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Flood risk management and governance: A bibliometric review of the literature

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Abstract

The study of flood management has experienced a paradigmatic shift over the past two decades. Particularly notable are the embracement of flood risk management (FRM) and comparative analysis of flood risk governance (FRG), meaning the complex institutional arrangements that shape the behavior of state and societal actors concerning FRM. Thousands of publications have addressed these themes, and this field of study is ripe for a systematic analysis that consolidates and structures this rapidly evolving literature. This study employed a bibliometric methodology to analyze the metadata (including authorship, keywords, abstracts, and citations) of 3059 such publications. The results reveal that both FRM and FRG scholarship have expanded over the past two decades; the United Kingdom and the Netherlands are the most prominent countries of origin, a small number of prolific authors stands out as major contributors, and a relatively small number of journals dominate as publication venues. The text mining results reveal that the bodies of FRM and FRG scholarship are highly correlated but yet differ in core subject matter, as demonstrated by the unique keywords found in the analysis. The findings are useful for researchers seeking relevant clusters for study and therefore offers reference value for future research and practice.

KEYWORDS

bibliometric analysis, flood risk governance, flood risk management

1 | INTRODUCTION

Globally, flooding is the most frequent and most costly natural hazard (United Nations, 2015). Population growth, climate change, and intensification and expansion of economic activity in flood-prone areas have all been identified as key drivers of increased future flood losses (Alfieri et al., 2016; Kundzewicz et al., 2014; Vitousek et al., 2017). Flooding has tremendous socioeconomic impacts on communities, and these impacts are

widespread and growing. According to the re-insurer Swiss Re, floods affect half a billion people every year—more than any other hazard—and cause \$50 billion USD in average annual losses (Swiss Re Group, 2018). Furthermore, the Intergovernmental Panel on Climate Change projects that global population growth, urbanization, and climate change will increase the social and economic costs of flooding into the future (Revi et al., 2014).

Given the scope and severity of its impacts, flooding has featured prominently in academic scholarship, as

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analysts around the world have sought to better understand its underlying causes and map out courses of action to reduce flood-related impacts on people and property. Analysis and evaluation of *flood risk management (FRM)*—a strategic approach to reducing flood impacts by sharing responsibilities and employing a diversity of instruments—is a well-established and distinctive body of scholarly literature (Klijn et al., 2008; Sayers et al., 2013; Simonovic, 2013). By contrast, *flood risk governance (FRG)*, meaning the complex institutional arrangements that shape the behavior of state and societal actors concerning FRM, is a relatively nascent topic (Raadgever et al., 2018).

Scholarly literature on both topics has expanded considerably in recent years, so it is an appropriate point to take stock of the ways in which this scholarship has developed. The purpose of this article is to analyze the nature and evolution of FRM and FRG literature over the past 20 years and to capture conceptual and intellectual convergence or divergence between the two fields of study. To this end, the article presents results of a bibliometric analysis of publications in these two research domains, which investigated the genesis, evolution, axiomatic characteristics, and research trajectory of these topics. Using textual analysis, the study also reveals similarities and differences in the subject matter addressed by the two bodies of literature.

Section 2 briefly contextualizes current scholarship on FRM and FRG. Section 3 describes the study's research design, including the sample selection, bibliometric and text mining method, and data analysis strategy. The fourth section presents the results of the study, beginning with a descriptive analysis of the meta-data, including research progress to date, influential players, and highly cited papers. It then turns to the content of the keywords and abstracts, using an inductive text mining approach to identify latent axiomatic characteristics of FRM and FRG scholarship and the differences between them. The results close with a deductive text mining approach, with an emphasis on discourses around the different stakeholders, types of flooding, and elements of flood risk that are illuminated in the scholarly literature. The fifth section discusses the implications of the results derived through the bibliometric analysis, while section 6 concludes the article with some broader observations and potential avenues for future research.

2 | CONTEXT

In many countries, the 20th century was marked by a “welfare state approach” to the management of flood hazards, whereby governments built structural controls

to separate people from water and offered public disaster relief to flood victims (Bergsma, 2019). Faced with the significant costs of rehabilitating and replacing flood control infrastructure, and saddled with an escalating disaster relief liability, states have increasingly embraced FRM as a cost-effective alternative to the traditional welfare state approach (Begum et al., 2007; Klijn et al., 2012; Thieken et al., 2016). FRM emphasizes sharing responsibility with nongovernmental stakeholders who contribute to flood risk, such as developers, builders, lenders, and property-owners themselves (Johnson & Priest, 2008; Tippet & Griffiths, 2007). Moving beyond the containment of flood hazards, FRM advocates for the adoption of a broad portfolio of strategies to reduce the exposure and vulnerability of people, property, infrastructure, and other assets to flooding (Hegger et al., 2018a).

The embracement of FRM principles has been documented in many different countries, such as England (Begg et al., 2015; Butler & Pidgeon, 2011), Germany (Klijn et al., 2008), the Netherlands (Jong & van den Brink, 2013; van Buuren et al., 2016), Scotland (Cook et al., 2016), the United States (Bergsma, 2019), and India and China (Sayers et al., 2013). Implementing FRM principles in policy and practice has faced several challenges, however, such as coordinating stakeholders with divergent (and often competing) interests, aligning FRM policy goals with existing laws and institutional norms, and allocating resources efficiently and effectively (Dieperink et al., 2016; Priest et al., 2016).

Recognizing these implementation challenges, scholars have increasingly turned their attention to governance, meaning the arrangements established to coordinate the actions of state and societal actors to achieve purposeful outcomes (Peters, 2014; Thistlethwaite & Henstra, 2019). FRG arrangements refer to the constellation of actors, institutions, resources, and discourses involved in the management of flood risk (Hegger et al., 2018b). Comparative analysis of these FRG arrangements across national borders has been fruitful in diagnosing the willingness and capacity of actors to collaborate, the efficacy and interplay of policy instruments, and the ways in which different institutional mechanisms—coordinating authorities, intergovernmental partnerships, and so on—shape interaction among actors and induce cohesion across sectors and scales (Kaufmann & Wiering, 2017; Liefierink et al., 2018; van Doorn-Hoekveld et al., 2016).

FRM and FRG are therefore complementary, in that efficient and legitimate FRG arrangements are considered pivotal for the effective implementation of diverse FRM strategies (Hegger et al., 2018b). Although FRM and FRG scholarship can be regarded as two parts of an integrated whole, a recent systematic review of FRM

literature found “limited research on governance frameworks...to organize and structure institutions, people, data, and responsibilities for building flood-resilient societies” (Morrison et al., 2018, p. 300). This finding is explained, in part, by the relative nascence of FRG literature, the bulk of which has been published since 2008. Review articles have typically engaged only specific aspects of FRM or FRG literature, such as the determinants of flood risk perception (Lechowska, 2018) and approaches to flood vulnerability assessment (Rehman et al., 2019). Others have limited their analysis to a particular country, exemplified through recent studies that have centered on the United States (Tyler et al., 2019) and Ghana (Mensah & Ahadzie, 2020).

In this study, we sought to provide a comprehensive view of contemporary scholarship on FRM and FRG. We combined several analytical techniques to capture the breadth of this literature, trace its evolution over time, identify influential contributors, and assess future research potential. A key objective was to illuminate any distinctive features of the two bodies of literature and to assess their complementarity or divergence. Another was to identify apparent gaps in existing literature and make observations about ways in which these fields of scholarship could be enhanced.

In addition, through deductive text analysis, we sought to draw insights about three aspects of the FRM and FRG literature. First, as noted above, the shift from a “welfare state” approach to FRM has emphasized the sharing of responsibility with non-governmental stakeholders who either contribute to flood risk or control resources that could be harnessed to reduce flood impacts (Doorn, 2016; Green & Penning-Rowsell, 2011). As such, we analyzed which actors were identified as stakeholders in FRM and FRG scholarship. Second, whereas the historical approach to flood management was focused heavily on riverine flooding (Shrubsole, 2007), development patterns, increased urbanization, and climate change have expanded the impacts of coastal and surface water (i.e., pluvial) flooding (e.g., Jha et al., 2012; Miller & Hutchins, 2017; Vitousek et al., 2017). With this in mind, we examined which types of flooding have been predominant in FRM and FRG literature over the past 20 years. Finally, it is now widely acknowledged that flood risk is the product of three interacting variables: the flood hazard, the exposure of people and assets, and the vulnerability of exposed populations and structures to flood impacts (Kron, 2005). Against this background, we analyzed which of these three elements of flood risk have been most prevalent in FRM and FRG literature over the study period.

3 | METHODS

We followed the five-step workflow developed by Zupic and Čater (2015) to conduct this bibliometric analysis. Bibliometrics—the use of statistical methods to analyze publications and their impact—has a deeply established history as a process by which to study research outputs quantitatively (Pritchard, 1969). Advances in computing capabilities and the development of specialized software tools have facilitated more rapid, robust, and comprehensive analyses using increasingly larger datasets (Aria & Cuccurullo, 2017; McLevey & McIlroy-Young, 2017; van Eck & Waltman, 2009). In this study, for instance, the analysis was conducted using the open-source R software and several packages including Bibliometrix (Aria & Cuccurullo, 2017), Tidytext (Silge & Robinson, 2016), and ggplot2 (Wickham, 2009).

Following the bibliometric analysis, the results turn to text mining and statistical analysis of unstructured text data (Feldman & Dagan, 1995; Feldman & Sanger, 2006) to examine latent axiomatic characteristics of publications on FRM and FRG. The method adopts natural language processing techniques, including text analysis, text categorization, information extraction, and summarization (Kao & Poteet, 2007) to describe the structure of scientific literature in an objective and rigorous manner. Simply, the method can discover previously unknown information that is implicit in the text but not immediately obvious, by examining trends and patterns across large amounts of textual data (Miner et al., 2012). Although still nascent in management literature, text mining methodologies have been used to examine trends in social media and reports on topics related to flooding and climate change (Aureli et al., 2016; Liew et al., 2014; Milne & Adler, 1999; Modapothala et al., 2010).

3.1 | Sample selection

To maximize validity and replicability, the study drew the sample for analysis based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol, which outlines reporting guidelines for transparency (Moher et al., 2009). Bibliometric information of publications was retrieved from the Web of Science and Scopus databases via a systematic search of academic literature relating to FRM and FRG. The associated queries as presented in Table 1 below, resulted in 7243 publications. Three screening measures were applied to identify relevant research outputs: (1) document type was restricted to articles in peer-reviewed journals, (2) language was restricted to English, and

TABLE 1 Sample selection

Query	Flood risk management		Flood risk governance			
	title+abstract+keywords ("flood risk manag*" OR "flood manag*")		title+abstract+keywords ("flood risk govern*" OR "flood govern*")			
	Database	WOS	Scopus	WOS	Scopus	Total
Initial Query		4542	2498	94	109	7243
Filter by date, document type, and language		2940	2296	71	109	5416
Exclude duplicates and incomplete metadata		3956		114		4070
Exclude references to hydrological and hydraulic modeling		2949		110		3059

(3) publication dates were restricted to articles published from 2000 to 2019.

The exclusionary screening resulted in 5416 relevant publications. Duplicates between Web of Science and Scopus were removed from the sample. Next, articles with missing metadata, such as those without indexed abstracts, were removed from the analysis. Articles with reference to hydrological and hydraulic modeling were also deemed out of scope and removed. The final sample included 3059 documents, comprising 2949 publications on FRM, and 110 publications on FRG. Metadata such as author, journal, abstract, and others were exported as a BibTeX file in July 2020. Although the number of publications addressing FRG appears relatively small (approximately 3 percent of articles), this result aligns with the composition of the broader field of scholarship, in which literature on "risk governance" (954 articles indexed on Web of Science) is approximately 2% of the size of literature on "risk management" (43,418 articles indexed on Web of Science).

Turning next to the content of the abstracts, we plotted the normalized frequency of each keyword using the number of publications in each corpus. We calculated the normalized frequency (as the instance of a select word in an abstract divided by the number of articles in the topic) to address the unequal size of the samples. After excluding terms related to FRM and FRG, lemmatizing words for common stems, and removing duplicate counts of a word in an abstract, the top words by frequency were quite distinct between FRM and FRG.

4 | RESULTS

4.1 | Research Progress (descriptive analysis)

The purpose of this study was to analyze the evolution of FRM and FRG literature over the past two decades and

to capture conceptual and intellectual similarities and divergence between the two fields of study. The bibliometric analysis revealed several descriptive insights about the number, growth, and geographic distribution of publications that address these topics, as well as the most prolific and influential authors, journals, disciplines, and institutions.

The number of publications that address FRM and FRG has grown considerably over the past two decades (Figure 1), increasing from 18 articles in 2000 to 443 articles in 2018, and growing at an average of 26.1 percent year-over-year. This growth demonstrates the enormous interest that the fields have garnered from scholars in recent years. Dividing the two topics allowed for more granular analysis, which revealed that FRM literature is more prevalent than scholarship on FRG. This result is not entirely surprising, since academic discourse about risk management dates back as far as the 1950s, whereas discourse on risk governance is relatively new. FRG is an even more nascent topic that emerged only recently as a field of study, which explains the lower number of publications compared to FRM. The terms often appear together within this broader body of literature; 81 percent of the FRG articles reference both management and governance in their title, abstract, or keywords. In addition to publication counts, research progress can be measured using total citations, which in this case surpassed 51,217, with an average 29.5 percent increase year-over-year. This indicates an expanding accumulation of knowledge about flood risk.

By region, the United Kingdom and the Netherlands were the most prominent countries of origin among the publications. The Netherlands appears to be at the forefront of FRG research, with a total of 35 publications. However, research from China and the United States has also accelerated within the past 5 years. Moreover, cross-country research collaboration appears to be on the rise: the average number of countries affiliated with each publication increased from 1.4 to 2.6 over the period of

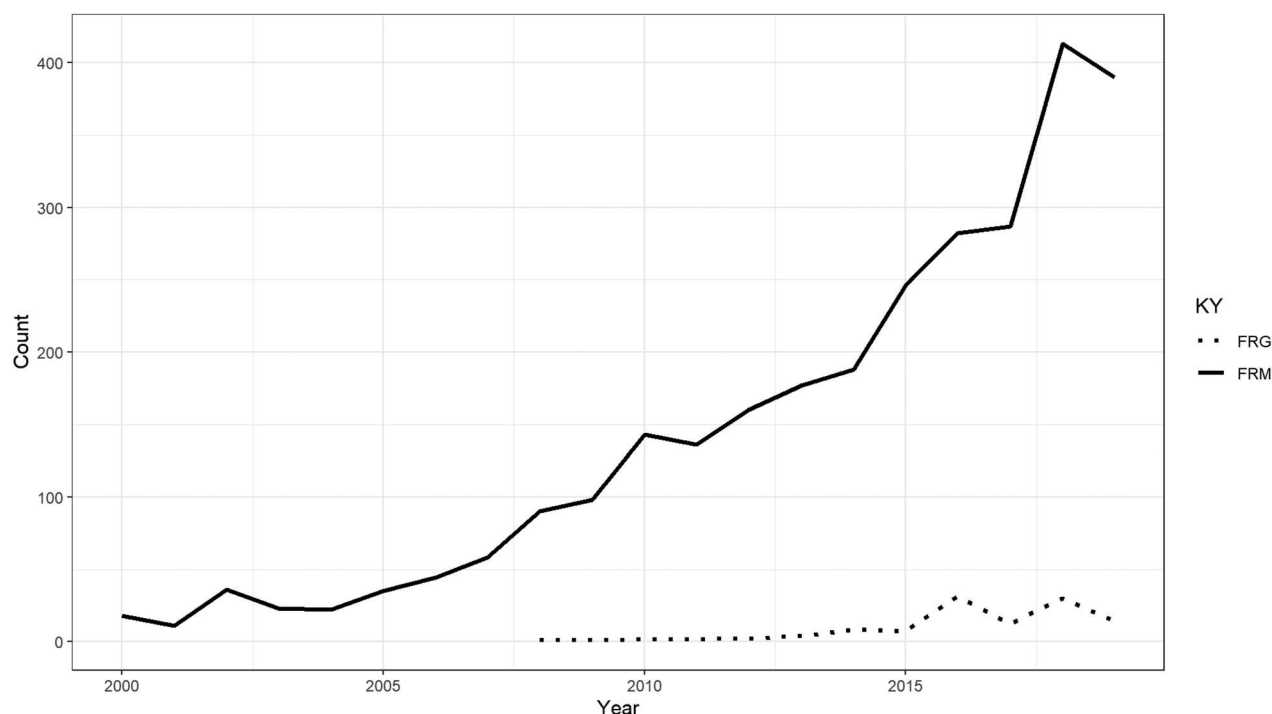


FIGURE 1 Publications per year by topic

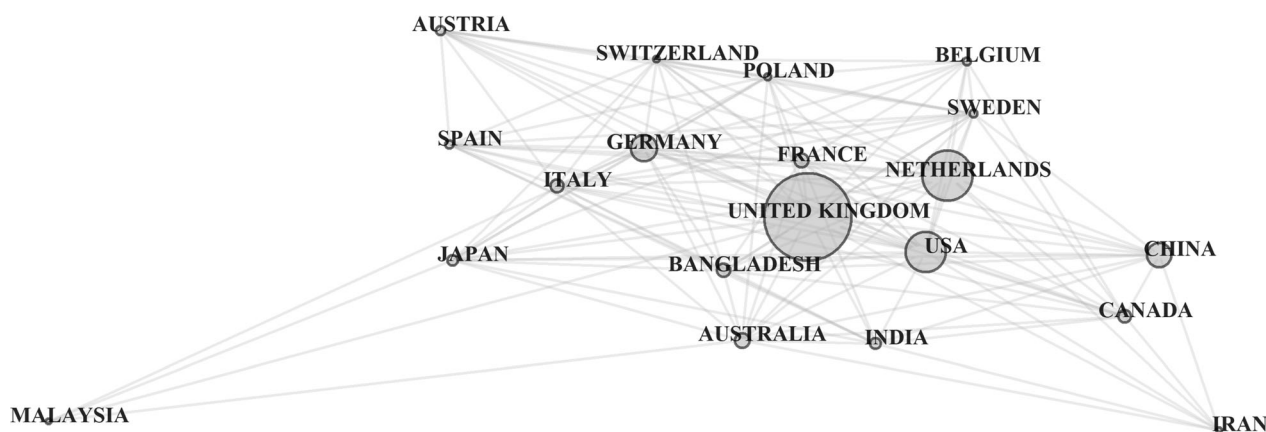


FIGURE 2 Network of regional collaborations

analysis, indicating more frequent international cooperation in flood-related research. In total, scholars from 97 countries were engaged in this body of literature. The prominence of flood-related research from European countries (four of the top 10) might be driven by the European Union's Floods Directive of 2007 (European Commission, 2007), under which member countries have developed regulatory frameworks, and which has spurred policy-based research on flood risk. Figure 2 illustrates the network of collaboration between scholars from the 20 most prolific countries of origin.

Researchers from Delft University of Technology were the greatest contributors to this body of scholarship,

with 103 publications on FRM and FRG (Figure 3). Utrecht University leads the charge on research on FRG with 27 publications. It is noteworthy that there are institutions that conduct research on FRM only (Deltares, for example), but all institutions involved in scholarship on FRG were also represented in research on FRM. Finally, there appears to be significant collaboration between institutions (transitivity = 0.506) (Figure 4).

Within the dataset, a relatively small number of prolific authors stood out as major contributors. Of the 6278 authors identified in this sample, only 767 have written two or more articles on the topic. Six of the top ten authors in the field (Zevenbergen, Kreibich, Aerts,

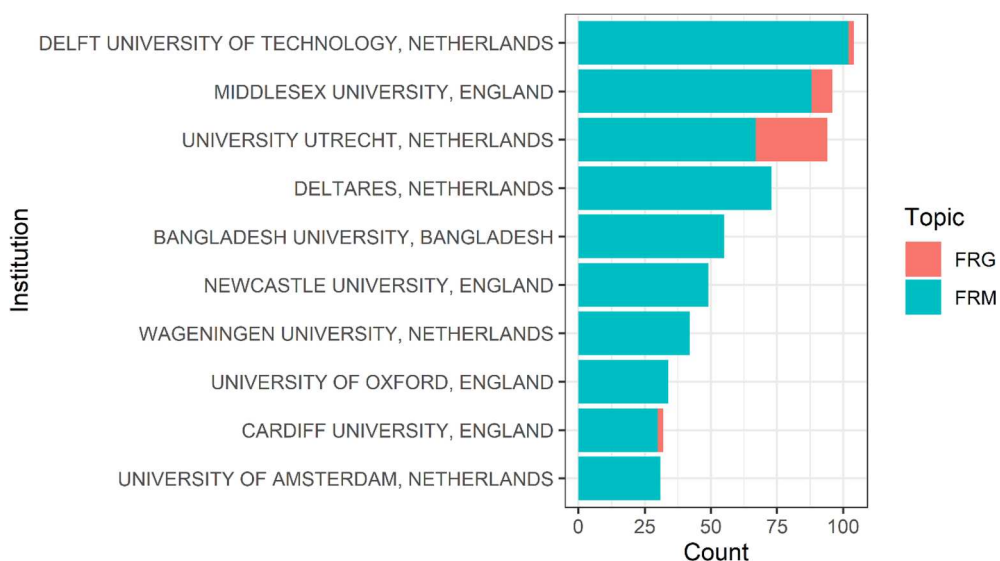


FIGURE 3 Publications by institution

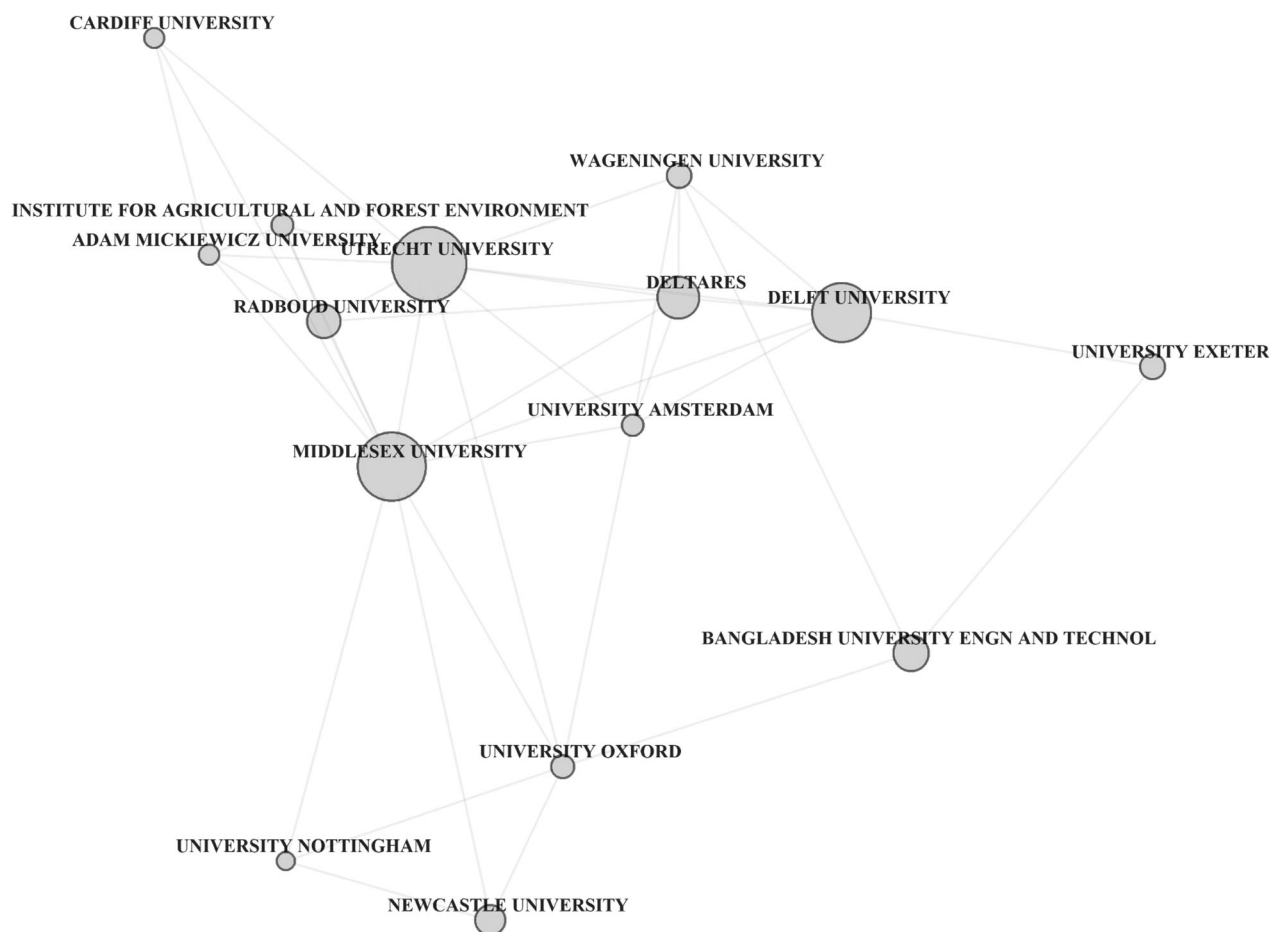
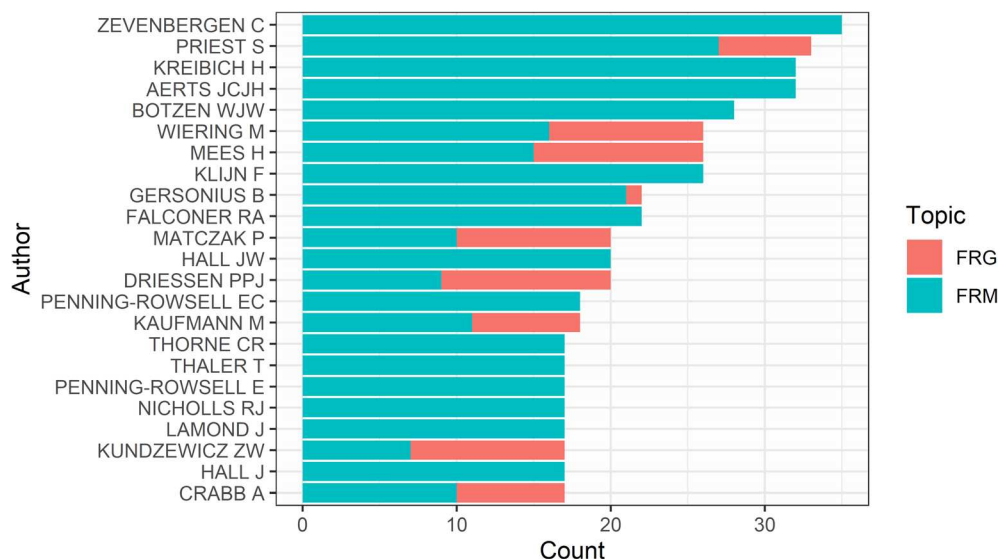


FIGURE 4 Institutional collaboration network

Botzen, Klijn, and Falconer) have each published over 20 articles but have written exclusively about FRM (Figure 5). In contrast, Mees and Driessen, who rank

eighth and thirteenth in the sample, lead on FRG research with eleven publications each. Other prevalent governance scholars include Kundzewicz and Hegger. No

FIGURE 5 Publications by authors



prominent author writes exclusively on FRG, which further confirms the complementarity of the two fields and the relatively large size of FRM scholarship compared to FRG. Table 2 presents the top contributing authors by topic.

The dataset revealed that collaboration among authors on these topics is common. The collaboration index, which calculates the average number of co-authors per publication across all multiauthored articles (Elango & Rajendran, 2012; Koseoglu et al., 2016), rose from 2.4 to 4.6 over the period of analysis, indicating a greater degree of research collaboration over time. The author collaboration network (Figure 6), which maps links between authors, suggests that there are several highly concentrated collaboration networks (transitivity = 0.698), likely clustered around formalized research groups such as the Society for Risk Analysis. Ninety-seven co-authorship connections were plotted among thirty of the most prevalent authors. Each node (circle) represents an author. The size of the node is indicative of the number of publications within the sample. Each edge (line) represents a co-authorship relationship between authors. Edge distance is indicative of the closeness of the authors by publication count and by shared co-authors. The node color indicates a single cluster or group of collaborating authors and dashed edges represent co-authorship and cooperation between clusters. The contributions of Priest of Middlessex University serve as a bridge between the FRM and FRG communities, which are otherwise relatively distinct.

Finally, there is a high degree of concentration among the top journals for FRM and FRG (Table 3). The *Journal of Flood Risk Management* was by far the most influential point of reference in this dataset, accounting for 490 publications (16.5 percent of articles in the dataset). It was followed by *Natural Hazards*, *Water Resources*

TABLE 2 Top authors by topic

Flood risk management		Flood risk governance	
Zevenbergen C	34	Mees H	12
Priest S	33	Driessen P	11
Aerts JCJH	32	Kundzewicz Z	10
Kreibich H	32	Matczak P	10
Botzen	28	Wiering M	10

Management, and Water, which were the outlets for 107, 70, and 49 publications, respectively. Combined, the top five journals for publications on FRM and FRG accounted for 25.4 percent and 34.5 percent of publications, respectively. This suggests there is a relatively narrow subset of journals that are especially influential in the flood-related research domains.

The remainder of the descriptive analysis turns to citation counts, to identify the most influential articles in the fields of FRM and FRG (Tables 4 and 5). Table 4 identifies the most influential articles within the sample, based on their total citation count and annual citation count. Table 5 in contrast identifies the most influential article cited by articles within the sample, based on the frequency by which a citation appears across the sample. This is useful for two purposes. First, it captures other relevant publications outside of our scoping criteria (important books, for example), and second, it captures articles that the study of FRM and FRG may be built upon (for example, there may be foundational texts in the field that do not explicitly mention flooding).

It is perhaps unsurprising that many of the highly cited articles in these fields were synthesis articles and methodological contributions, but there were some notable observations about these contributions. Highly cited

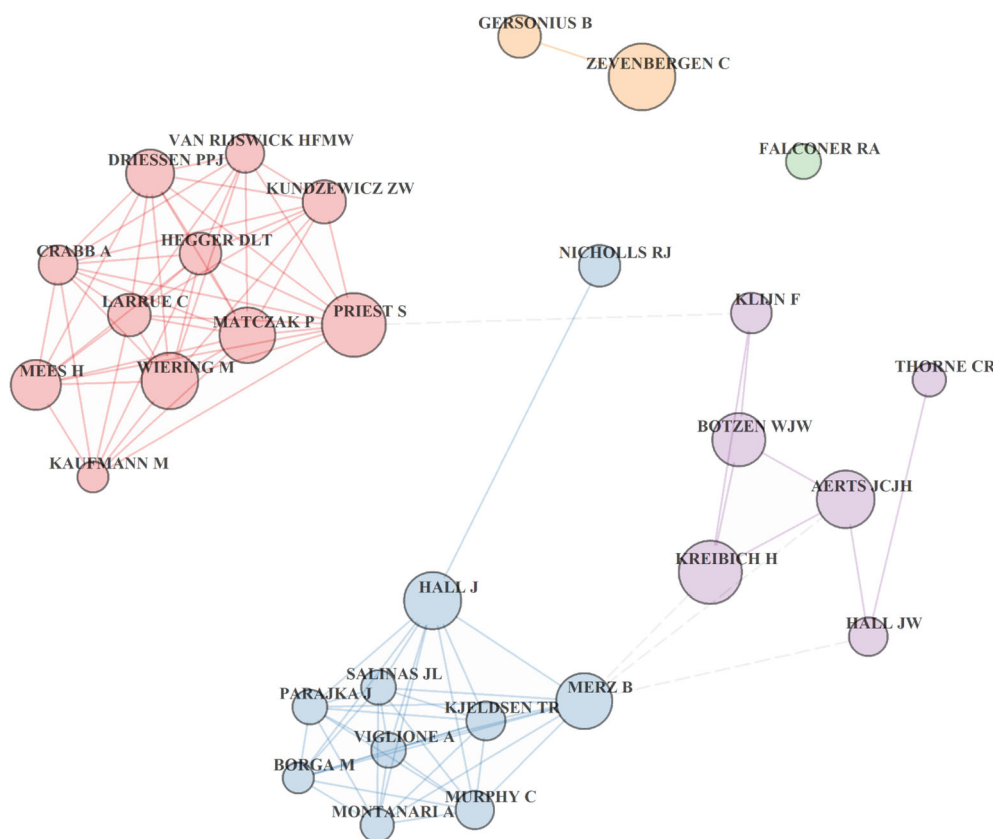


FIGURE 6 Network of author collaborations

TABLE 3 Top five journals by topic

Flood risk management		Flood risk governance	
Journal of flood risk management	476	Journal of flood risk management	14
Natural Hazards	107	Ecology and Society	8
Water Resources Management	70	Journal of Environmental Policy & Planning	8
Water	49	Environmental Science and Policy	7
Natural Hazards and Earth System Sciences	48	Regional Environmental Change	5

FRG literature was more likely to adopt a policy perspective, whereas influential FRM literature had a greater focus on risk assessment. Highly cited articles in both FRM and FRG scholarship also had a predominantly European focus. Furthermore, examining cited references offered insights well beyond the associated queries. Table 5 presents the top cited references outside the sample for each topic. There was overlap between the top publications and top cited references, suggesting a relatively siloed research focus.

4.2 | Delineating latent characteristics (inductive text analysis)

The bibliometric analysis of research progress and influence demonstrated that FRM and FRG are well-

established subjects in scholarly literature, with robust and diverse contributions across researchers, journals, disciplines, regions, and institutions. The next step was to determine if the scholarly literature clearly delineates axiomatic characteristics between the two topics. In other words, can the literature on FRG be considered a distinct line of inquiry, or is it more appropriately characterized as an extension of FRM literature? To answer this question, the study included an inductive text mining analysis to identify keywords across the sample, analyze how they relate to others, and how they differ between FRM and FRG literature.

Using unstructured data from the abstracts of publications (amounting to 634,000 words), we contextualized information about relevant topics and their connections, induced insights to reveal relationships among constructs, and theorized on the emergence and functioning

TABLE 4 Top publications by topic and citation count – Sample

Topic	Title	Author	Journal	Year	TC	TCY
FRM	A Review of Risk Perceptions and Other Factors That Influence Flood Mitigation Behavior	Bubeck P	Risk Analysis	2012	355	50.7
FRM	Institutional Adaptation To Climate Change: Flood Responses At The Municipal Level In Norway	Naess LO	Glob Environ Change	2005	291	19.4
FRM	Global Exposure to River and Coastal Flooding Long Term Trends and Changes	Jongman B	Glob Environ Change	2012	270	38.6
FRM	Flood Maps In Europe - Methods, Availability And Use	De Moel	Nat Hazards Earth Syst Sci	2009	270	24.5
FRM	Flood Risk And Flood Management	Plate EJ	J Hydrol	2002	239	13.3
FRG	Assessing Stability and Dynamics in Flood Risk Governance	Hegger DLT	Water Resour Manag	2014	62	12.4
FRG	Differences in Flood Hazard Projections in Europe: Their Causes and Consequences for Decision Making	Kundzewicz ZW	Hydrol Sci J	2017	59	29.5
FRG	Legitimate Adaptive Flood Risk Governance Beyond the Dikes: The Cases of Hamburg Helsinki and Rotterdam	Mees HLP	Reg Envir Chang	2014	50	10
FRG	Towards More Flood Resilience: Is A Diversification Of Flood Risk Management Strategies The Way Forward?	Hegger DLT	Ecolog and Society	2016	46	11.5
FRG	Evaluating Social Learning In England Flood Risk Management: An Individual-Community Interaction Perspective	Benson D	Environ Sci Policy	2016	43	10.8
FRG	Coproducing Flood Risk Management Through Citizen Involvement: Insights From Cross-Country Comparison In Europe	Mees HLP	Ecology and Society	2016	38	9.5

Note: This table presents top cited papers within the sample. TC refers to total citations. TCY refers to average total citations per year, calculated by dividing the total citations by the elapsed years from a baseline of 2019.

of latent topics, which would have otherwise been restricted with strictly quantitative data.

We began by examining the content of the abstracts. Excluding terms related to FRM and FRG and lemmatizing words for common stems, the commonly used words across topics were quite similar. A word commonality analysis can calculate the degree of overlap between the topics. We calculated, using a Pearson's product-moment correlation test, that the FRM and FRG literatures are highly correlated ($\text{cor} = 0.731$, $p < 0.01$). Thus, the literature on FRG is like that of FRM. Table 6 presents some words that appear frequently in both sub-samples, as well as words that are more distinct to each subfield. Some words with a high commonality include “distribution,” “complex,” “building,” and “society.” Other words were more distinct to one field, suggesting that FRG scholarship might adopt a more regionalized approach, whereas FRM research might place greater emphasis on the science of floods. Scores for FRG-related keywords are calculated as the difference between the percent frequency of the keyword in the FRG sample

minus the FRM sample. The opposite applies for FRM-related keywords. Common keywords appear equally frequently in both samples.

To gain a more precise understanding of the content of literature on FRM and FRG, we also analyzed author keywords. A keyword frequency analysis of the entire sample presented the top words based on their relative frequency in each sample (Figure 7). By proportion of words included in abstracts, “change” is the most common word in both FRM and FRG literature. Other common words in both FRM and FRG literature included “approach,” “events,” and “system.” As illustrated, the frequency analysis also delineates words that are more common in FRM literature (such as “water,” “data,” and “river”), and words that are more common in FRG literature (such as “actors,” “policy,” and “public.”)

We calculated the difference between the proportion of times each word appeared in FRM and FRG abstracts, to identify where the two fields differ the most. The words “model,” “data,” and “method” appear significantly more often in FRM abstracts compared to FRG

TABLE 5 Top publications by topic and citation count – Overall

Topic	Title	1 author	Journal	Year	TC
FRM	Review Article: Assessment of Economic Flood Damage	Merz B	Nat Hazard Earth Sys	2010	65
FRM	Flood risk management in England: a changing landscape of risk responsibility?	Johnson CL	Int J Water Resour	2008	49
FRM	People at Risk of Flooding: Why Some Residents Take Precautionary Action While Others do not	Grothmann T	Nat Hazards	2006	41
FRM	Stationarity is dead: Whither water management?	Milly PCD	Science	2008	34
FRM	The hazards of indicators: insights from the environmental vulnerability index	Cutter SL	Soc Sci Quart	2003	33
FRG	Assessing Stability and Dynamics in Flood Risk Governance: An Empirically Illustrated Research Approach	Hegger DLT	Water Resour Manag	2014	7
FRG	Political modernisation and the environment: the renewal of environmental policy arrangements	Van Tatenhove J	Political Modernisat	2000	7
FRG	Agendas, alternatives, and public policies	Kingdon J	Agendas Alternatives	1984	6
FRG	A game of give and take: the introduction of multi-layer (water) safety in the Netherlands and Flanders	Kaufmann M	Land Use Policy	2016	5
FRG	Legitimate adaptive flood risk governance beyond the dikes: the cases of Hamburg, Helsinki and Rotterdam	Mees HLP	Reg Environ Change	2014	5

Note: This table presents top cited papers based on how frequently they are cited by articles within the sample. TC refers to total citations. Consequently, this method results in publications outside of our scoping criteria.

FRG		FRM		Common	
Governance	0.014	Management	0.004	Distribution	0.000
Arrangements	0.004	Results	0.002	Structural	0.000
Literature	0.003	Flooding	0.002	Considered	0.000
Netherlands	0.003	Economic	0.002	Requires	0.000
Institutional	0.003	Proposed	0.002	Complex	0.000
European	0.003	Applied	0.002	Concept	0.000
Belgium	0.003	Rainfall	0.002	Include	0.000
Comparative	0.002	Compared	0.002	Building	0.000
Resilient	0.002	Coastal	0.001	Multiple	0.000
Legitimacy	0.002	Scenarios	0.001	Society	0.000
Research	0.002	Sustainable	0.001	Population	0.000

TABLE 6 Word commonality analysis

abstracts; between 8 and 15 percent more frequently. References to “river” and “water” are also more common in FRM literature (analyzed further in the deductive analysis below). Finally, words such as “uncertainty,” “probability,” and “scenarios” stand out as more commonly used by FRM scholars. By contrast, the word “actors” appeared in 40 percent of FRG abstracts, but in only 3.9 percent of FRM abstracts, a 36 percent variation. Moreover, associated words like “public,” “institution,” and “policy” were more common in FRG literature. This finding is analyzed further in the deductive analysis

below. Other words commonly found in FRG literature included “resilience” and “governance.”

4.3 | Elements of flood risk (deductive text analysis)

As noted above, our final analysis was designed to draw insights about three aspects of FRM and FRG literature, namely (1) which actors are commonly identified as stakeholders in the literature, (2) what types of flooding

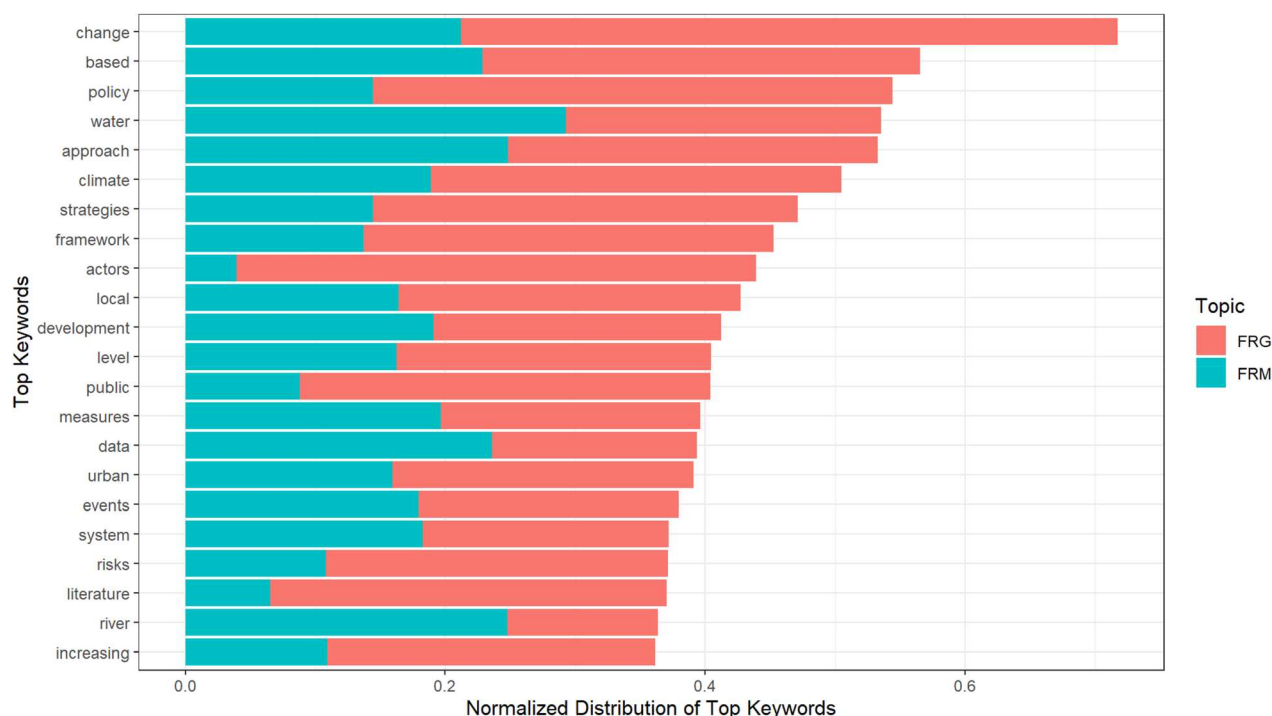


FIGURE 7 Keyword frequency

dominate the literature, and (3) which elements of flood risk (i.e., hazard, exposure, vulnerability) are most prevalent in FRM and FRG literature.

4.3.1 | Stakeholders

Although governments hold the primary legal responsibility in managing flood risk, many other stakeholders have a potential role to play. One point of interest in this study was the frequency by which FRM and FRG literature mentions stakeholders relevant to the implementation of flood management, including federal/national governments, provincial/state governments, municipal governments, private organizations, insurers, and individuals (Figures 8 and 9).

Across the two bodies of literature, there was a strong emphasis on individuals as key stakeholders, whereas federal/national governments received comparably little attention. The private sector has taken on greater prominence in scholarly literature since 2014, as mentions of insurers and provincial/state governments have increased since 2015, and there was a significant rise in mentions of municipalities in 2016. By topic, FRM scholarship prioritized individual and provincial/state responses and FRG literature prioritized municipal and private responses (Figure 9). Discourse around individual and provincial/state responses appear in 248 and 217 FRM publications, respectively. For comparability, we use the percentage frequency (number of appearances divided by

total number of articles in each topic group), rather than absolute frequency. In doing so, we find that FRG literature includes stakeholder discourse more frequently than FRM literature. A chi-square test showed that there was a statistically significant variation between the stakeholders and the bodies of literature ($p > 0.001$, Cramer's $V = 0.159$). Pearson residuals indicated that discourse around municipal and individual response is statistically more prevalent in FRG literature than in FRM literature.

4.3.2 | Types of flooding

Riverine flooding was the predominant focus of FRM and FRG literature, with urban and coastal flooding following closely behind (Figure 10). By topic, FRG focused more on urban flooding than riverine flooding, but both were important to the topic (Figure 11). A chi-square test estimated that there was statistically significant variation between the type of flooding and the bodies of literature ($p > 0.001$, Cramer's $V = 0.098$). Pearson residuals indicate that discourse on urban flooding is more prevalent in FRG literature, while coastal and river flooding is less prevalent.

4.3.3 | Elements of flood risk

Flood risk is typically conceptualized as the product of three elements: (1) a flood *hazard*, meaning riverine,

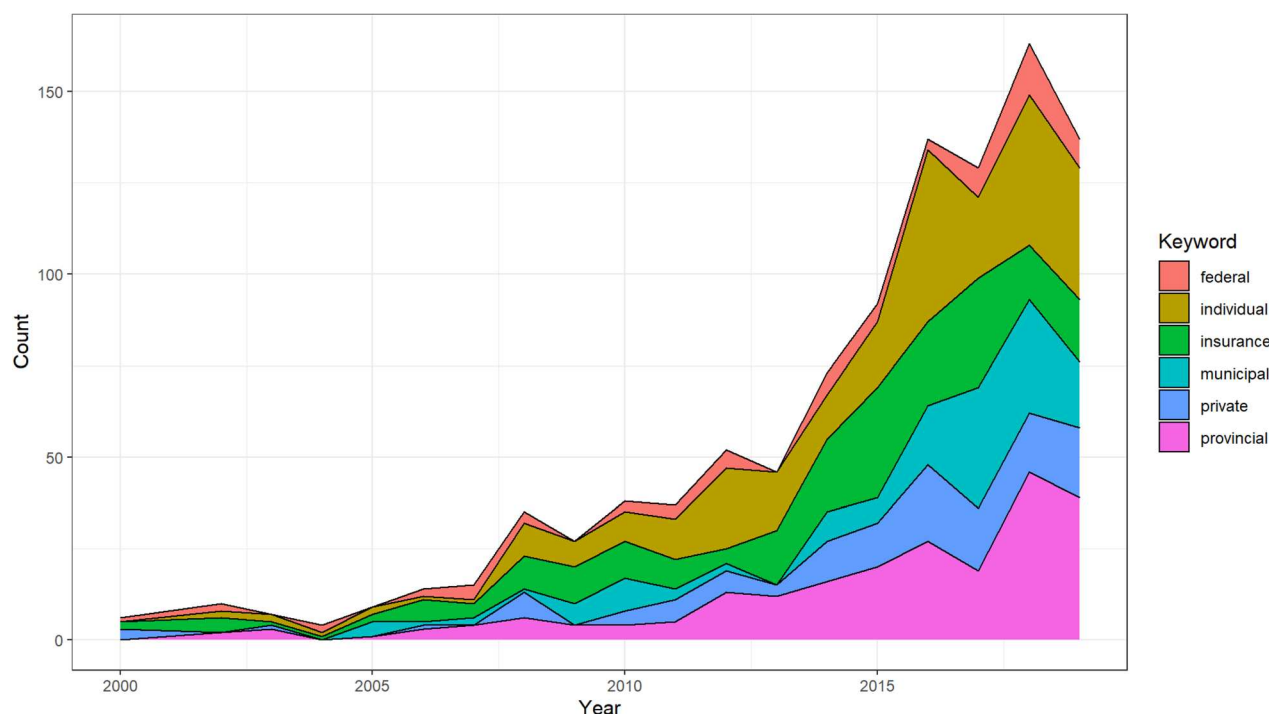


FIGURE 8 Stakeholders by year (entire sample)

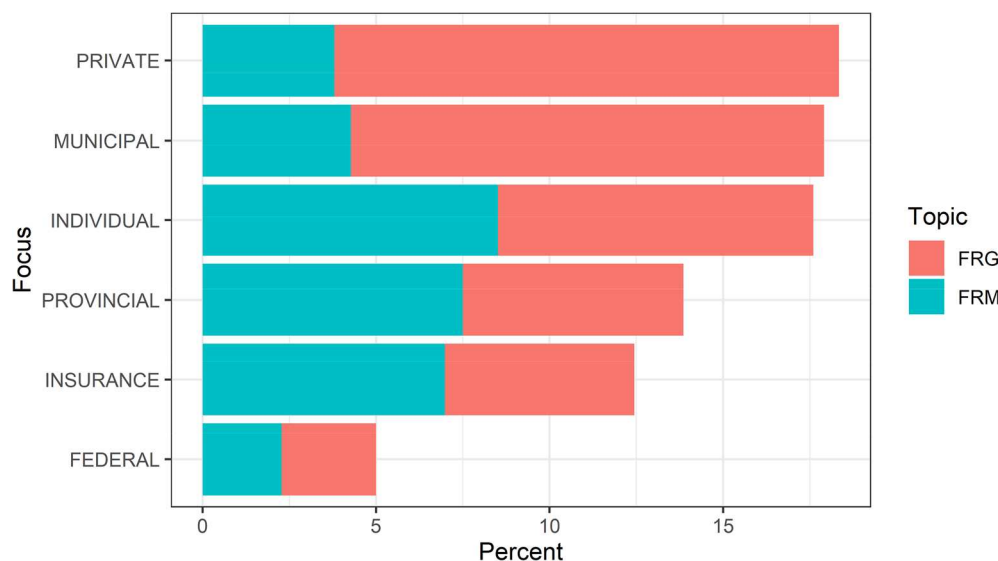


FIGURE 9 Stakeholders by keyword

coastal, or surface inundation of land that is normally dry; (2) the *exposure* of people, property, infrastructure, and economic activity in or near the flood hazard zone; and (3) *vulnerability* of people and assets to harm from flooding (Sayers et al., 2013). Flood hazards were the dominant focus of the scholarly discourse examined in this study, followed closely by vulnerability, and both subjects saw a spike in in 2015 (Figure 12). Although the focus on exposure has grown in recent years, it remains less prominent in scholarly literature than the

other two elements of flood risk. Flood hazards and vulnerability were the primary focus of FRM literature, whereas FRG scholarship focused most on vulnerability (Figure 13). A chi-square test estimated that there was a statistically significant variation between the elements of flood risk across these two bodies of literature ($p = 0.04$, Cramer's $V = 0.069$). Pearson residuals indicate that FRG literature places less emphasis than FRM literature on hazard and slightly more emphasis on exposure.

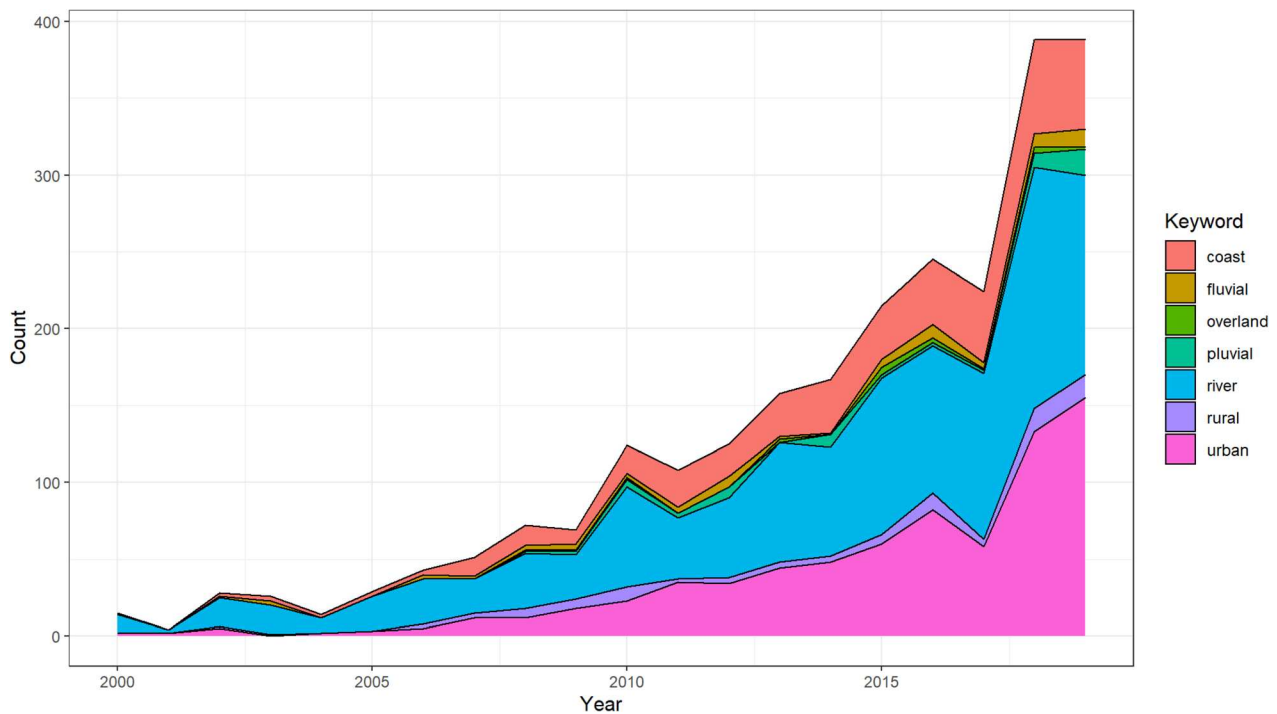


FIGURE 10 Type of flooding by year (entire sample)

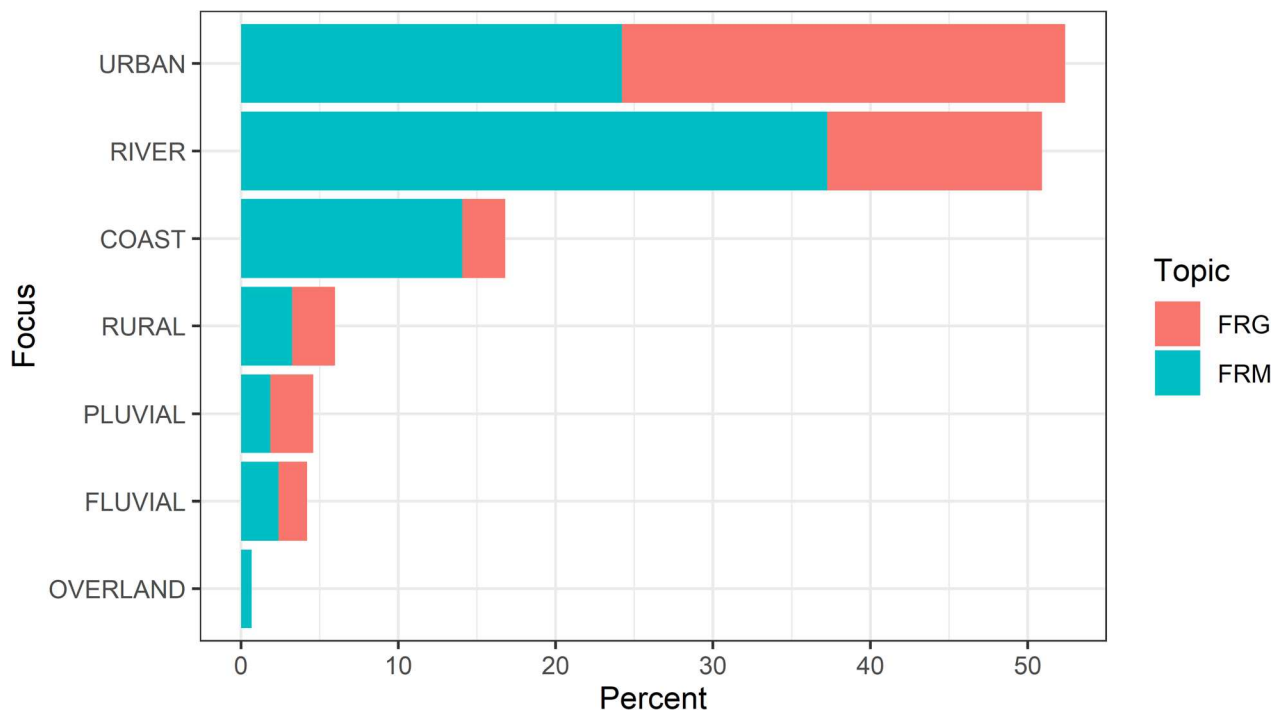


FIGURE 11 Type of flooding by keyword (proportional)

5 | DISCUSSION

Based on the analysis above, we draw several observations about the nature and evolution of FRM and FRG scholarship over the past 20 years. First, most of the

published research in these fields has a European lens. Comparatively less FRM and FRG research has been published with a focus on Africa, Asia, the Americas, and the Mediterranean and Middle East. Furthermore, most of the scholarship in these areas has focused on

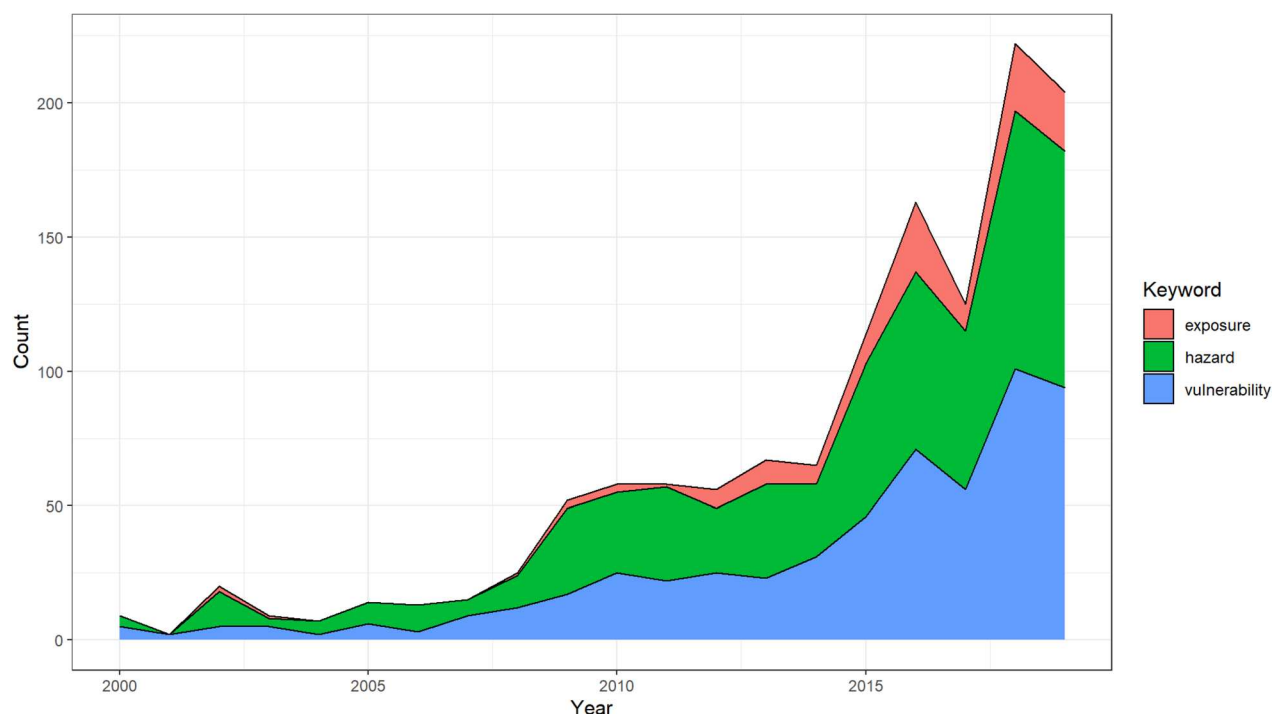


FIGURE 12 Flood risk elements by year (entire sample)

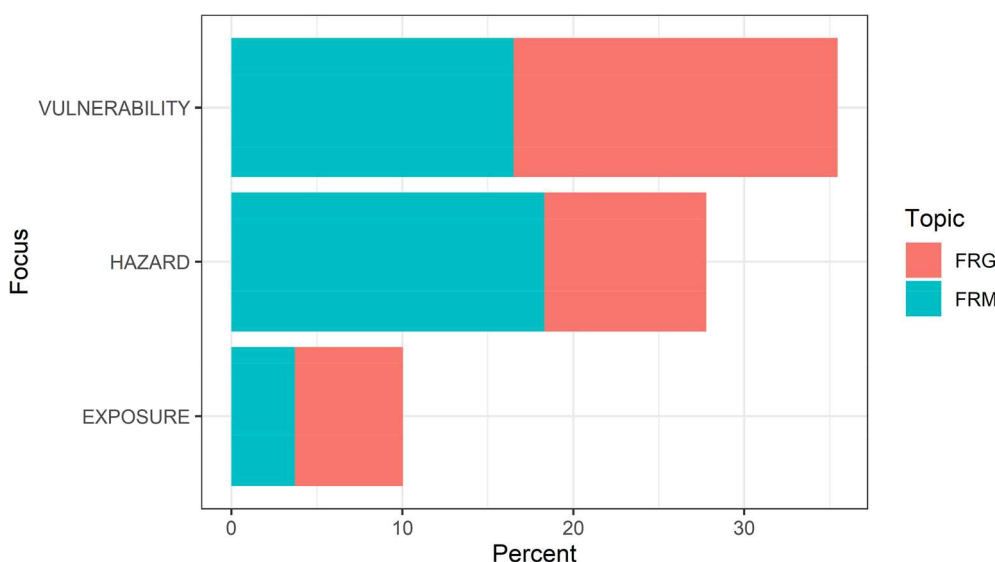


FIGURE 13 Flood risk elements by keyword

developed states, and there has been relatively little research on FRM and FRG in developing countries, despite the significant flood risk that many face. More research on FRM in developing countries could enable comparisons on the diversity of strategies adopted, success of implementation, and unique governance arrangements.

Second, although there has been significant and increasing collaboration among researchers in different countries, the analysis reveals a dense network of partnerships across European institutions, but collaboration

with researchers in developing countries has been less frequent. Comparative insights on FRM and FRG might be enriched by expanding the scope of analysis to developing countries and by increasing research collaboration between European and North American analysts and their counterparts in developing countries.

Third, a relatively small number of journals has emerged as dominant venues for FRM and FRG scholarship, which has firmly established their influence in these fields. On the one hand, this can be regarded as a positive development, in that scholars who read and

contribute to FRM and FRG literature have prominent outlets for their work that are recognized and well-regarded by their academic peers. On the other hand, the concentration of publications within these few journals might be driven by automated journal analytics, which suggest highly cited articles to site visitors, creating a self-reinforcing dynamic of citation. The potential implication here is that important, novel, or critical contributions that could further enrich the fields of FRM and FRG might not gain sufficient exposure to have an impact. For example, both fields could benefit from more engagement in political science, public administration, and policy journals to better identify barriers to implementation of FRM strategies.

In addition to exploring the dynamics of scholarship on FRM and FRG, there are several important observations from analysis on the two fields. While it is clear that research on FRM has grown substantially, the number of publications addressing FRG has remained largely static over the same period of time. This confirms concerns raised by some scholars that research on FRM requires more focus on aspects of governance, particularly the nexus between research and practice. Despite high correlation between the words found in FRM and FRG scholarship, the two bodies of literature differ in their core subject matter, as demonstrated by the unique keywords found in the analysis. In line with the findings of Morrison et al. (2018), this analysis found FRM literature is generally more technical, marked by prominent terms such as simulation, prediction, and probability. By contrast, FRG literature covers more social science aspects of FRM, such as actors, institutions, participation, and policy, all of which are keywords that were more frequent in FRG publications. This is an encouraging finding because effective implementation of the technical aspects of FRM requires a complementary framework of knowledge and tools designed to facilitate their integration into policy and practice (Müller, 2013; Priest et al., 2016; Verweij et al., 2021).

The deductive analysis also advanced understanding on the integration of several risk-based principles into flood management. First, the frequency of stakeholders that are mentioned in FRM and FRG research increases over time at the same rate as the literature. This is consistent with risk management theory that asserts flood risk should be shared across shareholders rather than be limited to governments. The increasing mention of individuals also reflects a growing emphasis among practitioners on property-level flood protection as FRM (Owusu et al., 2015). At the same time, this finding aligns with critical arguments that FRM represents a form of neoliberalism seeking to reduce the responsibility of the state in favor of private actors (i.e. individuals and businesses)

(Oulahen, 2021). Second, the distribution of mentions among the components of risk (e.g. hazard, exposure, and vulnerability) reveals an opportunity for further analysis to explain why exposure lags both hazard and vulnerability. The emphasis on vulnerability in particular is promising as it suggests research has responded to criticisms that flood risk assessments should more robustly incorporate social vulnerability analysis alongside hazard and exposure assessment (Mechler & Bouwer, 2015). Lastly, the increasingly frequent discussion of urban flooding reflects the growing recognition among policymakers that urban flooding represents an equal if not more significant risk to riverine flooding. These findings confirm that the principles of risk management are being reflected throughout research on FRM and FRG.

6 | CONCLUSION

Over the past two decades, flood management has shifted away from government dominated approaches that emphasize structural measures toward a risk-based model involving shared responsibility among stakeholders and a diversity of strategies to reduce flood impacts. The need for coordination among these stakeholders and strategies has increased interest in FRG, specifically the institutional arrangements that steer the efforts of government and nongovernment actors towards flood risk reduction. In response, the scholarly literature on FRM and FRG has grown substantially. This study analyzed 3059 articles within this area of scholarship from more than 100 countries. Although authorship from some countries, such as the United Kingdom and the Netherlands, are more prevalent, increasing collaborations among scholars from different countries reveals growth in the geographic scope of this work. Both FRM and FRG scholarship appear to have a narrow list of prolific contributors, and a small set of journals account for most publications in both FRM and FRG. An examination of the most cited articles revealed some divergence between FRM and FRG, with the former emphasizing risk assessment and the latter adopting a more pronounced policy perspective. A number of tests were conducted to assess whether this divergence is significant throughout the literature.

The findings suggest that some aspects of FRG are distinctive, but it is largely an extension from FRM scholarship. FRM abstracts, for example, often included different scenarios or sources of data, while FRG focused on policy concepts such as institutions. Although there is a statistically insignificant difference between the overall content of FRM and FRG abstracts, a more nuanced deductive analysis does indicate that FRM and FRG do

differ on several key metrics. Namely, FRG places greater emphasis on policies and actors while FRM places greater emphasis on the prediction and measurement of risk.

By examining the axiomatic characteristics of FRM and FRG literature over time, the study provides an important baseline for future research in these fields. First, as noted above, there is an opportunity to expand the geographical focus of research beyond Europe and specifically to include more analysis of FRM and FRG in developing countries, ideally through research collaboration across global regions.

Second, as was observed by Morrison et al. (2018) and further confirmed through this analysis, there is a plethora of FRM literature that offers technical tools to assess, track, and manage flood risk, but much less research on frameworks and tools that could aid in FRM decision-making and implementation of the kind that is more typical of FRG scholarship. Indeed, research on FRG remains limited compared to FRM based on the number of publications. As flood risk expands over time, social science analysis on governance processes and solutions will be increasingly important.

Third, a more detailed examination of the distinction between FRM and FRG scholarship could be achieved using manual or computer-assisted coding capable of capturing nuances in context, and one valuable line of inquiry is how the principles of risk management are aligned with flood management scholarship given some of the emerging findings. More broadly, the shift towards FRM in practice has coincided with a significant expansion in scholarship, and this expansion justifies further bibliometric analysis to identify the key tensions and barriers to knowledge transfer between the literature and decision-makers.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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