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Review

A Bibliometric Review and Interdisciplinary Analysis of the Brahmaputra River

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Abstract: In this study, we visualize and analyze the literature on the Brahmaputra river using a spectral clustering algorithm, tracking research trends over time. We found that the focus of research on the Brahmaputra has changed over time in the last decade, with a shift from geology to hydrology and geochemistry and a rapid growth in climate change research in recent years. In the future, potential hot topics may be "water resource management" and other topics related to transboundary water resource management and cooperation. At the same time, this study also analyzes in detail the keywords and clusters "geohydrology" and "ecological risk and sustainable development", among other topics. We believe that future research should carefully consider the potential effects of transdisciplinary research trends. For instance, it is urgent that transborder governance and management regimes be renovated through joint efforts and cross-border effective actions carried out by multifaceted and multi-scalar agencies along this river.

Keywords: Brahmaputra river; transboundary rivers; water politics; sustainable development; water resources

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1. Introduction

The Brahmaputra river, one of Asia's major transnational rivers and also famous for the Ganges Brahmaputra Meghna River system, originates from the northern foothills of the Himalayas in the Tibet Autonomous Region of China; its upstream in China is the Yarlung Zangbo River, and its headwater culminates specifically at the Jiemayangzong Glacier [1]. It serves as the "cradle" and "mother river" of a vast area of land in the Himalayan region of South Asia [2]. After a confluence with two other rivers near Pasighat in Assam, India, the Yalung Zangbo becomes the Brahmaputra river and is known as the Jamuna River after it enters Bangladesh, eventually merging with the Ganges at Goalundo Ghat, forming the vast Ganges Delta, and flowing into the Bay of Bengal. Additionally, several of its tributaries traverse a significant proportion of Bhutan's territory. In general, the Brahmaputra river, as a significant river in Asia, has a profound impact on multiple countries in South Asia, spanning a total length of 3969 km [3].

In the last few decades, scholars have carried out multifaceted and interdisciplinary studies on the Brahmaputra river, assessing groundwater hydrological variability [4], riparian variability, efficient disaster management practices [5], climate change and water storage [6], ecological changes in riparian vegetation growth [7], the water–energy–food–environment (WEFE) nexus [8], its socio-economic effects, etc.

Currently, research on the Brahmaputra is significantly less common than that on other important transboundary rivers in the world, and the existing research is relatively homogenous, focusing on specific areas such as hydrology, geology, and the environment. Research exploring the global impacts of the river, the socio-cultural interactions within the watershed, and its potential for economic development is weaker.

In view of its transnational attributes and research potential in the field of sustainable river governance, the region has witnessed relatively systematic research achievements in the natural sciences [9,10]. However, it is noteworthy that in the dimensions of humanities, social sciences, and interdisciplinary studies, the relevant research output remains relatively limited, and existing studies have not yet fully constructed a holistic cognitive picture of the Brahmaputra River Basin. To fill this gap, this study aims to synthesize and critically think about comprehensive knowledge gained from scientific research and extend broader global debates about this international transborder river. Specifically, we conducted a comprehensive search and summarization of the relevant literature on the Brahmaputra river basin. We also utilized BiblioShiny and Citespace, which are more scientific and intuitive than methods used in previous manual literature reviews, to visually analyze and categorize research hotspots, main research topics, and future research trends in different areas of the basin. This study is organized as follows: First, we introduce the materials and methods applied in our study. Following the methodology, we display the results of our review of dominant trends, literature sources, keywords, and literature clustering. We then extend our debates to diverse disciplines within research on the Brahmaputra. In the final part, we conclude this study.

2. Materials and Methods

Based on the theory of bibliometrics, this study utilizes Biblioshiny (Academic Spin-Off of the University of Naples Federico II, Naples, Italy, Version2024) and Citespace (Chen, C., Drexel University, Pennsylvania, USA, Version6.1.R6) bibliometric software to compile the literature on the Brahmaputra watershed, mining for trends in a number of publications, authors and countries, research themes, and research vectors. Biblioshiny is an open-source tool; it is programmed in the R language, which is flexible and easy to integrate with other statistical and graphics packages [11]. Citespace is a citation visualization and analysis software that presents the structure, law, and distribution of scientific knowledge through visual means; thus, the visual graphs obtained by such methods are also referred to as "Scientific Knowledge Mapping".

There are some index laws in the software, including betweenness centrality, which is a measure of the importance of a node in the network (in addition to degree centrality, proximity centrality, etc.). It indicates the extent to which a node in a network graph is a "mediator" of other nodes in the graph. Bradford's Law was first described by Samuel Bradford in 1934, which estimates that searching for references in scientific journals will bring exponentially diminishing returns. The g-index is a derivative of the h-index, mainly used to make up for the shortcomings of the h-index, which cannot respond well to highly cited papers.

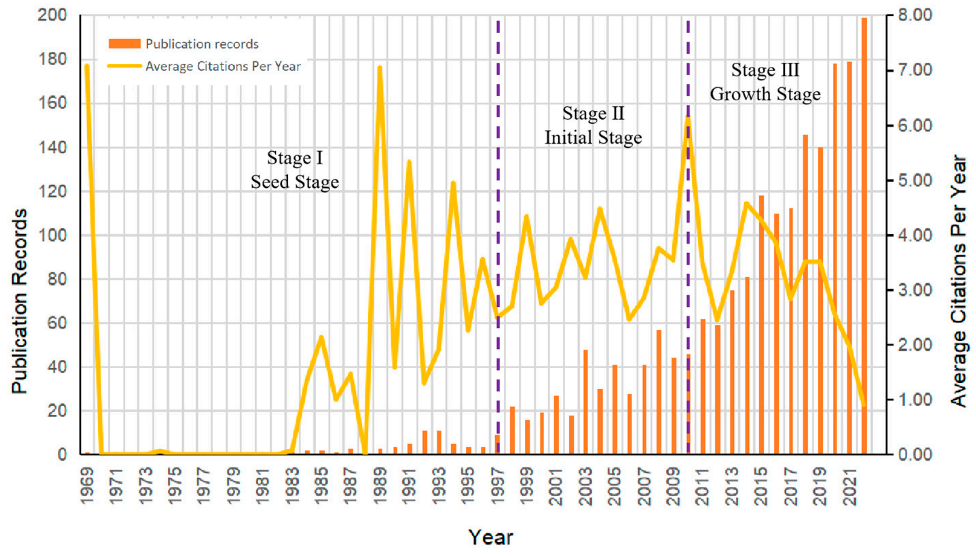
To enhance the credibility of the analysis results, this study uses the core journal database of Web of Science, and the citation index used is the Science Citation Index Expanded (SCI-Expanded). Only studies written in English were included. Based on our literature analysis, the subject term "Brahmaputra" was selected, and the publication period was not limited. The search was conducted by using TS = (Brahmaputra), which collected a total of 2093 documents, and each document's record included the title, authors, countries, abstracts, and citations of the documents. This study focuses on journal articles, so conference papers, book chapters, other editorial materials, book reviews, letters, and other literature that did not fall within the scope of this study were excluded. Through preliminary screening methods such as de-weighting the search results, a total of 1965 documents were screened and selected as the research data for this study. The publication period of 1 January 1969 to 31 December 2022 was selected, because the earliest article in this field was published in 1969.

3. Results

3.1. General Research Trend

The annual distribution of publication volume provides a visual representation and mapping of the overall quantity over time, serving as an important indicator for measuring growth characteristics. By analyzing data on the annual number of publications in the

English language literature from the Web of Science (WoS) platform (Figure 1), it is evident that the number of research articles related to the Brahmaputra River basin exhibits exponential growth. Based on the changes in publication volume, three distinct phases can be identified. The first phase, prior to 1997, witnessed relatively low publication numbers, indicating the early stage of research in this area. The second phase spans from 1997 to 2010, during which the literature count exhibited fluctuating growth patterns. This phenomenon may be related to the signing of the Treaty between the Government of the Republic of India and the Government of the People's Republic of Bangladesh on the Sharing of the Ganga/Ganges Waters at Farakka in 1996. Finally, the third phase encompasses the years 2010 to 2022, characterized by rapid and exponential growth in the number of research publications. The amount of literature related to the Brahmaputra River basin has consistently increased during this period, indicating a steady upward trend.

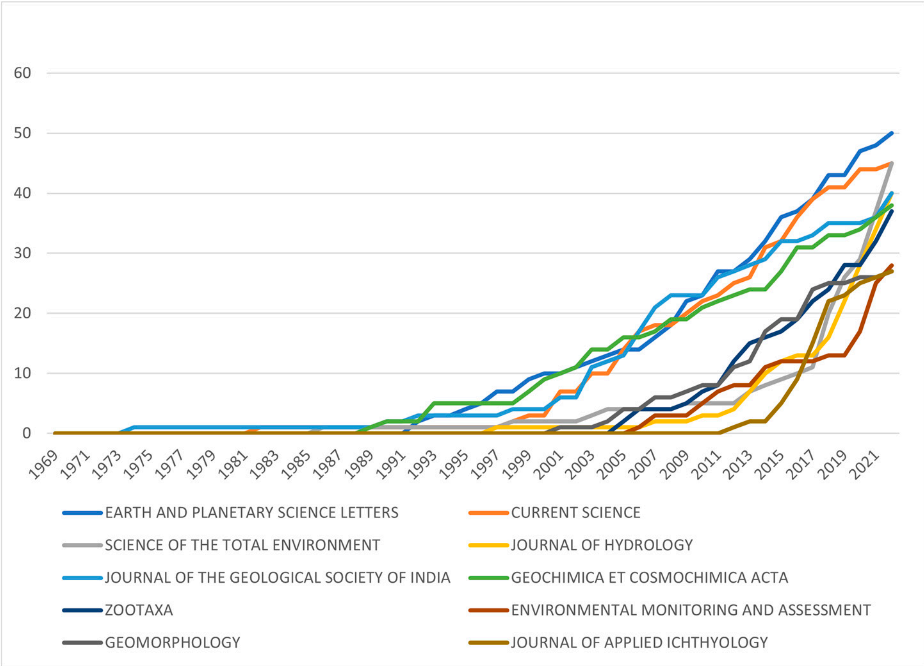


Source: Web of Science.

Figure 1. Annual trend of literature publication volume and average citation frequency.

After sorting the data based on the journal sources, it was found that in the literature database, the journal with the highest publication volume is "Earth and Planetary Science Letters", with a count of 50 articles. "Current Science" and "Science of the Total Environment" each have 45 articles, following closely behind.

In the analysis of "Sources' Production over Time", the "Occurrences" were selected as "Cumulative", and the number of sources was adjusted to 10. This analysis examines the growth of literature from the top 10 journal sources with the highest number of publications since 1969 (Figure 2). It is observed that before 1989, both the number of publications and the range of journal sources were relatively low. From 1989 to 1997, there was a gradual increase in the number of publications, along with a corresponding increase in the number of journals contributing to the literature. However, after 1997, there was a significant surge in the number of publications in four specific journals: "Earth and Planetary Science Letters", "Current Science", "Journal of the Geological Society of India", and "Geochimica et Cosmochimica Acta". The four journals have a significantly higher number of literature articles compared to the other six journals. In recent years, the literature on the "Science of the Total Environment" has experienced exponential growth.



Source: Web of Science.

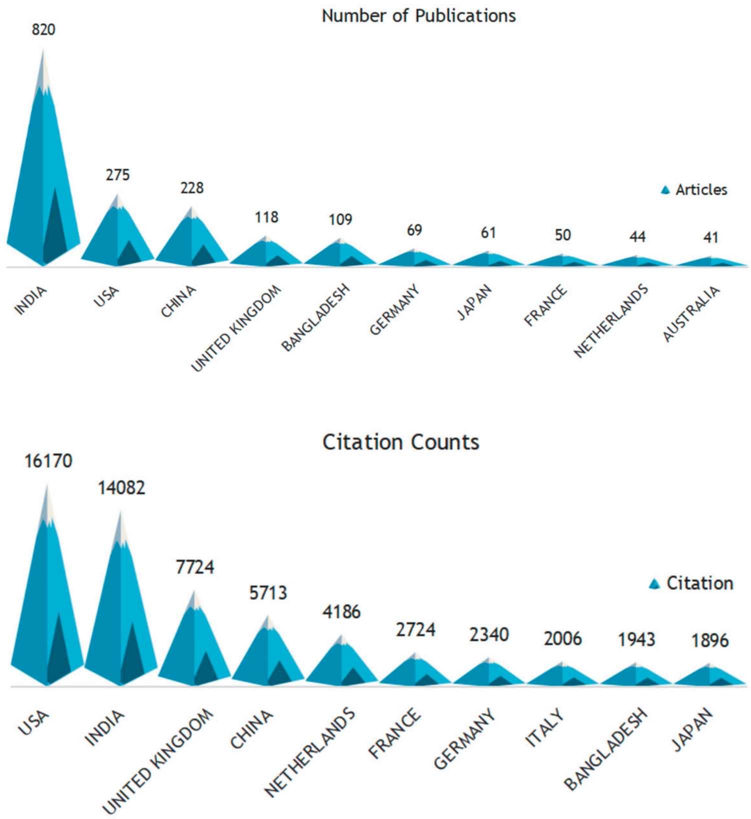
Figure 2. Sources' production over time.

3.2. Literature Sources

Due to the specialized nature of domain knowledge, the dynamic nature of knowledge growth, and the complexity of scientific development, individual scholars find it difficult to grasp all professional knowledge and research resources, as there are prevalent professional barriers that hinder a comprehensive understanding. As a result, contemporary research increasingly relies on communication and collaboration to address complex scientific research questions. Therefore, this study conducts a cooperative analysis among the major countries involved in research on the Brahmaputra river basin. This analysis is beneficial for identifying key countries in this field of research. By strengthening cooperation and communication with these key countries, researchers can enhance their academic capabilities and influence.

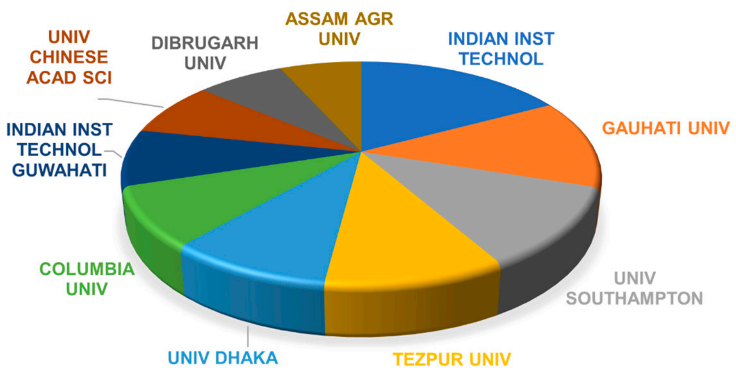
An analysis of the country's sources of published literature reveals that India has the highest number of publications (Figure 3), accounting for 40.6% of the total publications. The United States closely follows with a contribution of 13.6%, while China accounts for 11.3% of the publications. The United Kingdom represents 5.8% of the literature, while Bangladesh contributes 5.4%. However, in terms of citation counts, the United States has the highest number of citations received among the published literature.

The Indian Institutes of Technology (IITs) emerged as the institution with the highest number of published studies (Figure 4), with 113 publications, significantly surpassing other institutions. The IITs are prestigious, centrally government-owned technical institutes located across India. Gauhati University, also known as GU, secured the second position, with 85 published articles. It is a public state university located in Guwahati, Assam, India. The University of Southampton, a public research university in Southampton, England, ranks third, with 77 publications. Tezpur University, located in Tezpur, Assam, India, ranks fourth, with 68 published articles. Established in 1994 by an Act of Parliament, it is a central university. The University of Dhaka, the oldest university in Bangladesh, ranks fifth, with 62 publications. It is a public research university located in Dhaka, Bangladesh. Among the top ten institutions, six are from India, while the remaining four are from the United Kingdom, Bangladesh, the United States, and China, respectively. This indicates that Indian research institutions have made the most significant contributions to the study of the Brahmaputra river. China and Bangladesh have also undertaken significant research efforts along the course of the river.



Source: Web of Science.

Figure 3. Top 10 most published countries and top 10 most cited countries.



Source: Web of Science.

Figure 4. Top 10 institutions with the most published literature.

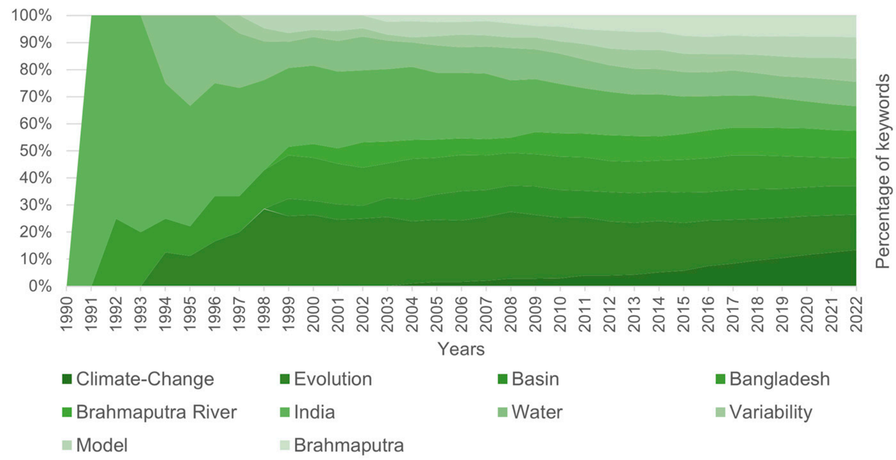
3.3. Keyword Analysis

Keywords provide a concise overview of the research topic and its content. The analysis of high-frequency keywords directly reflects the research hotspots in the Brahmaputra basin. We used the "Bibliometric" and "Biblioshiny" packages from the R tool to calculate keywords and create a word cloud map of the top 50 keywords with the highest frequency in this area (Figure 5). The figure shows that the first ten words are as follows: climate change, evolution, basin, Bangladesh, Brahmaputra river, India, water, variability, Brahmaputra, and model.

Source: Bibiometrix.

Figure 5. Keyword cloud map.

Figure 6 displays the main keywords based on the annual percentage. It can be seen that in the 1990s, the percentage of the keyword "India" in the research related to the Brahmaputra River was significantly higher compared to "Water", "Bangladesh", and "Evolution". Afterwords, various types of research became more detailed, and the percentage of keywords gradually converged in the 1990s. Currently, the annual variations in the proportion of different research directions in the basin are gradually decreasing, and research directions are moving towards stable diversification. Between 1990 and 1993, research on the Brahmaputra basin primarily focused on "India" and "Bangladesh". During this period, studies on the basin were predominantly conducted within these countries. From 1993 to 1998, the proportion of literature on "Water" and "Evolution" increased. In the context of "Evolution", the geological, riverine, and coastal evolution of the Himalayas and the Brahmaputra river delta and its surrounding areas is primarily discussed.



Source: Web of Science.

Figure 6. Annual trend of keyword proportion.

Upon entering the twenty-first century, the keywords "India" and "Evolution" became evenly divided. Between 2000 and 2010, the proportion of the "Basin" and "Brahmaputra River" began to rapidly increase, and the research focus in the basin gradually shifted towards the geochemical direction. This is related to the frequent outbreaks of arsenic poisoning in Bangladesh. In 2003, the Bangladesh Department of Public Health Engineering conducted testing for arsenic in tube wells across the country and found that 29% of them were contaminated with arsenic. During this period, research on evolution remained popular, but scholars employed more sophisticated geochemical methods for comprehensive investigation. From 2010 to 2022, the theme of "climate change" was the most frequently discussed topic in the literature over the past decade. With the increasing number of global climate anomalies in recent years, climate change has become a prominent topic. Ensuring harmonious coexistence between humans and nature requires research and prediction of natural climate patterns in order to prepare in advance and respond accordingly.

4. Discussion

4.1. Theme Clustering

Cluster analysis is a set of statistical analysis techniques that categorize research objects into relatively homogeneous clusters. By categorizing objects into relatively homogeneous clusters, researchers can better understand the intrinsic associations and characteristics in a dataset. In CiteSpace, we selected 'keyword' as the network node, 'pruning' as 'Pathfinder', 'Pruning sliced networks', and 'Pruning the merged network', while keeping the other options as default. We then ran CiteSpace and selected clusters. Based on the g-index (k = 25), the literature and co-cited links are divided into 17 clusters (Figure 7), which are as follows: Clu0 (Climate change), Clu1 (Precipitation), Clu2 (Indian Ocean), Clu3 (Remote sensing), Clu4 (Evolution), Clu5 (Chemical weathering), Clu6 (Geochemistry), Clu7 (Suspended sediment), Clu8 (Arsenic), Clu9 (Polymorphism), Clu10 (Satellite altimetry), Clu11 (Bengal basin), Clu12 (Condition factor), Clu13 (Brahmaputra river), Clu14 (Catchment), Clu15 (Ganges Brahmaputra), Clu16 (Adriatic Sea), Clu17 (Northeast India).

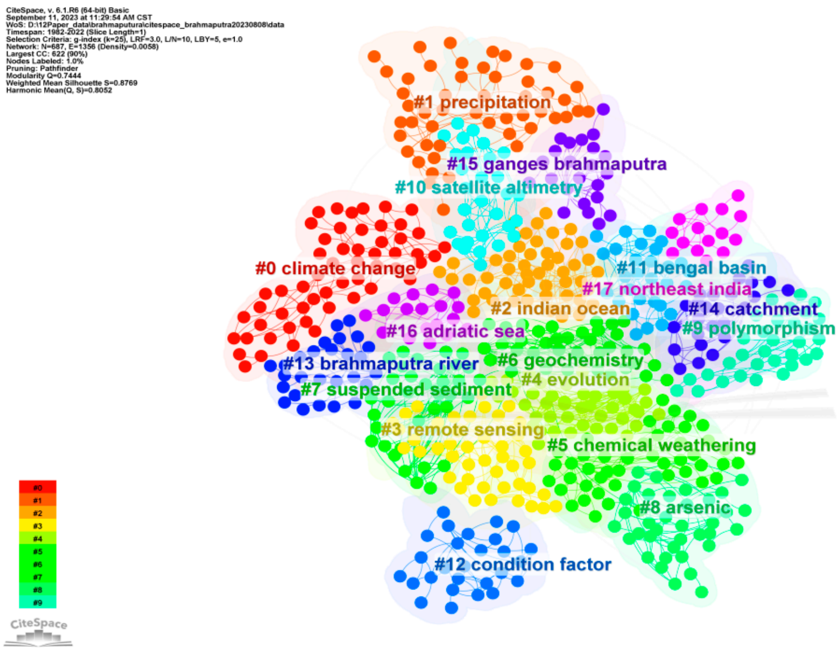


Figure 7. Document clusters by co-citation analysis.

The Modularity Q value is 0.7444, which is significantly greater than 0.3. This indicates that the clustering structure is highly significant. The weighted mean silhouette S value is 0.8769, which is greater than 0.7, indicating that the clustering is efficient and reliable [12]. The silhouette values of all 17 clusters exceeded 0.75, indicating that the clusters have strong cohesion and high diversity. The size of different clusters varies greatly, with the largest cluster, Clu0, containing 55 members, and the smallest cluster, Clu17, having 15 members.

Table 1 displays the cluster labels, member numbers, silhouette values, and highest-ranked terms obtained through the LLR algorithm for 17 DCA clusters. The terms are generated from noun phrases and index words in member article citations of each cluster. These clusters reflect the complexity and diversity of the Brahmaputra river. Researchers are not only focusing on environmental issues but also various aspects related to geography, climate, geology, and human activities. These studies contribute to a better understanding and management of the resources and environmental issues in the watershed. Below is a comprehensive analysis of the top ten themes.

Table 1. The term top 10 clustering determined based on spectral clustering.

ID	Size	Silhouette	Mean (Year)	Top Terms
0	55	0.898	2013	Climate Change; Sea Level Rise; Impact; Adaptation; Water Resources
1	51	0.895	2012	Precipitation; El Nino; Sea Surface Temperature; Cmip5; Uncertainty
2	49	0.818	2006	Indian Ocean; Bengal Fan; Bay Of Bengal; Provenance; Sediment Provenance
3	44	0.861	2013	Remote Sensing; Tectonism; Trmm; Satellite; High-Mountain Regions
4	43	0.872	2005	Evolution; Bay Of Bengal; Bengal; Luminescence Dating; Pattern
5	43	0.831	2008	Chemical Weathering; CO_2 Consumption; Major Ion Chemis
6	39	0.913	2000	Geochemistry; Weathering Processe; Fluxe; Chemistry; Amazon
7	36	0.925	2000	Suspended Sediment; Discharge; Transport; Stratigraphy; Fine Grained Sediment
8	36	0.782	2007	Arsenic; West Bengal; Groundwater; Aquifer; Contamination
9	32	0.749	2011	Polymorphism; Mtdna; Denudation Rate; Genetic Divergence; Situ Produced Be 10
10	30	0.951	2003	Satellite Altimetry; Ganges-Brahmaputra Delta; Braided river; Ecology; Provenance Analysis
11	29	0.887	2001	Bengal Basin; Crustal Structure; Zone; Atlantic; Swatch
12	27	0.912	2012	Condition Factor; Form Factor; Chela Cachius; Puntius Sophore; Carbon Dioxide
13	27	0.876	2005	Brahmaputra River; Bank Erosion; Bankline Migration; Sediments; Cyprinidae
14	25	0.958	2004	Arsenic; Catchment; Drinking Water; Fluoride; River Basin
15	23	0.858	2002	Ganges Brahmaputra; Clinoform; Subaqueous Delta; Gulf Of Papua; Compound Clinoform
16	18	0.975	2007	Adriatic Sea; Accumulation; Storm Surge; Organic Carbon Flux; Nature-Based Strategies
17	15	0.955	2005	Northeast India; Shillong Plateau; Collision; Earthquake; Fault Alignment

Note: Source: Web of Science.

Clu0 (climate change) is the largest cluster, indicating that the impact of climate change on the Brahmaputra basin has been a research focus in recent years. This includes literature on climate change trends in the Brahmaputra river [13], the impact of climate events on the region [14], and the potential impacts of climate change on water resources [15], ecosystems, and socio-economic aspects.

The most cited literature in the field of Clu1 (precision) is related to precipitation [16,17], floods [18], etc. There is an increased probability of flooding in the future in Bangladesh, India, and Pakistan due to climate change, strong monsoon precipitation, and other factors.

The main focus of the Clu2 (Indian Ocean) area has been the study of the Bay of Bengal region within the Indian Ocean. This includes the study of the geological structure of the Bay of Bengal fan [19], the study of climate change in the Bay of Bengal [20], and the study of the hydrology and geochemistry of the Bay of Bengal [21].

The field of Clu3 (remote sensing) focuses mainly on the study of glaciers, geology, elevation, etc., using remote sensing techniques. This includes the study of glacial changes in the Yarlung Tsangpo river basins using satellite altimetry data [22], the study of groundwater-level data [23], and the remote sensing characterization of the complex river system of the Yarlung Tsangpo [24].

The field of Clu4 (evolution) is concerned with the study of fluvial geomorphology, the evolution of river beds [25], mechanisms of sediment erosion, transport and accumulation [26], and geomorphic variables such as topographic relief [27].

The content of the Clu5 (chemical weathering) area covers geological and environmental sciences, with special attention to chemical weathering processes in the Yarlung Tsangpo river basin [28], rock dissolution and mineral alteration [29], and geochemical evolutionary processes [30].

The field of Clu6 (geochemistry) focuses on the composition, distribution [31], migration, enrichment and dispersion patterns of Earth's elements and their isotopes [32], and heavy metal pollution in watersheds [33].

The content of the Clu7 (suspended sediment) domain focuses on the effects of suspended sediment on surface structure, distribution patterns [34], erosion [35], and environmental pollution [36].

The content of the Clu 8 (arsenic) domain is mainly related to the study of arsenic contamination, which is closely related to the large-scale arsenic contamination incident in Bangladesh, including the mechanism of arsenic contamination [37,38] and redox process of arsenic migration in groundwater [39].

The Clu9 (polymers) domain focuses on biopolymers, vegetation distribution [40], disease [41], and other topics related to the Brahmaputra basin [42].

From an overall analysis of these literature clusters, the following key features can be summarized:

- Climate change impacts are the most important research focus. This includes not only the analysis of climate change trends but also the potential impacts of climate events on water resources, ecosystems, and socio-economics in the basin. This reflects the fact that climate change is the primary challenge facing the basin.
- Research on hydrological processes and geomorphology is widely emphasized. These include studies of precipitation, flooding, sediment transport, geomorphologic evolution, and other processes, which provide an important scientific basis for basin management. Remote sensing plays a key role in these studies.
- Geochemical characterization is another key area. It involves chemical weathering processes, element migration and enrichment, groundwater pollution, etc., which reveal the chemical processes in the context of the geological environment of the basin. This is of great significance to the environmental protection of the watershed.
- Ecological issues have also attracted wide attention. The biological processes, including vegetation distribution and disease transmission, reflect the complexity and vulnerability of the social-ecological system in the basin.
- These research results, while providing a scientific basis for integrated river basin management, also highlight the importance of transboundary cooperation within the river basin. In particular, there is a need to strengthen coordination among all parties in the management of transboundary shared resources, such as climate change, water resource development and utilization, and environmental protection.

4.2. Literature Theme Evolution

From the initial geological and geochemical aspects, such as the isotopic ratio “Sr-87/Sr-86” and the radionuclide “Pb-210”, to river hydrological research, such as the “Brahmaputra river system”, “Fluxes”, and “Himalayan rivers”, and then expanding the scope of research to include surrounding areas, it has become a popular research topic in recent years, focusing on regions like “India” and “Bangladesh” and their relationship to “climate change”. The research in the past three years has involved “management”, “GIS”, and “mineral claims”, indicating that research in this field has begun to shift towards social sciences and more advanced technological methods. Interested researchers can start exploring these aspects in the future.

4.3. Theme Hotspots

We analyzed the data obtained and collected a large number of news items about the Brahmaputra watershed and found that the content of papers in this field is closely related to current topical events.

The first type of event is major natural disasters; for example, after the earthquake in northeastern India on 12 June 1987, a number of scholars investigated the relationship between the local ground subsidence caused by the earthquake and the unusually deep, widespread, and long-lasting flooding that occurred in the Yarlung Tsangpo river section in the same year [43] (related to Clu0 (climate change)).

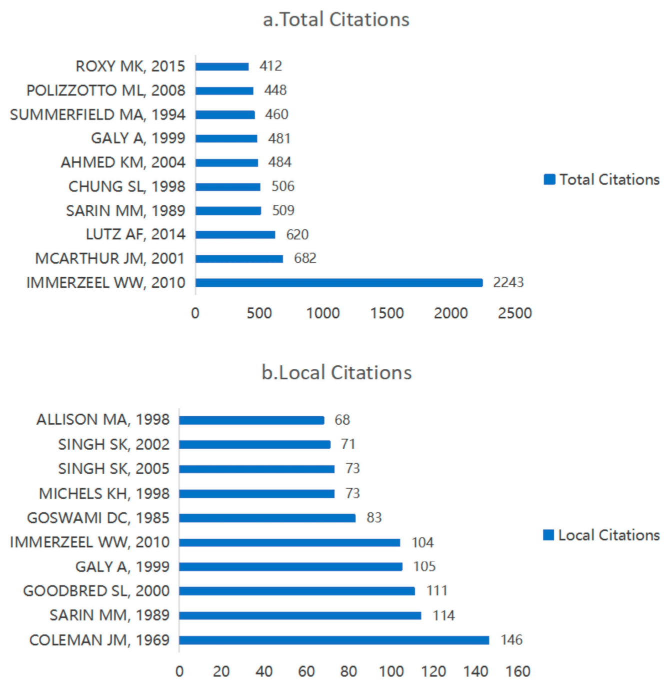
The second category is serious pollution incidents. According to a 2012 bulletin by the World Health Organization (WHO), arsenic-contaminated water in Bangladesh is the world's worst case of collective poisoning, resulting in at least 43,000 deaths from arsenic poisoning each year. Many scholars have studied this issue in depth, investigating the distribution, field relationships, and hydrogeological background of arsenic in groundwater of the Bengal basin [44] (related to Clu8 (arsenic)).

The third category is water management policy events. The Yarlung Tsangpo river flows through several countries and requires coordination of many aspects. For example, after the flooding of the Yarlung Tsangpo river, scholars explored water resource management policies and programs for the government [45].

4.3.1. Geological and Hydrological

Most of the research in the field is conducted from the perspective of natural sciences. The reason is that the Brahmaputra basin has a unique geographical environment. From a geological perspective, the primary indicator of Quaternary tectonic uplift is the presence of youthful slopes in the Darjeeling Himalayas, which are located prominently in front of the Ganges Brahmaputra river. The evidence of this uplift can be seen in the elevated fragments of river terraces and the newly formed fault scarps. Therefore, the Brahmaputra river holds great research value for scholars studying geological evolution. From a climate hydrological perspective, the Brahmaputra basin is affected by the southwest monsoon (June to September) and the Bay of Bengal cyclone, making it the region with the highest rainfall in the world. Due to climate change, water flow becomes highly unstable, leading to frequent floods and changes in river channels.

From the highly cited literature data, it is evident that research in the natural sciences receives the highest number of citations. This article analyzes the research methods and content of highly cited literature using LCS (Local Citation Score) and GCS (Global Citation Score) indicators (Figure 8). LCS represents the number of citations within the downloaded dataset, indicating the level of attention received from scholars in the same field. A higher LCS value indicates greater recognition within the specific field. On the other hand, GCS refers to the number of citations in the Web of Science Core Collection database, which includes citations from other fields, reflecting the global impact of the literature.



Source: Web of Science.

Figure 8. Highly cited literature based on LCS and GCS indicators [13,15,16,25,26,28,29,35,37,38,46–52].

The most frequently referenced literature in GCS relates to climate change in the Brahmaputra basin [13]. The second most cited article is related to arsenic [37]. The most cited literature in LCS is also the earliest SCI literature on watersheds, which was published in the field of geology in Semantic Geology [46]. The second highest citation was published in Geochimica Et Cosmochemica Acta, focusing on the study of chemical weathering and geochemistry [29].

4.3.2. Ecological Risk and Sustainable Development

The study of ecosystems has gradually evolved in recent years, and several scholars have started to conduct ecological studies on the Brahmaputra river basin, including ecological alterations and ecological risk analysis. These studies aim to gain insights into the ecosystem structure, functions, and processes of the Brahmaputra river basin and to assess the impacts of human activities on the ecosystem of the basin.

In the area of ecological alteration, scholars focus on the impact of factors, such as land use change, water resource development and management, biodiversity loss, and climate change, on the ecosystem in the Brahmaputra river basin. They use remote sensing technology, GIS, and ground surveys to quantitatively analyze and simulate the extent and spatial distribution of the impacts of different factors on the ecological environment to reveal the dynamic process of ecosystem change, for example, the impacts of potential climate change on the topography and ecology of wetlands in the middle reaches of the Brahmaputra river [53] and the human–nature interactions in the coastal floodplain of the Ganges-Brahmaputra delta [54].

In addition, ecological risk analysis is one of the important directions of ecological research in the Brahmaputra river basin. Scholars focus on potential ecological risks in the basin, such as flooding, soil erosion, and water pollution, and the impacts of these risks on the ecosystem and human society. They assess the probability, intensity, and vulnerability of different risk events by building risk assessment models, conducting site surveys, and analyzing data, to provide a scientific basis for the ecological protection and sustainable development of the watershed [55,56].

Sustainable development is an integrated strategy designed to guide and encourage sustainable development at the national and international levels. In support of the concepts of monitoring, evaluation, and adaptive management, the SDGs provide an adequate ethical basis through the development of indicators associated with each goal and sub-goal, based on social justice, equity, and transparency. Scholars have analyzed the SDGs in the Brahmaputra region, explored the trade-offs between the goals, and provided a scientific basis for developing integrated management strategies and decision making. The results of these studies are instructive for advancing sustainable development, protecting ecosystems, and promoting ecological and economic development [57–59].

4.4. Outlook and Perspectives: The Issue of Water Resource Management

Water resource management is the application of administrative, legal, economic, technical, and educational means by the competent water administration authorities to organize various social forces to develop water conservancy and prevent water hazards, to coordinate the relationship between socio-economic development and water resource development and utilization, to deal with the conflicts of water use among regions and sectors, to supervise and restrict unreasonable development and acts that endanger water sources, and to formulate optimal scheduling plans for water supply systems and reservoir projects. In the context of the Brahmaputra river basin, water resource management research focuses on addressing the region's water resource management challenges through scientific means and an integrated approach. This includes ensuring a balance between demand and supply and the sustainable utilization of water resources, addressing flood risk and disaster management, protecting and restoring river ecosystems, addressing water quality issues, and promoting transboundary cooperation and governance. These studies provide a scientific basis for the development of effective management strategies and decision making for the harmonization of sustainable water resource use and socio-economic development [60–62].

The upstream of the Brahmaputra river is located in China, with some tributaries crossing Bhutan. The midstream is in India, and the downstream is in the Bangladesh region. This means that multiple countries must collectively participate in basin water management. India is closely monitoring China's management and utilization of this river. To this end, they have held numerous talks and signed agreements to share hydrological data and promote exchange and cooperation.

To address governance issues such as inconsistent opinions from various countries and difficulties in coordination, the management work has been progressing slowly in recent years, and there are significant obstacles to watershed governance. At the same time, each coastal country has different interests and development agendas, which hinder the identification of shared interests in water cooperation. Therefore, many scholars have conducted research in the field of cross-basin cooperation in water politics [63].

In the future, the topics related to the transboundary basin governance of the Brahmaputra river may be developed from the following aspects:

- Coordination of transnational interests: The basin involves a number of countries, including China, India and Bangladesh, which have different interests in the use and development of water resources, which poses a challenge to transnational cooperation. How to balance the interests of all parties and reach a consensus is the key.
- Establishment of governance mechanism: Currently, there is no effective governance mechanism for basin management, and the coordination and communication among countries and the implementation need to be further strengthened. There is a need to establish a sound transnational water resource management organization and legal framework to promote joint cooperation.
- Technical and financial support: Basin water resource management involves many complex scientific and technological issues and requires continuous technical innovation and financial investment. However, the gap between the level of funding and technology may cause differences among participating countries.
- Responding to climate change: Climate change poses a growing threat of floods and droughts in the basin, requiring countries to strengthen emergency management capacity building and disaster risk prevention and control.
- Ecological and environmental protection: How to protect river ecosystems in the basin while developing and utilizing water resources is also a major challenge. Countries need to harmonize the relationship between economic development and ecological protection.

5. Conclusions

Drawing on the BiblioShiny and Citespace tools, we set out to explore the discipline trend upon the Brahmaputra river. Our research results indicate that the changes in research topics and hotspots are closely related to the natural geographical conditions, disaster events, and water pollution events in the Brahmaputra basin. Additionally, these changes are influenced by the water management strategies implemented by the countries and regions through which the basin passes. We found that research on this river has received significant attention in the last decade on the topic of climate change, while in recent years, research on transboundary water resource management and policy cooperation has been gaining multinational attention. The research focus related to the Brahmaputra river has shifted from the field of geology in the last century to hydrology, and then to geochemistry. In recent years, the field of climate change has been a hot topic, and future research may focus on areas such as "GIS" and "water management".

In an in-depth analysis of the Brahmaputra study, we found that, despite the growing importance of climate change and transboundary water resource management in recent years, the existing literature still fails to adequately cover the complexity of this area. Current studies tend to focus on a single dimension, such as hydrological change or ecological impacts, and lack an integrated perspective across socio-economic and cultural disciplines, a limitation that contributes to a poor understanding of the basin. At the same time, the current literature often lacks a focus on local knowledge and community engagement. Although scientific studies provide important data support, ignoring the experiences and traditional wisdom of local people may lead to less effective policies and management measures; therefore, future research should include a combination of interdisciplinary approaches and qualitative studies, and a more in-depth exploration of policy coordination and cooperation mechanisms in water resource management across different countries and regions will help to reveal deeper socio-ecological relationships and promote more inclusive water management strategies.

The Brahmaputra river flows and unfolds not in a standardized, cookie-cutter way but as an unpredictable and diverse process of human–nature interaction and interplaying. Heuristic comparisons of the theoretical and modeling implications of meteorological, hydrological, ecological, and socio-economic effects along the Brahmaputra river demand close attention and experimental analysis, especially under different scenarios of Anthropocene interferences and mega-infrastructure materials. Future research should carefully consider the potential effects of transdisciplinary research trends. For instance, it should utilize advanced technological methods to explore the issues related to the Brahmaputra basin, combining both natural and social science perspectives. Studies that investigate various uncertainties in riverine parameters and simulated streamflow would nurture robust modeling and sustainable watershed governance. Moreover, it is urgently needed that transborder governance and management regimes will be renovated through joint efforts and cross-border effective actions soon in the lens of multifaceted and multi-scalar agencies along this river.

This review has some limitations: the selected literature sources are English literature in the Web of Science; the selected research direction is transnational rivers; the keywords are mainly Brahmaputra river, which is the name of this river in international common use, in order to facilitate better study of transboundary zones, excluding all the names of minor tributaries of this river, which has some limitations and can be expanded in future research.

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