D, Gagen M, Poulter B, Siegwolf RTW, Andreu-Hayles L, Boettger T, Dorado Linan I, Fairchild IJ, Friedrich M, Gutierrez E, Haupt M, Hilasvuori E, Heinrich I, Helle G, Grudd H, Jalkanen R, Levanic T, Linderholm HW, Robertson I, Sonninen E, Treydte K, Waterhouse JS, Woodley EJ, Wynn PM, Young GHF. 2014. Spatial variability and temporal trends in water-use efficiency of European forests. Global Change Biology, 20, 3700–3712. doi: 10.1111/gcb.12717.

Savi T, Petruzzellis F, Martellos S, Stenni B, Dal Borgo A, Zini L, Lisjak K, Nardini A. 2018. Vineyard water relations in a karstic area: deep roots and irrigation management. Agriculture Ecosystems & Environment, 263, 53–59. doi: 10.1016/j.agee.2018.05.009.

Schwinning S. 2008. The water relations of two evergreen tree species in a karst savanna. Oecologia, 158, 373–383. doi: 10.1007/s00442-008-1147-2.

Shi PT, Zhang TS, Liu ZQ, Lan JC, Fan X. 2019. A Vulnerable Environment Study in Karst Regions between 1991 and 2017, A Bibliometric Analysis. Applied Sciences, 9, 5339. doi: 10.3390/app9245339.

Shi XY, Bai S, Chen W. 2022. Remote sensing of water use efficiency in Southwest China’s karst area. Environmental Science and Pollution Research, 29, 71166–71178. doi: 10.1007/s11356-022-20907-6.

Shiau WL, Dwivedi YK, Yang HS. 2017. Co-citation and cluster analyses of extant literature on social networks. International Journal of Information Management, 37, 390–399. doi: 10.1016/j.ijinfomgt.2017.04.007.

Siddiqui MH, Al-Whaibi MH, Faisal M, Al Sahli AA. 2014. Nano-silicon dioxide mitigates the adverse effects of salt stress on cucurbita pepol. Environmental toxicology and chemistry, 33, 2429–2437. doi: 10.1002/etc.2697.

Sohel MSI, Salam MA, Herbohn J. 2019. An Assessment of Woody Plant Water Source Studies from across the Globe: What Do We Know after 30 Years of Research and Where Do We Go from Here? Hydrology, 6. doi: 10.3390/hydrology6020040.

Song LN, Zhu JJ, Li MC, Zhang JX, Lv LY. 2016. Sources of water used by Pinus sylvestris var. mongolica trees based on stable isotope measurements in a semiarid sandy region of Northeast China. Agricultural Water Management, 164, 281–290. doi: 10.1016/j.agwat.2015.10.018.

Sternberg LDL, Swart PK. 1987. Utilization of fresh-water and ocean water by coastal plants of southern florida. Ecology, 68, 1898–1905. doi: 10.2307/1939881.

Stubbington R, Milner VS, Wood PJ. 2019. Flow intermittence in river networks: Understanding the ecohydrological diversity of aquatic-terrestrial ecosystems Editorial to the special issue “The ecohydrology of temporary streams”. Fundamental and Applied Limnology, 193, 1–19. doi: 10.1127/fal/2019/1265.

Sudhier KG. 2010. Application of Bradford's Law of Scattering to the Physics Literature: A Study of Doctoral Theses Citations at the Indian Institute of Science. DESIDOC Journal of Library & Information Technology, 30, 3–14. doi: 10.14429/djlit.30.3.

Tardieu F, Simonneau T. 1998. Variability among species of stomatal control under fluctuating soil water status and evaporative demand: modelling isohydric and anisohydric behaviours. Journal of Experimental Botany, 49, 419–432. doi: 10.1093/jexbot/49.suppl_1.419.

Teobaldelli M, Mencuccini M, Piussi P. 2004. Water table salinity, rainfall and water use by umbrella pine trees (Pinas pinea L.). Plant Ecology, 171, 23–33. doi: 10.1023/B:VEGE.0000029384.40192.cc.

Tollefson J. 2022. Extreme steps needed to avert climate disaster. Nature, 604, 413–414. doi: 10.1038/d41586-022-00951-5.

Trejo-Torres JC, Ackerman JD. 2002. Composition patterns of Caribbean limestone forests: Are parsimony, classification, and ordination analyses congruent? Biotropica, 34, 502–515. doi: 10.1646/0006-3606(2002)034[0502:CPOCLF]2.0.CO;2.

Trujillo CM, Long TM. 2018. Document co-citation analysis to enhance transdisciplinary research. Science advances, 4, 9. doi: 10.1126/sciadv.1701130.

Urli M, Porte AJ, Cochard H, Guengant Y, Burlett R, Delzon S. 2013. Xylem embolism threshold for catastrophic hydraulic failure in angiosperm trees. Tree Physiology, 33, 672–683. doi: 10.1093/treephys/tpt030.

Van de Water PK, Leavitt SW, Betancourt JL. 2002. Leaf delta C-13 variability with elevation, slope aspect, and precipitation in the southwest United States. Oecologia, 132, 332–343. doi: 10.1007/s00442-002-0973-x.

Vanhoorn JW, Katerji N, Hamdy A, Mastrorilli M. 1993. Effect of saline water on soil-salinity and on water-stress, growth, and yield of wheat and potatoes. Agricultural Water Management, 23, 247–265. 10.1016/0378-3774(93)90032-6.

Venable GT, Shepherd BA, Loftis CM, McClatchy SG, Roberts ML, Fillinger ME, Tansey JB, Klimo P. 2016. Bradford's law: identification of the core journals for neurosurgery and its subspecialties. Journal of neurosurgery, 124, 569–579. doi: 10.3171/2015.3.Jns15149.

Wang GX, Xia J, Li XY, Yang D, Hu ZY, Sun SQ, Sun XY. 2021. Critical advances in understanding ecohydrological processes of terrestrial vegetation: From leaf to watershed scale. Chinese Science Bulletin-Chinese, 66, 3667–3683. doi: 10.1360/tb-2020-1339.

Wang J, Turner NC, Feng H, Dyck M, He H. 2022. Heat tracer-based sap flow methods for tree transpiration measurements: A mini review and bibliometric analysis. Journal of experimental botany. doi: 10.1093/jxb/erac424.

Wang M, Ding Z, Wu CY, Song LS, Ma MG, Yu PJ, Lu BQ, Tang XG. 2021. Divergent responses of ecosystem water-use efficiency to extreme seasonal droughts in Southwest China. Science of the Total Environment, 760. doi: 10.1016/j.scitotenv.2020.143427.

Wang Q, Waltman L. 2016. Large-scale analysis of the accuracy of the journal classification systems of Web of Science and Scopus. Journal of informetrics, 10, 347–364. doi: 10.1016/j.joi.2016.02.003.

Wang R, Zhang XP, Dai JJ, Luo ZD, He XG, Guan HD. 2020. Study on Water Uptake Layers of the Cinnamomum camphora and Comparison of the Methods of Water Uptake in Subtropical Humid Region. Journal of Soil and Water Conservation, 34, 267–276 (in Chinese with English). doi: 10.13870/j.cnki.stbcxb.2020.05.037.

Wang XX, Li Y, Zhang B, Jia JQ, Feng MC, Zhang MJ, Yang WD. 2020. Effects of Drought Stress and Rehydration on Root Growth and Physiological Characteristics of Oats. Acta Agrestia Sinica, 28, 1588–1596 (in Chinese with English).

Wang ZQ, Newton M, Tappeiner JC. 1995. Competitive relations between douglas-fir and pacific madrone on shallow soils in a mediterranean climate. Forest Science, 41, 744–757. doi: 10.1093/forestscience/41.4.744.

Wu J, Zeng HH, Zhao F, Chen CF, Liu WJ, Yang B, Zhang WJ. 2020. Recognizing the role of plant species composition in the modification of soil nutrients and water in rubber agroforestry systems. Science of the Total Environment, 723, 11. doi: 10.1016/j.scitotenv.2020.138042.

Wu JE, Zeng HH, Zhao F, Chen CF, Singh AK, Jiang XJ, Yang B, Liu WJ. 2022. Plant hydrological niches become narrow but stable as the complexity of interspecific competition increases. Agricultural and Forest Meteorology, 320, 14. doi: 10.1016/j.agrformet.2022.108953.

Xia AT, Wu YY. 2022. Differential Responses of Nitrate/Ammonium Use to Bicarbonate Supply in Two Brassicaceae Species under Simulated Karst Habitat. Agronomy, 12, 17. doi: 10.3390/agronomy12092080.

Ye H, Roorkiwal M, Valliyodan B, Zhou LJ, Chen PY, Varshney RK, Nguyen HT. 2018. Genetic diversity of root system architecture in response to drought stress in grain legumes. Journal of Experimental Botany, 69, 3267–3277. doi: 10.1093/jxb/ery082.

Yu DJ, Kou G, Xu ZS, Shi SS. 2021. Analysis of Collaboration Evolution in AHP Research: 1982–2018. International Journal of Information Technology & Decision Making, 20, 7–36. doi: 10.1142/s0219622020500406.

Zeng HH, Wu JE, Singh AK, Zhu XA, Zhang WJ, Hahn P, Holscher D, Liu WJ. 2022. Effect of intercrops complexity on water uptake patterns in rubber plantations: Evidence from stable isotopes (C-H-O) analysis. Agriculture Ecosystems & Environment, 338, 13. doi: 10.1016/j.agee.2022.108086.

Zeng XM, Xu XL, Yi RZ, Zhong FX, Zhang YH. 2021. Sap flow and plant water sources for typical vegetation in a subtropical humid karst area of southwest China. Hydrological Processes, 35. doi: 10.1002/hyp.14090.

Zeng Y, Zhao CY, Kundzewicz ZW, Lv GH. 2020. Distribution pattern of Tugai forests species diversity and their relationship to environmental factors in an arid area of China. Plos One, 15, 17. doi: 10.1371/journal.pone.0232907.

Zhao YL, Jiang YG, Zhou ZF, Yang ZM. 2021. Global trends in karst-related studies from 1990 to 2016, A bibliometric analysis. Alexandria Engineering Journal, 60, 2551–2562. doi: 10.1016/j.aej.2020.12.052.

Zheng CC, Ma HM, Gao YZ, Sun H, Yang HJ, Baskin CC. 2019. The clonal grass Leymus chinensis overcomes salt stress by over-compensatory growth of individual ramets. Crop and Pasture Science, 70, 1004–1014. doi: 10.1071/cp18530.

Zhu J, Hua WJ. 2017. Visualizing the knowledge domain of sustainable development research between 1987 and 2015, a bibliometric analysis. Scientometrics, 110, 893–914. doi: 10.1007/s11192-016-2187-8.

Zhu JW, Liu WS. 2020. A tale of two databases: the use of Web of Science and Scopus in academic papers. Scientometrics, 123, 321–335. doi: 10.1007/s11192-020-03387-8.

Zou X, Yue WL, Hai Le V. 2018. Visualization and analysis of mapping knowledge domain of road safety studies. Accident Analysis and Prevention, 118, 131–145. doi: 10.1016/j.aap.2018.06.010.

Zwieniecki MA, Newton M. 1995. Roots growing in rock fissures - their morphological adaptation. Plant and Soil, 172, 181–187. doi: 10.1007/BF00011320.