



Review article: Global flood research across four decades: An analysis of 57,474 research articles based on a large language model

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Abstract. The proliferation of research literature has resulted in increasingly fragmented information and diversified knowledge structures, making it increasingly difficult to develop a systematic understanding of disciplinary research systems. This study employed a large language model to screen and organize flood research articles from 1985 to 2024, provided visual spatiotemporal insights into the quantity and quality of publications, contributions of institutions and countries, evolution of keywords, research types and topics, as well as the geographic characteristics of river basin and urban units. Findings indicate that annual publications on flood studies now exceed 5,500, with the average number of authors and institutions per publication increasing from 2.1 to 4.8 and from 1.4 to 2.6, respectively. Chinese and American institutions lead in publication quantity, while European and American institutions dominate in research influence. The disciplines of climate and remote sensing have gradually gained an undeniable influence in flood research field. The evolution of keywords focus traces a conceptual progression from “ecological-hydrological system interactions,” through “hydrological and hydrodynamic processes analysis” and “flood disaster prevention and management,” to “flood prediction and risk assessment under climate change.” River flood remains a consistent focus (averaging 55% of research), while urban flood has seen a notable rise in attention (increasing from 8% to 15% over the past decade). Research topics concentrate on management, simulation, monitoring, and risk assessment. River basin flood research has evolved from Mississippi River Basin leadership to bipolar dominance with the Yangtze River Basin. Urban flood research has shifted from leadership by Texas in the United States to a dual-core structure with Guangdong Province in China. This study aims to advance the application of large language models in flood research literature review, thereby enabling a more systematic and efficient understanding of the comprehensive characteristics of the field’s development.



30 1 Introduction

The world is suffering an extended period of climate change with multiple and increasing environmental and society-wide risks (Ekins et al., 2019). Among the most common and widespread extreme events, flood disasters have continuously increased in frequency, intensity, and spatial extent over the past decades (Tanoue et al., 2020; Troin et al., 2021). Compounding factors such as population growth, accelerated urbanization, and degradation of river basin ecosystems have
35 further exacerbated flood risks, making flood governance one of the central challenges in the global pursuit of sustainable development (Armstrong, 2012).

Over the past four decades, the widespread application of remote sensing, geographic information systems, high-performance computing, distributed hydrological models, big data and artificial intelligence has profoundly transformed the paradigm of flood research (Laidlaw and Percival, 2024; Ganguli and Merz, 2025). The field has evolved from a discipline
40 focused solely on river hydrology into a highly interdisciplinary domain integrating hydrometeorology, geography, hydraulics, engineering, computer science, and social sciences (Zounemat-Kermani et al., 2021; Saha and Pal, 2024). Research priorities have also shifted from physical process modeling toward broader concerns such as risk perception, disaster governance, and social resilience assessment (Guo et al., 2024; Zhang and Huang, 2024; Deo et al., 2025). While
45 this expansion has broadened the scope of flood research and increased methodological diversity, it has also raised growing concerns about knowledge fragmentation and information redundancy, issues particularly pronounced amid the exponential growth of academic publications (Rahman et al., 2022). This trend poses a critical question: How can structured, inferable knowledge be efficiently extracted from vast and heterogeneous unstructured texts, and how can multi-scale cognitive maps be constructed to represent the evolving landscape of flood research? Addressing these challenges is not only a matter of information integration efficiency, but also the foundation for determining whether hydrological science can advance to a
50 new phase of systematic understanding.

Literature reviews often rely on structured approaches, such as bibliometric analysis and meta-analysis (Van Raan, 1996; Hernandez et al., 2020). By systematically retrieving flood research outcomes and conducting qualitative or quantitative assessments and syntheses, researchers have made significant contributions to the development of flood-related knowledge. For instance, Lopes et al. (2025) performed a bibliometric analysis of 498 publications on flood resilience and risk
55 management from 1994 to 2023 to evaluate scientific progress in integrating disaster resilience into flood risk management. Zhu et al. (2025) conducted a bibliometric analysis of 454 academic articles on Natural Flood Management (NFM) from 1991 to 2023, evaluating the impact and effectiveness of NFM on flood characteristics. Byaruhanga et al. (2024) carried out a meta-analysis of 280 research literature on flood forecasting models from 1993 to 2023 to assist in model selection for flood prediction. Additionally, other scholars have conducted literature reviews on urban rainfall-runoff modeling (Nanda et
60 al., 2025), urban flood resilience assessment (Gao et al., 2022; Prashar et al., 2023), flood susceptibility, vulnerability and risk analysis (Rindsfuser et al., 2024; Ali et al., 2025), and methods for quantifying the impacts of climate change and urbanization on compound flooding (Ruan et al., 2024). However, traditional review studies face two major limitations. First,



meta-analysis typically covers a limited number of publications, usually no more than a few hundred, as this process involves a significant amount of manual effort (Gurevitch et al., 2018; Xu et al., 2022). Second, bibliometric analyses focusing on publication statistics are often restricted to surface-level metrics, such as keywords, journal distributions, and citation indicators (Wallin, 2005; Romanelli et al., 2021). These limitations are primarily driven by the exponential growth of academic literature, which makes it increasingly difficult for individual researchers to capture the dynamic and expanding knowledge perspective. Meanwhile, the substantial time and labor costs required to build structured literature databases from scratch often restrict the feasibility of customized bibliometric studies targeting specific methodologies or research themes. While such efforts remain feasible on a scale of thousands of documents, they clearly become unsustainable as the volume of domain knowledge expands to hundreds of thousands.

Faced with the dual challenges of massive accumulation of literature information and continuous expansion of knowledge structure, the development of large language models (LLMs) is fundamentally changing the working paradigm of literature review. It is like an efficient research assistant, freeing researchers from the knowledge sea of information overload and enabling them to focus on the high-value activities: raising key questions, conducting deep critical thinking, establishing innovative connections, and constructing theoretical frameworks (Han et al., 2024; Patil and Gudivada, 2024; Scherbakov et al., 2025). Trained through self-supervised learning on massive text corpora, LLMs can screen key information, identify semantic structures, infer conceptual relationships, and reconstruct knowledge networks from unstructured data (Luo et al., 2024; Smajic et al., 2025). This progress is transforming the traditional review process that has long relied on expert experience and manual synthesis into a more automated and systematic knowledge extraction mode (Lee et al., 2025), and has shown good results in review applications in fields such as medicine (Guo et al., 2024; Delgado-Chaves et al., 2025) and software engineering (Hou et al., 2024; Felizardo et al., 2025). Especially in the field of water resources, Miao et al. (2024) integrated an LLM with geographic coding to analyze the research characteristics of 310,000 publications related to hydrology from 1980 to 2023 across spatiotemporal scale, examining aspects like publications, keywords, institutions, countries, and basin attention. He et al. (2025) combined bibliometric analysis with an LLM to comprehensively review 3,106 literature from 1980 to 2025 on remote sensing applications in river obstruction research, analyzing features including publications, involved disciplines, keywords, countries, institutions, and basin attention. Jiang et al. (2022) proposed a natural language understanding-based deep clustering approach to conduct a meta-analysis of thematic evolution patterns in 130,000 lake-related research literature from 1900 to 2020. From the above research trends it suggests that LLM overcome limitations imposed by the sheer volume of literature and can efficiently provide researchers with extensive information, including research publications, keywords, authors, institutions, regions, types, topics, methods, etc. Depending on the research question, it may also include relevant information such as publication types, citations, collaborative networks, distribution patterns, and shifts in research hotspots (Tanaka and Sakata, 2016; Kim et al., 2023; Hassan and Duarte, 2024). This provides researchers with systematic and comprehensive insights, background, and a deeper understanding of research trends and impacts. Therefore, it is still necessary to fully leverage the cognitive potential of LLMs in reasoning and concept



reconstruction and further explore the development space of literature review research in the horizontal condensation of knowledge structure and the vertical depth of research perspective (Tang et al., 2025).

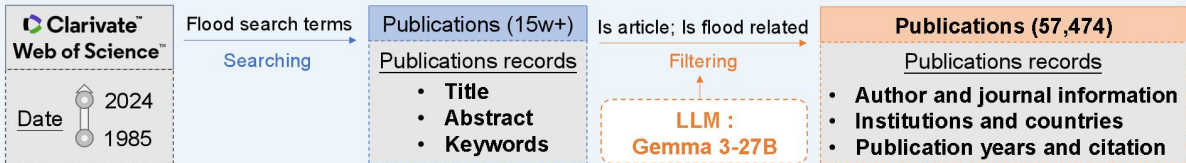
Currently, there is a lack of systematic literature review in the field of flood research. This study aims to advance the application of LLM in flood research literature reviews, with particular emphasis on gaining insights into its spatiotemporal dimensions and objective knowledge structures. This study retrieved 150,000 publications related to floods from Web of Science (WoS) between 1985 and 2024, filtered 57,474 research articles closely related to flood themes using the semantic recognition function of integrated LLM. Furthermore, it identified and analyzed deep-level information such as the types, topics, methods, and geographic locations of each flood study from the corresponding publication. Through methods including indicator statistics, word clouds, collaborative networks, and geographic distribution mapping, the quantity and quality of publications, contributions of institutions and countries, evolution in keywords, research types and topics, and geographic characteristics of river basin and urban units were visualized and analyzed from the spatiotemporal dimensions. This work comprehensively demonstrates the evolution of global flood research, systematically constructs flood knowledge and research organizational structure, and dissects thematic characteristics from diverse perspectives like river basin and urban, thereby providing a fundamental cognitive framework for understanding the development of flood research system.

2 Materials and methods

The LLM-based review and analysis of flood-related literature comprises three steps: metadata collection, in-depth information extraction, and data-driven interpretation, with the framework illustrated in Fig. 1. The metadata collection module involves searching and screening relevant literature to establish the foundational database for this study. The in-depth information extraction module focuses on identifying and categorizing information related to flood research types, themes, methods, and regions, etc., to construct the knowledge structure for the aspects of interest in this research. The data-driven interpretation module entails bibliometric evaluation and visual representation of multi-level information, providing a clear perspective for comprehensive and in-depth analysis.

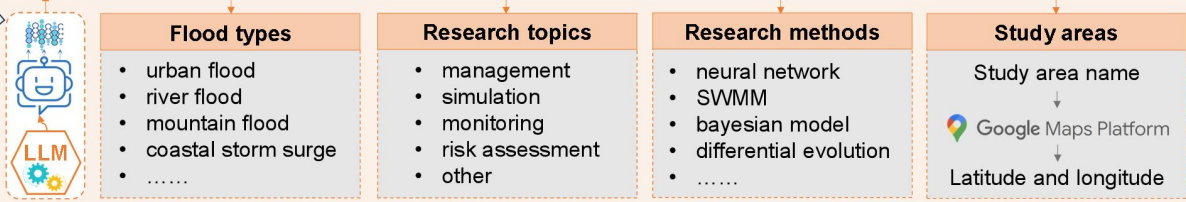


Step 1: Metadata collection



● Basic information database for flood research articles in this study

Step 2: In-depth information extraction



Step 3: Data-driven interpretation

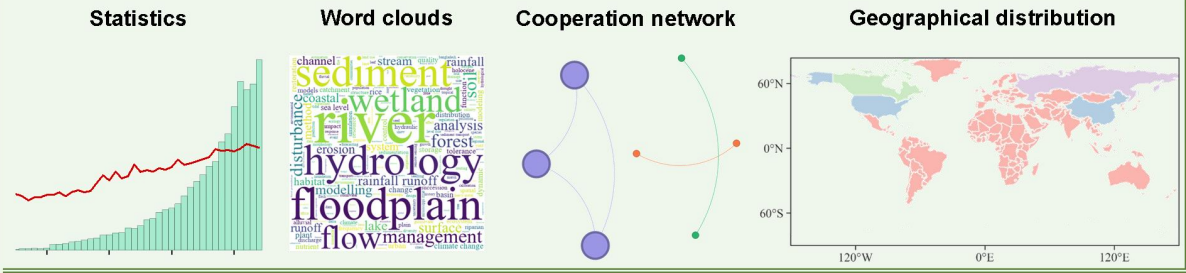


Fig. 1 The framework for reviewing and analyzing flood research.

2.1 Deployment of LLM framework

Gemma 3-27B, the most powerful version of the Gemma 3 series developed by Google DeepMind, serves as the foundational framework for the LLM in this study. Released on March 12, 2025, and freely available to developers through Google AI Studio, Gemma 3-27B demonstrates strong capabilities in long-context understanding, code generation, and multimodal tasks (Kamath et al., 2025), making it particularly suitable for extracting and reasoning from large volumes of textual data in this research. The LLM enables efficient structured parsing of publications by employing specific prompts designed to guide the model toward focused information extraction. All parsing prompts used in this study are provided in Appendix A1.

2.2 Metadata collection

The metadata collection was completed on 14 May 2025 using the Web of Science database, and the publication time span of the flood-related literature is from January 1985 to December 2024, totaling 40 years. To comprehensively cover the



diverse topics and disciplinary perspectives of flood research, 29 search terms (e.g. “Flood” and “Flooding”, details in Appendix A2) were defined and queried independently. To ensure that the included publications possess high academic originality and research value, the document type was restricted to “Article,” thereby systematically excluding review articles, conference papers, book reviews, and other literature with limited originality. After deduplication, 57,474 article records were obtained, and core metadata including titles, abstracts, keywords, journal names, publication years, and citation counts were extracted. The complete text of the “Author Information” section in each publication was parsed using LLM to directly extract the first corresponding institutions, all author affiliations, and their associated countries.

2.3 In-depth information extraction

The in-depth information extracted by the LLM primarily includes the study areas, flood types, research topics, and research methods. After extracting the names of study areas using the LLM, they were converted into geographic coordinates (latitude and longitude) via the geocoding API of Google Maps. Flood types were categorized into urban flood, river flood, mountain flood, coastal storm surge, ice flood, dam break flood, snowmelt flood, tsunami, and groundwater flood. This was a multi-label classification task, with any category not included in the predefined list classified as “other”. The same rule applied to research topics, which include management, simulation, monitoring, and risk assessment.

2.4 Data-driven interpretation

To facilitate quantitative statistics, correlation analysis, and visual representation of the collected data, this study adopted several representative quantitative indicators and visualization techniques, including academic collaboration intensity, influence index, collaborative network, word clouds, and geographic mapping. Academic collaboration intensity is the indicator used to evaluate the workload and complexity of research, which is measured by calculating the average number of authors or institutions per publication. The influence index is the indicator used to demonstrate the quality of articles within a research scope (covering a journal, institution, or country), which is assessed based on the average number of citations per article within the scope. Co-occurrence network analysis is employed to identify textual similarities under the same research topic, based on the visualization of similarities (VOS) method proposed by Van Eck and Waltman (2007). Gephi software is used to visualize collaborative networks (Bastian et al., 2009), aiming to explore collaborative relationships among keywords, institutions, and countries in this study. Among them, the size of nodes represents the frequency, and the thickness of connecting lines reflects the frequency of co-occurrence between nodes. Clustering is performed using the Louvain algorithm (Blondel et al., 2008), with different clusters represented by distinct colors. Word clouds are used to analyze keyword frequency, displaying the top 200 most frequent keywords; the larger the keyword appears, the higher its frequency ranking. During the construction process, the word cloud map filters common words with high frequency but low information, including [“flood”, “floods”, “flooding”, “model”, “water”] to avoid interference with trend recognition. The spatial distribution is analyzed at the river basin and urban scales, highlighting differences in research focus and objectives



across these distinct units, with the boundaries used detailed in Appendix A3. To facilitate understanding of temporal variation, the period from January 1985 to December 2024 was divided into eight 5-year intervals for analysis.

3 Multi-perspective analysis of results

165 3.1 Quantity and quality of publications

The LLM conducted a statistical analysis of the annual number of flood-related papers, the proportion of journals, and the journal influence factors from 1985 to 2024, as shown in Fig. 2. In terms of publication trends, Fig. 2a shows that over the past 40 years, the annual number of papers related to floods has been continuously increasing, especially since 2010 when the growth rate has been particularly fast. In 2024 alone, the number of publications reached 5,672, exceeding the total
170 number published over the 15-year period from 1990 to 2004 (5,574 publications). This notable surge reflects growing attention and investment in flood management at both policy and practical levels. The number of authors and institutions per publication reflects the breadth and depth of scientific collaboration. In 1985, each paper had an average of only 2.1 authors and 1.4 institutions, while by 2024, these numbers had increased to 4.8 authors and 2.6 institutions per paper. This trend suggests that under the growing challenge of frequent extreme hydrological events, flood-related research has become more
175 complex, and such changes may also be attributed to the continuous growth of the global research community, the expansion of education, and the improvement of international collaboration platforms.

This study ranked the impact of journals closely related to hydrology (under the subcategory of "Water Resources" in Web of Science, details in Table S1), with the top 15 as shown in Fig. 2b. The full names and corresponding abbreviations of journals are shown in Table S2. Journal of Hydrology (99.8) and Water Resources Research (98.1) exhibit both high average
180 annual paper cite. Other impactful water-related journals include Wetlands Ecology and Management (74.9), Water Research (67.3), and Wiley Interdisciplinary Reviews: Water (57.3). In addition, this study also ranked the impact of journals related to hydrology with over 100 publications, with the top 15 as shown in Fig. 2c. Journal of Hydrology and Water Resources Research continues to rank highly, reaffirming their leading status in both influence and productivity. Notably, several journals outside the "Water Resources" category also show strong citation performance in flood-related studies, such as
185 Climatic Change (95.9), Remote Sensing of Environment (94.9), Journal of Climate (94.0), and Risk Analysis (92.5). Detailed data can be found in Appendix A3. This trend suggests that future evaluations and bibliometric analyses should consider a broader range of journals across disciplines, rather than being narrowly confined to a single classification system.

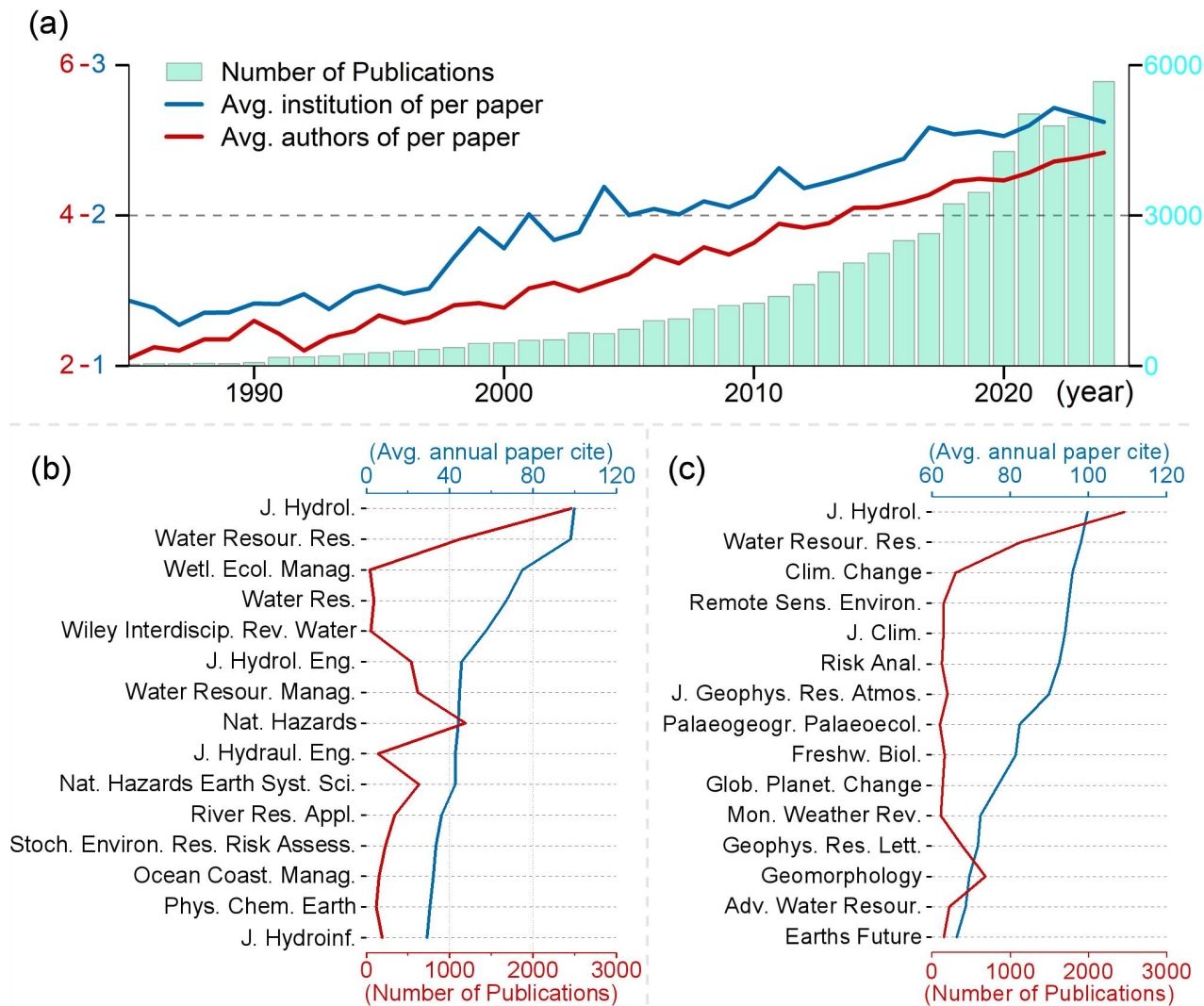


Fig. 2 Annual statistics of publication volume and journal impact. (a) Annual publication count, average author and institution number of per publication; **(b)** The top 15 journals with the highest impact, along with the cumulative number of publications. The journals under the subcategory “Water Resources” of WoS are included in the ranking. **(c)** The top 15 journals with the highest impact, along with the cumulative number of publications. The journals with at least 100 publications are included in the ranking.

3.2 Contributions of institutions and countries

The ranking of institutions and countries focuses on the first publishing institution, aiming to more accurately reflect the core driving forces and main contributors of scientific research output. In terms of volume of publications (Fig. 3a), flood research results mainly come from Chinese and American institutions. The Chinese Academy of Sciences (CAS) has become the world's most productive institution with 1282 publications (2.2% of the total publications), and the United States Geological Survey (USGS) also ranks among the top five with 429 publications. In addition, the Russian Academy of



Science in Australia and Vrije University Amsterdam in the Netherlands also rank in the top 15. Institutional influence
200 exhibits a distribution pattern distinct from publication volume (Fig. 3b). High-impact institutions mainly come from the
United States, the Netherlands, and the United Kingdom. Among them, the University of Arizona (the United States) leads
with an average citation performance of 115.1 per article, and Vrije University Amsterdam (Netherlands) ranks third (84.5),
followed closely by the University of Bristol (United Kingdom) at 82.3. Other institutions within the top 15 include
Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Japan's The University of Tokyo.
205 Among the top 15 countries in terms of total publication volume (Fig. 3c), the United States (10982) and China (8792) rank
in the first tier with a high publication volume advantage, while the UK, India, Germany, and others form the second tier
(911 to 3380). Moreover, in terms of the proportion of publications per year (Fig. 3d), these 15 countries account for
approximately 70% of the global total annual publications. Compared to others, the fluctuations in the reduction of
publishing share in the United States and the growth of publishing share in China are more pronounced. However, the
210 number of publications is not significantly proportional to their influence, and the influence of publications (Fig. 3e) is
clearly biased towards European and American countries. Switzerland ranks first with an average per article citation of 49.4,
and the Netherlands, UK, USA, Austria, and Belgium all have an average per article cite of over 40. In addition, in the past 5
years (Fig. 3f), the country with the highest influence is Vietnam (19.3), followed by Singapore, Austria, Finland,
Netherlands (>14). More and more key forces are being integrated into the group driving the evolution of global
215 hydrological science frontiers.

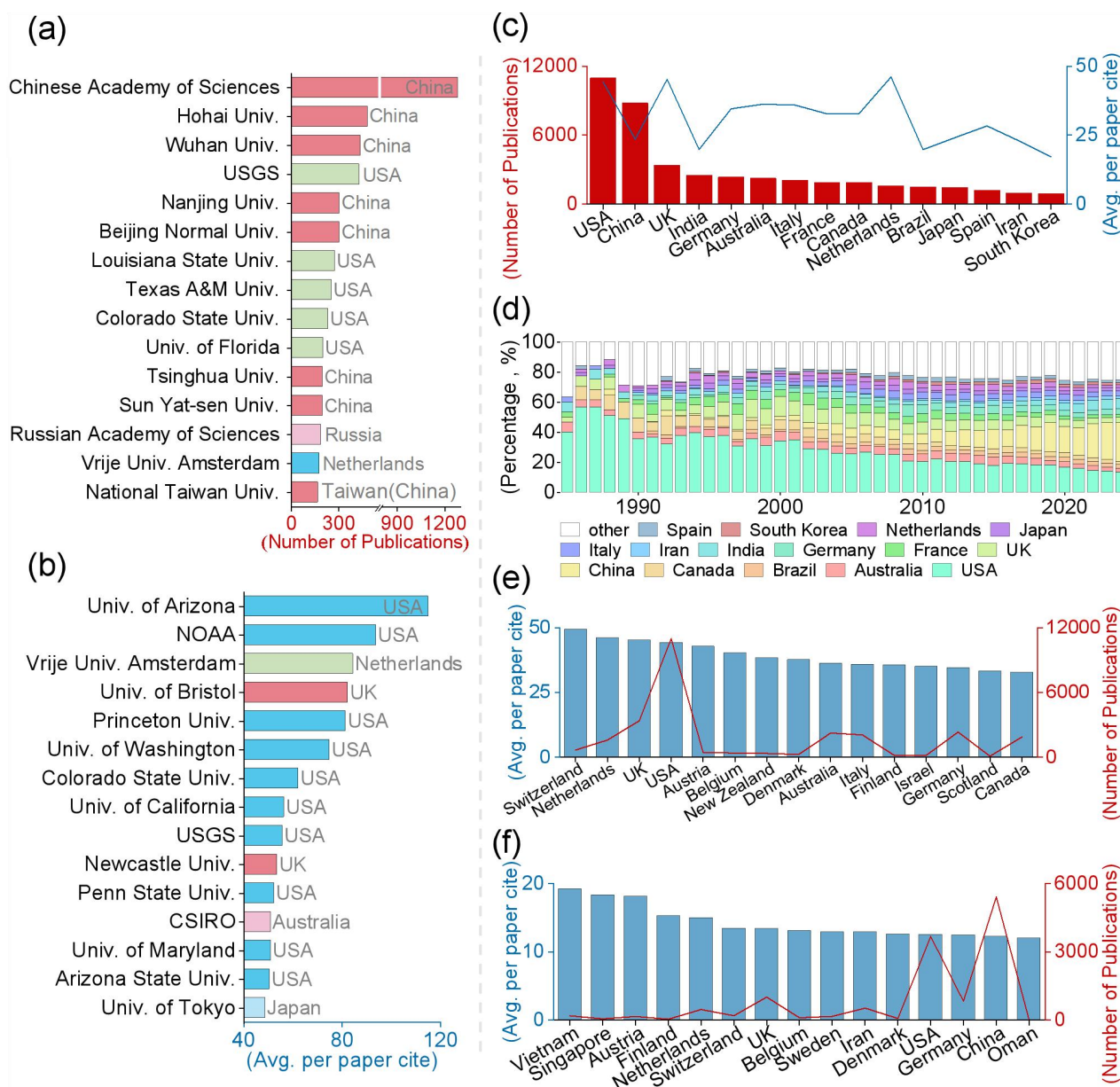


Fig. 3 Contributions and rankings of institutions and countries. (a) Top 15 institutions by number of publications. (b) Top 15 institutions by impact based on the average number of citations per article. (c) Top 15 countries by number of publications. (d) Annual trends in the share of publications in these countries. (e) Top 15 countries by impact based on the average number of citations per article; only countries with over 100 publications are included in the ranking. (f) Top 15 countries by impact based on the average number of citations per article over the past 5 years; only countries with over 100 publications are included in the ranking.

In the past 40 years of flood research, 69.6% of publications were the research of multi-institutional collaboration, with cross-border collaboration accounting for 31.1%. Fig. 4 shows the cooperation network of institutions. A central hub identified by green clusters, gathering numerous institutions such as Massachusetts Institute of Technology, Stanford



225 University, ETH Zurich, and the University of Cambridge. It has extensive international cooperation and active scientific
research exchanges, jointly forming a cooperative group for global flood research. Meanwhile, there are also several regional
clusters coexisting in the network. The yellow line network represents the French cluster, which includes institutions such as
the Conseil National de Recherches Scientifiques, Centre National de la Recherche Scientifique and University of
Montpellier. The gray line represents the United States cluster, which includes institutions such as the National Oceanic and
230 Atmospheric Administration, the United States Geological Survey and California Institute of Technology. The blue line
network represents some European clusters represented by the Netherlands and Italy, such as the Vrije Universiteit
Amsterdam in the Netherlands and the University of Bologna in Italy. The purple line network represents the Chinese cluster,
and a significant structure centered around CAS is observed. CAS collaborates with institutions such as Nanjing University,
Hohai University, and Wuhan University to form close cooperative connections with other regional clusters. The red line
235 network represents the Australian cluster, including institutions such as the University of New South Wales and Australian
National University, which have close cooperative connections with China and Singapore.

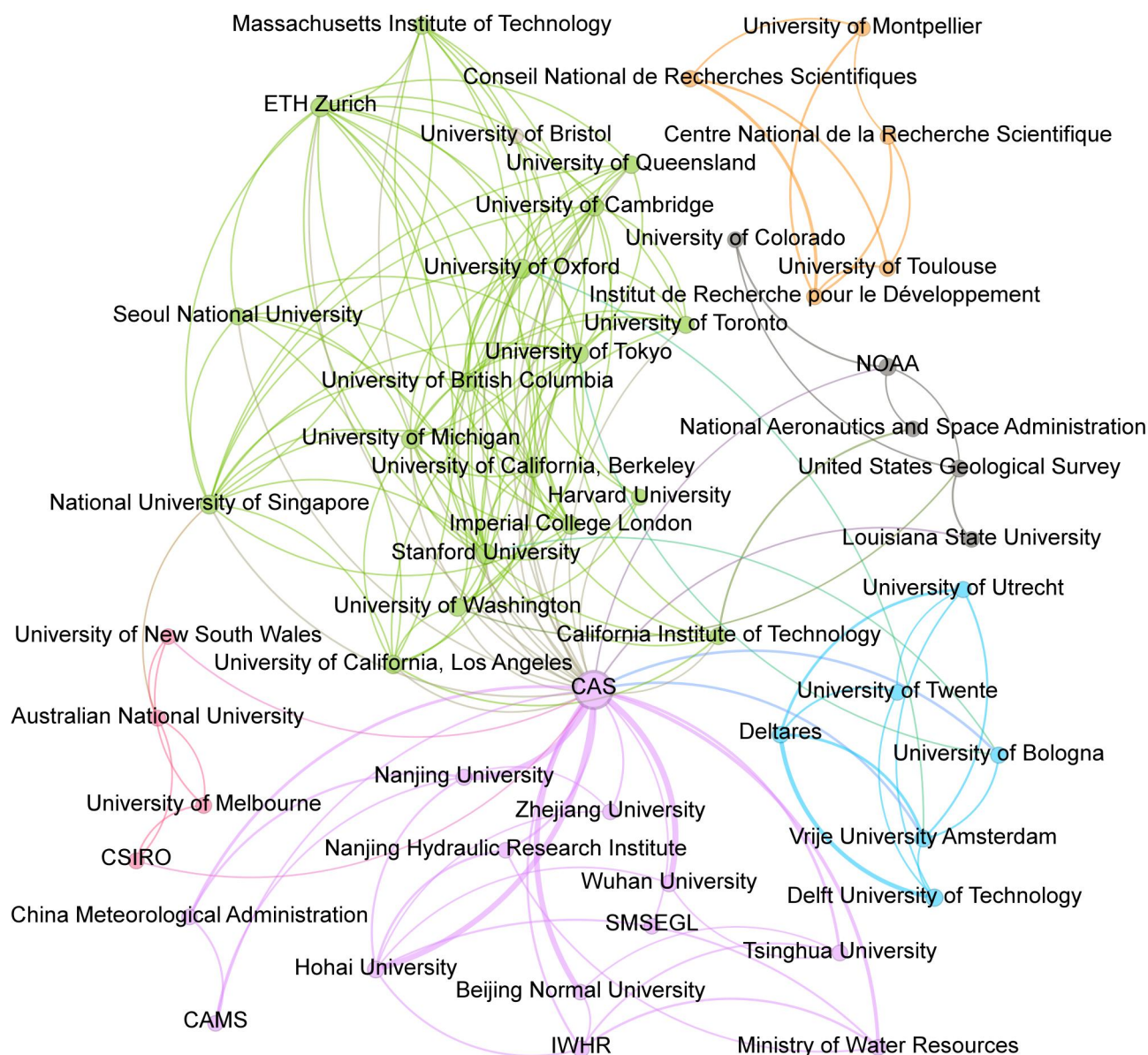


Fig. 4 Cooperation network of institutions. Institutions have been categorized into different clusters using co-occurrence clustering methods, and distinct clusters are represented by different colors.

240 3.3 The dynamic evolution process of keywords

The temporal evolution of keywords reveals a nuanced and continuous transformation in the cognitive structure and thematic priorities of flood-related research, reflecting the field's progression from disciplinary exploration to transdisciplinary integration. As shown in the keywords cloud (Fig. 5), early studies during 1985–1990 (Fig. 5a) were predominantly rooted in ecological and hydrological fundamentals, with high-frequency terms such as riparian, wood, dynamics, and ecotone



245 (Decamps et al., 1988; Groeneveld and Crowley, 1988), underscoring a scholarly focus on natural landscape evolution and the ecological dynamics of fluvial–terrestrial interfaces. Entering the 1990s (Fig. 5b and c), the vocabulary began to shift toward plume, sludge, channel, sediment, and wetland (Sirin et al., 1991; Rumsby and Macklin, 1994; Toner and Keddy, 1997), suggesting an expanding interest in sediment transport processes, river morphology, and wetland systems, marking a transition from static ecological descriptions to dynamic process-oriented analyses. This momentum further evolved between 250 2000 and 2004 (Fig. 5d), when keywords such as management, floodplain, and hydrology rose to prominence, indicating a paradigm shift toward integrated floodplain governance and holistic hydrological assessments that recognize the complexity of human–environment interactions (Kondolf et al., 2002; Kesel, 2003). From 2005 onwards (Fig. 5e to h), the emergence and subsequent dominance of climate change as a central keyword, alongside risk, modelling, management, and rainfall (Nogués-Bravo et al., 2007; Li et al., 2009), reflect a strategic reorientation of flood research toward understanding and 255 mitigating climate-driven hydrological extremes, situating flood studies firmly within the broader discourse of global environmental change. The increasing salience of urban flood and forecasting during 2010–2019 (Fig. 5f and g) further illustrates a rising concern with real-time prediction and early warning systems in the context of rapid urbanization and infrastructural vulnerability (Fernandez and Lutz, 2010; Chen et al., 2015). Since 2020 (Fig. 5h), the lexicon of the field has been further transformed by a surge in data-driven and artificial intelligence methodologies (Donnelly et al., 2024; 260 Mangukiya and Sharma, 2024). The evolving lexicon reflects a shift from core fundamentals to interdisciplinary problem-solving, aligning with global priorities in disaster resilience and climate adaptation.

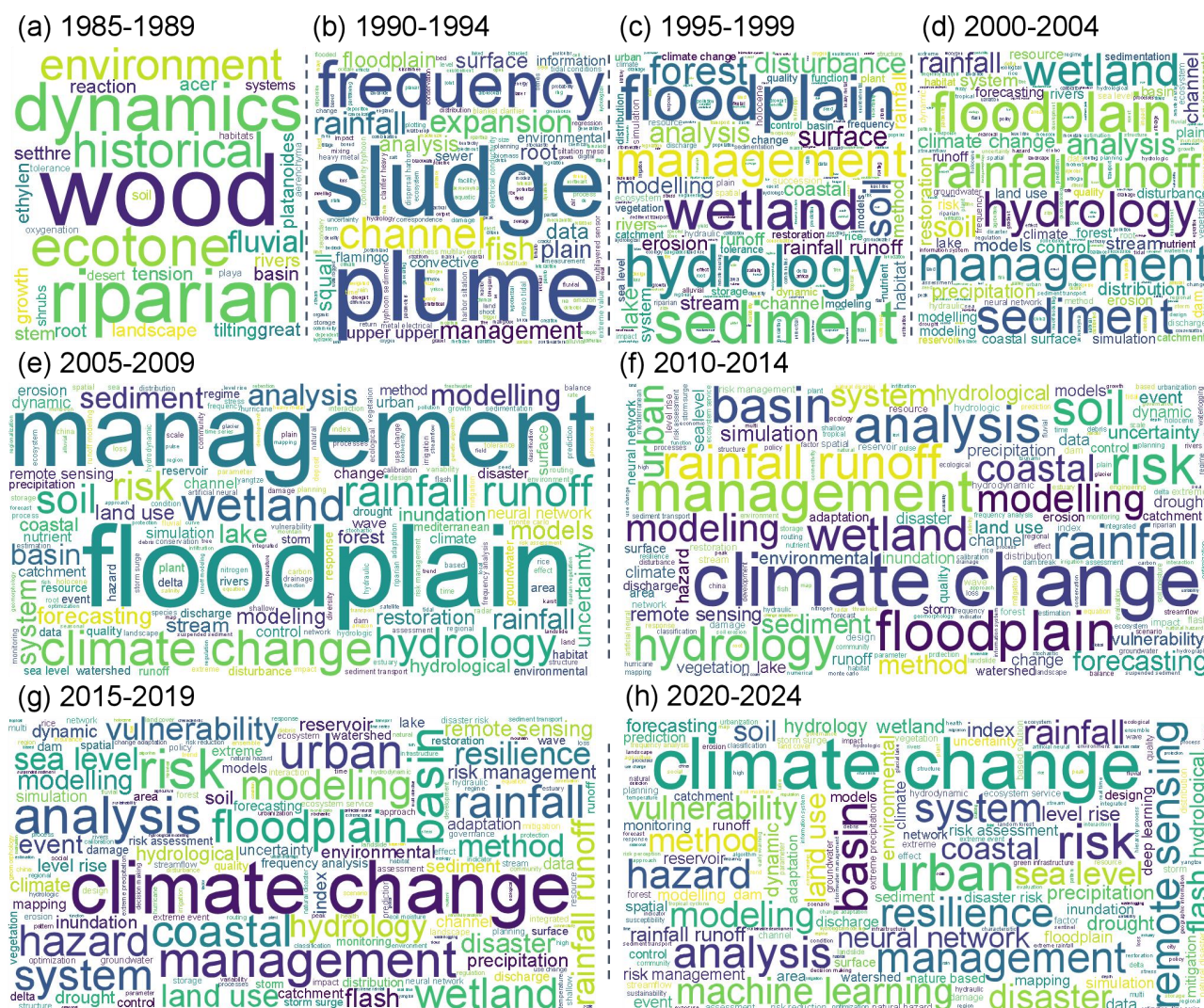


Fig. 5 Word clouds of keywords across different periods. The words in the figure represent the top 200 keywords with the highest frequencies of occurrence in the publications.

3.4 Types and topics of flood research

Fig. 6 presents the evolution trend of flood research types and topics in a proportional manner. In terms of flood research types (Fig. 6a), river flood has always dominated and is the most common and widely studied type in flood events (averaging 55% of research). The proportion of urban flood has shown a significant upward trend (increasing from 8% to 15% over the past decade), reflecting the acceleration of global urbanization and the increasing vulnerability of urban areas to flood disasters, prompting a shift in research focus towards the resilience of urban flood control and drainage systems. Coastal storm surge and mountain flood occupy a secondary but important share in the total research volume (averaging proportions of 8% and 7%, respectively), with coastal storm surge showing an upward trend while mountain flood remains relatively

stable. In contrast, the proportion of other flood types (such as snowmelt flood, ice flood, and dam break flood) has always been small, showing relatively low attention and output. In terms of flood research topics (Fig. 6b), LLM identified five categories: management, simulation, monitoring, risk assessment, and others. The research on the first four themes accounts for the vast majority and the proportion is relatively balanced. Risk assessment and management themes are showing a continuous upward trend, reflecting the increasing global emphasis on quantitative analysis of potential flood risks and safety management. In contrast, the proportion changes of simulation and monitoring topics are relatively limited, which may be related to the maturity of simulation tools and monitoring technologies or the wider integration of their research content into risk-assessment and management frameworks.

The commonly used methods for flood research types and topics are statistically analyzed and ranked (Fig. 6c). Overall, the hot methods in flood research can be summarized into three categories: data collection techniques, data analysis methods, and hydrological and hydrodynamic models. Remote sensing technology has become the main means of data collection in recent years, providing diverse avenues for obtaining high-quality data. The data analysis method focuses on three aspects: hydrological data improvement, correlation feature extraction, trend discrimination and prediction, in order to establish a fully representative sample database. Hydrological and hydrodynamic models include the common variable infiltration capacity model, lisflood-fp, hec-hms, hec-ras, SWMM, SWAT, etc.

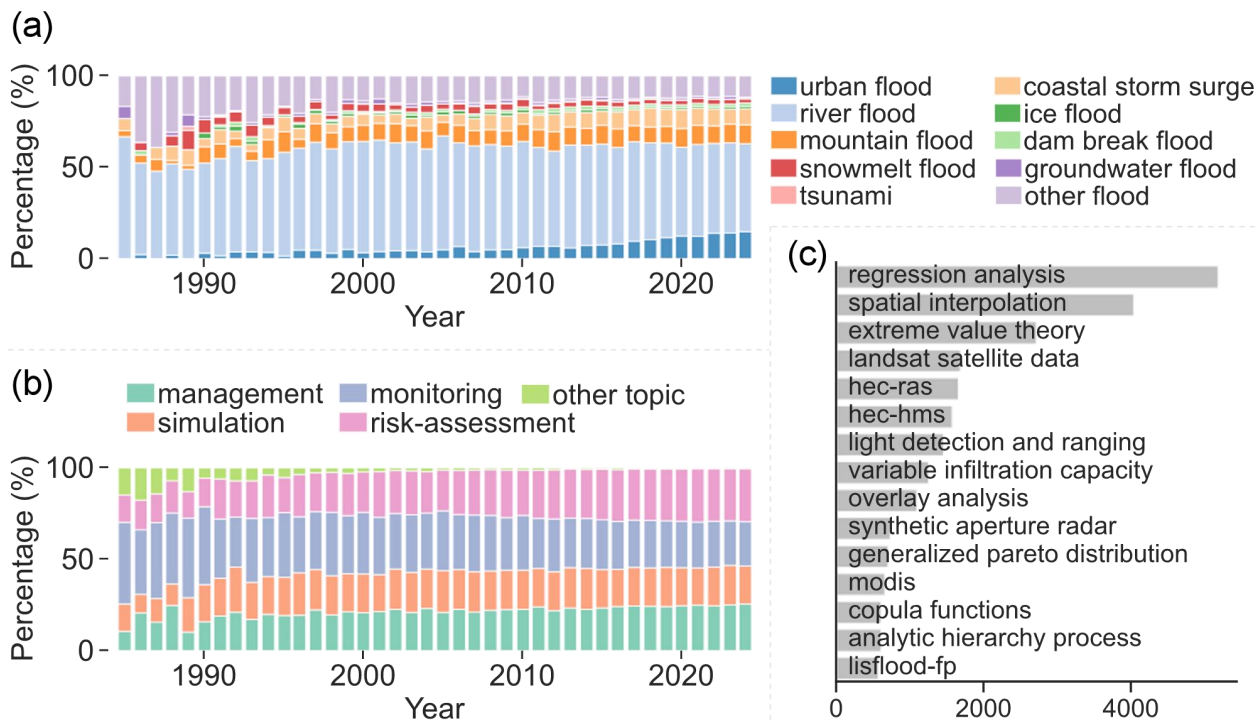


Fig. 6 Annual proportional changes and commonly used research methods statistics of flood research types and topics. (a) Annual distribution of flood research types. (b) Annual distribution of flood research topics. (c) The top 15 commonly used research methods in different flood research types and topics.



3.5 Geographical distribution characteristics of river basin and urban units

Through semantic parsing of 57,474 publications using the LLM, this study geographically identified 46,791 research areas. Based on differences in flood driving mechanisms and the impacts of human activities, floods are divided into two categories: river basin floods and urban floods, aiming to reveal the spatial preferences and evolutionary patterns in global flood research. The reason is that river basin floods (including river floods, mountain floods, storm surges, etc.) are usually closely related to natural factors such as topography, climate conditions, and hydrological cycles, with larger spatial scales of considerations. The research focus usually includes river basin rainfall-runoff analysis, hydraulic connections between rivers and lakes, and ecosystem impacts. In contrast, urban floods occur mainly in cities or urbanized areas, are considered at a smaller scope, and are more significantly influenced by human activities like urban planning, land use changes, and drainage system composition. Consequently, research on urban floods predominantly concentrates on the permeability characteristics of underlying surfaces, the hydrological and hydrodynamic coupling between surface runoff and underground pipe networks, as well as urban resilience assessment.

The geographical evolution of global river basin flood research focus is shown in Fig. 7. ① During 1985–1989, the United States held a global lead in computer hydrological modeling and remote sensing applications, leading to the formation of a unipolar dominant region for flood research centered in central North America. The Mississippi River Basin, covering the mid-southern part of North America, emerged as the global high-intensity core research area. The Saint Lawrence River Basin, spanning the mid-eastern part of North America, was a secondary research area. This was supplemented by several other sporadic hotspots: the Columbia River Basin and Colorado River Basin (mid-western North America), the Thames River Basin (northwestern Europe), the Murray River Basin (southeastern Oceania), the Nile River Basin (northeastern Africa), etc. ② From 1990 to 1994, the convening of the Rio Earth Summit propelled “global change” research (including climate change and land use change) to the forefront, driving a diffusion of flood research activity to surrounding basins. Research interest increased in the Mackenzie River Basin in northwestern North America (a Canadian high-latitude region), the Parana River Basin and Amazon River Basin in central South America (the world's largest river and tropical rainforest system), the Rhone River Basin in southwestern Europe (two major floods have caused significant impacts), and the Pearl River Basin in southeastern Asia (a forefront of China's reform and opening-up). ③ During the period of 1995–1999, against the backdrop of the development of the EU Water Framework Directive, transboundary European river basins like the Danube and Rhine gained significantly elevated research status, with their research activity ranking at the third tier globally in flood studies. ④ Between 2000 and 2004, the EU Water Framework Directive officially entered into force, while the Three Gorges Project (the world's major water conservancy hub) commenced impoundment in China. The pattern of secondary research areas expanded from the central North American river basins (St. Lawrence and Colorado River Basins) to include western European basins (Rhine and Thames River Basins) as well as the eastern Asian basin (the Yangtze River Basin). ⑤ During 2005–2009, with the deepening and integration of EU research, the secondary research areas of Western Europe developed systematically, forming contiguous research areas in the Rhine, Danube, and Elbe river basins. ⑥ During



325 2010–2014, sustained economic growth in countries like Brazil and India led to increased investment in scientific research. Their research outputs began gaining international recognition, resulting in the Paraná River Basin in south-central South America and the Ganges River Basin in southern Asia being elevated to secondary research areas. ⑦ The period 2015–2019 witnessed the Mississippi River Basin and the Yangtze River Basin standing as dual cores of global flood research, forming a bipolar dominant pattern (North America-Asia). Both basins face comprehensive management challenges under the
330 intervention of large-scale human activities, such as waterway regulation and mega-dams, giving them global paradigmatic significance. ⑧ From 2020 to 2024, international cooperation remained active, leading to a more diversified and networked research landscape. Research focus intensified on representative regions such as the Nile River Basin in northeastern Africa (facing concurrent water scarcity and flood risks), the Yellow River Basin in eastern Asia (experiencing changing water-sediment regimes and flood control pressures), and the Pearl River Basin (ensuring security for its major economic bay area
335 under composite storm surge flood threats).

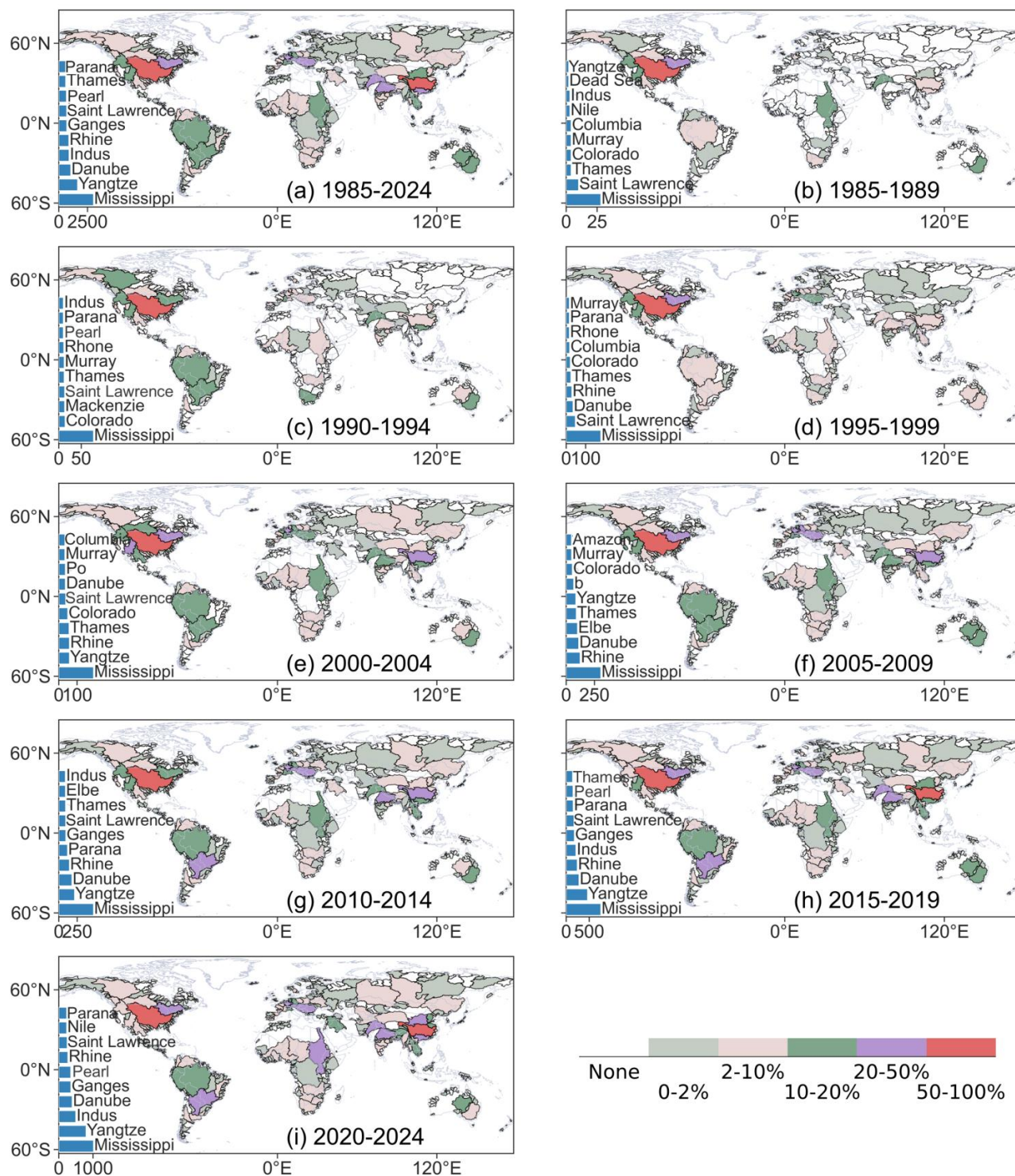


Fig. 7 The percentage of the basin where the research area of river basin floods is located across different periods. The bar chart in the bottom left corner of each subgraph displays the top 10 basins.



As shown in Fig. 8, among the keywords of the top ten river basins, climate change stands out as the primary driver of river basin flood research activities. The research paradigms are analyzed based on the physical geography of the river basin, combined with social attributes and historical development contexts. The Mississippi River and Saint Lawrence River are major river basins in North America that serve as vital economic corridors. They face flood threats from heavy rainfall, snowmelt, ice, and storm surges. The Mississippi River Basin enhances its flood prediction capabilities through advanced technologies such as remote sensing and machine learning (Palash et al., 2024; Rostami et al., 2024), while the Saint Lawrence River Basin employs quantitative analysis and numerical modeling to identify flood risks in estuarine and coastal regions under climate change impacts (Didier et al., 2019; Ebtehaj and Bonakdari, 2022). The Yangtze River and Pearl River are “economically driven” basins in Asia, threatened by heavy rainfall, snowmelt, and tropical cyclone-induced storm surges. Through the regulation of river–lake interactions by major water projects, integrated flood control safety and refined water resource management can be achieved (Ren et al., 2021; Tang et al., 2023). The Indus River and Ganges River are “religiously driven” basins in Asia, characterized by prominent geopolitical attributes. They face flood risks from heavy rainfall, snowmelt, ice, and coastal storm surges. Research in these basins focuses on assessing flood resilience across upstream and downstream regions to strengthen their leverage in international negotiations (Khan et al., 2020; Singh et al., 2023). The Danube, Rhine, and Thames represent three distinctive European river basins, respectively notable for flowing through multiple countries, possessing advanced industrial and shipping economies, and bearing profound historical–cultural heritage. The Danube and Rhine are mainly threatened by heavy rainfall and snowmelt floods, while the Thames faces flood risks from heavy rainfall and storm surges. The Danube River Basin emphasizes transboundary collaborative flood risk management (Blazquez et al., 2021; Eder et al., 2025), the Rhine River Basin focuses on hydrological modeling and ecosystem-based solutions to ensure flood safety and promote sustainable development (Halbe et al., 2018; Imhoff et al., 2020), and the Thames River Basin focuses on enhancing predictive capabilities for key flood factors through simulation technologies (da Costa et al., 2020; Fidal and Kjeldsen, 2020). The Paraná River, a major international shipping artery in South America and home to the world's largest tropical wetland, prioritizes research on flood mechanisms and their relationship with floodplain ecosystems (Lima et al., 2017; de Oliveira et al., 2020).

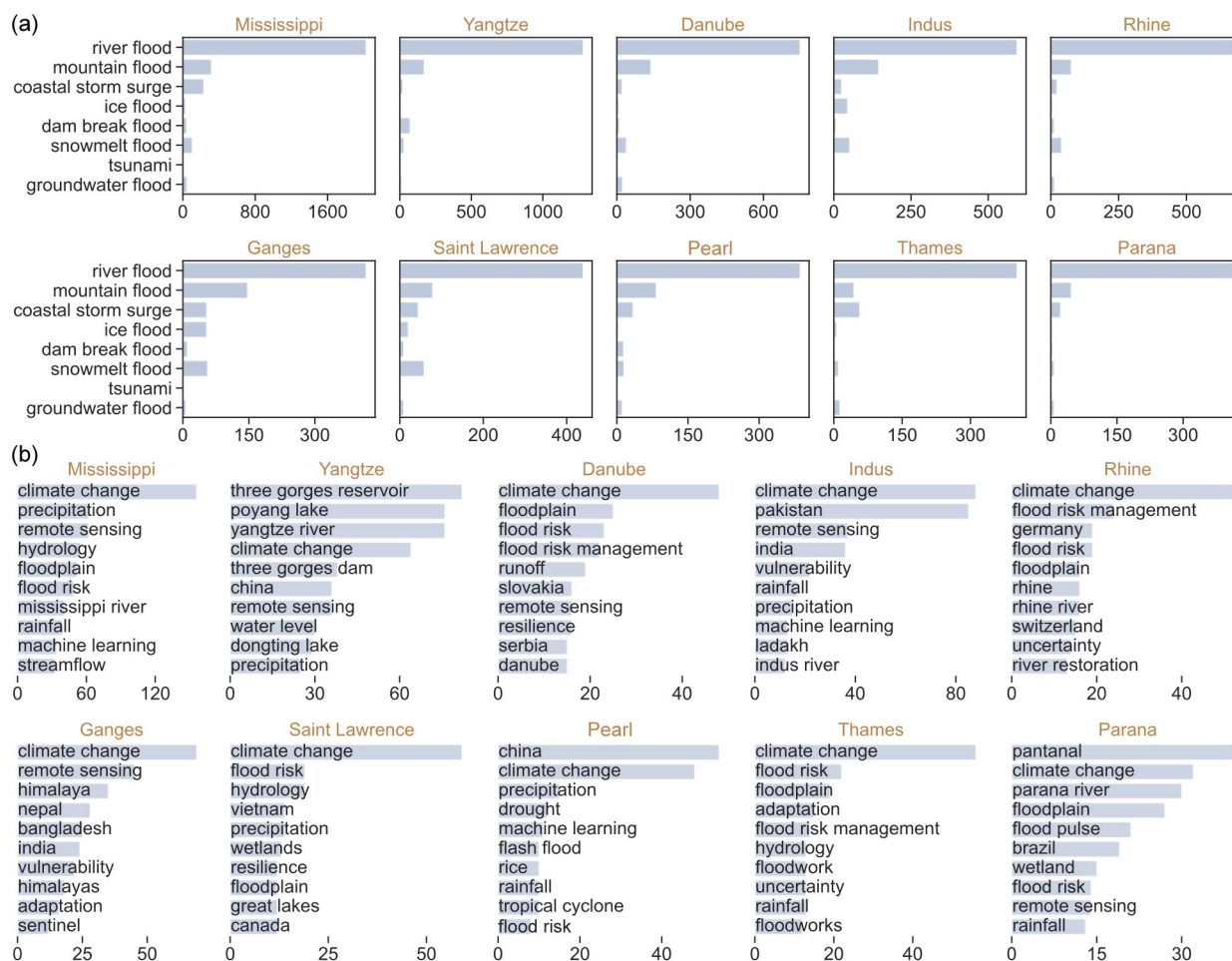


Fig. 8 Study the flood types and popular keywords of the top 10 river basins in terms of frequency ranking. (a) The flood types corresponding to each river basin is not displayed here for urban flood, as it always do not exist in this collection. (b) The top 10 popular keywords correspond to each river basin.

The geographical evolution of global urban flood research foci, analyzed at the provincial (state/region/municipality) level, is shown in Fig. 9. ① During 1985–1989, Arkansas (located within the Mississippi River Basin) and Maine in the United States pioneered urban flood research. ② From 1990 to 1994, Arkansas remained active and expanded its influence to surrounding areas, with scattered cities in eastern Asia (Japan, China, Singapore), western Europe (the United Kingdom, France, Serbia), and Oceania (Australia) lighting up research markers. ③ In 1995–1999, research activity in North America extended from the United States to Canada, with notable activity in British Columbia and Quebec. At the same time, the research attention of Paris in France and Madhya Pradesh in India also significantly increased. ④ Between 2000 and 2004, flood research in North America and Oceania showed a trend of continuous urban development. Meanwhile, Brazil's São Paulo state has drawn global attention due to severe flooding and favela issues exposed during its rapid expansion, marking



the first time South America has been highlighted in related research. ⑤ During 2005–2009, Hurricane Katrina's devastating impact on New Orleans exposed the vulnerabilities of modern cities and spurred comprehensive research efforts across the United States. Six of the top ten cities in terms of research activity were in the United States (including Louisiana, Texas, Illinois, California, Colorado, and Kansas), making it the most active region globally in urban flood research. ⑥ From 2010 to 2014, rapidly developing emerging economies experienced frequent urban waterlogging issues, with research hotspots emerging across South Asia (e.g., Dhaka in Bangladesh, Maharashtra in India) and East Asia (e.g., Guangdong in China). ⑦ In 2015–2019, flood research in Australia expanded to cover all major cities. Meanwhile, China formally elevated the “Sponge City” initiative to a national strategy, with the launch of hundreds of pilot projects driving explosive growth in related research. The Chennai major flood event in India became a typical case of concentrated public opinion analysis and further stimulated related research. ⑧ By 2020–2024, flood research had broadly covered cities in the United States, Canada, India, and China. Among them, China’s “Sponge City” practices accumulated vast data and experience, boosting advancements in both the quantity and quality of research. Half of the top ten regions in research rankings were in China (including Guangdong, Henan, Jiangsu, Beijing, Hubei, and Shanghai). Globally, a research landscape has formed, with the United States and China as dual cores, complemented by active contributions from India, Canada, Brazil, Australia, and Western European nations.

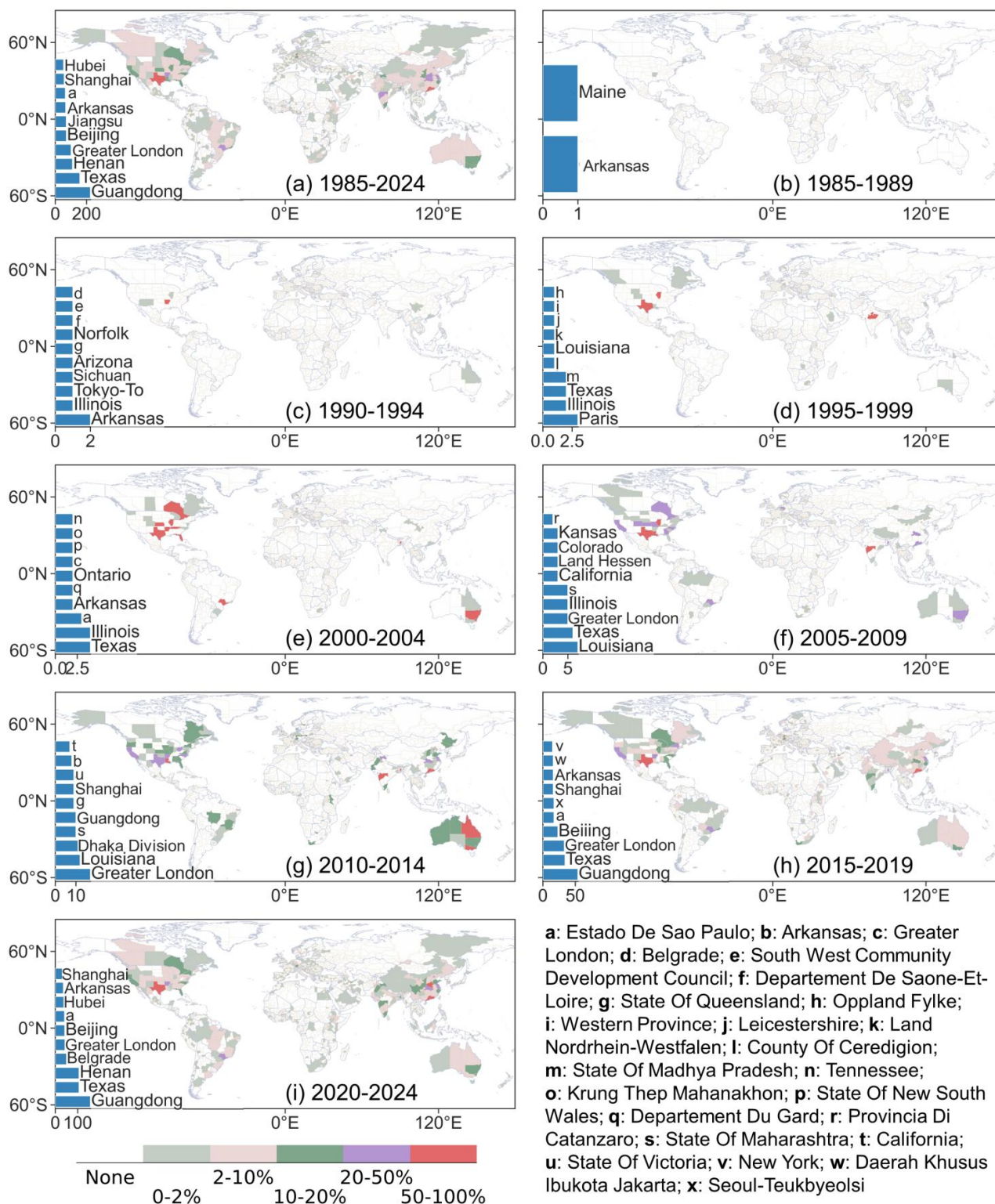




Fig. 9 The percentage of urban where the study area of urban floods is located in different periods. The bar chart in the bottom left corner of each subgraph displays the top 10 urban, with long names replaced with letters.

As shown in Fig. 10, among the flood research of the top ten urban areas, urbanization development and climate change are the main driving factors of urban flood risk assessment and management activities. The research paradigm varies depending on the environmental conditions and development positioning of the city. In terms of flood research types (Fig. 10a), river floods dominate as the core research object (with an average proportion of 71%), followed by mountain floods (18%) and storm surges (10%), which are directly related to the geographical location of the city. From the research characteristics of each city (Fig. 10b), Arkansas in the United States, located in the mid-lower Mississippi River Basin, addresses climate change adaptation challenges by constructing low-impact development facilities and developing stormwater management models (Liu and Merwade, 2018; Zellner and Massey, 2024). Texas, situated on the Gulf Coast plain, enhances its coastal resilience against hurricanes and rainstorms through advanced remote sensing technology (Koehn et al., 2011; Dong et al., 2020). China is carrying out large-scale and systematic practice and innovation based on the advanced rainwater management concepts borrowed from the United States. As the nation's capital, Beijing safeguards its core functional zones by implementing the “Sponge City” concept and applying digital modeling technologies (Scotti et al., 2020; Chang and Zhu, 2020). Henan and Hubei provinces are located in the middle-lower Yellow River basin and middle Yangtze River basin, respectively, preemptively assessing flood disaster chain risks by enhancing data monitoring analysis techniques and establishing rainstorm risk assessment frameworks (Wang et al., 2024; Zhang et al., 2022). Both Jiangsu Province and Shanghai City are located in the Yangtze River Delta Plain (eastern coastal region of China). Jiangsu Province improves the comprehensive management of floodplain risks by developing Sponge City and eco-collaborative models (Guo et al., 2024; Bai et al., 2019), while Shanghai City studies resilience enhancement strategies for the megacity through storm scenario simulation technology (Jia et al., 2014; Sun et al., 2022). Guangdong's Pearl River Delta Plain (southern coastal area of China), the province's most economically developed urban area, is committed to investigating the spatiotemporal dynamics of urban waterlogging induced by compound flooding, in order to support flood prevention and mitigation decision-making for the urban agglomeration (Li et al., 2024; Xu et al., 2024). Greater London in the United Kingdom, located in the low-lying plain of the Thames Estuary with frequent annual rainfall, emphasizes infrastructure enhancement and urban flood resilience assessment to better inform flood control engineering and strategy formulation (Kapetas and Fenner, 2020; Lou et al., 2024). São Paulo in Brazil, as a representative research case in South America, is absorbing international experiences to gradually improve sustainable urban stormwater management systems, addressing challenges from past rapid urbanization and increasingly severe climate change impacts (Caldas et al., 2018; Gesualdo et al., 2019).

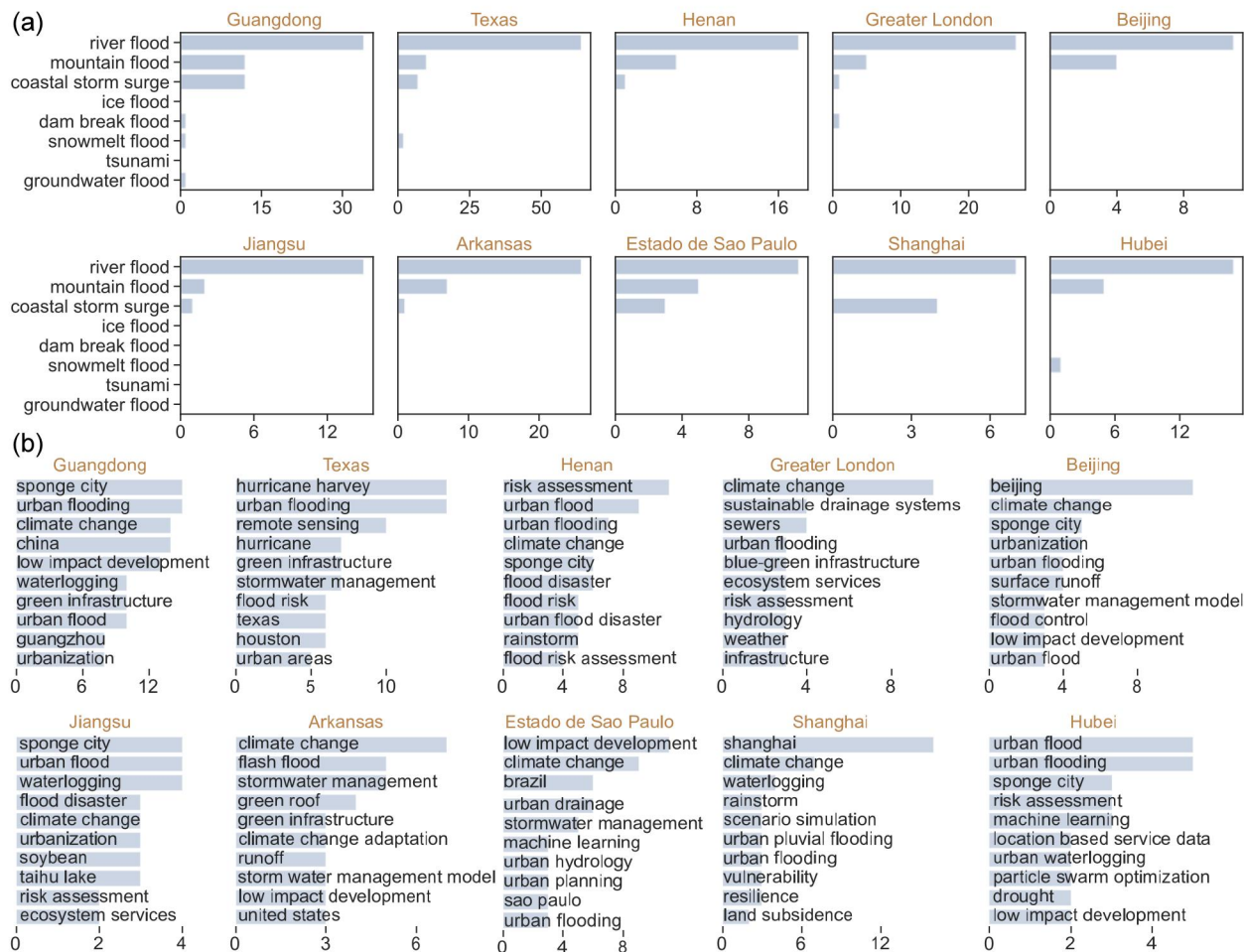


Fig. 10 Study the flood types and popular keywords of the top 10 urban in terms of frequency ranking. (a) The flood type corresponding to each urban is not displayed here for urban flood, as it always exists in this collection. (b) The top 10 popular keywords correspond to each urban.

425 **4 Conclusions**

This study reviews flood research articles from the past 40 years (1985–2024) based on a large language model. By extracting and quantifying information on the quantity and quality of publications, contributions of institutions and countries, evolution of keywords, research types and topics, and geographic distribution characteristics of river basin and urban units, the corresponding objective knowledge structures are comprehensively analyzed in the spatial and temporal dimensions.

430 This approach reflects the phased development process and trends of flood research, helping to deepen the systematic understanding of this field. The main conclusions are as follows:



- 435 (1) Quantity and quality of publications. The annual number of publications has now exceeded 5,500, with the average number of authors and institutions per publication increasing from 2.1 to 4.8 and from 1.4 to 2.6, respectively. *Journal of Hydrology* and *Water Resources Research* lead in terms of influence and productivity. Notably, journals outside the “water resources” category, such as *Climatic Change* and *Remote Sensing of Environment*, have gradually gained significant influence in the flood research field. This signifies a clear trend toward an interdisciplinary research paradigm.
- 440 (2) Contributions of institutions and countries. The top 15 countries in terms of publication output account for 70% of the global annual total. Chinese and American institutions lead in publication quantity, while European and American institutions dominate in research influence. Among them, the Chinese Academy of Sciences has become the most productive institution globally, while the University of Arizona ranks first nationally in terms of publication influence. Multi-institutional cooperation has become the mainstream research model. The collaborative network for global flood research presents a pattern driven by leading international institutional clusters and interconnected regional institutional groups.
- 445 (3) Dynamic evolution of keywords. The evolution of keyword focus traces a conceptual progression from “ecological-hydrological system interactions,” through “analysis of hydrological and hydrodynamic processes” and “flood disaster prevention and management,” to “flood prediction and risk assessment under climate change.” This trajectory reflects changing strategic priorities at different stages of development, specifically in deepening scientific theories, advancing technological capabilities, and formulating water security strategies. It also indirectly reflects the comprehensive consideration and gradual expansion of research perspectives on flood issues.
- 450 (4) Types and themes of flood research. River floods remain a consistent focus (averaging 55% of research), while urban floods have seen a notable rise in attention (increasing from 8% to 15% over the past decade). Mountain floods and coastal storm surges constitute a secondary yet important share of the total research volume (with an average proportion of 8% and 7%, respectively). The primary themes of flood research focus on management, simulation, monitoring, and risk assessment, with relatively balanced proportions. Commonly used research methods are broadly categorized into three types: data collection, data analysis, and hydrological modeling and simulation techniques.
- 455 (5) Geographic distribution characteristics of river basin and urban units. River basin flood research has shifted from being led by the Mississippi to a bipolar dominance shared with the Yangtze River, complemented by a multi-polar network of other active basins like the Danube, Indus and Saint Lawrence. Its research themes are strongly linked to drivers including economic development, technological innovation, hydraulic engineering interventions, geopolitical dynamics, transboundary collaborative management, and ecological-environmental interactions. Similarly, urban flood research has transitioned from leadership by Texas in the United States to a dual-core structure with Guangdong Province in China, complemented by multiple active urban areas such as Greater London in the UK, São Paulo in Brazil, and major Australian cities. Research themes in urban floods are relatively concentrated, primarily focusing on Sponge City infrastructure development and urban resilience assessment in the context of rapid urbanization.
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- 465



Appendix A1. Prompts for Large Language Model (LLM) to Obtain Information

(1) Identify whether the literature is article and is related to flood topics:

You are now a professional scholar in the field of hydrology, with a specific focus on flood and inundation research. You have deep expertise in analyzing flood-related scientific literature. I will provide you with information from a research paper, including its title, abstract, and keywords. Your task is to determine whether the content is closely related to the topic of floods or inundation, and it should clearly state that the content to be judged should be a research article, not reviews, comments, or letters. Relevant criteria include but are not limited to: whether the study focuses on typical flood types, such as urban flooding, river floods, flash floods, coastal storm surges, ice-jam floods, dam-break floods, snowmelt floods, tsunamis, or groundwater floods; whether it investigates flood-related causes, such as extreme precipitation, climate change, or land use change; whether it analyzes the impacts of flooding, such as economic losses, human casualties, or ecological damage; whether it conducts flood risk assessments, such as vulnerability analysis or disaster loss evaluation; whether it proposes flood management strategies, including engineering measures, non-engineering measures, or adaptive strategies; whether it involves flood inference, simulation, or prediction models. Carefully read all provided information before answering. Respond with True if the study is clearly related to flood or inundation topics based on the criteria above; respond with False otherwise. Do not include any additional words, punctuation, or whitespace. Only return True or False.

(2) Get the geographical location:

You will now receive information from a research paper, including its title, abstract, and keywords. Your task is to identify the geographical region studied in the article. Acceptable answers include rivers, lakes, oceans, cities, mountains, and other locations. The only requirement is to extract the most specific location possible. In your response, separate each hierarchical region with a comma, listing from the largest to the smallest. For example: Asia, China, Yellow River; Europe, France, Seine River; South America, Amazon; Africa, Niger River; Africa, Zambia, Lake Kariba; Asia, China, Beijing; Asia, China, Guangxi, Nanning; North America, USA, London; Asia, Japan, Tokyo; Asia, Japan. Important rules: If no specific geographical location can be determined, return None. If the article only refers to a global scale, also return None. If multiple locations are mentioned, only return one. Only provide geographic names; do not include any extra text, quotation marks, spaces, or line breaks. Carefully assess the content before providing the location. If a level of location cannot be determined, skip it; if it can be, include it. Strictly follow these rules and do not mess things up.

(3) Get the first corresponding address:

I will now give you a piece of text. Your task is to extract the name of the first correspondence address, removing any additional information such as department names, street addresses, postal codes, or countries. Only retain the core name of the university or research institution, which may include universities (e.g., “UNIV BOLOGNA”), national research centers (e.g., “Institute of Atmospheric Physics, CAS”), or scientific institutes (e.g., “Research Center for Eco-Environmental Sciences, CAS”). Then convert the extracted name into its official English name. For example, from “Free Univ Amsterdam, Fac Earth & Life Sci, Boelelaan 1085-1087, NL-1081 HV Amsterdam, Netherlands”, extract “Free Univ Amsterdam” and



convert it to “Vrije University Amsterdam”. From “UNIV BOLOGNA, INST HYDRAUL CONSTRUCT, VIALE
500 RISORGIMENTO 2, I-40136 BOLOGNA, ITALY”, extract “UNIV BOLOGNA” and convert it to “University of Bologna”.
From “Research Center for Eco-Environmental Sciences, CAS”, extract it as is and standardize to its official English name if
available. Return only the final official English name, without any punctuation, quotation marks, or explanatory dialogue. If
no recognizable institution name can be extracted, return None.

**(4) Identify the flood type(s) of the studies, including [urban flood, river flood, mountain flood, coastal storm surge,
505 ice flood, dam break flood, snowmelt flood, tsunami, groundwater flood], multiple choices, or choose [other]:**

You are now a professional scholar in the field of hydrology, with a focus on flood-related research and an in-depth
understanding of flood and inundation literature. I will provide you with information from flood-related papers, including the
title, abstract, and keywords. Your task is to determine the main type(s) of flood studied in the article. Please choose the
most appropriate one or more from the following categories: [urban flood, river flood, mountain flood, coastal storm surge,
510 ice flood, dam break flood, snowmelt flood, tsunami, groundwater flood]. Herein, urban flood, flooding caused by poor
drainage due to urban rainfall; river flood, river water level exceeding the warning line and overflowing; mountain flood,
sudden flood caused by intense rainfall in mountainous areas, for example, mudslide; coastal storm surge, abnormally high
sea levels inundating coastal areas due to typhoons, tsunamis, or strong storms; ice flood, floods caused by ice breaking or
melting in rivers; dam break flood, sudden flooding due to dam or levee failure; snowmelt flood, floods caused by rising
515 river levels due to melting snow; tsunami, large sea waves caused by underwater earthquakes or volcanic eruptions resulting
in coastal flooding; groundwater flood, surface flooding caused by rising groundwater levels; simulations, observations, or
predictions related to floods. Only return the category name(s). Avoid selecting multiple options if possible. Choose only
from the listed categories. Do not include any extra explanation. If you cannot determine the category, return "other" and do
not select any of the other categories. Do not add any extra text, only return the category name(s) in English, separated by (;).

520 Do not include any extra explanation.

**(5) Get the topic(s) of the studies, including [management, simulation, monitoring, risk assessment], multiple
choices, or choose [other]:**

You will now receive information from a research paper, including its title, abstract, and keywords. Identify the topic of the
study by selecting one or more from the following categories: [management, simulation, monitoring, risk assessment]. Here,
525 monitoring, methods used for tracking, observing, or measuring specific variables or phenomena over time; simulation, the
development of models or systems to replicate real-world processes for analysis or prediction; risk assessment, the process of
identifying, evaluating, and analyzing potential risks; management, using strategies, practices, or policies aimed at planning,
organizing, and implementing effective responses to flood-related challenges or risks, and other. If you cannot determine the
category, return "other" and do not select any of the other categories. Do not add any extra text, only return the category
530 name(s) in English, separated by (;). Do not include any extra explanation.

(6) Get specific research method(s) in studies:



You are now a professional scholar in the field of hydrology, with a focus on flood-related research and an in-depth understanding of flood and inundation literature. I will provide you with information from flood-related papers, including the title, abstract, and keywords. Please specify the research method used, using more professional terminology and specifying the type of method. Examples include: hydrological models (HEC-HMS, SWAT, MIKE SHE, VIC, WRF-Hydro), hydraulic models (FLOW-3D, HEC-RAS, MIKE 21, LISFLOOD-FP, Delft3D), remote sensing (Landsat satellite data, Sentinel data, MODIS, LiDAR, SAR), GIS analysis (spatial interpolation, buffer analysis, overlay analysis, topological analysis, network analysis, etc.), statistical analysis (frequency analysis, regression analysis, Copula functions, extreme value theory, generalized Pareto distribution, analytic hierarchy process, etc.), machine learning (support vector machines, random forests, neural networks, extreme learning machines, etc.). If no method is mentioned, do not fabricate one — simply fill in “None”. Only list the father research method followed by the specific method names in parentheses, and do not add any extra text. Use English punctuation. If there are multiple categories, separate them with a semicolon (;). Do not use line breaks; the correct reply format is: xxx (ttt); xxx (ttt).

(7) Obtain all agency addresses and their countries:

Now, I will give you a piece of text. Your task is to extract all institution names mentioned in it and remove any irrelevant non-primary unit information such as department names, faculty names, street addresses, or postal codes—these are not needed. Only retain the core names of universities, national research centers, scientific institutions, or companies. Then, convert each extracted name into its full official English name. For example, from “Free Univ Amsterdam, Fac Earth & Life Sci, Boelelaan 1085-1087, NL-1081 HV Amsterdam, Netherlands”, extract “Free Univ Amsterdam” and convert it to “Vrije University Amsterdam”; from “UNIV BOLOGNA, INST HYDRAUL CONSTRUCT, VIALE RISORGIMENTO 2, I-40136 BOLOGNA, ITALY”, extract “UNIV BOLOGNA” and convert it to “University of Bologna”; from “Research Center for Eco-Environmental Sciences, CAS”, extract “CAS” and convert it to “Chinese Academy of Sciences”. Finally, return all identified institutions in the text along with their corresponding countries. Use country names in forms like China, American, England, Japan, etc. Institution names must be written in full official form, without using any abbreviations, for example, do not use “UNIV” but write “University” instead. If no recognizable institution can be extracted, return None. Do not include any explanatory dialogue. Note, the correct return format is: xxx Institution (Country); xxx xxx Institution (Country); xxx Institution (Country).

Appendix A2. Search terms used for searching in Web of Science

Search terms include: Flood, Flooding, Flood Disaster, Flood Risk, Flood Management, Flood Simulation, Rainfall-Runoff Model, Flood Forecasting, Flood Warning, Flood Process, Flood Evolution, Flood Mechanism, Flood Response, Flood Resilience, Integrated Flood Management, Regional Flood, Urban Flooding, Mountain Flood, Flash Flood, Riverine Flood, Coastal Flood, Glacial Lake Outburst Flood, GLOF, Dam-Break Flood, Basin-Wide Flood, Slow-Onset Flood, Rapid-Onset Flood, Tidal Flood, Ice Jam Flood.



Appendix A3. Source of Boundaries

565 Country boundaries and world major cities' boundaries are obtained from <https://resdc.cn>.

River basin boundaries are obtained from <https://mrb.grdc.bafg.de>.

Appendix Table B1. Journals categorized under the subcategory “Water Resources” of Web of Science.

Journal	Web of Science category
International Soil and Water Conservation Research	Environmental Sciences Soil Science Water Resources
Irrigation and Drainage	Agronomy Water Resources
Irrigation Science	Agronomy Water Resources
Journal AWWA	Engineering, Civil Water Resources
Journal of Contaminant Hydrology	Environmental Sciences Geosciences, Multidisciplinary Water Resources
Journal of Flood Risk Management	Environmental Sciences Water Resources
Journal of Hydraulic Engineering	Engineering, Civil Engineering, Mechanical Water Resources
Journal of Hydraulic Research	Engineering, Civil Water Resources
Journal of Hydro-Environment Research	Engineering, Civil Environmental Sciences Water Resources
Journal of Hydroinformatics	Computer Science, Interdisciplinary Applications Engineering, Civil Environmental Sciences Water Resources
Journal of Hydrologic Engineering	Engineering, Civil Environmental Sciences Water Resources
Journal of Hydrology	Engineering, Civil Geosciences, Multidisciplinary Water Resources
International Soil and Water Conservation Research	Environmental Sciences Soil Science Water Resources
Irrigation and Drainage	Agronomy Water Resources
Irrigation Science	Agronomy Water Resources



Journal	Web of Science category
Journal AWWA	Engineering, Civil Water Resources
Journal of Contaminant Hydrology	Environmental Sciences Geosciences, Multidisciplinary Water Resources
Journal of Flood Risk Management	Environmental Sciences Water Resources
Journal of Hydraulic Engineering	Engineering, Civil Engineering, Mechanical Water Resources
Journal of Hydraulic Research	Engineering, Civil Water Resources
Journal of Hydro-Environment Research	Engineering, Civil Environmental Sciences Water Resources
Journal of Hydroinformatics	Computer Science, Interdisciplinary Applications Engineering, Civil Environmental Sciences Water Resources
Journal of Hydrologic Engineering	Engineering, Civil Environmental Sciences Water Resources
Journal of Hydrology	Engineering, Civil Geosciences, Multidisciplinary Water Resources
Journal of Waterway Port Coastal and Ocean Engineering	Engineering, Civil Engineering, Ocean Water Resources
Lake and Reservoir Management	Limnology Marine & Freshwater Biology Water Resources
LHB-Hydrosience Journal	Water Resources
Membrane and Water Treatment	Engineering, Chemical Water Resources
Mine Water and the Environment	Water Resources
Natural Hazards	Geosciences, Multidisciplinary Meteorology & Atmospheric Sciences Water Resources
Natural Hazards and Earth System Sciences	Geosciences, Multidisciplinary Meteorology & Atmospheric Sciences Water Resources
Natural Hazards Review	Engineering, Civil Geosciences, Multidisciplinary Meteorology & Atmospheric Sciences Water Resources
NPJ Clean Water	Engineering, Chemical Environmental Sciences Water Resources



Journal	Web of Science category
Ocean & Coastal Management	Oceanography Water Resources
Physics and Chemistry of the Earth	Geosciences, Multidisciplinary Meteorology & Atmospheric Sciences Water Resources
Proceedings of the Institution of Civil Engineers-Maritime Engineering	Engineering, Civil Engineering, Ocean Water Resources
Proceedings of the Institution of Civil Engineers-Water Management	Engineering, Civil Water Resources
River Research and Applications	Environmental Sciences Water Resources
Soil and Water Research	Soil Science Water Resources
Stochastic Environmental Research and Risk Assessment	Engineering, Environmental Engineering, Civil Environmental Sciences Statistics & Probability Water Resources
Tecnología y Ciencias del Agua	Engineering, Civil Water Resources
Urban Water Journal	Water Resources
Vadose Zone Journal	Environmental Sciences Soil Science Water Resources
Wasserwirtschaft	Water Resources
Water	Environmental Sciences Water Resources
Water Alternatives-An Interdisciplinary Journal on Water Politics and Development	Water Resources
Water and Environment Journal	Environmental Sciences Limnology Water Resources
Water Economics and Policy	Water Resources
Water Environment Research	Engineering, Environmental Environmental Sciences Limnology Water Resources
Water International	Engineering, Civil Water Resources
Water Policy	Water Resources



Journal	Web of Science category
Water Quality Research Journal	Water Resources
Water Research	Engineering, Environmental Environmental Sciences Water Resources
Water Research X	Engineering, Environmental Environmental Sciences Water Resources
Water Resources	Water Resources
Water Resources and Economics	Environmental Sciences Water Resources
Water Resources and Industry	—
Water Resources Management	Engineering, Civil Water Resources
Water Resources Research	Environmental Sciences Limnology Water Resources
Water Reuse	Engineering, Environmental Water Resources
Water SA	Water Resources
Water Science and Technology	Engineering, Environmental Environmental Sciences Water Resources
Water Supply	Engineering, Environmental Environmental Sciences Water Resources
Wetlands Ecology and Management	Environmental Sciences Water Resources
Wiley Interdisciplinary Reviews-Water	Environmental Sciences Water Resources

Appendix Table B2. The full names and corresponding abbreviations of journals.

Full name	Abbreviation
Earth's Future	Earths Future
Advances in Water Resources	Adv. Water Resour.
Geomorphology	Geomorphology



Geophysical Research Letters	Geophys. Res. Lett.
Monthly Weather Review	Mon. Weather Rev.
Global and Planetary Change	Glob. Planet. Change
Freshwater Biology	Freshw. Biol.
Palaeogeography Palaeoclimatology Palaeoecology	Palaeogeogr. Palaeoecol.
Journal of Geophysical Research-atmospheres	J. Geophys. Res. Atmos.
Risk Analysis	Risk Anal.
Journal of Climate	J. Clim.
Remote Sensing of Environment	Remote Sens. Environ.
Climatic Change	Clim. Change
Water Resources Research	Water Resour. Res.
Journal of Hydrology	J. Hydrol.
Physics and Chemistry of the Earth	Phys. Chem. Earth
Ocean & Coastal Management	Ocean Coast. Manag.
Stochastic Environmental Research and Risk Assessment	Stoch. Environ. Res. Risk Assess.
River Research and Applications	River Res. Appl.
Natural Hazards and Earth System Sciences	Nat. Hazards Earth Syst. Sci.
Journal of Hydraulic Engineering	J. Hydraul. Eng.
Natural Hazards	Nat. Hazards
Water Resources Management	Water Resour. Manag.
Journal of Hydrologic Engineering	J. Hydrol. Eng.
Journal of Hydroinformatics	J. Hydroinf.
Wiley Interdisciplinary Reviews-water	Wiley Interdiscip. Rev. Water
Water Research	Water Res.
Wetlands Ecology and Management	Wetl. Ecol. Manag.



570

Appendix Table B3. Journal rank based on the average number of citations per article, along with the cumulative number of publications. (These journals are filtered, which under the subcategory “Water Resources” of Web of Science, detail in **Appendix Table**. The abbreviation and corresponding full name of journals can be found in **Table B1**.)

Journal	Avg. annual paper cite	Total publication
J. Hydrol.	99.8	2458
Water Resour. Res.	98.1	1126
Wetl. Ecol. Manag.	74.9	44
Water Res.	67.3	91
Wiley Interdiscip. Rev. Water	57.3	54
J. Hydrol. Eng.	45.7	538
Water Resour. Manag.	44.7	617
Nat. Hazards	44.2	1189
J. Hydraul. Eng.	42.7	140
Nat. Hazards Earth Syst. Sci.	42.7	633
River Res. Appl.	36.1	341
Stoch. Environ. Res. Risk Assess.	33.4	229
Ocean Coast. Manag.	32.1	153
Phys. Chem. Earth	30.5	120
J. Hydroinf.	29.2	190

Appendix Table B4. Journal rank based on the average number of citations per article, along with the cumulative number of publications. (The journals with at least 100 publications were included in the ranking. The abbreviation and corresponding full name of journals can be found in **Table B1**.)

Journal	Avg. annual paper cite	Total publication
J. Hydrol.	99.8	2458
Water Resour. Res.	98.1	1126
Clim. Change	95.9	302
Remote Sens. Environ.	94.9	150



J. Clim.	94.0	147
Risk Anal.	92.5	127
J. Geophys. Res. Atmos.	89.9	199
Palaeogeogr. Palaeoecol.	82.4	102
Freshw. Biol.	81.4	162
Glob. Planet. Change	76.9	137
Mon. Weather Rev.	72.4	113
Geophys. Res. Lett.	71.7	388
Geomorphology	69.5	683
Adv. Water Resour.	68.6	222
Earths Future	66.3	152

575 Code and data availability

Code and data information can be found in the online version of this article.

Author contributions

Conceptualization: J.Z. and T.H.; Methodology: J.Z., T.H. and H.W.; formal analysis: J.Z., T.H. and S.Z.; data collection and curation: T.H. and Z.S.; visualization: C.Q. and S.J.; writing—original draft: T.H. and Z.S.; writing—reviewing and editing: all authors; supervision: J.Z.; project administration: J.Z.; funding acquisition: J.Z. and J.L.

Competing interests

A declaration of all potential conflicts of interest is required by Copernicus Publications as this is an integral aspect of a transparent record of scientific work. Please see our competing interests policy.

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Use of Artificial Intelligence (AI) tools

590 Artificial intelligence (AI) tools were used in this study to support literature processing and manuscript preparation. A large language model (Gemma 3-27B, Google DeepMind) was applied for literature screening and information extraction, as detailed in the Methods section. All AI-assisted outputs were carefully reviewed, validated, and interpreted by the authors. AI tools were also used for language editing (grammar, spelling, and clarity). No AI tool was involved in generating scientific conclusions independently. The authors take full responsibility for the integrity and accuracy of the work.

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