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River chief governance in China: trends and outlooks

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The issue of water resources is a perennial topic for achieving human sustainable development goals. Over the last decade, a renewed watershed governance regime, River Chief System emerged to solve the issue of river pollutions in China, and attracted attentions across the world. In this review article, we profiled River Chief System, including its origin, principle and characteristics, and found that the primary feature of River Chief System is its hierarchical structure and the implementation of responsibility. By triangulating bibliometric measurement of the Citespace tool, database of the Web of Science and the China National Knowledge Infrastructure, the development, research trends and hotspots of River Chief System research have been reviewed systematically. The number of publications of River Chief System is showing a significant growing trend, and their foci are diverse: water environmental effects, mechanisms of River Chief System, public participation and supervision and localization of River Chief System, and the implement of "One River, One Policy" plan. Finally, theoretical and practical suggestions for the future study of River Chief System are proposed. This review systematically introduces China's experience on river management to the world, which is of great significance for the world to fully understand the River Chief System of China and further improve and promote it.

KEYWORDS

River Chief System, bibliometrics, citespace, scoping review, water governance

1 Introduction

Water resources are one of the most crucial natural assets, playing an indispensable role in achieving the Sustainable Development Goals (SDGs) outlined by the United Nations General Assembly (2015). Among the 17 global primary SDGs and 169 specific objectives, a prominent target is to ensure "Clean water and sanitation" for all humans. This is closely linked to the sustainable management of water resources and the environment. River systems, which serve as significant components of water resources, offer essential natural, economic, and ecological functions. They play an irreplaceable role in ensuring water resource security, purifying water quality, regulating climate, and preserving biodiversity (Milly et al., 2005; Voeroesmarty et al., 2010; Vorosmarty et al., 2010). However, the accelerating pace of industrialization and urbanization has led to the degradation, decline, and deterioration of river ecosystems worldwide, including rivers and wetlands (Brinson and Malvarez, 2002; Malmqvist and Rundle, 2002; Dudgeon et al., 2006). China, like many other countries, faces a severe water shortage, with the *per capita* share of freshwater resources being only a quarter of the global average. In addition, several polluted water incidents have raised concerns of central government and local residents, such as the Huaihe River water incident in 1994 and the Taihu Lake incident in 2007 (Li and Pu, 2003; Qin et al., 2007). In light of escalating global water scarcity and widespread water challenges,

effective management, development, and protection of rivers have become imperative issues.

When examining the variance in water governance regimes globally, it becomes apparent that many countries have implemented diverse strategies. These can be broadly categorized into authoritarian regimes, decentralized regimes, and a combination of both models (Hurlbert et al., 2013; Hwang, 2017; Ozerol et al., 2018). The authoritarian (or centralized) management model establishes a cross-departmental institution to manage water resources from top to bottom, thereby facilitating comprehensive and equitable decision-making (Hueesker and Moss, 2015). In contrast, a decentralized system lacks a unified organization for centralized water resource management. This system encourages the participation of stakeholders and involves different organizations in water governance (Sigman, 2005). Furthermore, some countries have adopted a hybrid model, which combines both centralized and decentralized management approaches.

River Chief System, introduced in 2007, is a pioneering approach to water governance in China. River Chief System refers to the establishment of a river chief for each river, appointing local leaders as the river chiefs, and incorporating the achievements of river management into the performance evaluation. It is characterized by a diverse hierarchy and direct correlation between performance and environmental outcomes (Chien and Hong, 2018). Under this system, the leaders of the Chinese Communist Party's (CCP) standing committees at all levels are designated as river or lake chiefs. These leaders are primarily responsible for local water resource conservation tasks such as shoreline management, pollution prevention, and water environment monitoring (Zhu, 2017). Essentially, River Chief System can be seen as an innovative model of hydrological governance. In this model, government leaders act as river leaders, addressing broader river management challenges. The system establishes a river and lake management structure centered on the party-government leadership responsibility system, encourages public participation, and fosters a society-wide commitment to river and lake protection (Li, 2017). Since its inception, River Chief System has quickly gained political prominence. In 2016, the General Office of the State Council issued guidelines that emphasized the full implementation of River Chief System, marking its formal adoption (the Ministry of Water Resources, 2016). By June 2018, 31 provinces in China had fully implemented River Chief System, with over 300,000 river chiefs at the provincial, municipal, county, and township levels, and approximately 760,000 village-level river chiefs across 29 provinces.

River Chief System, which integrates environmental responsibility into the evaluative and promotional processes of local officials, initially garnered significant attention. However, the majority of research efforts still mainly undertaken by Chinese scholars (She et al., 2019; Liu et al., 2020; Wang and Chen, 2020). As a unique management paradigm, numerous scholars have elucidated its overarching characteristics, evolution, and applications, often with varying perspectives on its hydrological and environmental policy implications. In the face of the tension between economic development and environmental pollution, River Chief System has fostered a virtuous cycle of economic growth and environmental protection, thereby fostering green-oriented development (Huang and Li, 2023). Furthermore, while River Chief System has mitigated water pollution to an extent, it occasionally manifests as a superficial solution rather than addressing the underlying issues (Shen and Jin, 2020). At present, River Chief System remains a viable and appropriate tool for water management in China's national context, albeit requiring further refinement (Wang and Cai, 2011). Addressing these questions, summarizing the advancements of River Chief System, and analyzing the requirements for comprehensive planning of River Chief System, can assist scholars in gaining a deeper understanding of its strengths, weaknesses, and research trajectory. Additionally, it can aid government departments and related institutions in proposing strategies to enhance the comprehensive planning and coordination for major river basins.

Currently, numerous scholars have consolidated research advancements in the field of water resource management (Li et al., 2018). Huang and Xu (2019) conducted a critical literature review on the River Chief System, reflecting on the role of environmental bureaucracy in it. Wu et al. (2015) constructed a knowledge graph of Chinese water resources management research using CiteSpace, incorporating 2263 core journal papers from the China National Knowledge Infrastructure (CNKI) database from 1991 to 2013. However, they did not explore the research progression of River Chief System. In contrast, Ren et al. (2019) analyzed 500 journal articles on River Chief System from the CNKI database from 2009 to 2017. While this study provided a visual analysis of current literature on River Chief System, it did not consider articles from the Web of Science (WOS) database. Thus, there is a need for researchers to systematically review the latest WOS and CNKI databases to discern trends and focal points related to River Chief System. Given its nascent nature in water governance, River Chief System remains a topic of significant debate. A comprehensive literature review will facilitate scholars in rapidly, objectively, and thoroughly comprehending River Chief System and its research trajectory, which is integral to the study of River Chief System. This review aims to emphasize a holistic review that incorporates not only the WOS database but also the CNKI database, leveraging the divergent perspectives on River Chief System between China and the global community.

In this review, we aimed to elucidate the current state and features of River Chief System to further its application in water resources management and decision support. Initially, we introduced the profile of River Chief System, encompassing the history of river management in China and international water governance models, with a comparative analysis of River Chief System. To comprehend the existing research status and focal points of River Chief System, we reviewed all relevant articles from WOS database and 500 articles with the highest citation count from CNKI databases by using Citespace, followed by a keyword clustering analysis. Through literary measurement and systematic review, we can identify ongoing research progress and prevailing trends. The final section presents our conclusions and suggestions for future development, based on identified shortcomings and research directions of River Chief System.

2 Profile of river chief system

River Chief System has undergone a series of innovative governance developments in China. In response to the

cyanobacteria bloom crisis in Tai Lake, the Wuxi Municipal Party Committee and Wuxi Municipal Government established "River Chiefs" for the primary rivers in Wuxi in 2007, thus creating the prototype of River Chief System (Wuxi Municipal Party Committee, 2007). By 2016, River Chief System had expanded nationwide, indicating that it was not just a local practice but also a national initiative (the Ministry of Water Resources, 2016). The lake chief system, which is derived from River Chief System, has proven to be both timely and necessary as a supplement to River Chief System. In January 2018, the General Office of the Central Committee of the Communist Party of China and the General Office of the State Council issued the "Guiding Opinions on Implementing the Lake Chief System in Lakes", emphasizing the significant and unique nature of implementing the lake chief system in lakes (the Ministry of Water Resources, 2018).

The current River Chief System is a form of heuristic governance rooted in river-based heuristics. The establishment of a river chief enhances the protection and management of rivers, elevates water environment quality, and fosters ecological restoration and sustainable development. This hierarchical structure is deeply ingrained in traditional social structures (Yao, 1996). River Chief System is also a continuation of the ancient water management system in a certain sense, which not only has hierarchy, but also has a common value orientation in accountability, reward and punishment measures.

The history of water control in China dates back to ancient times, primarily focusing on flood management, irrigation, and transportation. This aspect was instrumental in maintaining social stability, political cohesion, and fostering economic growth (Research Group on Improving the Water Governance System, 2015). The political and historical factors that lead to Chinese centralization influenced the adoption of a centralized model, with the state assuming primary responsibility (Zhang, 1996). This model facilitates the mobilization of resources, enabling the construction of large-scale water conservation infrastructures that effectively mitigate floods and have long-term impacts. However, this ancient Chinese model of centralization has its shortcomings, including inadequate standardization and a network of corrupt officials (Zhang, 2015). Currently, water governance in China is progressing towards standardization, with legality being a defining feature. The introduction of responsibilities at all levels within River Chief System has resulted in more standardized management approaches and enhanced efficiency in water control. While a traditional hierarchical system still exists, the environmental responsibility system has significantly reduced corruption and malfeasance.

Countries globally have garnered localized experiences in water management, offering significant insights for China's River Chief System. International river governance, particularly cross-border river governance, is heavily reliant on effective judicial and interdisciplinary cooperation. This reliance is intrinsically tied to the unique river management institutions in place (Garrick et al., 2013; Moore, 2021). Within the context of the water resource management system, different countries employ varying management models for their river basins. These primarily fall into three categories: centralized, decentralized, and comprehensive (Xiao et al., 2018). The selection of a management system often aligns with the physical conditions or historical evolution of a country. The centralized management approach involves the establishment of specialized agencies by the state for unified management of water affairs activities. From a historical perspective, decentralized management systems are not without merit. In these systems, the state divides the management of water resources according to the responsibilities of relevant departments or entrusts this task to local governments while it only formulates relevant regulations and policies.

Based on the first two systems examined, comprehensive management has increasingly been recognized as a significant approach. A prime example of this is China's River Chief System. Despite its centralized institutional management, it lacks adequate legal constraints, particularly at the transnational level, leaving implementation methods up to individual countries. Unlike a single centralized management system, China has not established a new water management institution. Instead, it relies on administrative leaders who also serve as river chiefs to coordinate and oversee the management process. However, these river chiefs retain authority to command various departments, simplifying the complexity of personnel and departments to some extent. This Chinese-specific model effectively addresses the issue of difficult implementation of legal responsibilities of the government, providing valuable insights for international water governance. River Chief System also incorporates elements of a decentralized management model. Different river chiefs are assigned specific main and tributary sections, enabling the development of tailored management systems based on each tributary's unique conditions. However, in a decentralized system, artificially dividing the entire water system into sections may hinder the protection and utilization of water resources. In contrast, the hierarchical structure of River Chief System mitigates issues such as uneven coordination and contradictions arising from human segmentation, compared to decentralized management.

In general, River Chief System in China exemplifies a holistic approach to water management. The integration of centralized and decentralized components, coupled with the streamlining of personnel and departmental complexity, facilitates the effective execution of governmental legal obligations. This model offers significant insights for global water governance, especially in addressing challenges associated with transnational water management and the safeguarding and utilization of water resources.

3 General overview of the research on river chief system

3.1 Methods

Bibliometrics employs mathematical and statistical methods to examine the quantitative relationships and inherent correlations within literature. By quantifying and analyzing this literature, we can uncover information regarding its correlation, citation patterns, and developmental trends. Currently, the field of bibliometrics is progressing towards visualization, with charts and images being used to clearly and intuitively display research development trends.

In this study, we selected CiteSpace, designed and developed by Chen (2006), as the primary research tool. CiteSpace is a software for information visualization that allows for co-citation and cluster

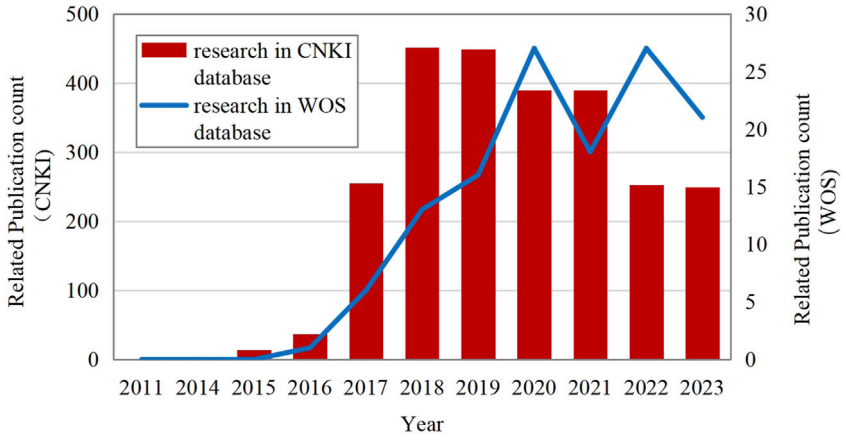

FIGURE 1
Number of research articles on River Chief System in China and Internationally.

analysis of high-frequency authors, keywords, document co-citations, and other parameters across different perspectives and time zones. It can display this data through a complex citation network structure map, facilitating the analysis of relevant research hotspots, evolution processes, and frontier trends within a certain field (Chen, 2017; Chen and Song, 2019). The most recent version of Citespace used in this study is 6.2.R4.

3.2 Author, journal, and number of publications

As we showed, there are a total of 131 relevant articles on River Chief System in all years in the WOS database and a total of 2280 relevant articles in CNKI database. Although River Chief System has been promoted nationwide in 2016, relevant articles have only been published on international journal since 2016. The earliest relevant article is "Design and implementation of river protection management system based on river chief mechanism" written by Yu et al. (2016), while the latest relevant article is "Evaluation Model and Application of the Implementation Effectiveness of River Chief System (RCS)-Taking Henan Province as an Example" written by Liu et al. (2023).

In the CNKI database, Chinese scholars initiated the researches on River Chief System in 2008, prior to its formal origin and promotion. The WOS database reveals a certain research lag compared to the CNKI database, indicating that River Chief System has gradually transitioned from a local system to international research. Initially, as an emerging water management institution, research primarily focused on River Chief System's inherent characteristics and highlighted its innovative aspects (Huang, 2015; Zhai and Tang, 2017). From 2017 to 2023, the number of publications related to River Chief System generally increased, reflecting its growing academic importance. Along with the policy promotion process of River Chief System, academic research has mainly gone through two stages. In the first stage, from 2017 to 2020, there were only three papers on the theme of River Chief System in 2017 due to its recent implementation. However, by 2020, the number of published articles peaked at 27. In the CNKI database, although the number of articles declined in 2020, the overall trend was still ascending. Scholars began to focus on its specific practices and mechanisms, such as responsibility contracting and cross-sectoral cooperation, and proposed suggestions for the future development of River Chief System (Liu and Zheng, 2018; Wang et al., 2019). In the second stage, from 2021 to present, it showed differentiated trends in the number of articles in the WOS and CNKI databases (Figure 1). In the CNKI database, the number of articles dropped sharply, reaching only half of its maximum, while in the WOS database, the number of articles posted fluctuated but remained largely unchanged. Following the issuance of relevant regulations on the river and lake chief system by the Ministry of Water Resources in 2021, more research directions have emerged for the study of the river and lake chief system, such as public participation and "One River (Lake), One Policy". The papers are mainly published in Journal of Yangtze River Scientific Research Institute, Water, China Population Resources and Environment, Iop Conference Series Earth and Environmental Science, Sustainability, Water Resources Protection, Environmental Science and Pollution Research International, International Journal of Environmental Research and Public Health and Journal of Water Resources and Water Engineering. Among them, the journal with the highest publication volume under River Chief System is Journal of Yangtze River Scientific Research Institute with a total of eight papers. Papers are often published in journals related to water and environment, and many of them are Chinese journals.

3.3 Keyword cluster analysis of the research of river chief system

We utilized Citesapce to construct a co-occurrence network on the Knowledge Graph of keywords, which aids in elucidating both international and Chinese research focal points within River Chief System. This study has selected all articles related to River Chief System in the WOS database From 2017 to September 2023, and the search keywords are "river chief system" or "river leader system" or "river head system" or "river chief" to make the search results as

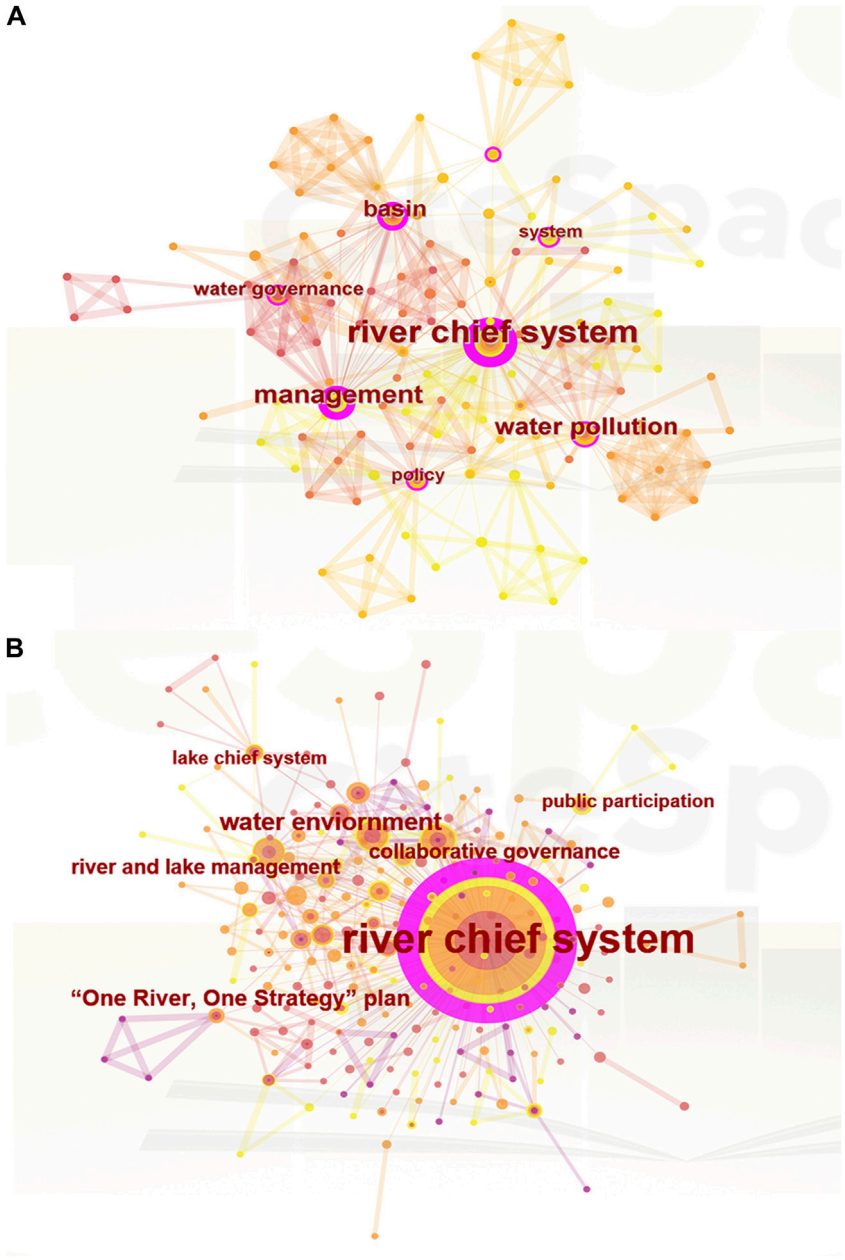

FIGURE 2
Co-occurrence graph of keywords in the articles about River Chief System **(A)**: from WOS database; **(B)**: from CNKI database.

comprehensive as possible. Among them, 131 articles are from the WOS core collection. Finally, the co-occurrence graph of keywords by frequency is obtained as follows (Figure 2A), where each circular node represents a keyword. The larger the node, the more times the keyword appears, and *vice versa*, the fewer times the keyword appears. Due to the fact that River Chief System is the search topic, the largest node is River Chief System, followed by "water pollution," "water governance," and "water management." This indicates that international research on River Chief System believes that River Chief System is a unique model for water governance and management to solve river pollution problems, and the researchers explore its pollution control effectiveness, and proposes suggestions and prospects for its advantages and disadvantages. Due to the fact that River Chief System is a water management system with Chinese characteristics and has a relatively small number of international publications, some research points have rare co-occurrence, with a frequency of only 1–2, including "sustainable management" and "ecosystem service," which also have research value and can be further studied in this regard.

Meanwhile, we searched the CNKI database using River Chief System as the keyword and selected the top 500 articles with the highest number of citations. The co-occurrence graph of keywords by frequency is obtained as follows (Figure 2B). The largest node is still River Chief System. Unlike before, key words such as "lake chief system," "collaborative governance," "public participation," and "water environment" co-occur with high frequency. This means

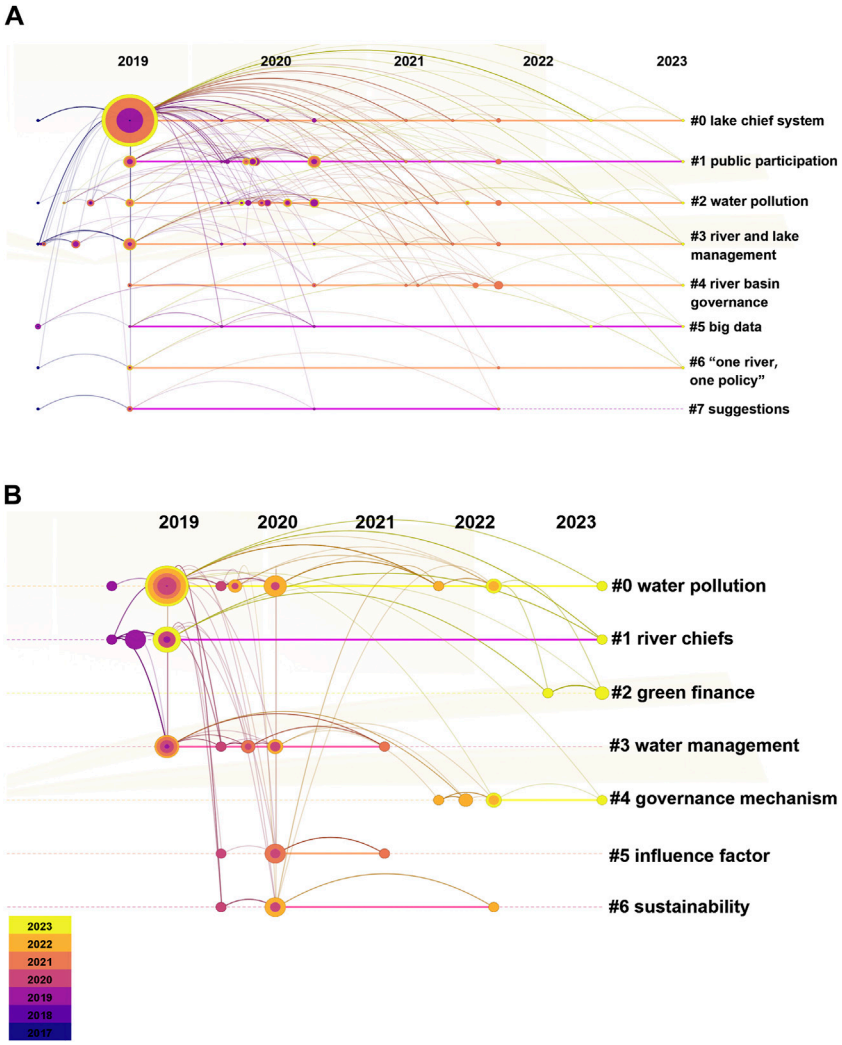

FIGURE 3
Timeline graph of keywords in the articles about River Chief System. Timeline graph of keywords in the articles about River Chief System **(A)**: from CNKI database; **(B)**: from WOS database

that Chinese research was not limited to River Chief System, but also focused on the lake chief system developed from River Chief System, with more diverse and in-depth research topics. For example, China's research not solely focused on water governance, but on collaborative governance. There are also similarities in the co-occurrence of keywords between the two databases, such as "management" and "governance".

At the same time, we used timeline clustering to analyze the trend of changes in the research topic of River Chief System, and the timeline clustering method keeps the default parameters. The results are shown in Figure 3. In the papers indexed by CNKI database, the clustering results are "lake chief system," "public participation," "water pollution," "river and lake management," "river basin governance," "big data," "One River, One Policy," and "suggestions." In the papers indexed by WOS database, the clustering results are "water pollution," "river chiefs," "green finance," "water management," "governance mechanism," "influence factor," and "sustainablility." Due to the short research time span of the River Chief System as a whole and the large number of articles published in CNKI, there is no specific change node for the research topic, and most topics run through the entire process. However, there are relatively clear nodes for the appearance and end of the topics in the articles published in WOS database. Before 2019, research published in China focused more on water pollution and river and lake management, while international research focused on river chief itself, which is basically a phenomenal level. In 2019, research focused on water pollution control. Starting from 2020 to 2021, research topics have begun to deepen, water pollution and water treatment still being a hot research topic, and the papers indexed by CNKI database have also begun to pay attention to public participation, and the papers indexed by WOS database have begun to pay attention to its influencing factors and sustainability. After 2022, the papers indexed by WOS database started to focus on deeper connotations such as governance mechanisms and green finance. It is worth noting that there are more early suggestions for this in the research published in Chinese journals. As clearly seen from the results, the entire research context is from simple to complex, from superficial approaches to intrinsic mechanisms, but the research topics published in international journals still lag behind.

4 Research trend of River Chief System

In recent times, the scholarly discourse on River Chief System has become increasingly diverse and its research level has deepened. Both quantitative and qualitative research on River Chief System have made significant strides. This study, based on highly cited papers in the scientific citation index from 2017 onwards, encapsulates the evolving research trends within the international River Chief System. Notably, these prominent articles emphasize topics such as the characteristics and evolution of River Chief System, the impact of hydrological and environmental policies on it, the underlying mechanisms of River Chief System, public participation and oversight, and the geographical localization and implementation of the "One River, One Policy" plan. Concurrently, novel issues like policy innovation transfer and legal systems are garnering increased attention (Shi, 2018; Xiong, 2022).

4.1 Water environmental effects of River Chief System

The escalating contradiction between economic growth and environmental pollution, driven by rapid scientific and technological advancements, is becoming increasingly critical (Li et al., 2019). Achieving a balance between these two factors is a pivotal issue for China's future development. To address this challenge, River Chief System has been implemented as a policy (Li et al., 2020a; Li et al., 2022). A notable advantage of this system is its emphasis on strengthening environmental performance assessment through clear responsibilities, specific tasks, and standardized assessment requirements for river leaders at all levels (Huang, 2015).

According to the Ministry of Ecology and Environment (2022), China's water environment has undergone a significant transformation over the past decade due to the implementation of River Chief System and high-quality development. This change is largely attributable to the construction of River Chief System. As reported in the Bulletin of China's Ecological Environment, the Yangtze River's main stream has consistently met the Class II water quality standard for three consecutive years, while the Yellow River's main stream has exceeded the Class III water quality standard. Despite River Chief System's success being recognized in official departments and media reports, many scholars are skeptical about whether this achievement is being whitewashed or fabricated. In researching China's environmental issues, the reliability and authenticity of data quality is an unavoidable challenge. This is because local environmental protection departments may be subject to interference from local governments, leading to inaccurate pollution data reporting (Ghanem and Zhang, 2014). In this context, researchers have formulated a series of research questions about River Chief System, which is a novel and distinctive policy. These include gauging the effectiveness of implementing River Chief System, assessing whether it can significantly enhance water environment governance across all facets, investigating potential lag effects, determining if this policy system can fundamentally address ecological and environmental issues related to rivers, and evaluating the impact of River Chief System on different pollutants in a heterogeneous manner (Xu et al., 2020; Zhou et al., 2021; Yao and Cheng, 2023; Zhang et al., 2023).

Numerous scholars have investigated the effects of River Chief System on water environmental policy, producing a range of results (Tang et al., 2020). The corresponding pollution indexes vary according to the source and nature of the pollutants, and some scholars have assessed the effectiveness of River Chief System based on these different pollutant indexes. Articles published in both Chinese and international journals often present contrasting views on the efficacy of River Chief System (Li J. et al., 2020; Xu et al., 2020).

Some scholars argued that River Chief System is not entirely effective, as it has differentiated effects on different pollutants (Li J. et al., 2020). The Difference in Differences (DID) method is often used to identify the water pollution control effect of River Chief System. Nationally, River Chief System has improved the pH and NH_3-N value, but it has triggered a deterioration in Chemical Oxygen Demand (COD) and dissolved oxygen value, which implies that the environmental governance efficiency of River Chief System is problematic, and local economic development still prioritizes environmental governance under River Chief System (Li J. et al., 2020). Zhou et al. (2021) have explored the effect of River Chief System on reducing agricultural non-point-source pollution, and found that its effect on alleviating water pollution caused by fertilizer use is minimal. In terms of detecting dissolved oxygen, ammonia nitrogen and other indicators, River Chief System has improved the dissolved oxygen in the water, but it has not significantly reduced the deep pollutants in the water. A study by Shen and Jin (2020) found that while River Chief System has improved some aspects of water quality, it has not significantly improved or even worsened certain pollutant indexes. Yao and Cheng (2023) combined questionnaire surveys and quantitative assessments and found that grassroots river chiefs had no positive impact on the prevention and control of river pollution. In summary, most doubts about the policy effectiveness of River Chief System lie in its heterogeneous influence, which does not significantly improve or even worsen some pollutant indexes.

Other scholars have reached the opposite conclusion, holding the view that River Chief System has been effective in water pollution control and has greatly alleviated the pollution situation of rivers in China. River Chief System was first proved to be effective in reducing point source COD pollution (She et al., 2019). River Chief System represents a significant advancement, as it has notably enhanced the quality of corporate water disclosure (Zhou et al., 2021b). Zhang et al. (2021) proposed an environmental production technology framework based on eutrophication levels and heavy metal concentrations caused by wastewater discharge, finding that the implementation of China's River Chief system has generally improved the wastewater treatment efficiency. In terms of ecological security assessment, the implementation of River Chief System has initially demonstrated positive effects, as reflected by the improvement of the overall water ecological security in the Chaohu Lake Basin from the lower threshold to the upper threshold of the generally healthy category (Tang et al., 2020). In the Yangtze River basin, water quality significantly improved under River Chief System, and COD and ammonia nitrogen content in the water are also reduced. Shen (2018) found that the implementation of

River Chief System has forced the transformation and upgrading of the economy, with the trend toward economic ecologization and ecological economization. Li et al. (2017) analyzed the long-term pollution control path of River Chief System and believed that the effect of River Chief System was significant. Based on the driver, pressure, state, impact and response (DPSIR) mode, after the implementation of the Tianjin River Chief System, the points increased faster, showing that the pollution control effect is obvious (Wang et al., 2022). Some scholars have also conducted research at the provincial level, such as in Jiangxi and Hunan provinces, where River Chief System has improved water quality and mitigated pollution (Liu et al., 2016; Wu and Xiong, 2017; Jiang et al., 2018). In addition to the environmental effects, River Chief System has also significantly increased the regional GDP and *per capita* GDP, and also produced positive economic benefits (Liu and Bai, 2022).

River Chief System, epitomizing the official responsibility system, is heavily reliant on performance appraisal. While this system is generally conducive to the achievement of easily quantifiable short-term goals, such as improving water quality, it falls short in attaining longer-term, non-quantifiable sustainable development goals (Ren, 2015). In summary, the institutional characteristics of River Chief System, including its assessment pressure and efficiency, are beneficial in mitigating water pollution issues within a certain scope. However, the degree and range of its policy effectiveness may vary. Lastly, in the study of environmental issues within China, the reliability and authenticity of data quality present an unavoidable challenge. The local environmental protection department may encounter interference from the local government, leading to the reporting of whitewashed pollution data. Consequently, different data sources can lead to varying conclusions. For future research, it is imperative to utilize more reliable data from diverse channels for verification purposes.

4.2 The mechanism of River Chief System

The study of what unique mechanisms improve River Chief System's effectiveness in pollution control has become a key research focus. Scholars have focused on various mechanisms within River Chief System, including cross-basin and cross-departmental cooperation mechanisms, and responsibility implementation mechanisms (Huang, 2015; Ren, 2015; Xiong, 2022), which is shown in Figure 4. These mechanisms share similarities but also differ. The investigation of River Chief System mechanism is not only instrumental in deepening our comprehension of ecological environment governance mechanisms, but also bolsters policy efficacy, furthering sustainable development and the advancement of ecological civilization. Over time, scholars have shifted from conceptual development and policy interpretation to incorporating case analysis mechanisms, providing future directions and recommendations for their research (Jiang, 2016; Zhou and Xiong, 2017; Shen and Jin, 2020).

The hierarchical system is a frequently discussed aspect in water governance research. The hierarchical structure of River Chief System is a typical feature, which is closely related to China's long-term national conditions. For a long time, China's environmental policies have been based on a top-down model, that is, the central government is responsible for formulating and deciding on environmental policies, while local governments are responsible for implementing them (Ye and Gao, 2012). The task of water governance was perceived as a political assignment, delegated by higher river chiefs to their subordinates (Huang and Xu, 2019). A characteristic feature of River Chief System is its use of hierarchical structures. River Chief System is divided into four levels: province, city, county, and township. In some places, village-level river chiefs, river patrollers, and river guards have been set up to clarify responsibilities and strengthen supervision systems. Ouyang et al. (2020) still regarded River Chief System as a top-down approach to environmental governance, which combines bottom-up supervision and citizen participation to better ensure the implementation of environmental policy. On the contrary, Chien and Hong (2018) interpreted River Chief System as "hierarchy through partification," which differs from the establishment of a temporary committee composed of representatives from different political jurisdictions or the establishment of a bureaucratic institution with a series of ascending and descending processes.

In cross-basin and cross-departmental cooperation mechanisms, cross-departmental collaboration can be defined as "the cooperative behavior of multiple departments that extend beyond organizational boundaries" (Klievink and Janssen, 2009; Liu and Zheng, 2018). This type of cooperation is observed across different policy areas and administrative regions, and is manifested at various levels of decision-making, execution, and service provision (Xu and Zhou, 2014). The primary reason for the need for collaboration among multiple departments is that the tasks or issues related to river governance exceed the jurisdiction of a single department (Krueathep et al., 2010; Yang et al., 2014).

The crux of Watershed Governance lies in the enhancement of the collaborative governance model among regions. Within the context of the current watershed management system, China's water-related departments are primarily comprised of environmental protection departments, tasked with environmental conservation and water pollution control, as well as water conservancy departments, which are charged with water resource management and safeguarding. Other departments such as housing and construction, agriculture, forestry, development and reform, transportation, fisheries, and oceans also undertake classified management functions related to water within their respective spheres (Zhou and Jiang, 2013). Moreover, governments located in different administrative regions across the upper, middle, and lower reaches of river basins face conflicts of interest regarding water. Given the inherently transboundary nature of water, it is inevitable that coordination and cooperation mechanisms will need to be established across basins and departments. However, the allocation of responsibilities among various water-related departments lacks clarity, leading to an absence of distinct responsibility boundaries (Li et al., 2021). This lack of clarity presents a challenge for interdepartmental collaboration. Wang and Chen (2020) developed an analytical framework based on the collaborative governance theory, and inferred that the system effectively addresses water management challenges through collaborative efforts, although it may face sustainability issues in the long term. Liu and Tan (2022) considered River Chief System as a network administrative organization and found that NAO model improves the shared

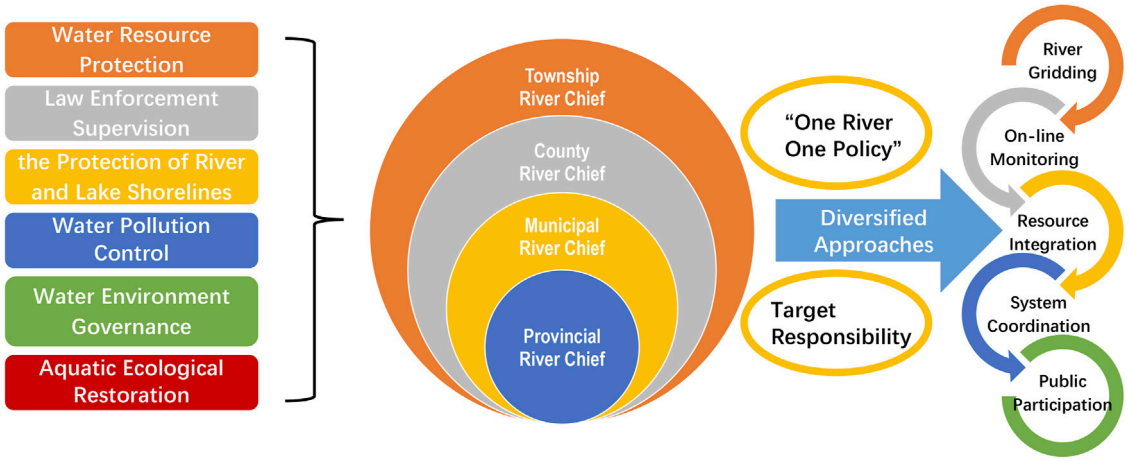

FIGURE 4
Multiple mechanisms and processes of River Chief System.

outcomes between local governments. Liu et al. (2020) considered RCS can save transaction costs and external costs in cross-regional SWRMA negotiations, which ensures that cooperative solutions are chosen in such negotiations. Ren (2015) believed that River Chief System is a new type of hybrid authority based hierarchical collaboration and this system greatly improves collaborative efficiency through coordination mechanisms at both horizontal and vertical levels. The hierarchical nature of the system, characterized by authority-based vertical coordination, has remained unchanged, leading to persistent problems in organizational logic and responsibility.

The essence of the "River Chief System" responsibility mechanism is the independent leader contracting system, its greatest advantage lying in the institutional solution to the issue of incentives (Liu et al., 2017). In the appraisal of official performance and promotion, environmental protection standards serve as a stringent criterion, which is to prevent the degradation of environment that arises from an exclusive focus on economic benefits (Liu and Wu, 2012). Under this system, responsibilities are not only very clear but also implemented to specific individuals. Due to the fact that promotion and evaluation of the river chief are all linked to the effectiveness of the river basin management, river chiefs work with high work efficiency, strong the execution, and it is easy to achieve results in the short term (Xiao, 2009). Wang et al. (2019) held the view that River Chief System reflects the routine and characteristics of the migration of national governance, and offers valuable lessons for other developing countries in designing their own river management systems.

In terms of its mechanism of action on the economy, One belief is that these regulations will increase production costs for enterprises and cause potential loss of productive output, which will suppress urban economic development (Boyd and Mcclelland, 1999). Another view is that environmental regulations can force enterprises to improve their technological innovation level, enhance regional technological innovation level, and optimize industrial structure, thereby offsetting the costs brought by environmental regulations and promoting green economic development (Porter and Linde, 1995). River Chief System can significantly improve the efficiency of urban green innovation, and there is significant regional heterogeneity. The influence of River Chief Systems in the eastern and southern regions on green innovation efficiency is more significant (Chen and Wei, 2024).

The role of "River Chief," who serves as the primary representative of the local government, is crucial. The river chief is the carrier, medium and the executor of the combined operation of many mechanisms, can consolidate resources from relevant functional departments for water pollution control. By doing so, they can effectively mitigate conflicts of interest among various government departments, ensure centralized management, and enhance both water resource conservation and basin-wide water environment governance. Such institutional design optimizes the integration of executive power at all governmental levels. By coordinating the distribution of power across these levels, there is a more efficient management of the water environment within the basin. This approach significantly reduces the management costs and challenges associated with decentralized management structures (Li Y. et al., 2020). It is recommended to establish a multi-support River Chief System to maximize the benefits of River Chief System (Li Z. et al., 2020). This unique collaboration model offers valuable insights for other resource management departments.

4.3 Public participation and supervision of River Chief System

One issue is River Chief System's heavy dependence on authority, which results in significant short-term effects but long-term organizational responsibility dilemmas. During implementation, local governments often exhibit a policy apathy towards the "act a part" style (Ren, 2015; Zhu, 2017). Multiple regions have implemented a four-tiered River Chief System, and there exists an assessment-to-be-assessed relationship between superiors and subordinates in the river chief administrative hierarchy. This poses challenges in ensuring fairness when superiors are held accountable for subordinates' mistakes (Li et al., 2017). Therefore, the assessment of river chiefs should not

be the sole criterion for evaluating River Chief System. Other monitoring mechanisms, such as public participation, should also be introduced.

Public participation in ecological environment governance refers to the general public's engagement through access to environmental information and participation in environmental protection activities (Reed, 2008). By incorporating stakeholders into environmental governance, it is argued that the quality and longevity of decisions can be significantly improved (Rall et al., 2019; Vercammen and Burgman, 2019). Stakeholders significantly contribute to the development of river management policies, thereby underscoring the necessity for public oversight within River Chief System (Ebun et al., 2022). The public possesses not only the right but also the capacity to protect their water-related rights and interests. They can further oversee local governments and relevant departments, compelling them to actively execute their respective responsibilities (Jiang, 2016).

In the sphere of public participation and oversight within River Chief System, numerous scholars have advocated for guiding public involvement. They contend that improved governmental efficiency and enhanced governance outcomes can be realized through increased public supervision (Liu, 2017; Wu and Xiong, 2017). Several models of public participation have been developed, including the Non-governmental River Chief, Village Deliberation Group, and Internet Plus River Chief System (Ma and Zhu, 2020). The "Non-governmental River Chiefs" model has demonstrated its efficacy as a mechanism for public participation in river basin management. It effectively integrates public needs into river management and supplements River Chief System (Lei, 2018). Factors such as group identity and the relationship between staff and the public significantly influence the public's willingness to participate in river chief governance (Wang et al., 2019).

At present, public participation within River Chief System remains largely symbolic due to a lack of positive government attitudes towards water environmental information disclosure and an inadequate method of communicating public suggestions (Wang, 2015; Ju et al., 2023). Public supervision in most regions can only meet the public's right to know, however, participation in decision-making and implementation of democratic supervision is difficult, and there is a lack of communication and feedback mechanisms for public reporting (Wu et al., 2020). Additionally, the general public has limited understanding of River Chief System and its role in river and lake management (Zhou and Xiong, 2017). Despite these challenges, scholars have identified the need for strengthening public participation and oversight, with recommendations made to improve both the participation and information disclosure of River Chief System. For instance, Zhu (2017) suggested establishing non-governmental organizations and independent river chiefs simultaneously to provide organized and continuous follow-up. Zuo et al. (2017) advocated for the creation of an information management platform for River Chief System as a means of enhancing social supervision. However, issues surrounding the evaluation and accountability mechanisms of River Chief System may undermine its long-term effectiveness in improving river water quality, therefore, Liu et al. (2019) emphasized the need to strengthen collaboration within River Chief System.

In summary, public supervision has become an increasingly significant aspect of environmental decision-making and is also gaining prominence in River Chief System. This has been a consensus among scholars. However, there is a general lack of comprehensive research into the Public Participation and Supervision of River Chief System. Specifically, there is a need for more in-depth exploration on the involvement and impact of different stakeholders in River Chief System's public participation.

4.4 The "One River, One Policy" plan

In the field of geography, "localization" often refers to the expression of elements or phenomena in a specific region in the world, taking into account the factors affecting them by local conditions (Schmidt and Huenteler, 2016). Within the concept of localization, each location possesses its own unique geographical environment, socio-economic conditions, and cultural background. Therefore, it is necessary to develop a localization plan that aligns with the local context. This suggests that local characteristics and differences should be adequately considered when formulating river governance strategies to ensure their feasibility and effectiveness (Liu et al., 2017). The localization of River Chief System extends from the national scale to specific rivers, and even their tributaries, as exemplified by the "One River, One Policy" plan.

River Chief System has been advanced, leading to the proposition of the "One River, One Policy" plan. This initiative addresses the unique characteristics of each river by tailoring regulation schemes to their respective conditions. The ideological underpinnings of "One River, One Policy" plan align with the traditional Chinese principle of "adjusting measures to local conditions" (Lu and Hong, 2014). In September 2017, the General Office of the Ministry of Water Resources issued guidelines for formulating the "One River, One Policy" plan, emphasizing the importance of identifying key issues, setting goals, outlining tasks, designing measures, and assigning responsibilities (the Ministry of Water Resources, 2017). The "One River, One Policy" plan within River Chief System encompasses six primary tasks: water resource conservation, pollution prevention, water environment management, ecological restoration, shoreline oversight, and legal enforcement in water administration. This multidisciplinary approach requires expertise from various fields. Scholars acknowledge the pivotal role of the "One River, One Policy" plan in advancing River Chief System and support its comprehensive implementation (Li and Hu, 2017).

Many scholars use unique cities or rivers as examples to explore the formulation of their "One River, One Policy" plans, analyzing the innovative points that can be referenced and offering suggestions for improvements. The formation of the "One River, One Policy" plan is considered a crucial foundational technical task in the comprehensive implementation of River Chief System and requires multiple areas of improvement (Liu et al., 2017). Wu (2018) presents key points from the preparation of the "One River, One Policy" plan, providing valuable insights for its preparation. Zhao (2018) examines issues in the management and protection of the main stream of the Huai River in Anhui Province and explores its "One River, One Policy" plan. Li et al. (2019b) discuss the compilation method of "One River, One Policy"

plan for urban rivers with a case study of the Qing River Basin in Beijing City, identifying four major issues including objectives, tasks, projects, and responsibilities. In Jiangning District, Nanjing, ensuring effective drainage function of river channels is a key priority in the "One River, One Policy" plan. Through robust management of the "Three Red Lines" for water resources and the deployment of advanced purification equipment, significant improvements in water quality have been achieved, fostering a positive cycle in the river's water environment (Yuan et al., 2018). The "One River, One Policy" plan also effectively addresses the issue of black and odorous water bodies, with appropriate plans formulated through cause analysis (Chen et al., 2019; Chi et al., 2019).

The "One River, One Policy" plan is pivotal for the holistic implementation of River Chief System, the advancement of water environment governance, and the ecological development of rivers and lakes. Yet, given China's vast river networks that traverse varied geographical terrains, there are pronounced disparities in topography, meteorology, hydrology, biological diversity, and regional socio-economic conditions across different watersheds. The nation comprises seven principal river systems: Songhua River, Liao River, Hai River, Yellow River, Huai River, Yangtze River, and Pearl River Systems, each exhibiting distinct attributes. Notably, even rivers from analogous regions can manifest unique differences in their evolutionary nature, hydrological traits, pollution intensities, and ecosystems (Jiang, 2009). As a result, it is imperative to customize governance strategies based on the unique characteristics of each river rather than adopting a universal solution. The exploration of "One River, One Policy" necessitates a synergistic relationship between research and practical application to refine problem-solving and formulate precise strategies in real-world scenarios.

5 Conclusion and discussions

Since the debut of 2007, River Chief System produced in China gained international prevalence. In this review, we first introduce the profile of River Chief System, including its origin, principle and characteristics, and compare it with other international river governance systems. Next, to understand the current research status and characteristics of River Chief System, we review River Chief System related published articles in WOS database and CNKI database based on Citespace. Through literature measurement and systematic review, we identify the current research progress and hot spots. Finally, we put forward enlightenment and prospects for the future development of River Chief System according to the shortcomings and research direction of River Chief System. In general, the number of publications of River Chief System is showing a significant skyrocketing trend featured by increasingly diverse foci. We identified the research hotspots, embodying policy effects of water pollution control, the mechanism of River Chief System, as well as localized policy toolkits, named by "One River, One Policy" at local scale. We also elaborated on its positive short-term effects of this policy, as for resource, hydrological and environmental aspects, while it remains to be seen its long-term effects. Moreover, Chinese academic circle remains the mainstay upon the study of River Chief System, which also opens up spaces of international engagement and transborder collaborative possibilities.

As shown by our study, we suggest considering more studies upon the heuristic effects, not only hydrological and ecological effects, but also economic and social benefits of River Chief System. We advocate for scholars to delve into the integration of River Chief System with alternative governance models. Examples of such integrations could be with ecological compensation mechanisms or ecological protection incentive systems, among others. The ultimate goal is to foster a more diverse and comprehensive governance framework. A reinvigoration of comparative and cross-referenced studies upon the implementation effects of River Chief System at different sites across different temper-spatial scales is urgently needed. This has future implications concerning on the public participation and supervision, and be warier of such questions as how to improve the public's participation and supervision ability in River Chief System, how to establish an effective information disclosure and feedback mechanism, and how to strengthen the interaction and communication between the public and the river chief. Indeed, understanding the motivation of stakeholders to participate in monitoring is crucial for identifying and selecting participants and relevant monitoring indicators (Verbrugge et al., 2017), thus future research also needs to include more types of stakeholders. Moreover, we find that it is also worth combing the history of water governance in China from ancient times to the present and comparing River Chief System with other international water governance system, which remain less-attention potential research question in hydrological and related scholarship.

We advocate for scholars to delve into the integration of River Chief System with alternative governance models. Examples of such integrations could be with ecological compensation mechanisms or ecological protection incentive systems, among others. The ultimate goal is to foster a more diverse and comprehensive governance framework.

Author contributions

CY: Data curation, Methodology, Validation, Visualization, Writing–original draft, Writing–review and editing. TS: Conceptualization, Funding acquisition, Supervision, Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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