

A quantitative analysis of research trends in flood hazard assessment

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Abstract

Although the scientific investigation into flood hazard assessment (FHA) has increased in recent years, a global analysis of FHA-related studies is still rare. This research aims to elucidate trends in FHA-related scientific inquiry from a quantitative perspective. A bibliometric analysis was conducted to analyze a sample of 723 articles published in the period 2000–2020 from the Web of Science databases (WoS). *Bibliometrix* R-Tool was used to explore the trends and themes in this field by analyzing substantial documents, sources, and authors. Results show a growing number of scientific publications during the past two decades and a poor collaboration network between countries in this field. Keyword analysis shows that the themes of this research domain were focused on modeling. The main finding is that FHA remains an under-investigation field of study that focuses on specific geographical areas. Nevertheless, international collaborations present an increasing trend in FHA-related research, and a growing number of scholars have significant interests in FHA, whose topics are gradually systematized. These findings offer a comprehensive picture of FHA-related research and suggest the need for and benefits of collaboration across geographical study areas.

1. Introduction

Globally, floods have become more frequent in recent decades, a finding that is consistent with observations of anthropogenic climate change (Stott, 2016). Meanwhile, floods are becoming increasingly severe, leading to enormous economic loss and death (Lehner, Döll, Alcamo, Henrichs, & Kaspar, 2006; Luo et al., 2019). Despite substantial flood prevention efforts, the resultant loss of human life and property persist at high levels, with floods accounting for 34 and 40%, respectively, of all global natural disasters in quantity and losses (Lyu, Shen, Zhou, & Yang, 2019; Petit-Boix et al., 2017). Flood hazard assessment (FHA) is considered an important means of decreasing flood disaster losses and ensuring the healthy and sustainable development of human society. Therefore, research in this area is imperative to meet human needs (Wang et al., 2015).

With growing interest in FHA, it is essential to keep track of the key trends and the direction it is heading. FHA, a qualitative or semi-quantitative method, is focused on the combined influence of disaster-inducing factors and environments (Hallegatte, Green, Nicholls, & Corfee-Morlot, 2013; Mu et al., 2021). Comprehensive flood hazard assessment has generally been used in flood insurance, floodplain management, disaster evacuation, disaster warning, disaster evaluation, flood influence evaluation, the improvement of the public's flood risk awareness and understanding of flood disasters (Luo et al., 2020; Zou, Zhou, Zhou, Song, & Guo, 2013). In recent years, FHA research has increased in quantity and sophistication because more new technologies are integrated, such as remote sensing (RS), GIS, and open data (including social media data, volunteer geographic information) (Fang, Hu, Shi, & Zhao, 2019; Sajjad, Chan, & Kanwal, 2020; Thaler & Hartmann, 2016).

Most FHA-related studies were focused on modeling and proposing a new hydrological risk framework. For example, some scholars developed and examined a novel approach for assessing flood risk in river catchments in a spatially consistent way (Falter et al., 2015; Zhu, Luo, Zhang, & Sun, 2020). Their research was based on a set of coupled models that generated long time series of spatially consistent meteorological fields, through the subsequent models, into long time series of flood damage deriving flood risk estimates directly from the simulated damage. A similar study proposed a univariate and copula-based bivariate hydrological risk framework for advancing traditional flood risk analysis (Guo, Chang, Wang, Huang, & Zhou, 2018). Their

research considers the design flood of downstream hydraulic structures and instream flow requirements for sediment transport.

Some scholars also offer a multi-criteria index approach to classify potential flood risks at the river basin scale (Toosi, Calbimonte, Nouri, & Alaghmand, 2019). Their research spatially analyzes seven parameters (runoff coefficient, elevation, slope, distance from the drainage network, rainfall intensity, soil erosion and land use), combining the information in the Flood Hazard Index. In another study, based on long-term monthly streamflow data from 9 gauging stations covering the period of 1960–2014, nonstationary analysis was used to quantify flood frequency and flood risk (Sun et al., 2018).

A case study introduced an approach that employs a future land-use simulation model for scenario-based 100-year coastal flood risk assessment (Lin, Sun, Nijhuis, & Wang, 2020). The research explores the possible implications of future land-use changes due to the ongoing urbanization on projected environmental changes (sea-level rise, storm surge, and land subsidence). Moreover, some scholars provided a risk assessment framework for flash floods induced by tropical cyclones under climate change scenarios (Zhang, Wang, Chen, Liang, & Liu, 2019).

In addition, several recent comparative studies reported promising results using machine learning methods in FHA-related research. Some scholars presented a semi-supervised machine learning model (the weakly labeled support vector machine) to assess flood-prone areas with limited flood inventories (Huo et al., 2020; Zhao, Pang, Xu, Peng, & Xu, 2019). Their study is a novel attempt to introduce a semi-supervised machine learning model in urban flood susceptibility assessments and proves that it has good performance in FHA. Finally, some studies provided state-of-the-art ensemble models of boosted generalized linear model and random forest, and Bayesian generalized linear model methods for higher performance modeling (Hosseini et al., 2020).

As comprehensive research is limited, it is vital to analyze global trends in FHA-related publications. This work starts with the three main pillars of scientific publication: who writes this article (authors), who publishes magazines on the topic (sources) and what was written (documents) (Rodriguez-Soler, Uribe-Toril, & Valenciano, 2020). This study provides a detailed analysis performed for FHA conducted during 2000–2020 using the *bibliometrix* R-tool. The bibliometric analysis entails several steps, including numerous analyses and mapping software tools, usually available only under commercial licenses, resulting in a very complex process (Guler, Waaijer, & Palmblad, 2016). The complexity of the process reduces the potential and the possibilities of bibliometrics, especially for researchers without general programming skills (Aria & Cuccurullo, 2017). In recent years, bibliometrics has assembled specialized software into a comprehensive and organized data flow through automated workflows, suitable for multi-step analyses using different types of software tools (Guler et al., 2016; Munim, Dushenko, Jimenez, Shakil, & Imset, 2020). Consequently, we can investigate, in detail, the leading edge of academic articles, publication data, and information about authors, journals, countries, and institutions with significant contributions in FHA using the *bibliometrix* R-tool (Shikoh & Polyakov, 2020).

Compared with previous literature reviews, the literature search process detailed here is robust, repeatable and transparent. Published studies related to FHA and the analysis of mapping the conceptual structure of this field and determining future research avenues were reviewed. The remainder of the article is structured as follows. First, the methods and databases are described. Second, the investigation results are obtained through

descriptive and bibliometric analysis. Finally, limitations and suggestions for future research are provided in the conclusions section.

2. Methodology

Publications are the record of scientific trends: "Communication in science is realized through publications. Thus, scientific explanations, and in general scientific knowledge, are contained in written documents constituting scientific literature" (Riviera, 2013). Bibliometric analysis, a quantitative approach that aims to map and evaluate the body of literature to identify potential research gaps and emphasize the boundaries of knowledge, is considered an effective means of grasping critical trends in the scientific investigation (Tranfield, Denyer, & Smart, 2003).

The search was divided into three sub-stages concerning the data collection stage, as shown in Fig. 1.

In the first sub-stage, to initiate systematic bibliometric analysis, the search for relevant literature (from 2000 to 2020) was conducted in the "Web of Science" (WoS) portal using a predefined keyword string, i.e., "flood hazard assessment OR flood hazard analysis." In total, 4135 documents were extracted from WoS after the keyword selection.

In the second sub-stage, 776 documents were filtered. To this end, the following measures were performed:

- The year 2021 was excluded because the year had just begun at the time of this research.
- Before the year 2000 were excluded because there are few records of FHA in the WoS.
- The document types were limited to articles and reviews, which excluded 557 items.

In the third sub-stage, the authors adopted the research area, title, abstract and keyword filter, which excluded many unrelated documents. Hence, the final sample consisted of 655 articles, 3 early access, 54 journal paper, and 11 reviews. All data were gathered in February 2021.

While language was not used as a filter, it is well known that the database was developed utilizing English, which could be understood as a "quasi filter."

The study was performed using an open-source R-package called "*Bibliometrix*," which provided various routines for both bibliometric and scientometric quantitative research by building data matrices for citation, scientific collaboration analysis, and co-word analysis (Aria & Cuccurullo, 2017; Xianbao Zha, 2021). Specific codes and commands for bibliometric indices were entered. Subsequently, detailed analysis graphs and tables related to the most productive authors, affiliations, countries, sources, highly cited articles were produced (Fig. 2). Finally, all the documents were independently coded by the author to recognize the units of analysis in the selected samples to increase the reliability of the research outcomes.

3. Results

3.1 Documents

Figure 3 shows FHA-related statistical data based on scientific productions published during 2000–2020. The trend of annual publications shows that there has been a steadily increasing interest in FHA. The 2010–2020 period was shown to be an active period with a high yield of documents. Remarkably, the number of scientific productions increased rapidly between 2018 and 2020.

As shown in Table 1, which includes the main topics associated with bibliometric analysis, FHA-related research has been published from 222 sources. During the past 20 years, 723 FHA-related scientific productions have been published. Nevertheless, the total number of citations was more than 8 000, with an average number of citations per document at 11.16. Regarding authorship, 2,596 individual authors have contributed to the field so far. On average, each article is written by three authors (3.6), which indicates that the study requires scholarly collaboration. The collaboration index, which is the ratio of total authors of multi-authored articles (2574) to the total multi-authored articles (698), is at a high level (3.69), and the number of single-authored documents was found to be only 24.

Table 1
Summary of the main information obtained in the
bibliometrix.

Description	Results
Years	20
Documents	722
Sources (Journals, Books, etc.)	222
Average citations per document	11.16
Keywords Plus (ID)	1029
Author's Keywords (DE)	2755
Authors	2596
Authors of multi-authored documents	2574
Single-authored documents	24
Documents per Author	0.278
Authors per Document	3.6
Co-Authors per Documents	4.26
Collaboration Index	3.69

The top 10 most cited articles on FHA are shown in Table 2. More accurately, the total citations that can be retrieved in the WoS are shown. The results coincide well with the research areas defined in this study. Interestingly, all articles on this list come from different journals. The maximum number of citations reached was 861, which occupies an important position in the FHA-related research.

Table 2
Main information of the 10 highly cited articles.

Rank	Article	Source	Year	Total Citations
1	Global flood risk under climate change	Nature Climate Change	2013	861
2	Future Coastal Population Growth and Exposure to Sea-Level Rise and Coastal Flooding - A Global Assessment	PLOS ONE	2015	606
3	Flood susceptibility assessment using GIS-based support vector machine model with different kernel types	CATENA	2015	225
4	Flood hazard risk assessment model based on random forest	Journal of Hydrology	2015	183
5	Flash flood risk estimation along the St. Katherine road, southern Sinai, Egypt using GIS based morphometry and satellite imagery	Environmental Earth Sciences	2011	171
6	Assessing flood risk at the global scale: model setup, results, and sensitivity	Environmental Research Letters	2013	168
7	A framework for global river flood risk assessments	Hydrology and Earth System Sciences	2013	168
8	Flood Prediction Using Machine Learning Models: Literature Review	Water	2018	155
9	Assessment of flood hazard based on natural and anthropogenic factors using analytic hierarchy process (AHP)	Natural Hazards	2013	153
10	Fluvial flood risk in Europe in present and future climates	Climatic Change	2012	119

Table 3 shows the top20 frequent keywords of FHA-related research. The most frequent keyword used by authors in their documents was model (98), illustrating that model has played an essential role in FHA. In fact, using the model to simulate the flooding process is the basis of non-engineering measures for flood prevention and control. (Díez-Herrero & Garrote, 2020). The second most frequent word is climate-change (74), followed by management (67), vulnerability (65), risk (56) and impact (47), suggesting the FHA-related challenges.

Table 3
Top20 frequent keywords.

Rank	Words	Occurrences	Rank	Words	Occurrences
1	model	98	11	inundation	39
2	climate-change	74	12	risk-assessment	37
3	management	67	13	rainfall	33
4	vulnerability	65	14	simulation	32
5	risk	56	15	damage	31
6	impact	47	16	hazard	31
7	uncertainty	44	17	river-basin	29
8	gis	42	18	areas	28
9	river	41	19	basin	27
10	impacts	39	20	precipitation	27

Figure 4 shows the conceptual structure map of keywords associated with scientific publications in the FHA-related research. It presents the co-word analysis performed using the word co-occurrences network to map FHA-related articles' keywords in the WoS database (Cobo, López-Herrera, Herrera-Viedma, & Herrera, 2011). It can be seen from the figure that, by multiple correspondence analyses, the articles involved in the study are mainly divided into three clusters of documents that express common concepts, which reveal the intellectual structure of FHA-related research. Thus, it can be observed that the first cluster deals with model themes while cluster two concerns support activities (urbanization).

3.2 Sources

According to Source dynamics, which shows the trend of the sources depending on the scientific FHA publications (Fig. 5), the evolution of the most productive journals can be divided into three typologies:

- *Natural Hazards*, which was initiated to publish FHA-related documents in 2010, continued to increase throughout the studied period.
- Some journals (*Natural Hazards and Earth System Sciences*, and *Sustainability*) characterized by an apparent original production level prior to 2018, but after which conspicuously reduced their FHA-related production with marked intervals of inactivity.
- The rest of the journals, including *Journal of Hydrology, Water, Journal of Flood Risk Management*, and *Science of the Total Environment*, began to publish FHA-related documents relatively late but present significant and continuous growth.

The h-index, g-index, m-index, total citations, number of publications, and year of first publication on FHA-related research for the top 15 productive sources contributing to the FHA-related research are shown in Table 4. The h-index was defined as the number of articles of an author that have citation count larger than or equal to the **h** of all co-authors of each article, as a valuable index to quantify an individual's scientific output, which considers the effect of multiple authorship (Voor Hirsch, 2005). The g-index was defined as the largest number **g**

of articles that together received g^2 or more citations ($g \geq h$). Interestingly, the higher the number of citations in the top class (in other words, the skew of the citation distribution), the higher the g-index will be (Egghe, 2006). The m-index is the h-index divided by the number of years that have passed since each journal released its first publication in the dataset (Hirsch, 2007). The m-index enables researchers to weigh productivity with their career length. *Natural Hazards* had the highest number of total citations (1199), followed by *Journal of Hydrology* (578) and *Science of the Total Environment* (456). However, the average number of citations per article was 17.63, 23.12 and 26.82, respectively, implying that *Science of the Total Environment* is the most influential, which was confirmed by the research shown in the h-index, g-index and the m-index.

Table 4
Top 20 Sources in the field of FHA.

Source	h-index	g-index	m-index	TC	NP	PY-start
Water	8	19	1.143	422	69	2015
Natural Hazards	19	32	1.583	1199	68	2010
Journal of Flood Risk Management	9	14	0.818	259	30	2011
Journal of Hydrology	11	24	1.375	578	25	2014
Science of the Total Environment	11	17	1.571	456	17	2015
Sustainability	5	7	0.625	66	17	2014
Natural Hazards and Earth System Sciences	6	12	0.667	163	15	2013
Geomatics Natural Hazards & Risk	8	12	0.667	248	12	2010
International Journal of Disaster Risk Reduction	9	11	1.5	178	11	2016
Hydrological Processes	5	7	0.227	58	10	2000
Arabian Journal of Geosciences	3	7	0.273	60	9	2011
Environmental Earth Sciences	7	8	0.636	300	8	2011
Stochastic Environmental Research and Risk Assessment	5	7	0.556	52	7	2013
Water Resources Research	3	7	0.333	58	7	2013
Environmental Modelling & Software	5	6	1.25	53	6	2018

Among the most productive sources, *Journal of Hydrology* is not the journal with the highest impact factor, but it represents the high level of FHA in the industry. As shown in Fig. 6, the above sources account for 33% of the total scientific publications on FHA, forming a core area of FHA research, which confirms Bradford's law – which can be summarized as follows - if sources in a research field are divided into three parts by the number of articles, each area accounting for around one-third of the total articles. The sources in each area will be proportional to $1: n: n^2$, while the first area is usually defined as the essential area (Xiao, Wu, Wang, & Mei, 2021).

3.3 Authors

Regarding the analysis at the Authors level, Fig. 7 shows their distribution over time. The circle area is proportional to the annual number of articles, and the colour depth of the circle is proportional to the total article citations per year. Among the top 20 most productive authors, *Wang H* (6 articles) published the most articles, and the scholars analyzed a large number of issues in dealing with flood disasters. Based on statistics, *Xu Youpeng* had the first article on FHA in 2005 and has sustained a steady output ever since. For most researchers, once they initiated the work on FHA, they would constantly conduct research, which implies the importance of FHA in research programs. The documents published by *Nicholls, RJ*, in 2015 have the greatest number of citations, which implies that, to a large extent, it has performed an important role in the FHA-related study.

Table 5 presents the top 30 productive countries defined by the total FHA-related scientific production counted by the corresponding author's country. Among 30 countries, China makes the top of the list, followed by the USA and the UK, a distant second and third place. Even though flood hazards are among the most severe disasters globally, research indicates that the losses caused by flood hazards are severe in China, which drives significant volumes of FHA-related research.

Table 5
The top30 publishing countries in FHA.

Rank	Region	Freq	Rank	Region	Freq	Rank	Region	Freq
1	China	961	11	France	34	21	Vietnam	18
2	USA	141	12	Canada	31	22	Belgium	16
3	UK	94	13	Iran	30	23	Austria	14
4	Italy	85	14	Mexico	27	24	Singapore	13
5	Spain	66	15	Pakistan	27	25	Slovakia	13
6	India	56	16	Egypt	21	26	Sweden	13
7	Germany	54	17	Saudi Arabia	20	27	Switzerland	13
8	Netherlands	52	18	Australia	19	28	Thailand	12
9	Japan	45	19	Portugal	18	29	Chile	11
10	South Korea	45	20	Romania	18	30	Turkey	11

The proportion of FHA-related scientific production for both multi-country publications (MCP) and singular country publications (SCP), China still tops the list, as shown in Fig. 8. MCP relates to articles where at least one of the co-authors is from various countries, yet SCP refers to cooperation within a country. Most countries prefer to form national cooperation instead of international cooperation as a rule. Among 20 countries, only four countries, including the Netherlands, Australia, Egypt, and Austria, have a greater proportion of articles published in MCP. The maximum number of citations per article might suggest an inclination toward the formation of MCP (rather than SCP) since they approved of the use of resources and technologies that might be lacking in one country, leading to a more profound citational impact.

Table 6 shows the top 15 affiliations publishing the largest number of documents, with many of them having an excellent prestige for scientific research and innovation. Two-thirds of the top 15 affiliations are located in China, which is related to the fact that China has much FHA-related research. Hohai University is the most productive affiliation with 57 articles published, and its research on FHA has a well-known reputation in Chinese academia. Hohai University is followed by Beijing Normal University (47 articles), Huazhong University of Science and Technology (41 articles), and East China Normal University (34 articles), all top universities in China.

Table 6
Top 15 productive affiliations in the field of FHA.

Affiliations	Articles
Hohai University	57
Beijing Normal University	47
Huazhong University of Science and Technology	41
East China Normal University	34
Nanjing University	24
Sun Yat-Sen University	20
China Institute of Water Resources and Hydropower Research	16
Indian Institute of Technology	16
Texas A&M University	14
Deltares	13
Shaanxi Normal University	13
Nanjing University of Information Science & Technology	12
Tianjin University	12
Vrije University Amsterdam	12
COLL.	11

Figure 9a shows some essential collaboration among countries around the world, and countries shaded with the darker blue turn out to be the more productive concerning scientific publications. The pink curves represent the collaboration network established among countries worldwide - the more robust the curves, the more frequent collaboration. Obviously, the most international collaboration between China and the USA supports the research shown in Fig. 9b. Meanwhile, it shows a more visible scenery of international collaboration by the visualization of connections among the top 20 contributing countries, which indicates that the more robust collaborations are being established by scholars from various countries, who form connections with their partners in different countries around the world.

According to the analysis of a sample of FHA-related research, the h-index, g-index, m-index, total citations, the number of publications, and year of first publication on FHA-related research for the top 15 authors are shown in Table 7. Ward PJ, Zhang Q, Merz B, Nicholls RJ and Pradhan B have the highest h-indexes in the table, all having an h-index greater than 5, indicating they published at least 5 articles with at least 5 citations each. In terms of productivity, Wang J, Wu ZN and Zhang Q were the best ranked. Among the three authors, Zhang Q has the highest citations and the greatest h-index. Nicholls RJ got the highest number of citations (676). Although Ward PJ and Pradhan B are not the authors with the highest number of citations, the total number of citations is 465 and 489, respectively, but the h-index and g-index are equal, indicating that each of their articles has a high quality. To avoid excluding younger scholars, the m-index was also calculated. Although the total citation of Hong HY is only 41, his articles (4) are published in 2020, and the m-index (2) is the highest in the table, indicating that Hong HY is the author with the most potential.

Table 7
Top 20 Authors in the field of FHA.

Author	h-index	g-index	m-index	TC	NP	PY-start
Wang J	4	7	0.333	52	7	2010
Wu ZN	3	3	1	20	7	2019
Zhang Q	5	7	0.556	134	7	2013
Kreibich H	4	6	0.571	196	6	2015
Merz B	5	6	0.714	231	6	2015
Nicholls RJ	5	6	0.5	676	6	2012
Wang HL	3	3	1	17	6	2019
Ward PJ	6	6	0.667	465	6	2013
Pradhan B	5	5	0.455	489	5	2011
Shen YX	3	3	1	11	5	2019
Vorogushyn S	3	5	0.429	90	5	2015
Wang H	3	5	0.333	28	5	2013
Chstterjee C	3	4	0.375	55	4	2014
Chen XH	3	4	0.429	282	4	2015
Hong HY	4	4	2	41	4	2020

Finally, a comprehensive analysis of the relationship between keywords, sources and countries is carried out. Figure 10 provides the three-field plot of FHA-related studies from 2000 to 2020, which shows the interactions among the leading journals (left), keywords (middle) and countries (right) within FHA-related research. The visualization results more intuitively reflect the close relationship between the three.

4. Discussion And Conclusion

This study provides a structured review of a bibliometric analysis of a total of 723 articles on the flood hazard assessment (FHA) published between 2000 and 2020. Although a few literature reviews on FHA have been published, a comprehensive bibliometric and network analysis to objectively and scientifically identify influential documents, sources and authors have not been completed. The R package *bibliometrix* was adopted to evaluate the scientific publication's performances and visualize its related conceptual, social, and intellectual structures. The research was conducted using various bibliometric indicators to estimate the productivity ratio (e.g., total article) and relevance (e.g., total citations, h-index, g-index and m-index) of documents, sources and authors.

The document analysis demonstrated that the interest in research on FHA has increased in recent years, particularly between 2018 and 2020, as more than half the documents were carried out during this period, and the number of sources, authors and documents increased accordingly. Furthermore, for those seeking to do study in related fields and for instructional purposes, the identified "core" documents may prove a good starting point. Analysis of keywords shows that climate change, management and model played an essential role in FHA-related research. The prevention and control of flood disasters rely on many aspects of work. Among them, many non-engineering measures are based on model simulation of storm and flood processes.

The source analysis suggests that *Natural Hazards* led the research from 2010, with the highest number of citations and h-index impact. However, the FHA-related documents were not monopolized by a specific journal or group of journals. As a matter of fact, through a comprehensive analysis, it is concluded that the journals *Science of the Total Environment* and *Journal of Hydrology* were ranked first as the most influential journals.

The author analysis shows that Influential scholars should be noted since they may set the stage for future development. The sample study using various bibliometric indicators identified Kreibich H, Ward PJ and Pradhan B as the more prominent authors. Monitoring their works and their co-authors can provide some guidance for further research. For instance, recent works of some famous scholars have almost focused on modeling to simulate flood hazards. Moreover, the results suggested that China, the USA and the UK have conducted more research in FHA-related scientific publications. These obtained results show that FHA-related publications are very limited in the research field.

We can also find some weaknesses in these researches and the area overall. First of all, the small number of researchers and repetitions in the studies may lead to slow progress in FHA-related research. We hope that the situation is not the case and trust that various scholars will contribute and influence the field in effective and innovative directions. Moreover, not only is there a relative lack of diversity in the authorship, but also the lack of international collaboration limits the transdisciplinarity of this field.

Overall, FHA-related research is growing and maturing. Considering the small number of articles, there are only 723 related documents, which still has significant room for development. In view of the existing research, this number must continue increasing. In particular, opportunities for additional research on FHA's modeling and practical applications abound (Fahimnia, Sarkis, & Davarzani, 2015). The findings of this article can assist scholars in the field by offering a comprehensive picture of FHA-related research.

Declarations

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Figures

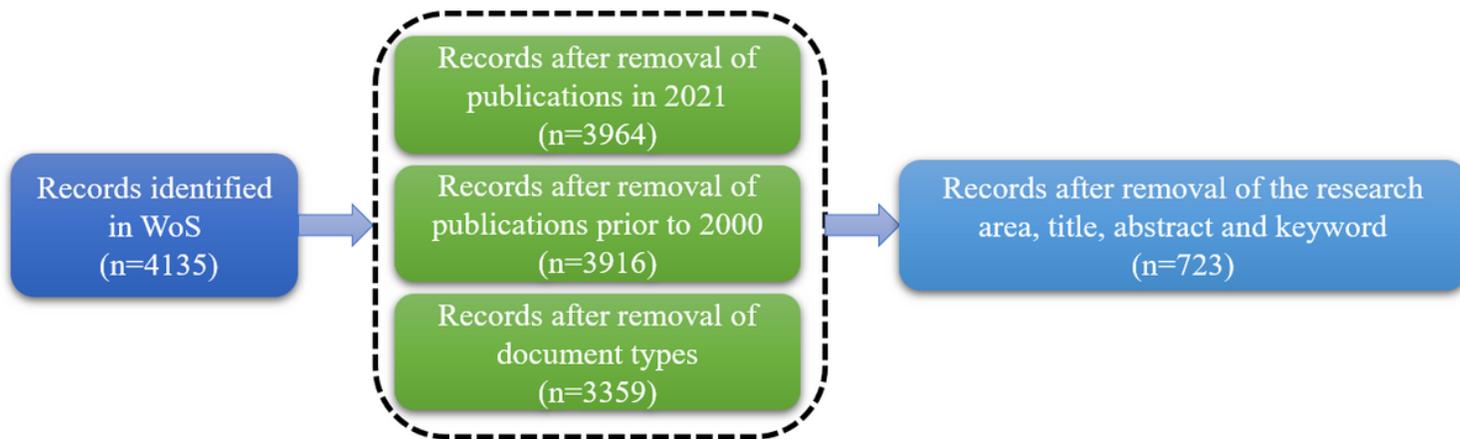


Figure 1

Data collection flow diagram.

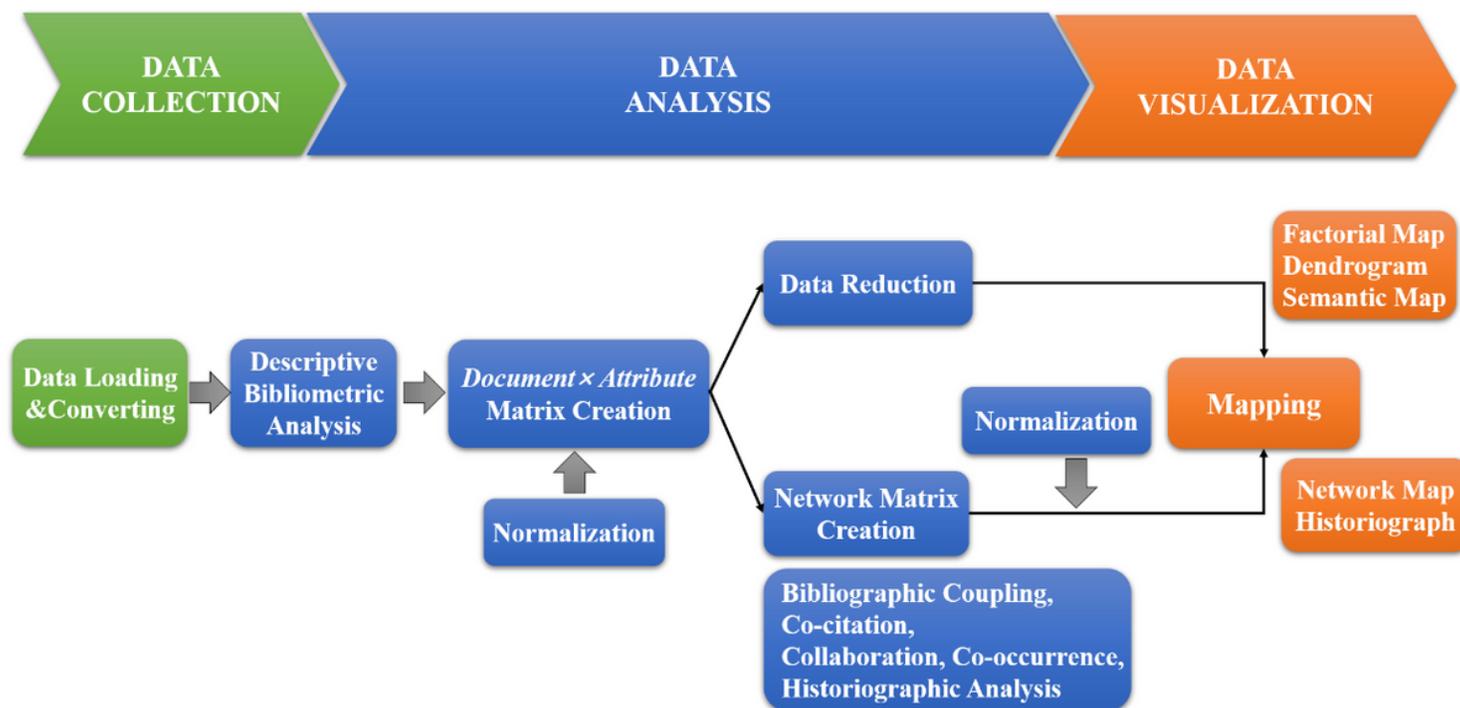


Figure 2

The science mapping workflow of *bibliometrics*.

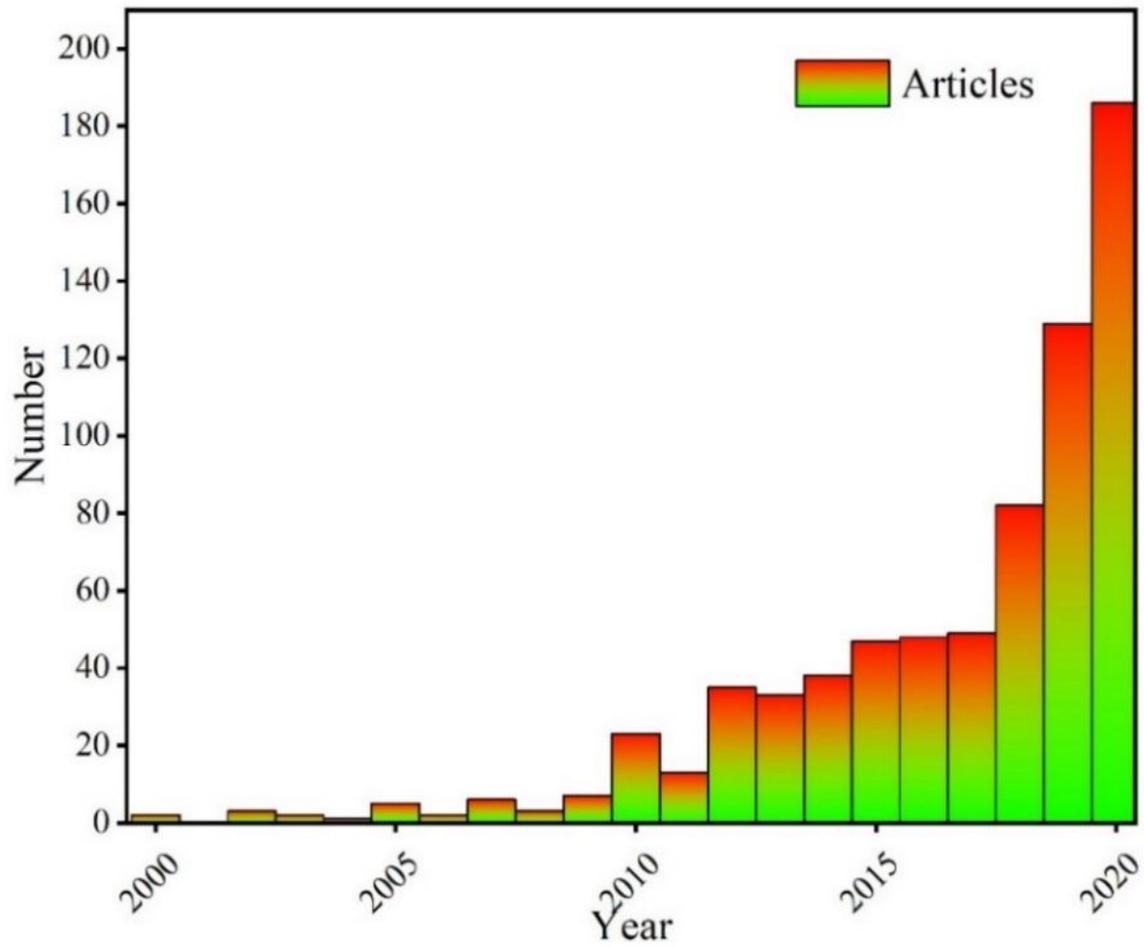


Figure 3

Annual Scientific Production published between 2000 and 2020.



Figure 4

Conceptual map of keywords in FHA

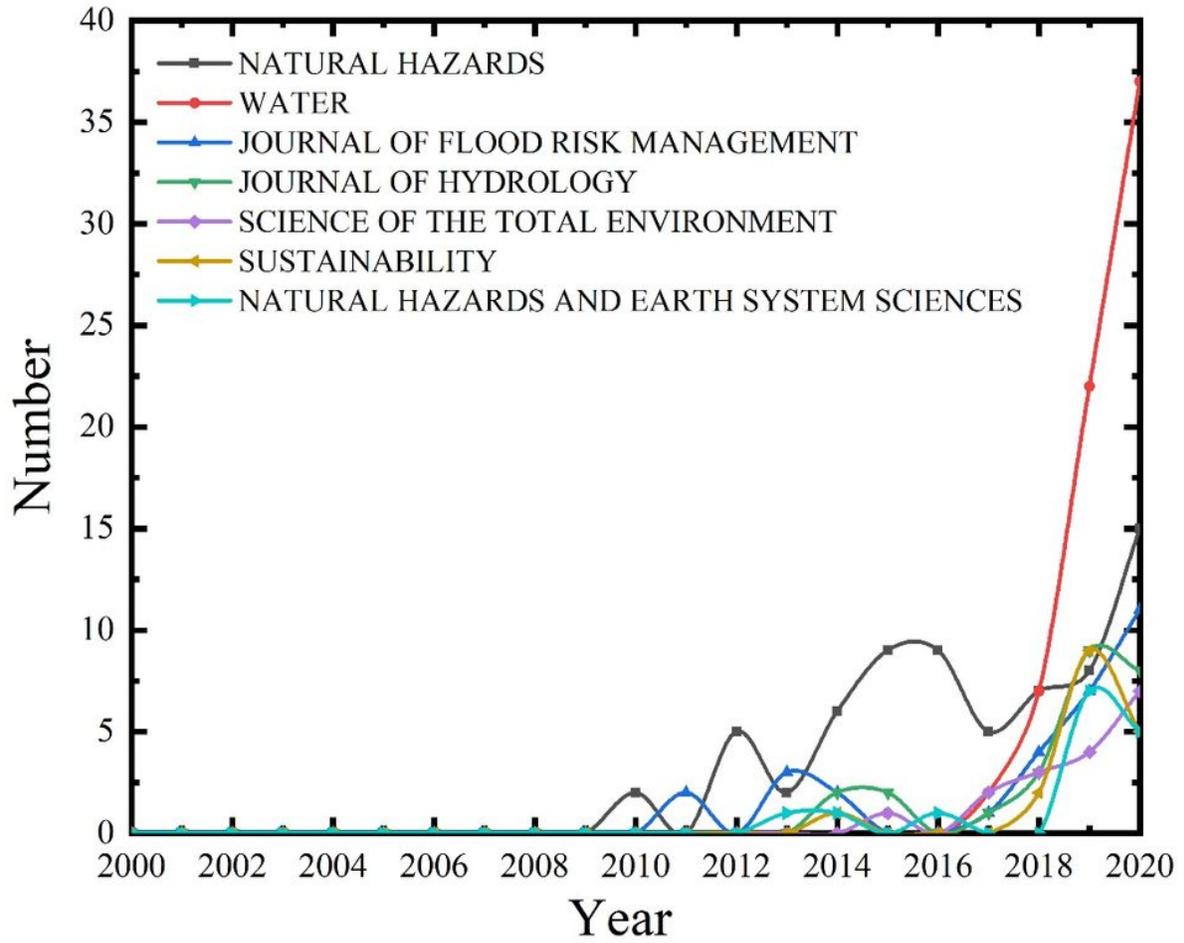


Figure 5

Growth in Sources using *bibliometrix*.

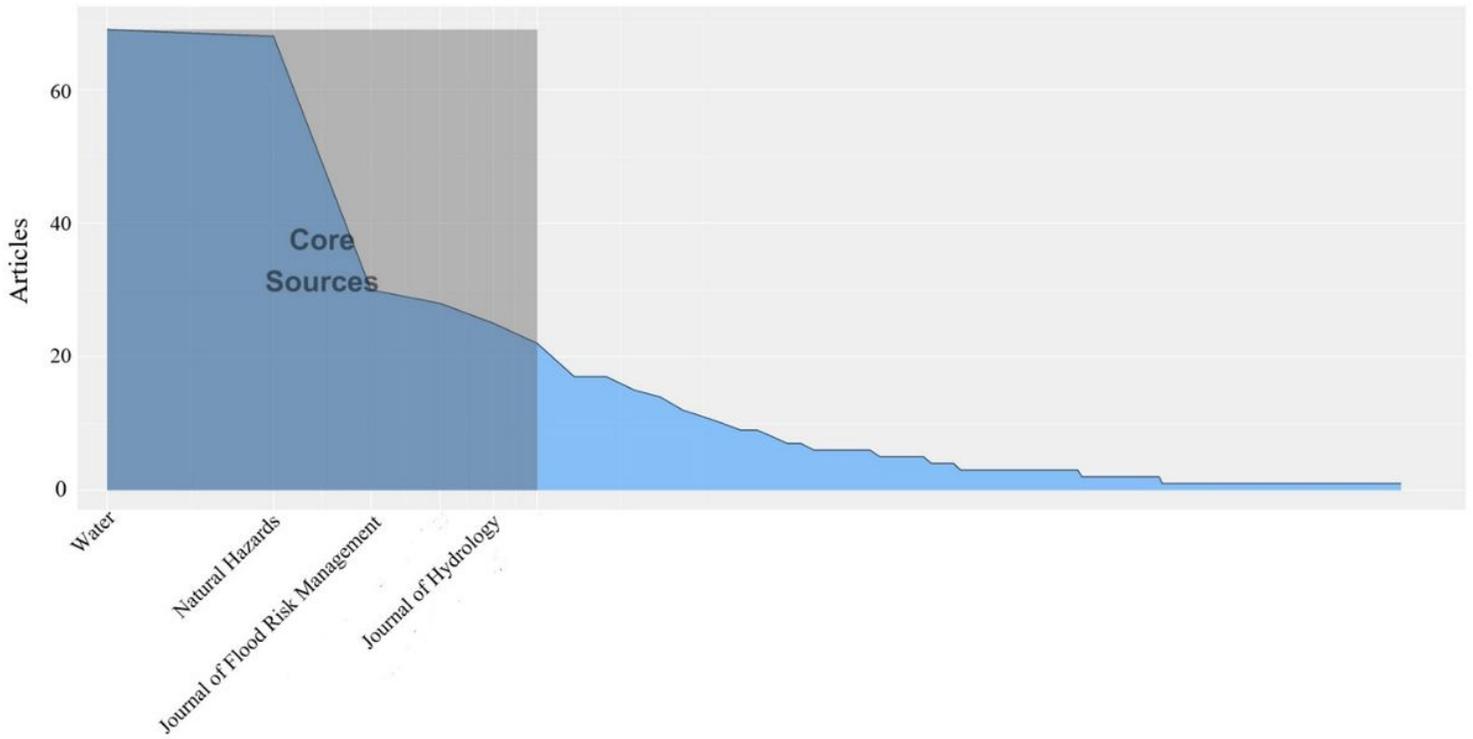


Figure 6

Bradford's law of journals on FHA

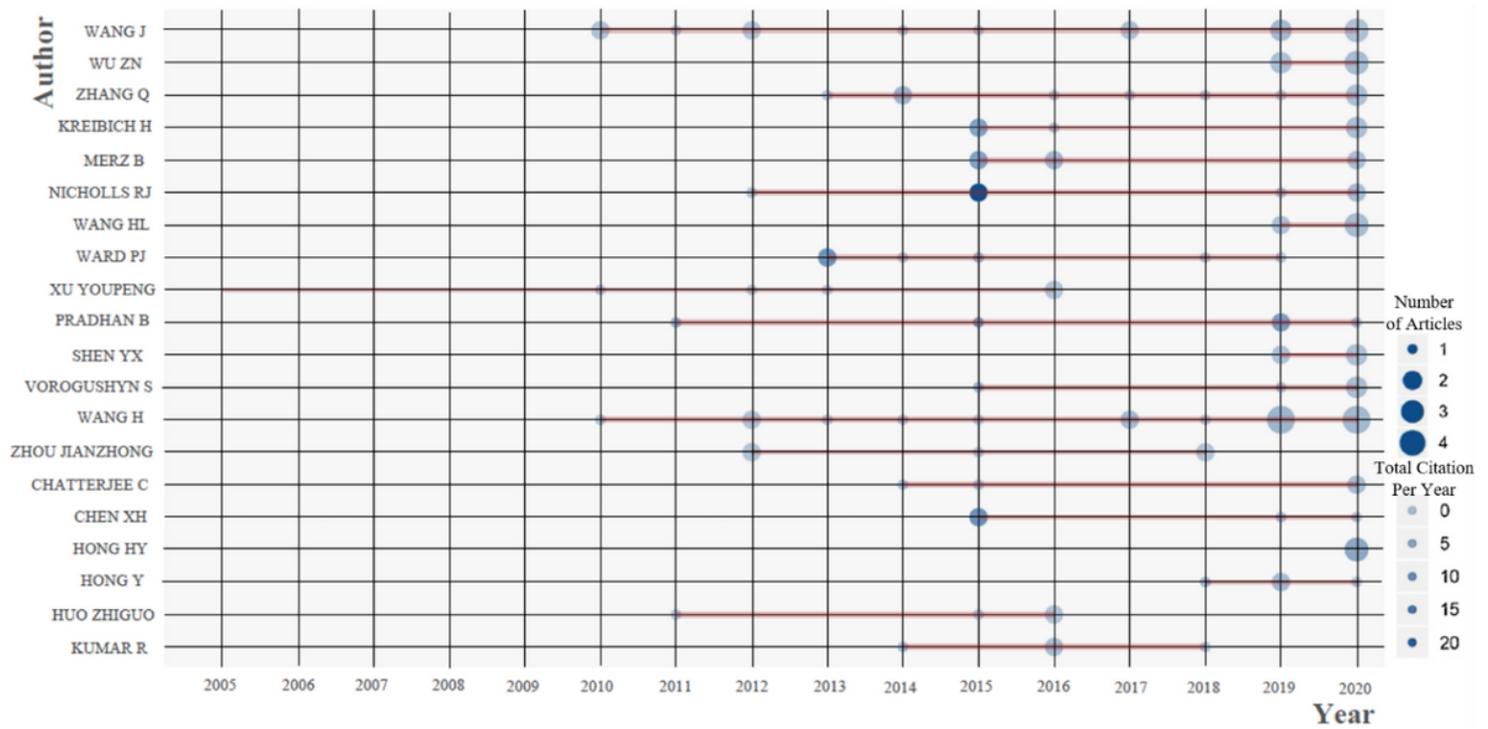


Figure 7

The top 20 Authors' production overtime in the FHA

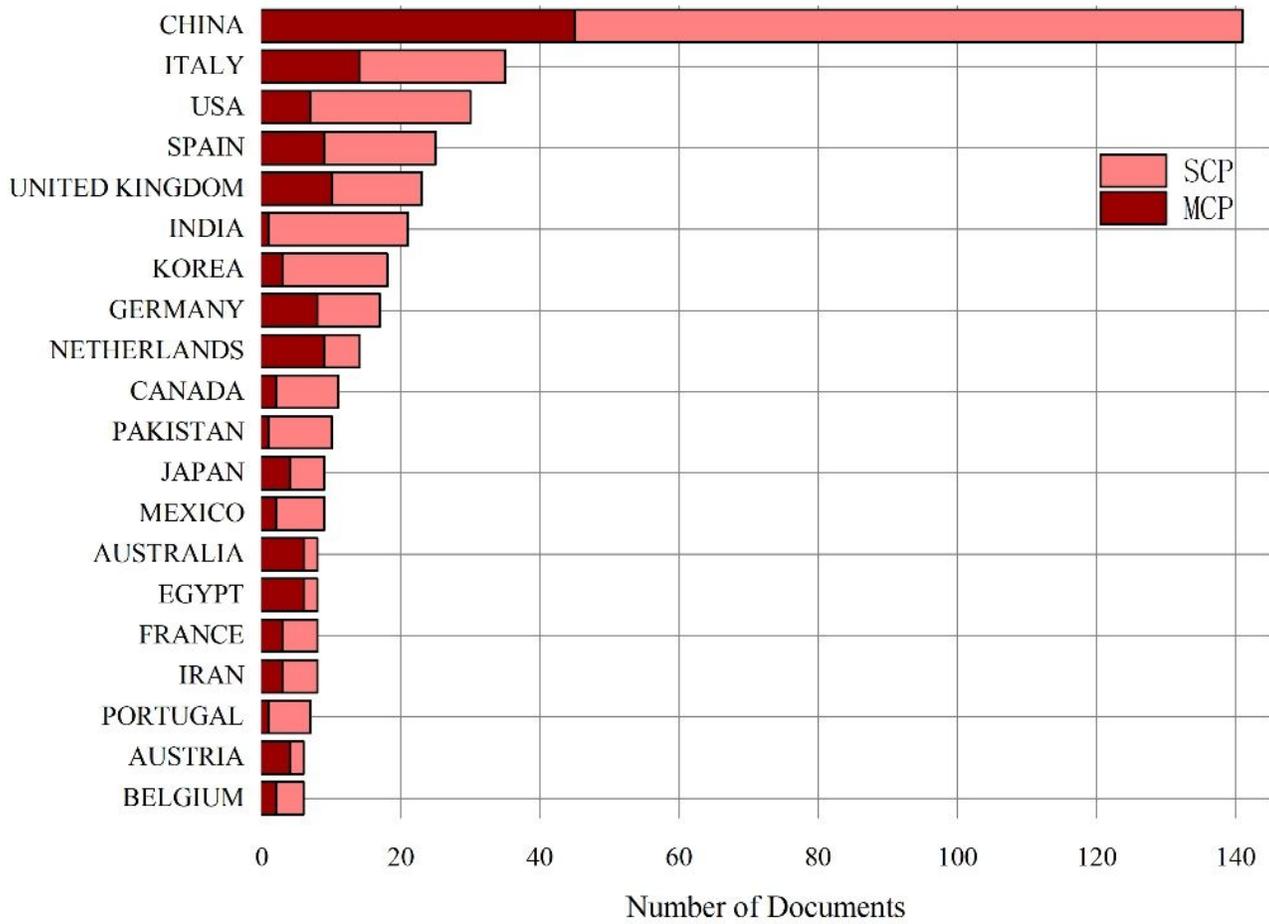


Figure 8

Top20 collaborative countries. MCP = multi-country publication;
 SCP = singular country publication.

Figure 9

(a) the scientific collaboration World-Map. (b) Bibliographic coupling of top 20 countries.

Figure 10

Three-fields-plot depicting the top 20 keywords.