

## Smart Drainage Education Governance: A Bibliometric Exploration of Disaster Education and Digital Innovation for Sustainable Urban Waterlogging Mitigation

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### Abstract

*Rapid urbanization and climate variability have increased the frequency of urban waterlogging, a short-duration surface inundation resulting from insufficient drainage capacity. This phenomenon poses significant challenges to daily urban life and highlights the need for more integrated approaches that combine digital innovation, drainage governance, and disaster education. This study conducts a bibliometric analysis to examine the global research landscape on smart drainage governance and educational approaches to disaster mitigation in urban contexts. Two datasets were analyzed from Scopus: Tier 1 (188 journal articles) focusing on smart city technologies, ICT-based or drainage systems, and urban resilience, and Tier 2 (17 journal articles) centered on disaster education, risk perception, and community awareness on urban flood or waterlogging mitigation. Keyword co-occurrence mapping using VOSviewer revealed five dominant clusters in Tier 1, emphasizing technological and infrastructural perspectives, and two minor clusters in Tier 2, focused on human-centered and educational themes. The comparative analysis indicates a thematic and epistemological gap between technological governance and educational participation. While global research increasingly advances digital flood and urban waterlogging management, the integration of educational and participatory dimensions remains limited. The findings highlight the need for interdisciplinary collaboration between engineering, education, and information sciences to develop more inclusive and knowledge-driven approaches for sustainable urban waterlogging mitigation, supporting the goals of SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action).*

**Keywords:** *Urban Waterlogging; Smart Drainage Governance; Disaster Education; Digital Participation; Urban Resilience; Sustainable Development Goals (SDGs)*

## INTRODUCTION

Urban flooding and waterlogging have become increasingly frequent in Southeast Asian cities, where rapid urbanization and inadequate drainage infrastructure intersect with poor waste management and changing rainfall patterns [1]. Unlike large-scale river flooding, urban waterlogging refers to short-term surface inundation caused by the inability of drainage systems to discharge rainwater effectively [2]. This condition is often worsened by solid waste accumulation that blocks drainage channels, leading to localized inundations even after moderate rainfall events. Studies have shown that plastic and domestic waste are major contributors to drainage blockage and localized flooding in many developing cities [3, 4].

In Southeast Asia, waste-related clogging has become one of the dominant causes of drainage failure and small-scale flooding. Many urban residents still perceive drainage systems merely as waste channels rather than as essential infrastructure in urban hydrology [5]. This misconception contributes to the continuous misuse of drainage facilities, reducing their hydraulic performance and increasing vulnerability during extreme rainfall events. Moreover, limited public awareness of how drainage systems function within the urban water cycle prevents communities from engaging effectively in preventive actions [6].

Meanwhile, technological innovations in drainage management have advanced rapidly, introducing sensor-based monitoring, Internet of Things (IoT) systems, and real-time data platforms that support decision-making and early warning for urban waterlogging [7, 8]. These smart drainage technologies are integral to smart city initiatives that aim to build more resilient and adaptive urban environments. However, despite the proliferation of digital tools, community participation and behavioral change remain limited, particularly in waste management and drainage maintenance. The lack of integration between technological innovation and public education continues to hinder effective drainage governance [9].

In this context, disaster education plays an essential role in building collective understanding and fostering community participation in flood and waterlogging mitigation. Educating citizens—especially younger, digitally literate generations—about drainage systems, urban hydrology, and environmental responsibility can bridge the gap between technology and behavior. Linking smart drainage governance with participatory education may therefore represent a key pathway toward sustainable and resilient urban water management [10].

## METHOD

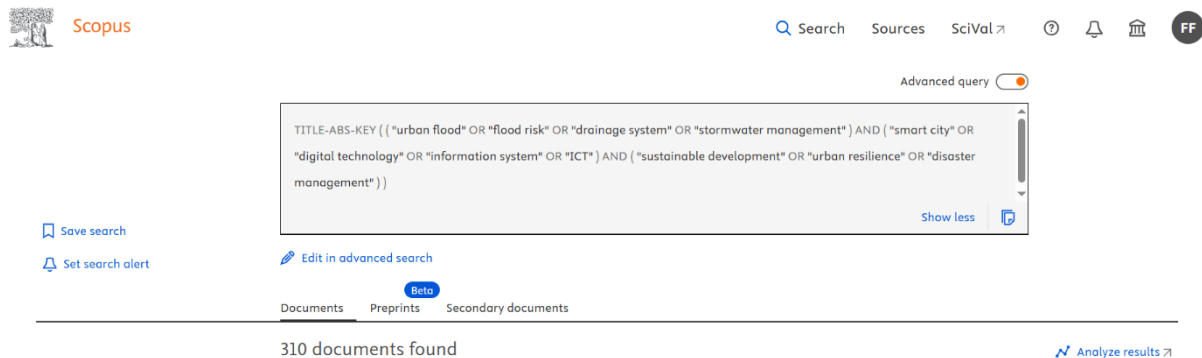
The bibliometric method was employed to quantitatively analyze publication patterns, collaboration networks, and thematic trends related to smart drainage, urban waterlogging, and disaster education. This method enables a systematic exploration of the intellectual structure of a research domain based on bibliographic data, including keyword co-occurrence, authorship networks, and research. The data were retrieved from the **Scopus** database, which was selected because it indexes high-impact international journals and provides complete metadata suitable for

bibliometric visualization. Other databases such as Web of Science or IEEE Xplore were excluded due to access limitations, while Google Scholar was excluded because of unstructured metadata and duplication risks.

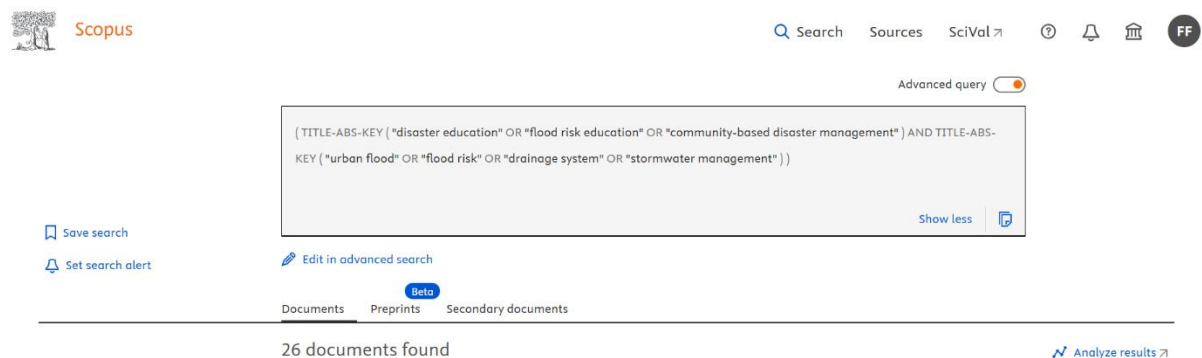
The research process comprised five stages: (1) Search procedure using predefined Scopus queries, (2) Screening for relevance and duplication removal, (3) Data cleaning and completeness checking, (4) Bibliometric analysis using VOSviewer software with fractional counting and association-strength normalization, and (5) Interpretive synthesis comparing Tier 1 and Tier 2 clusters. Complementary qualitative content analysis was conducted for Tier 2 articles to explore educational and participatory dimensions absent from the technological clusters.

### Search Procedure

The bibliometric analysis was conducted in **two tiers** to capture both the technological and educational dimensions of flood and drainage research. Figure 1 illustrate Tier 1 that focused on the intersection of *urban flood management*, *smart city innovation*, and *sustainability governance*, yielding 310 documents. Figure 2 represent Tier 2 that concentrated on *disaster education* and *community participation* in flood-related contexts, resulting in 26 documents on **October 21, 2025**.



**Figure 1.**  
**Tier 1**



**Figure 2.**  
**Tier 2**

**Bibliographic Screening**

After identifying the documents, the next step was to apply inclusion and exclusion criteria to filter the results. The following table summarizes the criteria used in this study:

**Table 1.**

**Inclusion and Exclusion Criteria**

Criteria Category	Inclusion Criteria	Exclusion Criteria
Source Type	Articles published in Scopus-indexed journals	Publications not yet in final form (e.g., preprints or conference abstracts)
Language	Articles written in English	Articles published in languages other than English
Document Type	Articles published in peer-reviewed journals	Conference papers, reviews, editorials, notes, book chapters, or letters
Publication Stage	Final publication stage	Articles in press or under review
Subject Relevance	Studies addressing urban flood, drainage systems, disaster education, smart city, or agricultural irrigation, marine flooding, or sustainability	Studies unrelated to the core themes (e.g., non-urban contexts)

The use of English as an inclusion criterion is based on its wide reach in the global academic community and its dominance in bibliometric databases. However, this may result in the exclusion of relevant studies in other languages. After screening, the number of documents analyzed was reduced to 188 journal articles for Tier 1, and 17 journal articles for Tier 2. This screening ensured that the documents met clear academic standards and were relevant to the research objectives.

**Bibliometric Completeness**

This stage guarantees that every selected article possesses complete and readable metadata compatible with bibliometric tools such as VOSviewer. The verification process covers essential fields, including author names, institutional affiliations, keywords, and publication sources. Any documents with incomplete or corrupted metadata are removed to ensure the accuracy, consistency, and reliability of the subsequent mapping and visualization results.

**Bibliometric Analysis**

The final stage of this study involved a bibliometric analysis conducted using VOSviewer version 1.6.19. VOSviewer was selected because of its robust capability to visualize bibliometric relationships and reveal research structures, trends, and collaboration networks within the domains of smart drainage, urban waterlogging, and disaster education. The bibliometric procedure was carried out through several steps: (1) exporting the search results from Scopus in CSV format, (2) cleaning and verifying metadata to ensure accuracy, (3) importing the data into VOSviewer, (4)

mapping and clustering keyword co-occurrences using fractional counting and association strength normalization, and (5) interpreting the resulting visual networks and density maps.

This analysis enabled the authors to identify thematic clusters, collaboration patterns among countries and institutions, and emerging research directions that bridge smart urban drainage systems, digital governance, and educational participation. Comparative visualization between Tier 1 (technological) and Tier 2 (educational) datasets revealed the current fragmentation and highlighted the need for an integrative framework under the concept of Smart Drainage Education Governance (SDEG).

### Research Process Flow Diagram

The overall data extraction and filtration process used in this study, consisting of four main stages: *identification*, *screening*, *eligibility*, and *inclusion*. The initial search yielded a total of 205 documents, consisting of 188 articles from the Tier 1 (technology-governance-sustainability) query and 17 articles from the Tier 2 (education-flood context) query. After screening, duplicates and documents that did not meet the inclusion criteria—such as non-journal publications, non-English texts, articles under review, or those unrelated to urban flooding and disaster education—were removed.

The final dataset comprised 205 journal articles that met all inclusion criteria and were subsequently analyzed using VOSviewer to map keyword relationships, collaboration networks, and thematic distributions. These steps ensured that only high-quality, relevant publications were included in the bibliometric mapping for the SDEG study.

## RESULTS AND DISCUSSION

### Analysis of Publication Trends by Year

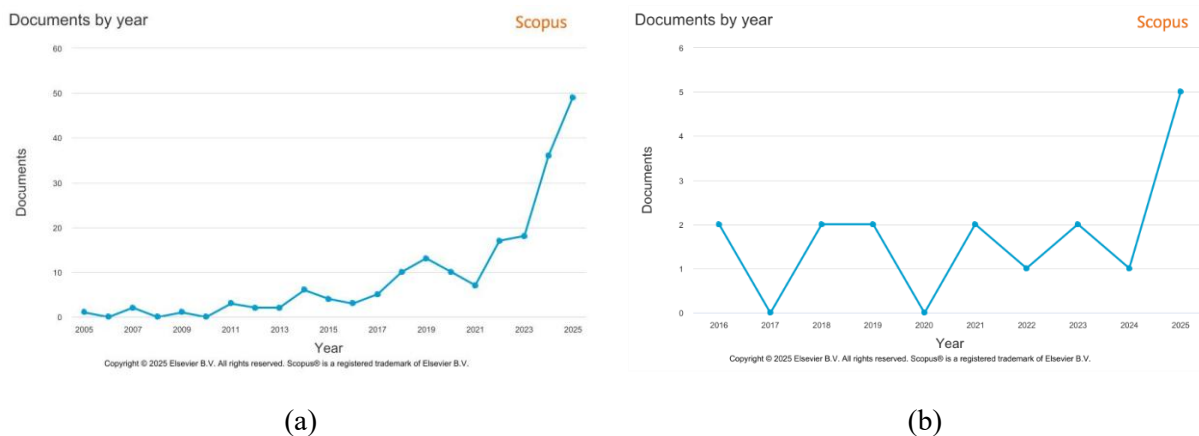


Figure 3.

**Annual publication trends of Tier 1 and Tier 2 studies.**

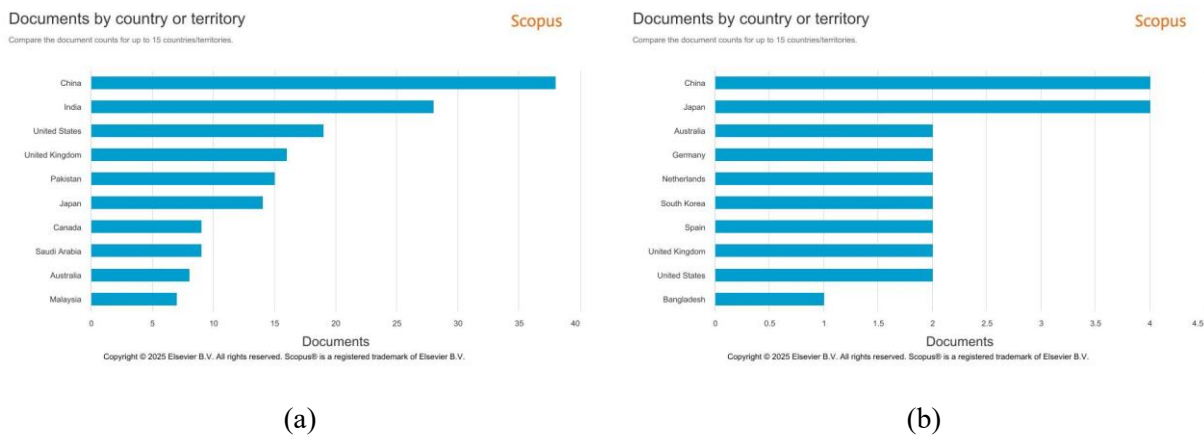
*(a) Tier 1: Smart drainage, governance, and technology-related studies.*

*(b) Tier 2: Disaster education and community-based studies on urban waterlogging or flood.*

Figure 3 illustrates the annual publication trends of Tier 1 and Tier 2 studies. The Tier 1 dataset shows a steady but slow publication growth from 2005 to 2016, followed by a notable increase starting in 2018. This upward trend aligns with the global rise of *smart city* initiatives and digital infrastructure policies. The number of publications significantly surged between 2021 and 2025, reaching its peak in 2025, with nearly 50 documents published. This sharp increase indicates a growing research focus on smart and sustainable drainage systems, urban water governance, and climate-resilient infrastructure. The acceleration after 2020 can also be associated with post-pandemic urban adaptation studies emphasizing digital transformation and resilience planning.

In contrast, the Tier 2 dataset shows irregular and relatively low publication activity between 2016 and 2025, with annual outputs ranging between 1 and 5 documents. Despite the small number, there is a visible peak in 2025, mirroring the broader attention toward climate awareness and disaster preparedness in recent years. However, the fluctuation pattern reflects that research in disaster education and human-centered flood management remains fragmented and underexplored compared to the more technology-driven Tier 1 domain. The limited number of studies suggests that educational and participatory perspectives have not yet been fully integrated into smart urban drainage research. This divergence suggests that although cities are becoming smarter, communities have not yet become equally “smart” in managing and responding to urban waterlogging risks.

**Country-Based Analysis**



**Figure 4.**

## Country-Based Distribution of Publications in Smart Drainage and Disaster Education Domains.

- (a) Tier 1: Smart drainage, governance, and technology-related studies.  
(b) Tier 2: Disaster education and community-based studies on urban waterlogging or flood

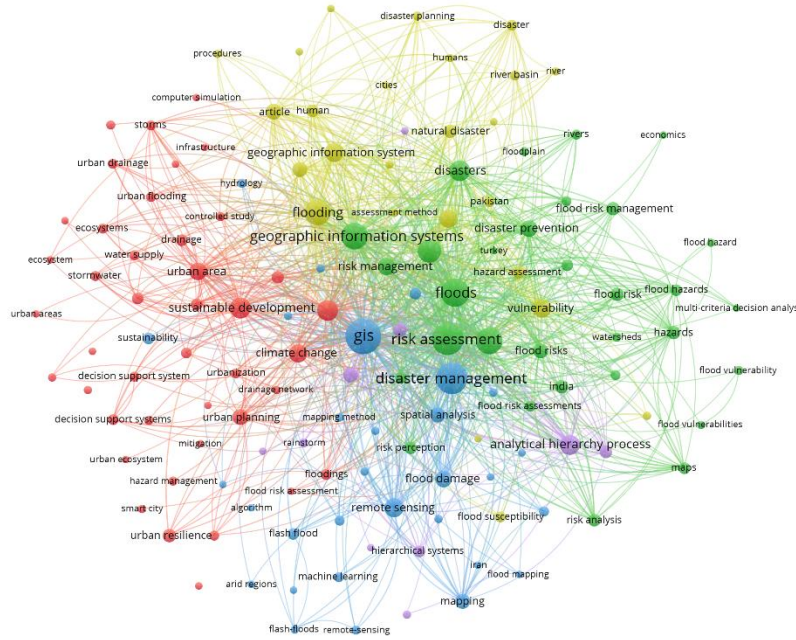
As illustrated in Figure 4, the country-based distribution demonstrates an evolving research trajectory in the field of Smart Drainage Education Governance (SDEG). Leading contributors in Tier 1, such as China, India, Japan, and the United States, also appear in Tier 2 publications, indicating a gradual expansion of focus from technological innovation toward educational and participatory aspects of flood risk mitigation. This trend suggests that nations with established expertise in smart city infrastructure and digital drainage management are beginning to recognize the importance of disaster literacy and community engagement as essential components of sustainable flood resilience.

The presence of these countries in both tiers implies a strategic integration phase, where technological capability is increasingly complemented by human-centered approaches. China and Japan, for example, show consistent productivity across both domains, reflecting their dual emphasis on advanced flood-control technologies and public education in disaster preparedness. Similarly, the emergence of Australia, Germany, and Bangladesh in Tier 2 highlights diverse motivations—ranging from innovation-driven initiatives to vulnerability-based community education programs.

Overall, this convergence signals a paradigm shift in global urban flood research: from infrastructure-oriented resilience toward educationally empowered resilience. The growing recognition that smart technologies must be supported by informed citizens aligns directly with the conceptual foundation of Smart Drainage Education Governance (SDEG), which advocates the integration of digital governance and disaster education for achieving long-term urban sustainability.

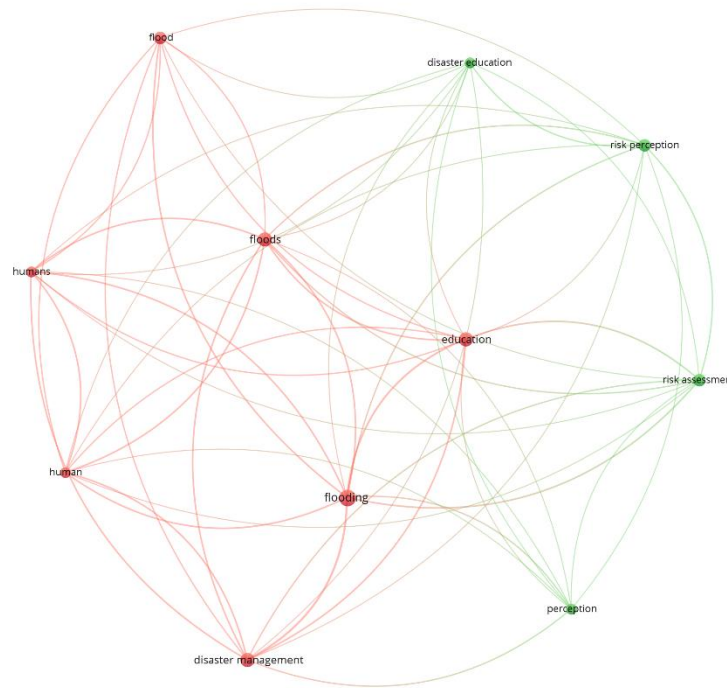
### Keyword Co-occurrence Analysis

The keyword co-occurrence analysis was employed to explore the conceptual structure and thematic interconnections within the body of research. This method identifies how frequently keywords appear together across documents, revealing clusters of related themes and research orientations. The more often two keywords co-occur, the stronger their conceptual linkage. Consequently, the analysis provides insight not only into dominant research terms but also into the underlying intellectual framework and evolution of the field. In this study, the analysis was conducted using VOSviewer with the *fractional counting* method, generating cluster and network visualizations for both Tier 1 and Tier 2 datasets.



**Figure 5.**  
**Keyword Co-occurrence Map of Tier 1 Publications**

The Figure 5 from Tier 1 (188 documents) show that global research on flood and drainage issues is heavily dominated by technical, infrastructural, and system-based perspectives. The mapping produced five major clusters representing the thematic structure of the field. The first cluster centers on Smart City and Sustainable Drainage Systems, emphasizing urban innovation and eco-hydrological design. The second cluster focuses on Flood Risk Management and Resilience, highlighting systematic approaches to hazard mitigation and vulnerability reduction. The third cluster revolves around GIS, Spatial Analysis, and Remote Sensing Technologies, which dominate as analytical and monitoring tools. The fourth cluster addresses Environmental Management and Adaptive Planning, while the fifth concerns Analytical Models and Decision Support Systems. The dense interconnections around keywords such as GIS, risk assessment, flood management, and machine learning reflect a technocratic orientation, portraying flooding primarily as an engineering and modeling problem. Notably, there is an absence of socio-educational terms such as education, awareness, or participation, indicating that the global literature largely overlooks the educational and behavioral dimensions of flood resilience.



**Figure 6.**  
**Keyword Co-occurrence Map of Tier 2 Publications**

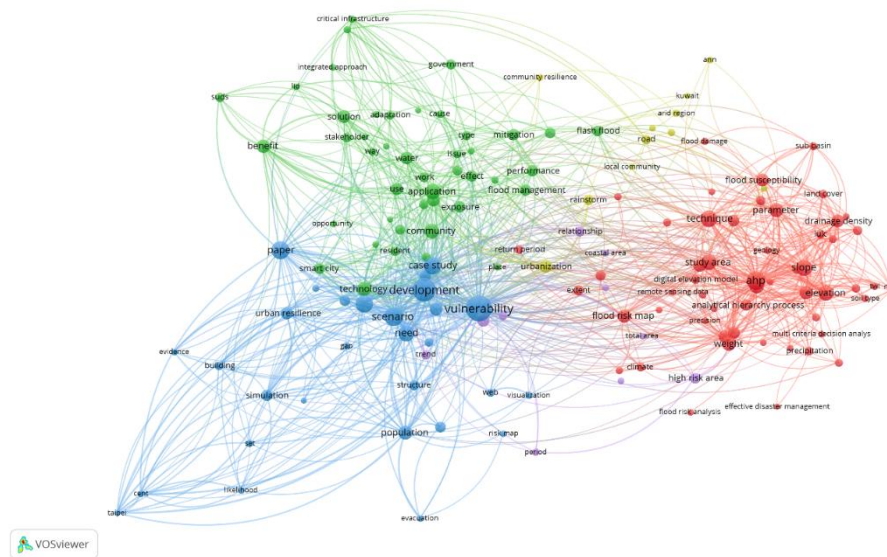
In contrast, Figure 6 that shows the Tier 2 (17 documents) analysis reveals a different thematic orientation. Two major clusters emerge: Human-Centered Flood Management and Perception and Risk Education. Research in this group focuses more on human, educational, and behavioral aspects of disaster risk management, featuring keywords such as disaster education, risk perception, awareness, and community preparedness. These studies emphasize participatory and learning-based approaches in which communities play an active role in risk reduction and disaster awareness. Although the number of publications in Tier 2 is relatively small, their contribution is significant in addressing the conceptual gap left by the Tier 1 body of work — particularly in integrating human and educational perspectives into flood risk management.

A comparative view between the two tiers illustrates a distinct thematic gap between technology-driven and human-centered research orientations. Tier 1 represents a data-intensive, engineering-focused knowledge structure, while Tier 2 highlights a participatory and educationally grounded approach. This fragmentation indicates that current global research still treats smart flood management as a largely technical matter, with limited integration of socio-educational strategies. Therefore, future research should aim to bridge these two paradigms by combining

smart governance and participatory disaster education, fostering a balanced model that enhances both infrastructural resilience and social adaptability in urban flood contexts.

### Term Co-occurrence Analysis

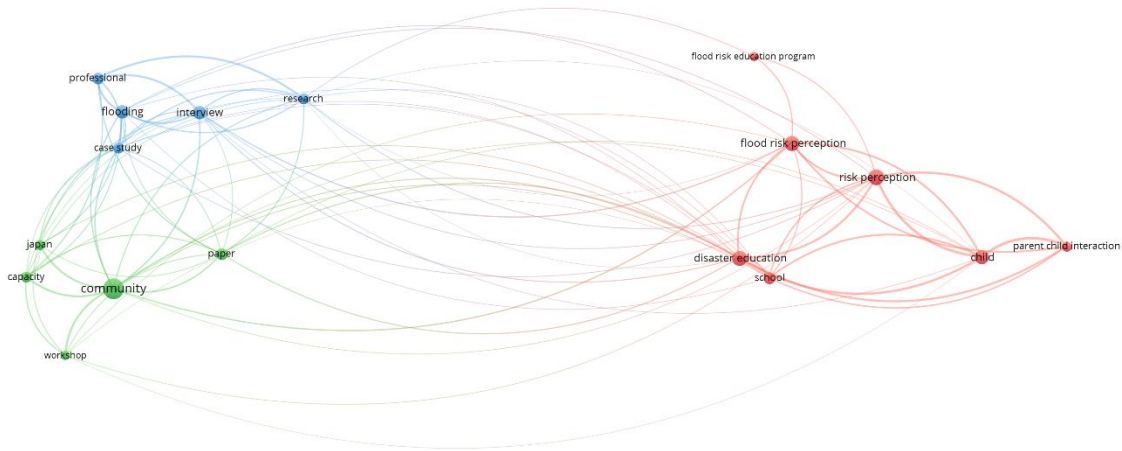
The *term co-occurrence analysis* derived from title and abstract data provides a deeper semantic understanding of the literature compared to the keyword-based network. As shown in Figure 7, the term co-occurrence map for Tier 1 (188 documents) reveals five major clusters that capture the evolving intersection between technical, social, and governance dimensions in urban drainage and flood management research. The red cluster is dominated by terms such as *flood susceptibility*, *drainage density*, *AHP*, and *slope*, representing analytical and spatial modeling approaches commonly used in flood-risk assessment. The green cluster features *community*, *application*, *mitigation*, *benefit*, and *government*, highlighting a growing awareness of community engagement and policy relevance within technically driven studies. Meanwhile, the blue cluster emphasizes *technology development*, *urban resilience*, and *scenario*, indicating a transition toward adaptive and technology-oriented approaches to urban water management.



**Figure 7.**  
**Term co-occurrence map based on text data (Tier 1)**

Compared to the keyword co-occurrence network, the text-based mapping in Figure 7 reveals the frequent use of relational and action-oriented terms such as *need*, *solution*, *use*, and *performance*. These indicate a shift in discourse from purely technical modeling toward social utility, technological usability, and practical implementation. Thus, while Tier 1 research remains dominated by quantitative and engineering perspectives, the textual narratives subtly introduce

human-centered and sustainability-oriented considerations that are not explicitly represented in author keywords.



**Figure 8.**  
**Term co-occurrence map based on text data (Tier 2)**

In contrast, Figure 8 presents the *term co-occurrence map* for Tier 2 (17 documents), illustrating a more compact but human-centered thematic structure. Two main clusters emerge: the first cluster encompasses *disaster education*, *school*, *child*, and *parent–child interaction*, which depict formal and intergenerational educational approaches; the second cluster consists of *community*, *workshop*, *case study*, *interview*, and *capacity*, representing community-based experiential learning and participatory knowledge-building. Unlike Tier 1, Tier 2 shows an almost complete absence of terms related to digital or spatial technologies, suggesting that disaster education research remains oriented toward behavioral and perceptual aspects rather than smart data integration.

The comparison between Figures 7 and 8 highlights a thematic fragmentation between technologically oriented research (Tier 1) and socially driven educational research (Tier 2). However, shared terms such as *community*, *application*, and *case study* act as semantic bridges, implying potential convergence between smart drainage development and participatory disaster learning.

### Highly Cited Studies on Urban Flood and Waterlogging Disaster Education

Table 2 presents the ten most-cited articles related to disaster education in the context of urban flood and waterlogging (Tier 2), as indexed in the Scopus database. These studies represent the most influential contributions shaping academic discourse in this domain, offering insight into how knowledge transfer, community preparedness, and governance models are conceptualized and implemented in disaster-related education and communication. Analyzing these highly cited studies provides a deeper understanding of the dominant theoretical orientations, methodological approaches, and geographical focuses within the literature.

**Table 2.**  
**Inclusion and Exclusion Criteria**

No.	Author(s)	Article title	Number of citations	Journal Name	Key Findings/Recommendations
1	Zhong, S., Cheng, Q., Zhang, S., Huang, C., Wang, Z.	An impact assessment of disaster education on children's flood risk perceptions in China: Policy implications for adaptation to climate extremes	55	Science of the Total Environment	The study found that disaster education significantly improved children's flood risk perception, especially when combined with <b>parent-child interactions</b> . <b>Classroom education, public campaigns, and professional guidance</b> all had positive effects, increasing awareness by 118%. This highlights the importance of integrating formal education with family and community engagement to strengthen disaster resilience—aligning with the bibliometric insight that human-centered and participatory approaches are crucial for urban flood mitigation.
2	Bosschaart, A., van der Schee, J., Kuiper, W.	Designing a flood-risk education program in the Netherlands	32	Journal of Environmental Education	The study developed a flood-risk education program using <b>serious games and simulations</b> to enhance students' flood-risk perception through experiential and analytical learning. By combining learning theory and risk communication, the program effectively increased awareness and coping appraisal among students. This supports the bibliometric finding that integrating digital and interactive educational tools can bridge the gap between disaster education and technological innovation in urban flood management.
3	Bosschaart, A., van der Schee, J., Kuiper, W.	Evaluating a flood-risk education program in the Netherlands	21	<a href="#">Studies in Educational Evaluation</a>	The study evaluated a flood-risk education program for Dutch students and found that it significantly improved flood-risk perception but did not increase preparedness

No.	Author(s)	Article title	Number of citations	Journal Name	Key Findings/Recommendations
	W., Schoonenboom, J.				intentions. <b>While awareness rose, behavioral change remained limited.</b> This finding aligns with the bibliometric insight that disaster education research often enhances cognitive understanding but still <b>lacks integration</b> with participatory and action-oriented approaches needed for effective flood resilience. The study introduced a conceptual graph-based visualization system to enhance flood disaster education by making complex information more intuitive and engaging. The prototype system outperformed traditional expert reports in <b>attractiveness and comprehensibility</b> , proving effective in disseminating flood knowledge and improving public awareness. This aligns with the bibliometric finding that integrating digital visualization and knowledge representation technologies can strengthen disaster education and public participation in smart flood governance.
4	Guo, Y., Zhu, J., You, J., ... Lai, J., Dang, P.	A dynamic visualization based on conceptual graphs to capture the knowledge for disaster education on floods	18	<a href="#">Natural Hazards</a>	The study emphasized the role of community volunteers in improving flood early warning dissemination in Bangladesh, highlighting that technological systems alone are insufficient without local engagement. Integrating trained volunteers into national disaster management policies enhances communication, accessibility, and community preparedness. This supports the bibliometric finding that effective flood governance requires linking technological infrastructure
5	Al-mueed, M., Chawdhery, M.R.A., Harera, E., ... Althunayyan, S.M., Al-wathinani, A.M.	Potential of community volunteers in flood early warning dissemination: A case study of Bangladesh	14	<a href="#">International Journal of Environmental Research and Public Health</a>	

No.	Author(s)	Article title	Number of citations	Journal Name	Key Findings/Recommendations
6	Freimund, C.A., Garfin, G.M., Norman, L.M., Fisher, L.A., Buizer, J.L.	Flood resilience in paired US–Mexico border cities: a study of binational risk perceptions	12	<a href="#">Natural Hazards</a>	<p>with participatory and community-based education approaches.</p> <p>The study on Ambos Nogales (U.S.–Mexico border) highlighted how differing yet overlapping community perceptions influence flood preparedness and risk management. Results showed that individuals’ past flood experiences shaped their concern about future risks, with gender differences revealing lower preparedness among women. Despite national boundaries, both communities shared similar views on insufficient flood readiness and emphasized the need for flood-risk education, awareness programs, and improved infrastructure. These findings reinforce the bibliometric insight that cross-border and community-based approaches, integrating education and participatory planning, are essential for enhancing socio-ecological resilience to flooding.</p> <p>This study applied the Comprehensive School Safety (CSS) framework to analyze the effects of the 2013 Jakarta floods on education continuity and infrastructure. Findings revealed significant disruptions in students’ access to quality learning, damage to school facilities, and varying effectiveness of institutional responses. The CSS framework proved valuable in identifying post-disaster educational vulnerabilities and guiding recovery strategies. In relation to the bibliometric study, this article underscores the growing intersection between disaster</p>
7	Lassa, J., Petal, M., Surjan, A.	Understanding the impacts of floods on learning quality, school facilities, and educational recovery in Indonesia	11	Disasters	

No.	Author(s)	Article title	Number of citations	Journal Name	Key Findings/Recommendations
8	Handayani, W., Hapsari, S.P.I., Mega, A., Sih, S.J.	Community-based disaster management: Assessing local preparedness groups (LPGs) to build a resilient community in Semarang City, Indonesia	11	Disaster Advances	<p>education and school resilience frameworks, highlighting how structured, education-centered approaches can enhance preparedness and adaptive capacity in flood-prone urban areas.</p> <p>This study assessed the disaster preparedness capacity of Local Preparedness Groups (LPGs) in flood-prone Semarang, Indonesia through perceptual and evidence-based evaluations across six variables: knowledge, skills, communication, financial resources, leadership, and organizational systems. The results showed a moderate overall capacity score of 0.64, indicating that while community-based disaster management structures exist, challenges remain in sustaining coordination, funding, and leadership effectiveness. Within the context of the bibliometric study, this article highlights the role of community capacity-building as a central theme in flood disaster education research, emphasizing participatory and locally grounded approaches to urban flood resilience.</p>
9	Bhattacharya-Misra, N., Lamond, J., Montz, B., ... Chan, F., Proverbs, D.	Flood risk to commercial property: Training and education needs of built environment professionals	10	<a href="#">International Journal of Disaster Resilience in the Built Environment</a>	<p>This study identified that built environment (BE) professionals—such as surveyors, valuers, and project managers—play a limited role in advising on flood risk management for commercial properties due to regulatory barriers, lack of guidance, and insufficient training. Across five countries (Australia, UK, USA, China, and Germany), the main challenge was a shortage of professionals with adequate flood risk education. The findings emphasize a global need for improved training and formal education in flood risk management to enhance professional capacity and cross-disciplinary collaboration.</p>

No.	Author(s)	Article title	Number of citations	Journal Name	Key Findings/Recommendations
10	Choi, C., Choi, J.	Distribution and application of community-based disaster risk information: Lessons from Shiga prefecture in Japan	6	Journal of Distribution Science	The study emphasizes the vital role of community-based disaster risk information sharing in effective flood management, using Shiga Prefecture, Japan, as a case study. It found that active collaboration among multiple stakeholders and the use of local cultural knowledge, volunteer networks, and mutual support systems enhance community resilience. The findings highlight the importance of empowering local residents to take proactive roles in disaster preparedness and response. In the context of the bibliometric study, this aligns with themes of community engagement, local knowledge integration, and participatory education in flood risk management.

An analysis of the ten most highly cited articles in Tier 2 reveals that research on disaster education related to flooding remains largely centered on general *flood-risk education* themes. These studies primarily focus on improving risk perception, community preparedness, and the effectiveness of educational interventions across different geographical contexts. Most of the research emphasizes the development of school-based learning models, the integration of family engagement, and the strengthening of community capacities to cope with flood hazards. The approaches employed are diverse, ranging from classroom-based education and simulation or serious games, to data visualization, conceptual mapping, and the use of community volunteers in early warning systems. Thematically, these studies demonstrate a multidisciplinary tendency—combining learning theories, risk communication frameworks, and disaster management policies within educational and social resilience contexts.

However, a notable finding is that none of the highly cited studies specifically address disaster education related to *urban waterlogging*—a recurring urban phenomenon caused by inadequate drainage systems, land-use changes, and limited stormwater infrastructure. While several studies discuss urban flooding in general, the specific issue of *waterlogging* as a micro-scale disaster with significant social and environmental implications remains largely unexplored. This gap highlights an important research opportunity: future studies should expand their focus from large-scale riverine flooding toward issues of *urban hydrology* and drainage governance, which are central to understanding and mitigating waterlogging in densely populated urban areas.

## CONCLUSION AND RECCOMENDATIONS

This bibliometric study provides a comprehensive overview of global research trends on disaster education related to urban flooding and waterlogging. The analysis of publication trends indicates a steady increase in scholarly attention after 2018, reaching a significant surge between 2021 and 2025. This growth corresponds with the expansion of smart city policies, climate adaptation frameworks, and digital governance initiatives, suggesting that the issue of flood resilience has become a crucial aspect of urban sustainability discourse.

The country-based analysis reveals that most studies originate from nations with advanced disaster management frameworks—such as China, the Netherlands, and Indonesia—indicating that the integration of flood education research often follows technological or policy maturity in flood management. Interestingly, countries that are highly productive in smart drainage or urban resilience research also begin to invest in educational and participatory approaches, showing an emerging awareness that disaster mitigation must involve public learning and behavioral adaptation rather than relying solely on technical interventions.

The keyword and term co-occurrence analyses further support this pattern, showing a dominant presence of engineering and infrastructure-related terms (e.g., stormwater management, GIS, risk analysis, resilience) in Tier 1 publications. Meanwhile, Tier 2 research clusters emphasize

education, awareness, and risk perception, yet remain fragmented and underrepresented. The absence of strong linkages between technological and educational clusters highlights a persistent gap in the integration of socio-educational frameworks with smart urban drainage systems.

Moreover, the analysis of highly cited studies shows that most influential works focus on general flood-risk education, particularly on school-based learning, risk perception improvement, and community preparedness. However, none of these highly cited studies directly address urban waterlogging—a critical but understudied issue stemming from poor drainage management in rapidly urbanizing areas. This indicates that while the educational dimension of flood management is gaining attention, the specific urban context of waterlogging disasters remains insufficiently explored in global literature.

Overall, this study concludes that research on disaster education for urban flooding and waterlogging is still in its formative stage, with a clear imbalance between technical innovation and social learning perspectives. Future research should aim to bridge this divide by integrating participatory education, behavioral change frameworks, and digital technology in urban flood literacy. Strengthening this interdisciplinary nexus will be essential to advance climate-resilient and socially adaptive urban water management in the coming decade.

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