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Comparing Chinese and international studies of riparian forests: A bibliometric survey (1981–2014)

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ABSTRACT

A bibliometric analysis based on the Web of Science Core Collection (WoSCC) and the China National Knowledge Infrastructure (CNKI) databases was conducted to identify the differences between Chinese and international studies of riparian forests as well as their future research directions. The analysis included publication output, geographical and institutional patterns, research priorities and hot topics. International riparian forests research has experienced notable growth over the past three decades, while Chinese research did not expand rapidly until 2000. The United States housed 16 of the 20 most active institutions in riparian forests research, while the Chinese Academy of Sciences ranked 20th among the most active institutions. The priorities of international research included focuses on multiple scales and ecological processes in riparian forests. In comparison, Chinese research was strongly regional in scope and prioritized large-scale inland river basins and desert riparian forests. For both international and Chinese research, the hot topics were dynamic changes in riparian forests and the human impact on riparian forests ecosystems, which may become priority areas for future research. However, compared to international studies, fewer Chinese studies have tried to predict future scenarios ofriparian forests. Therefore, this subject may be a direction for future Chinese riparian forests research.

Contents

1. Introduction

Riparian zones are an important ecotone for material, energy, and information exchange between terrestrial and aquatic ecosystems [1]. Riparian forests, the riparian zone made up of forest communities, are

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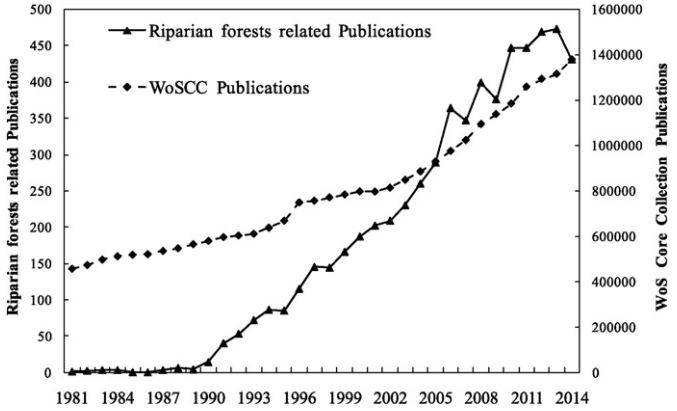

Fig. 1. Growth in the total number of WoSCC publications versus international riparian forests related publications.

mainly distributed on each side of the watercourse [2,3]. The eco-hydrological processes in riparian forests organically link the atmosphere, vegetation, soil, and hydrology and these areas constitute part of the Earth's Critical Zone [4–6]. Riparian forests not only serve as critical habitats for species survival but also act as biological corridors and contaminant filters [2,3]. Riparian forest ecosystems also provide a variety of ecosystem services for humans, including water conservation and purification, sand stabilization, energy supplies, and recreation. Therefore, riparian forest ecosystems have great ecological and economic value and are important for societies and human welfare [7,8]. Since the onset of the Anthropocene epoch, the impact of human activities on riparian forests has become increasingly prominent, leading to ecosystem degradation and even community succession [9,10]. These effects have seriously undermined the ecosystem services provided by riparian forests, negatively affecting human welfare and the sustainable development of these ecosystems [11,12]. To better protect riparian forest ecosystems and achieve sustainable development, extensive studies have been conducted on riparian forests, and substantial results have been obtained [13–15]. Many of these studies of riparian forests have focused on Chinese inland rivers, where a large amount of energy and resources have been invested to address water resource management and sustainable development issues in inland river basins. One of these major research programs is the Heihe River Program, which was implemented in 2010 and prompted further achievements in Chinese riparian forests research [16]. As riparian forests research is important for the sustainable management of ecosystems in China, it is essential to address the priorities and hot topics in riparian forests research and compare international and Chinese research to provide a reference for future Chinese riparian forests research.

Bibliometrics, which is the application of mathematical and statistical methods to books and other communication media, was first introduced in 1969 [17]. In recent years, it has been widely used to assess research trends in multiple disciplines and countries by investigating publication characteristics, such as the productivity of institutions and countries, major journals, and research trends [18,19].

In this study, a bibliometric approach was used to investigate trends in riparian forests research from 1981–2014. To systematically review the current state of riparian forests research and clarify the difference between international and Chinese studies, we qualitatively analysed publications that reported international and Chinese riparian forests research. Furthermore, we summarised and discussed the priorities and hot topics in international and Chinese studies to characterize the trends in riparian forests research and identify key topics that should be emphasized in future Chinese studies of riparian forests.

2. Data sources and methods

Data for international riparian forests research was collected from the online version of the Web of Science Core Collection, which consists of 7 main databases. These databases include the Science Citation Index Expanded database and the Conference Proceedings Citation Index-Science database, which cover the world's leading journals of science and technology [20]. We searched for articles from 1981 to 2014 with the keywords “riparian forest*” or “riverine forest*” in the title, abstract, or keywords, and used the results to compile a bibliography of articles related to international riparian forests research. Articles originating from England, Scotland, Northern Ireland, and Wales were reclassified as being from the United Kingdom (UK). Articles from Hong Kong were grouped with articles from China. For each publication, the contributions of different institutes and countries were estimated based on the affiliation of at least one author. The compiled articles were assessed based on the following aspects: the characteristics of publication output, the publication distribution of each country, the institution, and author keywords for priorities and hot topics.

We included articles published in both Chinese journals and articles published in international journals by Chinese authors to analyse the Chinese riparian forests research. The international riparian forests

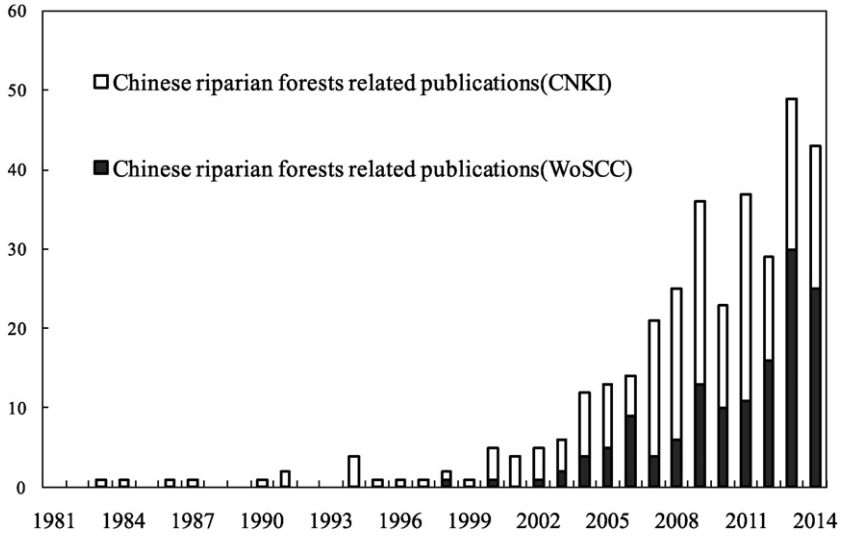

Fig. 2. The growth of Chinese riparian forests related publications based on the CNKI and WoSCC databases.

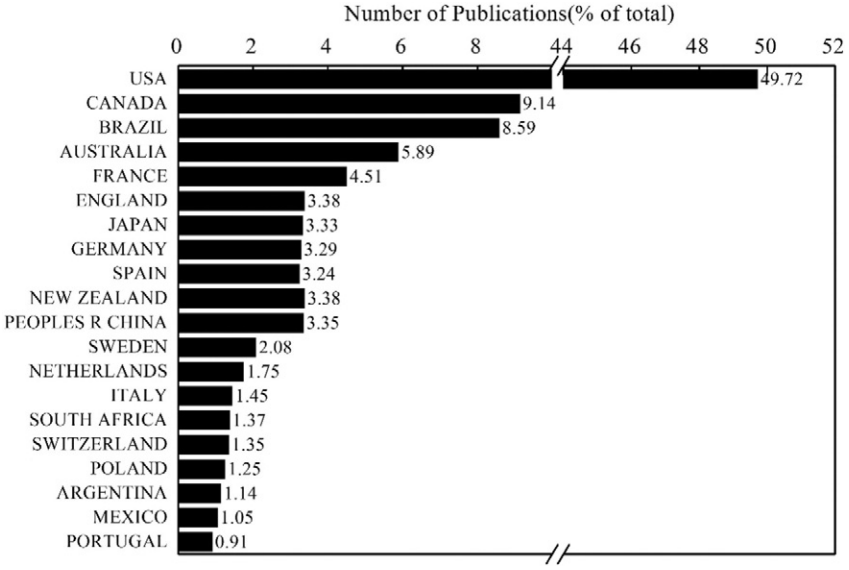

Fig. 3. Geographical distribution of riparian forests related publications (only the top 20 countries are shown).

articles published by Chinese researchers were identified by restricting the country/territory field of the international riparian forests research data to "Peoples R China" in WoSCC. Chinese articles were collected from the China National Knowledge Infrastructure (CNKI) database, which contains almost all of the Chinese journals of science and technology. We searched for articles from 1981 to 2014 that had the Chinese keywords "riparian forest*" in the title, abstract, or keywords. Based on the riparian forests related articles published in both Chinese journals and international journals by Chinese authors, we analysed the characteristics of publication output, the author keywords for priorities and the hot topics of Chinese riparian forests research.

3. Results and discussion

3.1. General publication characteristics of riparian forests research

3.1.1. Development of international and Chinese riparian forests research

Changes in international riparian forests studies over different time periods were characterized based on literature searches using the WoSCC database (Fig. 1). The earliest papers indexed in the WoSCC appeared in the 1960s. Thompson [21] published an article entitled *Riparian Forests of the Sacramento Valley, California* in 1961 that provided a foundation for future studies of riparian forests. Substantial interest in riparian forests did not emerge until the 1980s, after which riparian forests research gained momentum during the 20th century, motivated by increasing concerns about water quality and its societal implications [13,22]. Meanwhile, a series of events promoted the international development of riparian forests research. The development of the eco-hydrology and the implementation of the 4th International Hydrological Programme (IHP) greatly contributed to riparian forests research [23, 24]. The quantity of riparian forests research has increased rapidly since 1990; approximately 6050 research articles related to riparian forests were retrieved from the WoSCC database for 1990–2014. The two curves in Fig. 1 show that riparian forest-related publications had a steeper growth trend (20.07% from 1990 to 2014) than all WoSCC publications (15.92%).

Chinese riparian forests studies published in domestic and international journals were retrieved from the CNKI and WoSCC databases, respectively (Fig. 2). Chinese research on riparian forests began in the 1980s; the number of publications began to grow rapidly in 2000 and has fluctuated but continued to increase from 2008 to the present. The earliest Chinese study was published in the 1960s (CKNI) and the first international study by Chinese scholars was published in 1998 (WoSCC). As ecological degradation in arid inland rivers has drawn attention, the number of riparian forests related publications by Chinese scholars has increased rapidly since 2000 [10,15]. More publications by Chinese scholars were found in the international database than in the CNKI database during the past 3 years, indicating that Chinese riparian forests research is having a greater international impact.

A comparative analysis of the trend in research output demonstrates that international riparian forests research began earlier and entered a rapid growth stage during the 20th century. In contrast, Chinese research began a relatively concentrated and rapid period of growth during the 21st century; this rapid growth lagged the rapid growth stage of international research. International riparian forests research publications have increased rapidly in recent years, with an average annual growth rate greater than that of all publications in the WoSCC database. In contrast, the quantity of Chinese riparian forests research publications has fluctuated in recent years but generally increased. Specifically, the number of publications by Chinese scholars in the WoSCC database has gradually increased to exceed the number of publications in the CNKI database, indicating that Chinese scholars have progressively emphasized international communication regarding achievements in riparian forests research in recent years.

3.1.2. Major countries and institutions publishing riparian forests research

The contributions of different countries and territories were estimated based on author affiliations in published papers. The majority of the 20 most-productive countries for publications of riparian forests research were located in Europe (11) and the Americas (5) (Fig. 3). American scholars published almost half of these publications, taking a leading role in riparian forests research. China ranked 11th and only accounted for 2.3% of the total number of publications, a much smaller contribution compared to the United States and other countries. At the institutional level, Table 1 showed the dominant position of the United States in international riparian forests research; 16 of the 20 most active research institutions were in the United States. This institutional activity was led by the United States Forest Service, which accounted for nearly 10% of all publications. The Chinese Academy of Sciences ranked 20th, accounting for 1.3% of the total number of publications (Table 1). This result indicates that Chinese riparian forests research does contribute to the field; however, a large gap compared to other countries still exists.

Table 1
Publications of the 20 most-productive institutions.

Institution	Total
United States Department of Agriculture (USDA), USA	530
United States Forest Service, USA	392
United States Geological Survey, USA	270
Oregon University System, USA	216
University of California System, USA	194
Oregon State University, USA	193
Centre National de la Recherche Scientifique (CNRS), France	167
University System of Georgia, USA	136
University of Washington, USA	133
University of Washington Tacoma, USA	131
University of Washington Seattle, USA	129
University of Georgia, USA	127
University of North Carolina, USA	119
University of British Columbia	109
Florida State University System, USA	86
Universidade de Sao Paulo, Brazil	85
Virginia Polytechnic Institute, USA	85
Colorado State University, USA	83
United States Environmental Protection Agency, USA	80
Chinese Academy of Sciences, China	78

3.2. Priority areas for riparian forests research

The number of times an article is cited indicates its peer recognition and impact within its study area [18]. Articles that have been cited more than 100 times or that are among the 100 top-cited articles are often regarded as "classic articles" [19,25,26]. A keyword analysis of the classic articles can reflect the priority research areas of the field. In this paper, we analysed the author keywords of classic articles to identify the priority areas for international and Chinese riparian forests research.

3.2.1. Priorities of international research

A total of 6072 riparian forests articles were retrieved from the WoSCC database, from which 157 articles cited more than 100 times were selected. The keyword analysis in our study utilized author keywords as statistical objects. To obtain accurate results, we pre-processed the keywords by merging singular and plural forms of the same keyword, as well as keywords that were expressed differently but had the same meaning (we excluded the search keywords "riparian forest", "riparian", "riverine", and "forest"). The 20 most frequently used keywords in the classic international riparian forests research articles are listed in Table 2. We further analysed these priorities of international riparian forests research (below).

(1) Ecohydrology processes

The frequent use of the keywords "Stream", "River", and "Groundwater" indicates that ecohydrology processes is a priority in riparian forests research. Rivers, precipitation and groundwater are the main water resources for riparian forests vegetation. Using isotopic techniques, studies have shown that riparian forests generally use groundwater and precipitation, which together account for 50% of the total water utilization; riparian forests adjust their water use pattern according to changes in runoff [27,28]. However, the pattern of water use has been shown to differ by ecosystems, with deciduous plants mainly using groundwater, evergreen plants relying mostly on rainfall and desert riparian vegetation mainly consuming groundwater, as well as condensation water [29,30].

Various water resources are converted to soil moisture to support vegetation growth, and the depth of soil moisture affects vegetation. The shallow layer, recharged by the river flooding, mainly affects the richness of herbaceous plant, while the deep layer of soil moisture, recharged by the groundwater, mainly affects the abundance of shrubs and trees [31]. In addition to their water utilization, riparian forests affect hydrological processes by redistributing rainfall (i.e., canopy interception, stream flow, and through fall) and hydraulic lifting, which changes the vertical distribution of soil moisture available to the plant community [32–35]. Meanwhile, riparian forests also act as an essential part of the hydrological process by serving as a filter zone: intercepting pollution and maintaining water quality [36,37]. Common research topics include (i) the role of riparian forests in filtering non-point source pollution in stream ecosystems [38–40] and (ii) the effects of riparian forests on stream habitat, especially the reproduction of large invertebrates and the food chain structure of stream ecosystems [41,42].

(2) The structure of riparian forests

Riparian forests are functionally defined as four-dimensional zones, including the longitudinal gradient (i.e., from the upper to the lower reaches), the lateral gradient (from fluvial to upland areas), the vertical gradient (from the stream to the groundwater) and the temporal variance [43,44]. These four dimensions impart a complex structure to riparian forests and are also the foundation for its function and stability. Some studies of riparian forests structure focused on community composition and stream-groundwater interactions. Others examined the spatial and temporal changes in community structure that followed disturbance by human activities such as land use change and landscape variations, aiming to explore the mechanisms by which community structure varies and provide a scientific basis for future management [45–47]. Because riparian forests are located at the land-water interface and are areas where substantial matter-energy exchanges occur, as well as frequent disturbances, these environments are heterogeneous and have high biodiversity [48,49]. These features mean that riparian forests provide crucial habitats for various species and lead to the formation of complex food chains [50,51]. At the same time, riparian forests can also serve as corridors for exotic invasions [52,53]. Non-native species have the potential to influence ecosystem dynamics and negatively affect ecosystem biodiversity and functioning [54,55]. However, due to the inherent variability of riparian forests, it is difficult to monitor dynamic changes in ecosystem structure. Therefore, species typical to certain riparian forests, such as cottonwood trees and birds, have often been used as indirect indicators of dynamic changes in riparian forests and additional techniques should be developed and deployed to detect this dynamic more accurately [56–58].

(3) Macronutrient cycling and nutrient filtering

Table 2
The 20 most frequently used keywords in the top-cited international studies of riparian forests.

Keyword	Frequency
Stream	11
Nitrogen	11
Denitrification	8
Nutrient	8
Biodiversity	7
Flood	7
Carbon	6
Groundwater	6
Nitrate	6
Landscape	6
River	6
Dissolved organic carbon	5
Bird	5
Habitat	5
Cotton wood	5
Sediment	4
Woody debris	4
Invasions	4
Land use	4
Food	4

Table 3
The 10 most frequently used keywords from the top-cited Chinese studies of riparian forests.

Keyword	Frequency
Desert riparian forests	17
Populus euphratica	11
Tarim River	7
Wenyu Watershed	5
Biodiversity	5
Nitrogen	5
Land use/land cover	5
Community succession	4
Extreme arid region	4
Groundwater table	4

As connections between terrestrial and aquatic ecosystems, riparian forests function as corridors for mass-energy interactions, especially macronutrients (i.e., carbon and nitrogen). These are important processes that connect the vegetation, river and groundwater in the riparian forest ecotone [59,60]. Riparian forests are also regarded as nutrient filtration zones that control non-point source pollution from agricultural watersheds via sediment trapping and plant uptake [61,62]. The research on both macronutrient cycling and nutrient removal has mainly focused on macronutrients such as nitrogen and carbon. Nitrogen (N) is an essential element for plant growth and a typical pollutant to riparian ecosystems [60,61], while dissolved organic carbon (C) is the primary indicator of natural organic C, as well as an important indicator of water quality [63]. Current research has mainly focused on (i) chemical processes in groundwater, especially the impacts of nitrate pollution on groundwater quality [64,65], and (ii) comparisons between pollution interception processes in natural versus artificial riparian forests [66,67]. However, the buffer width, which directly affects filter functioning [37], is difficult to delineate precisely because of the heterogeneous mosaic of landforms, communities, and environments that make up different geomorphic and hydrologic patterns in riparian forests [68]. Current studies have mainly defined the buffer range qualitatively, which may lead to inaccuracies; thus, quantitative measurements should be conducted in different regions to better protect buffer zones [69].

(4) Disturbance and stability

The multi-dimensional structure and high biodiversity of riparian forests are the foundation of their stability as ecosystems and their capability to withstand disturbances [43]. Studies of ecosystem stability inextricably include ecosystem disturbance. Situating at the ecotone, riparian forests are exposed to disturbances from both natural processes and human activity. Various disturbances, including woody debris, floods, and land use change are driving forces of ecosystem evolution and also causes of dynamic change in riparian forests [70,71]. The presence of woody debris in riparian forests areas can affect the convergence of river flows and change erosion processes in riverbeds [72,73]. At the same time, the woody debris also serves to mobilize nutrients stored in riparian forest areas and acts as a corridor for amphibians [74]. Floods, which occur frequently in riparian zones, can be generated naturally or under human control (i.e., ecological water conveyance). Moderate floods link the land and water ecosystems, creating favorable conditions for riparian forest habitats, while extreme flood events can affect the pattern of riparian forest vegetation as well as hydrological processes in the riparian zone [75,76]. As human impacts have intensified, land use change and groundwater exploitation have become the major disturbances in many riparian forests. Changes in land use largely alter the distribution of riparian forests because of the extension of farmland, wood harvesting and grazing. These changes affect the structure of riparian forests, as well as ecosystem functioning (e.g., corridor transport, riverbank consolidation, and pollutant filtration) [77–79]. The overexploitation of groundwater mainly occurs in arid zones, where water scarcity causes conflicts between human and natural ecosystems. Extensive exploitation of groundwater for farming or household use may negatively affect riparian forests survival and lead to ecosystem degradation [80,81]. Research regarding disturbances in riparian forests is important to maintaining ecosystem stability under changing environmental conditions and intensive human activity. Recent studies have focused on the mechanisms and impacts of disturbances on riparian forests ecosystems. Various models have been used to evaluate how natural and anthropogenic disturbances influence riparian forests, including statistics-based models (i.e., regression analyses and generalized linear models), as well as empirics-based and analytics-based models [82,83].

3.2.2. Priorities of Chinese research

To analyse the priorities of Chinese riparian forests research, we selected the 100 most cited articles (only one article had been cited more than 100 times) among both international and domestic articles published by Chinese researchers. We extracted keywords from these articles and used the top 10 keywords (frequency > 4) to analyse the priorities of Chinese research on riparian forests (Table 3).

We found that desert riparian forests and *Populus euphratica* are the main research topics. Desert riparian forests, which are mainly composed of *Populus euphratica* forests, constitute the majority of the riparian zone in hyper-arid areas and primarily located in the floodplains of major Central Asian rivers [84]. They can survive in harsh habitats and provide critical habitats for species. They also act as windbreaks, sand fixation, as well as the protection of ecological security within the hyper-arid zone [85–87]. The Tarim River, one of the largest inland rivers in China, is located in an extremely arid region of north-western China and characterized by low rainfall, fragile ecosystems, and serious desertification [16,80]. The groundwater level strongly affects the dynamics of desert riparian forests because of the scarcely rainfall. Over the past century, increasing population has resulted in land use conversion from riparian vegetation to farmland and residential areas. By the 1990s, overexploitation of water resources had led to dried-up channels and a decline in the groundwater level, causing community succession from riparian forests to desert shrubland. In 2000, China began to implement ecological restoration projects such as water conveyance and vegetation conservation in the extreme arid regions to restore desert riparian forests [88,89]. This measure has effectively protected desert riparian forests from degradation. Concurrently, studies on vegetation restoration, groundwater promotion and land use change have become more common [10]. In spite of the arid inland river basin, Wenyu River

Table 4
The 20 most frequently used keywords in international riparian forests articles from 2012–2014.

Keyword	Frequency
Habitat	77
Streams	55
Management	54
Nitrogen	51
Restoration	47
Conservation	42
Land use	40
Vegetation	36
Diversity	36
Disturbance	33
Groundwater	28
Biodiversity	28
Hydrology	27
Soil	27
Floodplain	23
Agriculture	21
Denitrification	21
Riparian zone	20
Nitrate	20
Climate change	19

Table 5
The 10 most frequently used keywords in Chinese riparian forests articles from 2012–2014.

Keyword	Frequency
Populus euphratica	12
Groundwater	11
Desert riparian forest	8
Land use/land cover	7
Tarim River	7
Distribution pattern	6
Extreme arid zone	5
Remote sensing	5
The low reaches of Heihe	4
Hydraulic redistribution	4

Basin is also the main research area. The Wenyu River Basin is located in a semi-humid region where riparian forests play an important role in controlling non-point source pollution, especially nitrogen from farmland. It is also characterized by high biodiversity and provides a large amount of forest products and ecosystem services. These features have made the Wenyu River Basin a crucial site for research concerning river basin management and sustainable forestry [90,91].

3.2.3. Comparison between international and Chinese research priorities

Both Chinese and international research focus on the structure, function and stability of riparian forests (including studies of land use change, nutrient removal and human disturbance). Compared to the priorities of international research, Chinese riparian forests research is strongly regional, concentrating on riparian forests associated with arid inland rivers and in sub-humid regions (such as the Tarim, Heihe, and Wenyu Rivers), while research on riparian forests in humid regions is less prominent. In addition, Chinese studies are generally conducted on the scale of large inland river basins (e.g., the Tarim and Wenyu River Basins), and the primary research topics are eco-hydrological problems in the sustainable development of river basins [16]. In contrast, international studies are conducted on multiple scales and address the ecological processes in riparian forests.

3.3. Hot topics in riparian forests research

Recent publications often reflect hot topics in the field. Keyword analysis can be used to identify research hotspots and recognize scientific research trends [92]. The author keywords of riparian forests articles from 2012–2014 were analysed to identify hot topics in international and Chinese riparian forests research (Table 4).

3.3.1. Hot topics in international research on riparian forests

A total of 1433 riparian forests articles were retrieved from the WoSCC database (2012–2014). Keyword statistics were used to identify the 20 keywords most frequently used in these articles. Hot topics of riparian forests research were identified after excluding words that repeated the research priorities. The resulting hot topics included the following three aspects: "vegetation-soil-water" processes in the Critical Zone, the dynamic of riparian forests in the changing world, and the management of riparian forests.

(1) The "vegetation-soil-water" processes in the Critical Zone

The impact of human activities on the natural world has become ubiquitous. The geosphere at the surface of the Earth is characterized by significant interactions between the geological environment and human activities [93]. This near-surface geosphere plays a crucial role in regulating natural habitats, supporting economic development, and providing ecosystem services. The United States National Research Council defined the region extending from the canopy to the groundwater level as Earth's Critical Zone [94]. This Critical Zone provides support for almost all human activities and is an important study area for sustainable development research. Soil and water, which support vegetation growth, are key components of the Critical Zone [95]. Riparian forests, which contact both aquatic and terrestrial ecosystems, are an important part of it. Vegetation-soil-water interactions are key processes in the mass-energy dynamics of the riparian zone. Research into these processes has covered numerous scales, from the water utilization strategies of individual plants to source-sink processes at the plot scale and water resource management over entire basins [96]. Further analysis of articles using the keywords "Streams", "Groundwater", "Hydrology", "Nitrogen", "Floodplain", "Vegetation", and "Soil" revealed that the hot topics of riparian forests research centre on "vegetation-soil-water" processes in the Critical Zone. The major research topics include eco-hydrological processes, C pool reserves, and nutrient (N and P) cycling in riparian forests, as well as the impact of urbanisation and modern agricultural expansion on riparian forests [66,97–99].

(2) The dynamic of riparian forests in the changing world

Climate change and land use are two main topics in the changing world. Riparian forests provide crucial habitats for various species and their function as carbon sinks can be regarded as an essential component of climate change adaptation and mitigation strategies [100]. Environmental change can directly affect the structure and functioning of riparian forests, which are crucial for sustainable development [101,102]. However, research on the dynamics of riparian forests is challenging because of these areas' high landscape heterogeneity, rapid matter-energy exchanges and large disturbances. In addition, ecological processes also vary at different scales. At the plot scale, isotopic and sap flow techniques have been used to monitor ecological processes of riparian forests communities [103,104]. These plot observations effectively illustrate the mechanisms of ecological processes and the response of individual communities to environmental change, which form the basis for ecosystem restoration [35,105]. At the scale of regions and landscapes, where plot observations are impossible, techniques involving eddy covariance, dendrochronology, unmanned aerial systems, remote sensing and geographic information systems have been used to understand the spatial and temporal dynamics as well as long-term data in riparian forests [106–108]. Additionally, various types of models have been applied to simulate ecological dynamics in riparian forests and make future projections. Hydrological models such as the Soil and Water Assessment Tool (SWAT) and the Système Hydrologique Européen (SHE) have been used in riparian forests, as the hydrologic cycle is sensitive to the climate change and also the core process in the ecosystem [109]. In addition, as human activities have become an essential part of watershed management, synthetic models that integrate ecosystem and economic processes have been designed for various river basins to accommodate both human use and riparian forests health in future scenarios [110,111].

(3) The management of riparian forests

Riparian forests, which provide humans with a variety of ecosystem services, are an essential part of sustainable ecosystem development. However, because of the increasingly prominent impacts of climate change and human activities, riparian forests are being destroyed and degraded, to the extent that it is difficult to achieve rapid restoration solely through their own ecosystem functioning [112]. In addition, in the Anthropocene, human activity can no longer be treated as an exterior driver but must be considered as an essential part of the hydrological cycle in integrated water resources management [113]. Riparian forests play an important role in both terrestrial and aquatic ecosystems, are crucial components of river basin management. To stabilize ecosystem structure and ensure human welfare over the long term, understanding how to effectively manage riparian forests is crucial to

achieve a balance in the coupled human-nature system and maximizing the benefits for both sides [114]. A number of management cases have been implemented in well-known river basins worldwide. In basins such as the Murray-Darling (Australia) and the Rhine (Germany), the demand for ecosystem services and economic development were evaluated to achieve balanced river management [115,116]. In China, the Heihe River has been the focus of many studies of riparian forests management. There are trade-offs between increasing demand for agricultural irrigation in the middle reaches and ecological water requirements for the growth of desert riparian forests in the lower reaches [117]. Considering the effects of climate change and increasing human demands on both the middle and lower reaches, many studies have examined future dynamic changes in riparian forests and ecological water requirements to make recommendations for sustainable management.

3.3.2. Hot topics in Chinese research

A total of 142 Chinese articles on riparian forests were retrieved from the WoSCC database (83 articles) and the CNKI database (59 articles) for 2012–2014. The top 10 most frequently used keywords were used to identify hot topics and possible future research directions (Table 5).

In addition to the existing research priorities, we found that the hot topics of Chinese research focused on the distribution pattern and ecohydrological processes of riparian forests [90,91]. The distribution pattern of riparian forests reflects environmental changes that can be used as indicators of ecosystem variability. Studies of the distribution patterns of desert riparian forests and the factors that determine these patterns are crucial to understanding the interaction between these communities and the environment. In addition, ecohydrological processes are important in determining mass-energy interactions in the riparian zone, especially in hyper-arid regions where water is central to ecosystem stability. In addition to the water utilization processes of individual species, studies have shown that there is hydraulic redistribution on community level, that is, phreatophytes (such as *Populus euphratica* and *Tamarix ramosissima*) can lift water from deeper soil layers into shallower, drier soil layers, benefitting nearby plants with shallow root systems [118,119]. This affects the distribution of soil moisture and is a mutualism strategy among species in hyper-arid regions. These studies have laid the foundation for further analyses of the mechanisms of community dynamics and a deeper understanding of functional relationships in riparian forests. The lower reaches of the Heihe River have also become a focus of research in recent years. It maintains one of the largest oases in the extremely arid region and serves as the major distribution area for desert riparian forests in the Heihe basin. As water usage increased in the midstream of the Heihe River, the lower reaches have suffered greater land desertification, ecosystem degradation, and increasing water usage conflicts between humans and ecosystems. Therefore, the low reaches of the Heihe River have become a case study for water resource management and the sustainable development of riparian forests [81,120]. In recent years, remote sensing has been frequently used to monitor the changes in riparian forests to better investigate their dynamic characteristics [121]. For example, China's Heihe Watershed Allied Telemetry Experimental Research (HiWATER) program represents a multi-scale comprehensive observational experiment in the Heihe River Basin. It involves the coordination of satellite, aerial remote sensing, and ground-based observations. The HiWATER program covers the upstream runoff, midstream oasis, and downstream riparian forests areas and provides an eco-hydrological parameter set for the dynamic simulation of river basins [122].

3.3.3. Comparison between international and Chinese hot topics

A comparative analysis showed that the hot topics of both international and Chinese domestic research focused on the comprehensively simulation of the dynamic processes in riparian forests, especially under the impact of human activities. International research emphasized the protection and management of riparian forests, while Chinese domestic research focused more on the distribution pattern and processes of riparian forests. Moreover, compared to the hot topics of international research, Chinese domestic research involved less work on predicting future scenarios of riparian forests in the changing world, which could be emphasized in future studies.

4. Conclusions

This paper describes a bibliometric survey of international and Chinese riparian forests research based on the WoSCC and CNKI databases (1981–2014). The quantity of international riparian forests publications increased rapidly after the 1990s, while Chinese riparian forests research was mainly conducted after the 2000s; Meanwhile, Chinese scholars have published more international than domestic publications in recent years. The majority of the most productive countries were located in Europe and the Americas, while China ranked 11th and accounted for only 2.3% of the total publications. In terms of the research priorities, both Chinese and international studies largely focus on the structure, function and stability of riparian forests. However, Chinese riparian forests research was mainly conducted in inland river basins and desert riparian forests areas, and studies commonly emphasized ecohydrological problems with implications for the sustainable development of the river basin. The hot topics of international research included the "vegetation-soil-water" processes in the Critical Zone, the dynamics of riparian forests in the changing world, and the management of riparian forests. The hot topics of Chinese riparian forests research included the distribution patterns and processes of riparian forests, the water utilization strategies of riparian forests in hyper-arid regions, monitoring dynamic changes in riparian forests and riparian forests management. Studies of the dynamic processes in riparian forests and the influence of human activities on riparian forests are hot topics in both international and Chinese research, and these may become research priorities in the future. We note that international research has highlighted the importance of using ecological and economic coupled models for riparian forests to predict their future response to climate change. These topics have been less reported in China and may possibly signalling future research trends for Chinese riparian forests research.

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