

Review

Integrating Technology into Sustainable Urban Planning: Assessing Urban Flood Vulnerability and Strengthening Community Preparedness for Enhanced Water Security

Ahyahudin Sodri ^{1,*}, Mauliza Fatwa Yusdian ², Haruki Agustina ¹, Nuraeni Nuraeni ¹
and Riska Nur Azizah ³

- ¹ Department of Environmental Science, Graduate School of Sustainable Development, Universitas Indonesia, Salemba, Jakarta 10430, Indonesia; nuraeni21@ui.ac.id (N.N.)
- ² Social Environment, Community Engagement, and Environmental Economics Research Cluster, Department of Environmental Science, Graduate School of Sustainable Development, Universitas Indonesia, Salemba, Jakarta 10430, Indonesia
- ³ Magister Social Welfare Science, Faculty of Social and Political Science, Universitas Indonesia, Depok 16426, Indonesia; riska.nur51@ui.ac.id
- * Correspondence: ahyahudin.sodri@ui.ac.id

Abstract

The increasing frequency of climate change and extreme weather makes the issue of urban flood vulnerability an important one. Flood disaster mitigation efforts have progressed rapidly with the utilization of technology in flood risk assessment and community preparedness. However, there is still a gap between technology and community engagement in preparedness. This study was conducted to analyze the trend of technology-based urban flood vulnerability and community preparedness integration. The study used bibliometric methods to see research trends and a systematic review of Scopus data with Biblioshiny, VOSviewer, and Convidence to identify relevant research articles. Trends in urban flood vulnerability show an increasing use of advanced technologies such as multivariate LSTM (Long Short-Term Memory) artificial neural networks, LiDAR (Light Detection and Ranging), GIS (Geographic Information System), and blockchain for flood risk assessment. There are gaps in community engagement and preparedness, highlighting the need for a comprehensive approach that combines technology with community-based strategies. A balance between technology implementation and community engagement is needed to improve community preparedness and safeguard water security in flood-prone urban areas. The development of an urban flood vulnerability index can bridge the technology gap with standardized community engagement. All the articles in the study contribute greatly to the changes and improvements in flood disaster mitigation, as well as to the role of technology and preparedness. The gap between technology and community engagement in preparedness requires an urban flood vulnerability index with comprehensive strategies.



Academic Editor: Jianming Cai

Received: 10 May 2026

Revised: 3 July 2026

Accepted: 8 July 2026

Published: 12 July 2026

Copyright: © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article

distributed under the terms and

conditions of the [Creative Commons](#)

[Attribution \(CC BY\)](#) license.

Keywords: community preparedness; risk mitigation; technology; urban flood vulnerability; water security

1. Introduction

The problem of global warming and climate change is one of the most important problems that the modern world is dealing with [1,2]. One of the noticeable impacts of these changes is the increase in extreme weather conditions, including droughts and heat waves. More importantly, there is an increase in heavy rainfall, frequently in the form of

torrential downpours [3,4]. Climate change (CC) presents a significant societal risk, leading to increasing demands for immediate mitigation and adaptation actions [5]. In recent years, multiple studies have emphasized the importance of adaptation by testing ecosystem-based approaches. This is crucial for understanding and enhancing the integration of these approaches into climate change adaptation and mitigation strategies [6,7]. According to previous research, climate change has caused a systematic increase in the frequency of heavy rainfall events in various regions of the world. This condition has an impact on increasing surface runoff, reducing water infiltration into the soil, and increasing the rate of soil erosion [8,9]. Various climate projections also indicate that this trend is expected to continue, and even potentially intensify in the future [10,11]. This phenomenon is primarily caused by increasing average air temperatures on Earth, leading to increased evapotranspiration and elevated water vapour levels in the atmosphere, thus promoting the formation of intense rainfall [12,13].

The heightened frequency and increased intensity of rainfall have worsened the severity of Pluvial Flooding (PF) incidents. PF is instigated by brief but highly concentrated rainfall, leading to a situation where the volume of precipitation surpasses the capacity of urban drainage systems and the soil's absorptive capability [14]. Altered precipitation patterns, frequent floods, rising sea levels, and extreme weather events have already impacted local communities [15–17], threatening water security across affected regions. Urban areas, with their close proximity to smaller streams and main rivers, are especially susceptible to the immediate and severe risks of flash floods [18,19]. This risk increases during periods of heavy and relentless rainfall, especially in small, poorly drained watersheds [20]. The proportion of the population at risk from flooding has increased globally, with urban flooding being a major and highly destructive issue. Over 80% of the global GDP is generated in cities. However, the estimated annual direct loss from disasters in cities is approximately USD 314 billion [21,22]. The traditional urbanization approach, which depends entirely on impervious paving of surfaces and grey infrastructure for stormwater management, is no longer sustainable or suitable with climate change adaptation strategies [23–25]. In urban areas, the layout of rivers is significantly altered due to human development, which can negatively impact their natural geometry [26]. This problem is worsened by transforming of these waterways into closed pipe systems within the city, adding complexity to an already challenging situation [27]. This approach may address short-term urban planning requirements; however, it frequently leads to inadequate hydraulic capacity to the significant amounts of stormwater generated by heavy rainfall [28]. The abundance of impermeable surfaces in urban areas, such as concrete and asphalt, also exacerbates the challenges of this approach. These surfaces inhibit natural water absorption into the soil, increasing surface runoff [29,30]. The rapid expansion of urban areas is causing an increase the number of impervious surfaces, such as concrete and asphalt, leading to a higher risk of flooding and overwhelming stormwater systems, further compromising water security in densely populated areas. As a response, the implementation of blue–green stormwater infrastructure and nature-based solutions is gaining recognition as effective strategies to address the growing flood risk in urban area [31–33].

Understanding flood risk perception is imperative for effective risk communication, offering valuable insights into residents' level of preparedness while facilitating the identification of potential vulnerabilities and inequities within the community [34–36]. Local communities should be equipped with comprehensive information about flood risks and preventative measures. This helps improve awareness and preparedness for flash floods [37]. Despite the devastating impact of floods, most citizens, over 52%, lack the necessary knowledge to act appropriately during flood events. Additionally, only 30% feel personally responsible for addressing flood risks. There is a clear reluctance among

residents to support the development of a sustainable urban drainage infrastructure, indicating a concerning lack of engagement in mitigating flood hazards. Concerns about climate change do not significantly affect people's behaviour during flood events or their willingness to invest in sustainable solutions. Addressing this issue requires more than just improved preparedness; it necessitates direct, targeted educational efforts in the community [38]. In flood-prone areas, many residents often do not have sufficient insurance coverage or take necessary precautions to protect themselves from potential flood damage [39]. Socio-economic and socio-spatial inequalities create disparities in vulnerability and resilience to flooding, which influence exposure to flood risk and the capacity to recover from its impacts [40].

Disaster preparedness refers to the range of actions and measures taken to mitigate the impact of natural or man-made hazards. These could include steps to reduce the risk of injury and damage, as well as establishing the capacity to manage and recover from temporary disruptions caused by hazardous events [41]. The geographical location significantly influences disaster preparedness, independent of individual socio-demographic and family socio-economic factors. Notably, the preparedness levels in the lowland areas surpassed those in the mountainous and highland regions. Furthermore, individuals who migrated for employment exhibited higher levels of disaster preparedness compared with local residents. It is essential to acknowledge the substantial impact of both community dynamics and the surrounding environment on individual disaster preparedness [42]. The levels of risk and vulnerability differ based on the specific characteristics of each location, including variations in landforms [43].

Given the increasing threat and consequences of urban flooding exacerbated by climate change, urgent action is needed to improve technological and community-based responses. Conventional methods of urban stormwater management and flood risk communication have proven inadequate, given the increasing frequency and severity of extreme weather events. Therefore, it is crucial to employ innovative approaches that combine cutting-edge technological tools with strong community engagement. The application of technology and comprehensive data analysis can provide accurate information on flood vulnerability and water security risks. Furthermore, active community participation in preparedness initiatives holds great promise in significantly reducing the adverse impacts of flooding.

Despite the rapid rise in technology-based flood assessment tools, the existing literature remains fragmented: predictive modelling studies, spatial analysis approaches, and community preparedness research have largely developed separately, with little attempt to integrate them within a single analytical framework. Furthermore, most previous reviews have catalogued individual technologies without critically evaluating how effectively these tools translate into measurable community preparedness, particularly in data-poor, low-income urban contexts. This gap is significant because technological sophistication alone does not guarantee increased resilience; the practical value of flood risk management technologies ultimately depends on the extent to which affected communities can access, trust, and act on the information they generate. To address this gap, this review synthesizes evidence on technology-based urban flood vulnerability assessment and community preparedness, identifies key barriers to their integration, and establishes a conceptual foundation for a comprehensive urban flood vulnerability index. The study's research question is how urban flood vulnerability can be assessed based on the integration of technology and community preparedness. Specifically, the study will use bibliometric analysis to provide insights into emerging trends relevant to urban flooding and a systematic review to delve deeper into existing related research. In doing so, this study contributes both to the methodological literature on systematic technology assessment and to the policy discourse on equitable and community-centred flood governance.

2. Materials and Methods

2.1. Search Strategy

Considerations for selecting articles for this systematic review were articles published in international scientific journals from 2014 to July 2025 that focused on technology-based urban flood vulnerability assessment and community preparedness integration. The database analyzed was Scopus. The search was conducted under the following conditions: ‘urban AND flood’ and “community AND preparedness” keywords, all open-access articles, publication year 2014–2025, article document type, journal source type, and English language. We ensured that publications that met the search criteria in title, keywords or abstract were included in this review, depending on the search features allowed by the database used. The multiple Boolean operators and domain-specific terminology used are intentionally consistent with a targeted search strategy employed in focused systematic reviews in interdisciplinary disaster science [44]. The search tables and terms used in the databases considered are presented in Table 1.

Table 1. Search terms from Scopus sources.

	Search Terms from Scopus Sources
Keywords	urban AND flood community AND preparedness
Open Access	All open access
Year	2014–2025
Document Type	Article
Source Type	Journal
Language	English

2.2. Bibliometric Analysis

Bibliometric analysis has been used in CE research [45], sustainable development [46], open innovation [47] and waste management [48]. Bibliometric analysis can identify future research directions in a field of study by providing the visualization of the relationships between articles, journals, keywords, citations and co-citation networks [49]. This study used Biblioshiny and VOSviewer version 1.6.20 to conduct bibliometric analyzes such as research [50]. This study analyzed research contributions by country and research trends.

2.3. Systematic Review Analysis

After a general article analysis using bibliometrics, this study conducted an in-depth analysis of the most relevant articles using a systematic review. This will help researchers to find new findings from the combination of previous studies.

2.3.1. Research Question

This systematic review study adopted PICO from the National Institute for Health and Clinical Excellence [51]. This framework includes P (population or problem), I (intervention), C (comparator or control), and O (outcome). Population (P) is an urban area vulnerable to flooding; Intervention (I) is the application of technology and integration of community preparedness in dealing with flood risk; Comparison (C) is the level of flood preparedness and vulnerability; and Outcome (O) is the assessment of the effectiveness of technology and integration of community preparedness in reducing flood vulnerability. This study then conducted this systematic review through an analysis of 27 relevant articles. The data extraction process involved the components of flood, urban, preparedness, and community. This study analyzed technology-based urban flooding and the integration of community preparedness.

2.3.2. Inclusion Criteria

The article data was selected by excluding articles that were not relevant to the research topic of technology-based urban flood vulnerability assessment and community preparedness integration. Next, more specific inclusion criteria were set to ensure that only the most relevant and high-quality articles were included in the analysis. The inclusion criteria included articles that discussed flooding, rivers, cities, community, and preparedness. Articles that met these inclusion criteria were then selected for data extraction and further analysis was assisted by Covidence [51]. The article selection process was conducted independently to increase the reliability and security of the selection process. Articles that met the inclusion criteria at various stages were considered for data extraction and analysis. Thus, data were collected from a number of articles relevant to the research topic.

2.3.3. Trial Flow

In the initial stage of this research, a review was conducted of the title and keywords of each article to ensure that the articles addressed technology-based urban flood vulnerability assessment and community preparedness integration. The research workflow involved identifying articles from the Scopus database ($n = 47$) and screening for relevant articles. With the exclusion criteria, 20 articles were eliminated. All 27 relevant articles were included in this review, with no studies in progress or awaiting classification (Figure 1). The article selection process reached 100%, thanks to the simple and clear selection criteria. This multi-stage screening process enabled the researchers to progressively refine the application of the predefined inclusion and exclusion criteria by comparing screening decisions across the title, abstract, and full-text review stages. Any uncertainties regarding article eligibility were resolved through repeated evaluation against the established criteria, ensuring consistency, transparency, and reproducibility throughout the selection process.

The final 27 articles included reflect a purposive and quality-focused strategy of selection rather than a volume-maximizing one. This is in line with the methodological tradition of focused systematic reviews, which prioritize depth of analysis and inter-study comparability over breadth [44,52]. The decision to limit the corpus to articles that explicitly reference both technology application and community preparedness but not either dimension alone necessarily limited the pool of eligible articles. The dual-criteria design is a conscious methodological decision which maintains analytical focus and improves the internal coherence of the synthesis. The 27 articles included in the corpus come from 15 countries, four quartile categories, and include research using predictive modelling (LSTM, ML), spatial analysis (GIS, LiDAR), and community engagement frameworks, demonstrating a breadth of thematic and geographic diversity that is conducive to meaningful comparative analysis despite the limited size of the corpus. The bibliometric aspect is used here as an additional perspective for trend visualization, not as an independent scientometric claim, in line with its application in recent interdisciplinary reviews [48]. However, it is constrained by the size of the corpus.

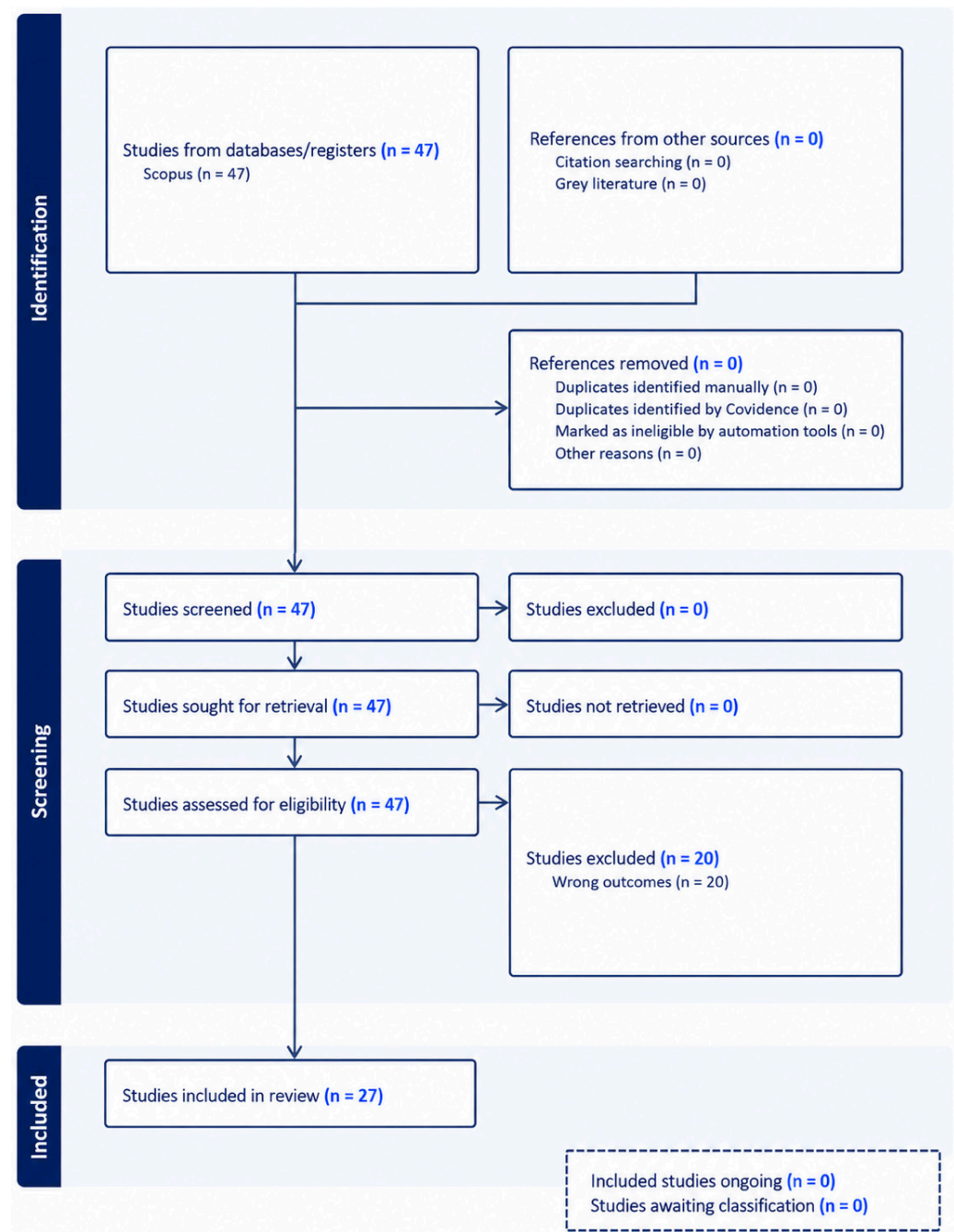


Figure 1. Flowchart of the study selection process.

2.3.4. Article Quality Assessment

This study also systematically evaluated the quality of the research included in the review. Similarly to the previous systematic review study of research [53], the assessment was based on a set of predefined criteria. Each study was reviewed against the criteria to ensure a comprehensive understanding of its strengths and limitations. Each quality criterion (Q1–Q10) was rated as Yes/No according to explicit and predetermined decision rules based on established quality appraisal frameworks for systematic reviews, namely the Mixed Methods Appraisal Tool (MMAT) Version 2018 [54]. A ‘Yes’ result was only recorded if there was explicit evidence reported in the article, not inferred. Where evidence was lacking, not described adequately or was equivocal, ‘no’ was assigned. Each article was evaluated against the criteria by two reviewers independently and disagreements were resolved by discussion and consensus. Table 2 is a quality assessment including the

following columns: Title, Year of Publication, Author, Country, and answers to ten quality assessment questions (Q1–Q10). These questions evaluate the important aspects of each study, ensuring a thorough and standardized assessment process.

Table 2. Quality assessment of research articles (Criteria Q1–Q5).

No	Title	Journal	Country	Q1	Q2	Q3	Q4	Q5
1	Correlates of flood preparedness in urban households: Evidence from the Greater Accra Metropolitan Area of Ghana [55]	Environmental Challenges	Ghana	Yes	Yes	No	Yes	Yes
2	Multivariate Hydrological Modelling Based on Long Short-Term Memory Networks for Water Level Forecasting [56]	Information	Colombia	No	Yes	Yes	Yes	No
3	Urban anthropization: community vulnerability and resilience to flood hazards in eastern Democratic Republic of Congo [57]	Environmental Research Communications	Congo	Yes	Yes	No	Yes	No
4	Characterizing flood risk perception in urban communities of Pakistan [58]	International Journal of Disaster Risk Reduction	Pakistan	Yes	Yes	No	Yes	No
5	Evaluating the Utility of Selected Machine Learning Models for Predicting Stormwater Levels in Small Streams [37]	Sustainability	Poland	Yes	Yes	Yes	Yes	No
6	The rainbo platform for enhancing urban resilience to floods: An efficient tool for planning and emergency phases [59]	Climate	Italy	Yes	Yes	Yes	Yes	No
7	Vulnerability of human settlements to flood risk in the core area of Ibadan metropolis, Nigeria [60]	Journal of Disaster Risk Studies	Australia	Yes	Yes	No	Yes	Yes
8	Analyzing flash flood risk perception through a geostatistical approach in the village of Navaluenga, Central Spain [61]	Journal of Flood Risk Management	Spain	Yes	Yes	No	Yes	Yes
9	Worry about climate change and urban flooding risk preparedness in southern Italy: A survey in the simeto river valley (sicily, Italy) [38]	Resources	Italy	Yes	Yes	No	Yes	Yes
10	Flood Risk Management: The Flood-Prone Area of Phra Nakhon Sri Ayutthaya, Thailand [62]	Sustainability	Thailand	Yes	Yes	Yes	Yes	Yes
11	Study of Households Preparedness for Disasters and Emergencies in West Regions of Tehran Province, Iran [63]	Health Emergencies and Disasters Quarterly	Iran	No	Yes	No	Yes	Yes
12	Relationship between community attitudes and flood mitigation in the Welang watershed in the Karangketug urban village, Pasuruan city [64]	The Malaysian Journal of Nursing	Indonesia	Yes	Yes	No	Yes	Yes

Table 2. Cont.

No	Title	Journal	Country	Q1	Q2	Q3	Q4	Q5
13	Urban flooding: Coping with Weija Dam spillage by downstream communities in Ghana [65]	Journal of Disaster Risk Studies	Ghana	Yes	Yes	No	Yes	Yes
14	Effectiveness of flood early warning system from the perspective of experts and three affected communities in urban areas of Pakistan [66]	Environmental Hazards	Pakistan	Yes	Yes	No	Yes	No
15	Conceptualizing risk communication barriers to household flood preparedness [67]	Urban Governance	Australia	Yes	No	No	No	No
16	Agent-based modelling and inundation prediction to enable the identification of businesses affected by flooding [68]	WIT Transactions on Ecology and the Environment	UK	Yes	Yes	Yes	Yes	No
17	Analysis of urban households preparedness and municipal interventions to build flood resilience in Durban, South Africa: Implications for SDG 11 [69]	Environmental and Sustainability Indicators	South Africa	Yes	Yes	No	Yes	No
18	A Comparative Assessment of Household Flood Disaster Preparedness in Flood-prone Rural and Urban Communities in Kaduna State, Nigeria [70]	Journal of Community Medicine and Primary Health Care	Nigeria	Yes	Yes	No	Yes	Yes
19	Flood risk perception, disaster preparedness and response in flood-prone urban communities of Rivers State [71]	Journal of Disaster Risk Studies	Nigeria	Yes	Yes	No	Yes	Yes
20	A non-immersive virtual reality serious game application for flood safety training [72]	International Journal of Disaster Risk Reduction	Italy	Yes	Yes	Yes	Yes	No
21	Predicting road flooding risk with crowdsourced reports and fine-grained traffic data [73]	Computational Urban Science	USA	Yes	Yes	Yes	Yes	No
22	Navigating Flood Resilience: Challenges, Solutions, and Lessons Learnt from the Dominican Republic [74]	Water	UK	Yes	Yes	Yes	Yes	No
23	Flood risk assessment and quantification at the community and property level in the State of Iowa [75]	International Journal of Disaster Risk Reduction	USA	Yes	Yes	Yes	Yes	Yes
24	Evaluation of geohazards in the Cape Girardeau area using LiDAR and GIS, Southeast Missouri, USA [76]	Environmental Earth Sciences	USA	No	Yes	Yes	Yes	No
25	Addressing pluvial flash flooding through community-based collaborative research in Tijuana, Mexico [77]	Water	USA	Yes	Yes	Yes	Yes	Yes

Table 2. *Cont.*

No	Title	Journal	Country	Q1	Q2	Q3	Q4	Q5
26	Overcoming the Challenges of Water, Waste and Climate Change in Asian Cities [78]	Environmental Management	The Netherlands	Yes	Yes	No	Yes	No
27	Climatic and Hydrological Factors Affecting the Assessment of Flood Hazards and Resilience Using Modified UNDRR Indicators: Ayutthaya, Thailand [79]	Water	Thailand	Yes	Yes	Yes	Yes	Yes
Total ‘Yes’ per Criterion				24	26	12	26	13

Criteria Descriptions

Q1: Research questions clear and relevant to urban flood risk and community preparedness?

Q2: Research design and methodology transparently explained and appropriate?

Q3: Technology-based tools clearly described, standardized, and valid?

Q4: Data analysis appropriate and results accurately interpreted?

Q5: Sample size sufficient and representative to reflect vulnerability and preparedness?

Table 2 presents the first five quality criteria (Q1–Q5) for each of the 27 articles reviewed. The remaining five criteria (Q6–Q10), along with the Total Score—calculated as the number of “Yes” responses, with a maximum of 10—are reported separately in Table 3 below to improve readability and avoid layout clutter identified during the review.

Table 3. Quality Assessment of Research Articles (Criteria Q6–Q10 and Total Score).

No	Title	Q6	Q7	Q8	Q9	Q10	Total Score (max 10)
1	Correlates of flood preparedness in urban households: Evidence from the Greater Accra Metropolitan Area of Ghana	Yes	No	Yes	No	Yes	7
2	Multivariate Hydrological Modelling Based on Long Short-Term Memory Networks for Water Level Forecasting	Yes	No	Yes	No	No	5
3	Urban anthropization: community vulnerability and resilience to flood hazards in eastern Democratic Republic of Congo	Yes	No	Yes	No	Yes	6
4	Characterizing flood risk perception in urban communities of Pakistan	Yes	No	Yes	No	Yes	6
5	Evaluating the Utility of Selected Machine Learning Models for Predicting Stormwater Levels in Small Streams	Yes	No	Yes	No	Yes	7
6	The rainbo platform for enhancing urban resilience to floods: An efficient tool for planning and emergency phases	Yes	No	Yes	No	Yes	7
7	Vulnerability of human settlements to flood risk in the core area of Ibadan metropolis, Nigeria	Yes	No	Yes	No	Yes	7
8	Analyzing flash flood risk perception through a geostatistical approach in the village of Navaluenga, Central Spain	Yes	No	Yes	Yes	Yes	8

Table 3. Cont.

No	Title	Q6	Q7	Q8	Q9	Q10	Total Score (max 10)
9	Worry about climate change and urban flooding risk preparedness in southern Italy: A survey in the Simeto river valley (Sicily, Italy)	Yes	Yes	Yes	Yes	Yes	9
10	Flood Risk Management: The Flood-Prone Area of Phra Nakhon Sri Ayutthaya, Thailand	Yes	Yes	Yes	Yes	Yes	10
11	Study of Households Preparedness for Disasters and Emergencies in West Regions of Tehran Province, Iran	Yes	No	No	No	No	4
12	Relationship between community attitudes and flood mitigation in the Welang watershed in the Karangketug urban village, Pasuruan city	Yes	No	No	No	Yes	6
13	Urban flooding: Coping with Weija Dam spillage by downstream communities in Ghana	Yes	No	Yes	No	Yes	7
14	Effectiveness of flood early warning system from the perspective of experts and three affected communities in urban areas of Pakistan	Yes	No	Yes	No	No	5
15	Conceptualizing risk communication barriers to household flood preparedness	No	No	No	No	No	1
16	Agent-based modelling and inundation prediction to enable the identification of businesses affected by flooding	Yes	No	No	No	Yes	6
17	Analysis of urban households preparedness and municipal interventions to build flood resilience in Durban, South Africa: Implications for SDG 11	Yes	No	Yes	No	Yes	6
18	A Comparative Assessment of Household Flood Disaster Preparedness in Flood-prone Rural and Urban Communities in Kaduna State, Nigeria	Yes	No	Yes	No	Yes	7
19	Flood risk perception, disaster preparedness and response in flood-prone urban communities of Rivers State	Yes	No	No	No	Yes	6
20	A non-immersive virtual reality serious game application for flood safety training	Yes	Yes	Yes	Yes	Yes	9
21	Predicting road flooding risk with crowdsourced reports and fine-grained traffic data	Yes	No	Yes	No	Yes	7
22	Navigating Flood Resilience: Challenges, Solutions, and Lessons Learnt from the Dominican Republic	Yes	Yes	Yes	No	Yes	8
23	Flood risk assessment and quantification at the community and property level in the State of Iowa	Yes	Yes	Yes	Yes	Yes	10
24	Evaluation of geohazards in the Cape Girardeau area using LiDAR and GIS, Southeast Missouri, USA	Yes	No	No	No	Yes	5
25	Addressing pluvial flash flooding through community-based collaborative research in Tijuana, Mexico	Yes	Yes	No	Yes	Yes	9
26	Overcoming the Challenges of Water, Waste and Climate Change in Asian Cities	Yes	Yes	Yes	No	Yes	7

Table 3. Cont.

No	Title	Q6	Q7	Q8	Q9	Q10	Total Score (max 10)
27	Climatic and Hydrological Factors Affecting the Assessment of Flood Hazards and Resilience Using Modified UNDRR Indicators: Ayutthaya, Thailand	Yes	Yes	Yes	Yes	Yes	10
Total 'Yes' per Criterion		26	8	20	7	23	6.851851852
Criteria Descriptions							
Q6: Methodology, tools, results, and interpretations described in detail, and make new contributions?							
Q7: Conflicts of interest and funding sources explained transparently?							
Q8: Limitations of the study adequately explained?							
Q9: Research results can be replicated or validated, with effort to avoid publication bias?							
Q10: Tools and methods valid and appropriate for assessing flood risk and preparedness?							

3. Results

In recent years, research on technology-based urban flood vulnerability assessment and community preparedness integration has become crucial in international research. Research contributions from different countries have varying numbers of documents and levels of collaboration. The analysis of bibliometric results is used to show the contributions of countries in the world in terms of the number of documents, citations and the strength of the relationship, showing the level of collaboration between countries in research. In addition, this study analyzes the development of the research focus from 2019 to 2025. This analysis visualizes the contribution and development of research globally related to technology-based urban flood vulnerability and community preparedness integration. The number of documents, citations and level of research collaboration between countries can be seen in Figure 2.

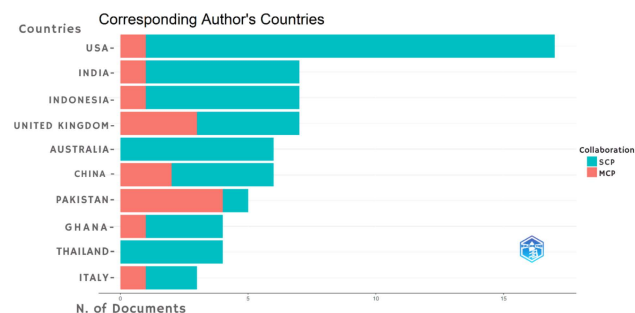


Figure 2. Corresponding authors' countries.

Figure 2 illustrates the distribution of countries based on the number of corresponding author publications, with a division between single-country publications (SCPs) and cross-country collaborations (MCP). The United States dominates the number of publications, followed by India and Indonesia, which have made strong contributions to independent research. Meanwhile, countries such as the United Kingdom and Pakistan are more prominent in international collaborations. Thailand, as part of Southeast Asia, also plays an important role, although its contribution is still limited. Overall, the participation of Asian countries, including Indonesia and Thailand, reflects the growing potential of global research. However, cross-country collaborative networks still need to be strengthened to increase the visibility and scientific impact of this region.

Meanwhile, in addition to country analysis, keyword analysis is also important in explaining the emphasis of current research directions. Figure 3 shows the most relevant keywords in disaster-related studies, with “climate change” occupying the top position

(31 occurrences), followed by “risk assessment” (28), “flooding” (26), and “floods” (23). The main focus of research appears to be on the relationship between climate change and flood risk, as well as the importance of risk management and disaster management in the context of human vulnerability. Keywords such as “flood control,” “vulnerability,” and “disasters” reflect mitigation efforts as well as impacts on humans. This indicates a research trend that increasingly emphasizes climate risk assessment and disaster adaptation as an integral part of flood disaster management.

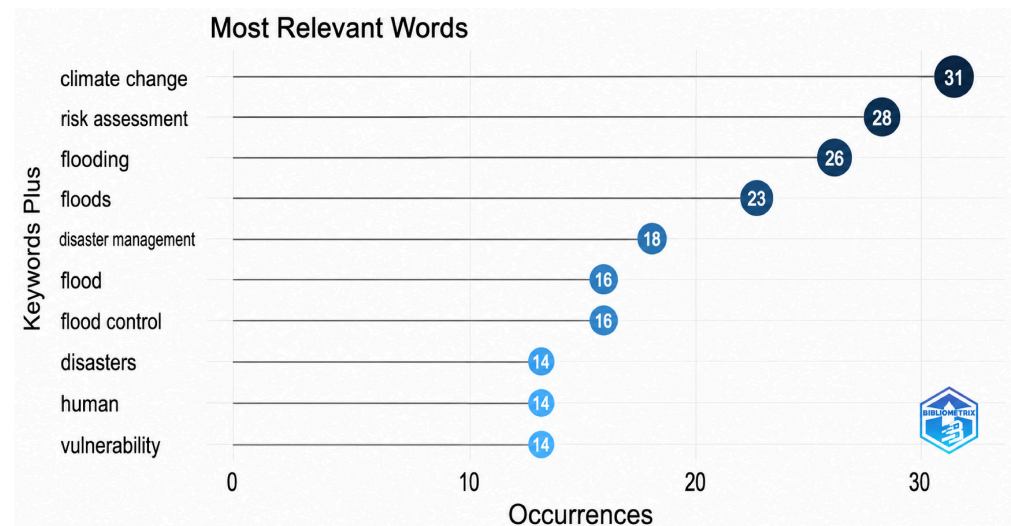


Figure 3. Most relevant words.

The treemap in Figure 4 also sharpens the current direction of publications by visualizing the frequency of keywords in scientific publications, showing that topics such as environmental monitoring and water quality dominate (6% each), followed by rivers, river pollution, and risk assessment (5% each). Other frequently occurring keywords include river basin, article, water pollutant, and nonhuman, highlighting the diverse focus of research, ranging from water quality to specific contaminants such as mercury, lead, and arsenic. This visualization reflects the broad research trend toward environmental monitoring and risk assessment, with an emphasis on water pollution and its impacts on humans and ecosystems, underscoring the growing concern for water security in the face of increasing contamination threats.

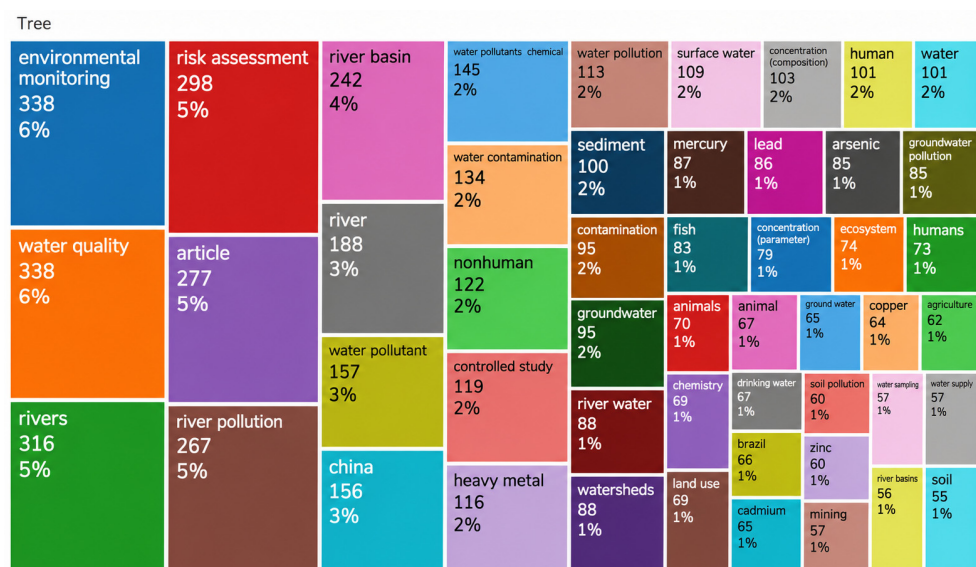


Figure 4. Treemap of keyword.

These keywords are then interconnected and form a network visualization that displays a conceptual map linking the various domains of disaster risk management and urban planning (Figure 5). Key nodes such as “risk assessment,” “disaster management,” “climate change,” and “flooding” form thematic clusters that are interconnected through edges with varying weights, indicating the strength of correlation between concepts. The network structure shows three dominant clusters that are visually distinguished by colour gradients: a red cluster that focuses on flood risk and management aspects (flood risk, risk perception, preparedness), a blue cluster that concentrates on policy and assessment dimensions (hazard assessment, vulnerability, disaster prevention), and a green cluster that emphasizes the geographic and socio-economic context (Australia, human, socio-economics). This topological configuration of the network implies that disaster risk management is an interdisciplinary domain that requires the integration of technical, social, and policy approaches in a specific spatial context, with flooding and climate change as critical links between these domains.

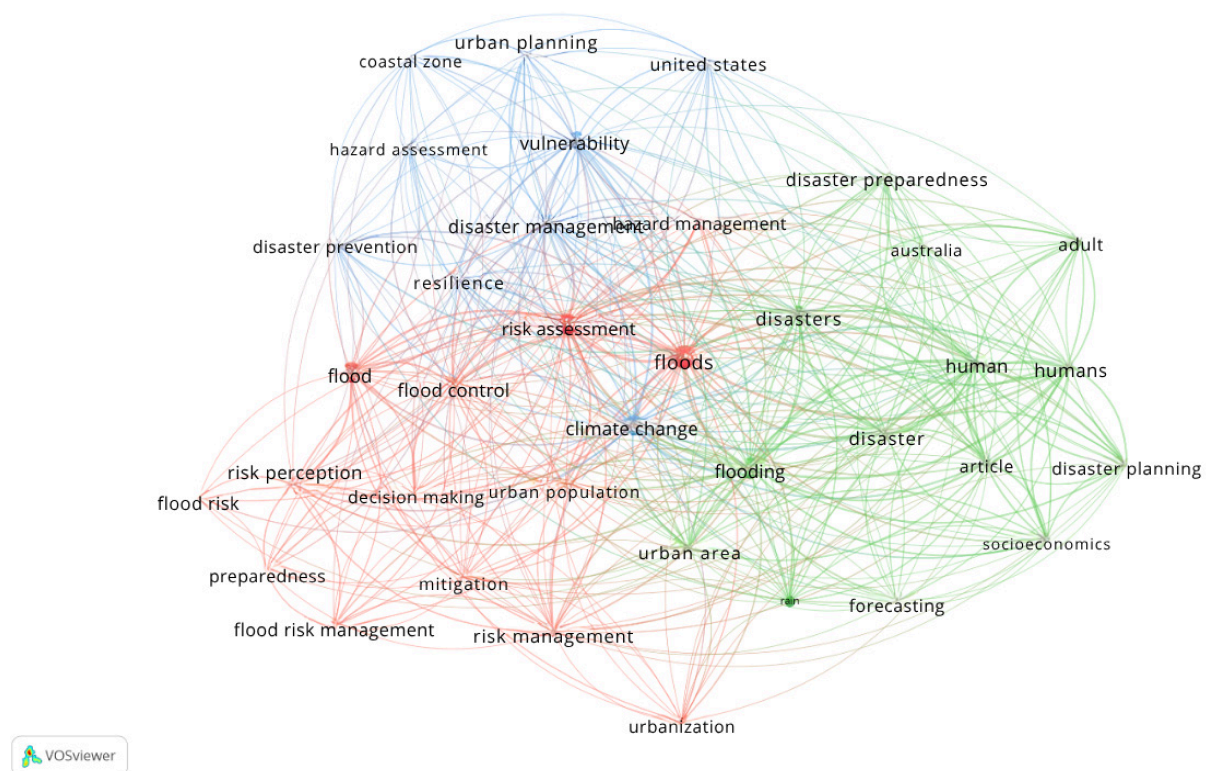


Figure 5. Co-occurrence of keyword.

This Sankey diagram also shows the thematic evolution in the scientific literature from 2014–2023 to 2024–2025, with initial dominant themes such as climate change, disaster risk reduction, and disaster preparedness evolving into more specific issues such as flood risk, risk perception, flood risk management, and resilience. This shift in thematic flow reflects the shift in research focus from macro issues related to climate change to micro approaches emphasizing flood risk mitigation, preparedness, and adaptation to future climate disasters (Figure 6).

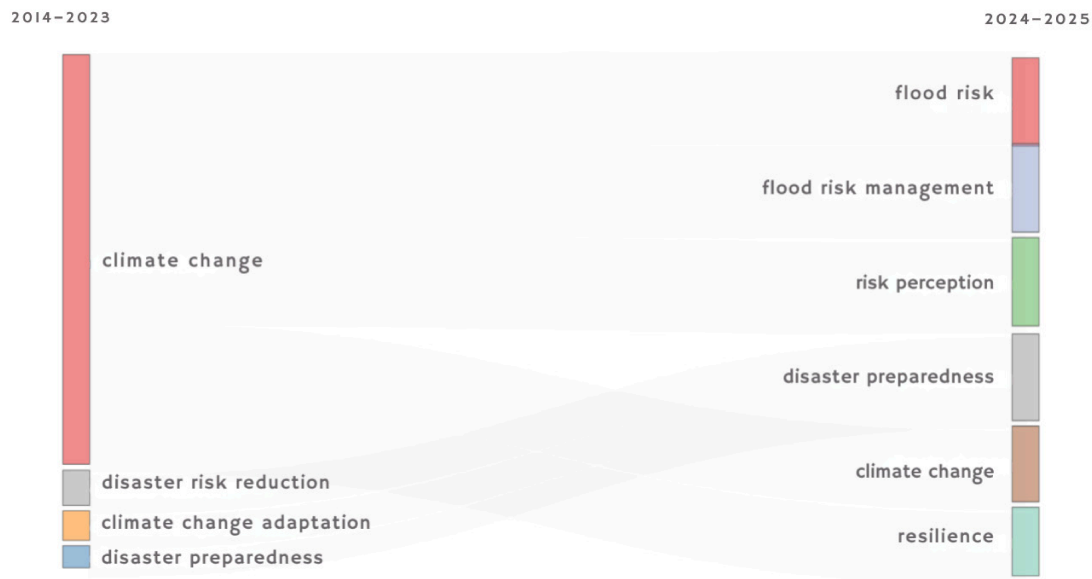


Figure 6. Thematic evolution of keyword.

Systematic Review Results

Among the 27 selected studies, 15 were published in Q1 journals, followed by eight in Q2 and four in Q4. The studies originated from a geographically diverse range of countries. Q1 publications were distributed across North America, Europe, Asia, and Africa, while Q2 and Q4 publications also represented multiple regions. Figure 7 illustrates the geographical distribution of the selected studies according to journal quartile.

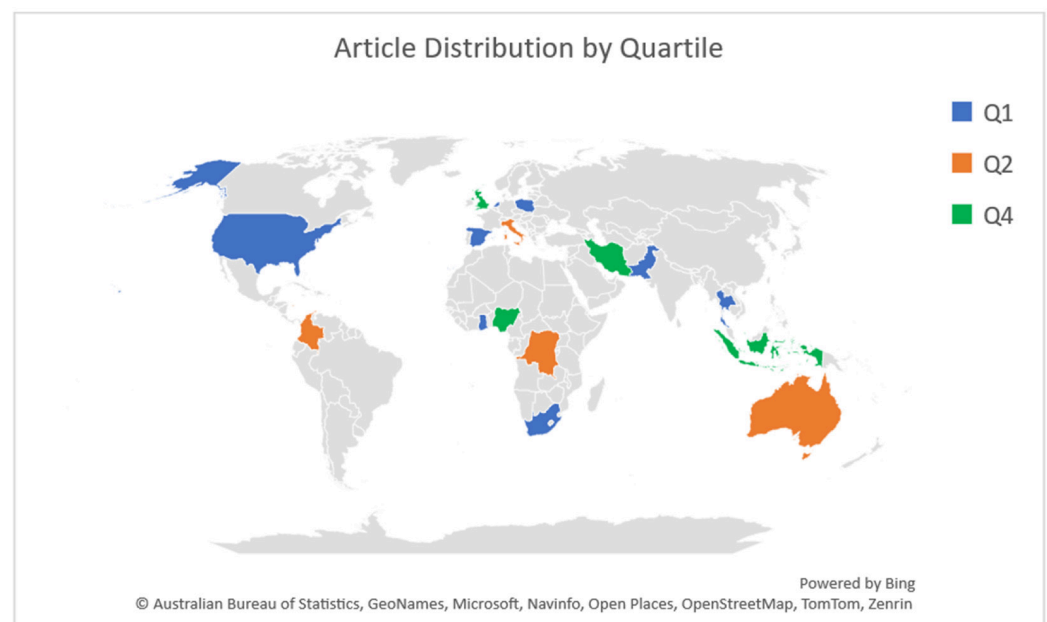


Figure 7. Article distribution of quartile.

There were 27 research articles analyzed on technology-based urban flood vulnerability and community preparedness integration. The selected studies have been summarized based on findings ranging from urban flood vulnerability, technology application to the level of community preparedness. This can illustrate the development of research and key contributions to the study of urban flood vulnerability by applying technology and integrating community preparedness. The core research including innovations and discoveries has been presented based on the objectives, methods, and conclusions in Table 4.

Table 4. Core of the research.

No	Title	Research Objectives	Research Methods	Research Conclusions
1	Correlates of flood preparedness in urban households: Evidence from the Greater Accra Metropolitan Area of Ghana	Investigate some of the factors that drive households' decision-making to prepare for floods and policy options for managing floods in Ghana.	Integration of survey data with meteorological and hydrological data to assess the effectiveness of flood early warning systems and the role of communities in improving preparedness.	The importance of community involvement in flood preparedness efforts with institutional support for community opinions with coordinated disaster mitigation adaptation to effectively reduce the impact of flooding in urban areas.
2	Multivariate Hydrological Modelling Based on Long Short-Term Memory Networks for Water Level Forecasting	Building flood prediction and prevention with the development of Long Short-Term Memory (LSTM) neural networks and increasing public awareness so that the level of preparedness increases.	Construct a multivariate LSTM artificial neural network model with data from two hydrological stations, namely water level, flow and rainfall measurements, so as to learn the long-term dependence between successive data series for water level prediction.	The multivariate LSTM artificial neural network model is proficient in the analysis of complex dynamics and cross-correlation of hydrological data, so it can be proposed as an effective flood early warning system.
3	Urban anthropization: community vulnerability and resilience to flood hazards in eastern Democratic Republic of Congo	To analyze land use change in Uvira from 1995 to 2021 and to assess the vulnerability and effectiveness of community resilience strategies in responding to flood impacts or future flood risks.	Spatial analysis of land use and land change by considering community perceptions of vulnerability and flood mitigation measures obtained from direct surveys of flood survivors living in refugee camps and those who have returned to their places of origin. The Mann–Whitney U statistical test was used to analyze the influence of residential location and household lifestyle.	As the level of vulnerability to flooding is influenced by urbanization, household resilience can be assessed by the area where people live and their socio-economic and institutional lifestyles. Preventive and sustainable interventions should be undertaken by the government and relevant stakeholders to stimulate community awareness and involvement in disaster risk management.
4	Characterizing flood risk perception in urban communities of Pakistan	Understanding risk perceptions through socio-economic factors that have a direct impact on potential disaster adaptive capacity and preparedness and thus appropriate disaster risk reduction strategies.	Ordinary Least Squares (OLSs) and odds-ratio regression models were applied to analyze data from all communities collectively so as to check the consistency and validity of the interpreted results by comparing the impact of socio-economic factors across different urban areas.	Historical floods and proximity to hazards influence flood risk perceptions in urban communities in Pakistan, highlighting the spatial variability of socio-economic determinants such that disaster risk communication and flood risk reduction strategies tailored to the unique characteristics of different urban communities need to be undertaken by disaster risk management authorities.

Table 4. Cont.

No	Title	Research Objectives	Research Methods	Research Conclusions
5	Evaluating the Utility of Selected Machine Learning Models for Predicting Stormwater Levels in Small Streams	Evaluate the effectiveness of the Artificial Neural Network (ANN) and XGBoost learning models, in accurately predicting maximum rainwater levels in small streams, identifying meteorological and hydrological factors that influence predictions and assessing the potential of the models to improve flash flood forecasting, especially in small watersheds that require rapid response.	Using ANN and XGBoost models, to predict rainwater levels based on meteorological and hydrological data such as rainfall depth, rainwater level, air temperature, and dew point temperature. Identification of the most significant factors influencing the model using Shapley Additive exPlanations (SHAP) analysis. Evaluation of model performance with Root Mean Square Error (RMSE) and R-squared (R^2) to compare its prediction accuracy.	The ANN model outperforms the XGBoost model in predicting the maximum rainwater level in small rivers; the most important factors affecting the prediction are the temporal rainfall distribution and the previous rainwater level with high accuracy. This modelling approach can be adapted to other regions.
6	The rainbo platform for enhancing urban resilience to floods: An efficient tool for planning and emergency phases	An assessment of the effectiveness and efficiency of the RainBO platform in supporting decision-makers in disaster management so as to improve urban flood resilience by integrating meteorological, hydrological and regional data.	Integration of real-time meteorological, hydrological and territorial data into the RainBO platform was evaluated through a case study. Comparison of RainBO with URBAN-PREX, RAINGAIN, and STAR-FLOOD. Platform analyzes, including vulnerability mapping, hydrological simulation models, early warning systems, and operational reliability of the platform's rainfall monitoring system by technology.	The RainBO platform is capable of combining territorial data, historical records, real-time monitoring, and modelling techniques, improving cities' resilience to flooding by integrating multiple data sources and providing comprehensive support for decision-making in flood management. The RainBO platform is capable of combining territorial data, historical records, real-time monitoring, and modelling techniques, improving cities' resilience to flooding by integrating multiple data sources and providing comprehensive support for decision-making in flood management. The RainBO platform is capable of combining territorial data, historical records, real-time monitoring, and modelling techniques, improving cities' resilience to flooding by integrating multiple data sources and providing comprehensive support for decision-making in flood management.
7	Vulnerability of human settlements to flood risk in the core area of Ibadan metropolis, Nigeria	Evaluate the vulnerability of settlements to flood risk, focusing on factors that influence vulnerability and propose effective mitigation measures to reduce the impact of flood disasters in urban areas. Evaluate the vulnerability of settlements to flood risk, focusing on factors that influence vulnerability and propose effective mitigation measures to reduce the impact of flood disasters in urban areas.	A multi-method approach involving spatial analysis, field surveys and interviews with local residents. Remote sensing and GIS to map flood-prone areas (spatial data), surveys and interviews to collect socio-economic data on community perceptions and strategies. All data were statistically analyzed to determine the relationship between variables influencing vulnerability and the effectiveness of mitigation strategies.	Urban flood vulnerability to flood risk is influenced by a combination of physical factors, such as topography and land use, and socio-economic factors, such as income and access to infrastructure. In addition, community preparedness has not been balanced due to the lack of coordination of relevant stakeholders as well as community awareness and participation.

Table 4. Cont.

No	Title	Research Objectives	Research Methods	Research Conclusions
8	Analyzing flash flood risk perception through a geostatistical approach in the village of Navaluenga, Central Spain	To identify the social, economic and environmental factors that influence risk perceptions among local residents, and to evaluate how these perceptions may influence preparedness and response to flash flooding.	Identify spatial patterns and factors contributing to variations in risk perceptions in different parts of the village using a geostatistical approach from direct survey data on personal experiences with flooding, perceptions of flood risk, and preventative measures taken by Navaluenga villagers.	The perception of flash flood risk in Navaluenga village is influenced by proximity to the river and historical flood experience. A locally tailored approach to flood risk management and community engagement is needed to improve flood preparedness.
9	Worry about climate change and urban flooding risk preparedness in southern Italy: A survey in the simeto river valley (sicily, Italy)	Assessing the relationship between community awareness of climate change and urban flood preparedness, as well as willingness to engage in appropriate emergency response during flood events and proactive approaches to sustainable infrastructure investment in the Simeto River Basin, Sicily.	A large-scale survey was conducted, collecting data from over 1000 residents of the Simeto River Basin. The survey included a combination of multiple-choice and Likert-scale questions from over 1000 Simeto River Basin residents designed to measure concern for climate change, knowledge of appropriate flood response and willingness to invest in flood mitigation measures. Data analysis included cross-sectional analysis for correlations between climate change concerns and flood preparedness, as well as regression models to test factors influencing willingness to adapt and qualitative insights from community discussions and media content analysis to contextualize survey findings.	High levels of awareness of climate change are not accompanied by increased urban flood preparedness or willingness to invest in flood adaptation among Simeto River Basin residents. There is a gap between climate change awareness and practical resilience behaviours, indicating that education and media efforts are not sufficient to improve community preparedness.
10	Building a Resilient City through Sustainable Flood Risk Management: The Flood-Prone Area of Phra Nakhon Sri Ayutthaya, Thailand	Evaluate and improve flood risk management strategies with the integration of multi-stakeholder engagement, infrastructure resilience, and community preparedness to propose a management framework tailored to the needs and challenges in Phra Nakhon Sri Ayutthaya based on the effectiveness of current flood resilience strategies and identify opportunities for continuous improvement.	Surveys and assessments of flood risk indicators, including infrastructure resilience and emergency response effectiveness as well as interviews and focus groups involving local stakeholders, experts and community members to understand perceptions, challenges and gaps in current flood management strategies assessed by Analytic Hierarchy Process (AHP) and Spearman correlation so as to evaluate and prioritize flood resilience factors.	The alignment of expert assessments with community perspectives on flood preparedness with awareness and effective coordination has not been balanced, necessitating a multi-faceted approach that integrates stakeholder collaboration, infrastructure and strong disaster response mechanisms.
11	Study of Households Preparedness for Disasters and Emergencies in West Regions of Tehran Province, Iran	Evaluate and assess the effectiveness of the disaster assessment and education guide provided by the Ministry of Health, and identify strengths and weaknesses in household preparedness to reduce the impact of disasters and emergencies in the western region of Tehran Province in 2018.	The study design was a cross-sectional design using data from the ‘Disaster Assessment and Education Guide’ covering 314 health and therapy centres covering 1,726,803 households in the western region of Tehran Province provided by the Ministry of Health.	Household preparedness levels in the western and northwestern regions of Tehran Province were low, with significant variations between health centres. The efforts of the health centres should be accompanied by an increase in the level of education and disaster preparedness of the community.

Table 4. Cont.

No	Title	Research Objectives	Research Methods	Research Conclusions
12	Relationship between community attitudes and flood mitigation in the Welang watershed in the Karangketug urban village, Pasuruan city	Analyze the relationship between different attitudes towards flood risk influencing the implementation and success of flood mitigation strategies at the community level and evaluate the impact of these attitudes on flood preparedness and response in the Welang River Watershed in Karangketug Village, Pasuruan City.	A cross-sectional survey with a structured questionnaire was used to assess community attitudes towards flood risk and their involvement in mitigation efforts which was analyzed using Spearman correlation analysis to determine the strength and significance of the relationship between community attitudes and the effectiveness of flood mitigation efforts, as well as the incorporation of local secondary data and interviews with stakeholders to provide an understanding of flood mitigation in the Welang watershed.	There is a significant correlation between proactive and informed community attitudes towards flood risk increasing preparedness and community involvement in mitigation practices, and the effectiveness of flood mitigation measures in the Welang watershed.
13	Urban flooding: Coping with Weija Dam spillage by downstream communities in Ghana	Identify the socio-economic impacts and challenges of the Weija Dam spill on downstream communities in Ghana, with countermeasures adopted by residents, effectiveness of institutional support, and potential strategies to improve flood resilience.	The survey assessed the level of flood impact, coping strategies, and perceptions of institutional support. Structural adjustments to buildings and community-based responses were also analyzed. Qualitative data was used to provide insights into the effectiveness of government interventions, including the activities of the National Disaster Management Agency (BNPB). In addition, spatial analyzes were conducted to assess flood-prone areas and evaluate the effectiveness of existing flood management infrastructure.	Communities downstream of the Weija Dam rely heavily on family and social networks for post-flood recovery, with insufficient support provided by government agencies. Structural adjustments to buildings and drainage systems have been adopted as coping mechanisms by some residents, but are inadequate despite recurrent flooding. Stronger, community-based flood management strategies, better government support and improved early warning systems are needed to reduce the vulnerability of communities to future flood events.
14	Effectiveness of flood early warning system from the perspective of experts and three affected communities in urban areas of Pakistan	Evaluating the effectiveness of flood early warning systems (EWSs) from the perspective of experts and affected urban communities, identifying challenges and gaps and integration of community engagement in improving the reliability and responsiveness of EWS to reduce flood risk in urban Pakistan.	Expert interviews and focus group discussions were conducted to gather insights on existing flood SPD infrastructure, data collection, processing, and dissemination mechanisms. Simultaneously, a survey was distributed to three flood-prone urban communities to assess their awareness, understanding, and trust in EWS. Data were analyzed using thematic analysis for qualitative data and descriptive statistics for quantitative data to identify patterns and correlations related to EWS effectiveness.	Flood EWS in Pakistan has the potential to significantly mitigate flood risk, but its effectiveness is limited by technological inadequacies and a lack of community trust and understanding, making it important to improve EWS infrastructure and two-way communication that includes active community participation.
15	Conceptualizing risk communication barriers to household flood preparedness	Identify and analyze risk communication barriers that affect households' flood preparedness and evaluate risk communication strategies currently in use.	A systematic approach to reviewing the existing literature on flood risk communication and household preparedness involves critically analyzing previous research and considering theories of adaptive behaviour and how they can be applied in the research design to evaluate the effectiveness of flood risk communication.	Effective risk communication is key to improving households' flood preparedness, but there is a barrier of a mismatch between the messages conveyed and households' risk perceptions, which requires the design and implementation of educational programmes as an integrated communication strategy.

Table 4. Cont.

No	Title	Research Objectives	Research Methods	Research Conclusions
16	Agent-based modelling and inundation prediction to enable the identification of businesses affected by flooding	Develop an agent-based model that identifies affected businesses in urban areas, using inundation predictions and detailed business classifications to improve business preparedness and response strategies in flood-prone areas, particularly in the Lower Don Valley area of Sheffield.	Geo-flood modelling and agent-based simulation for inundation prediction integrated with OS MasterMap helped classify and map businesses based on flood risk. In addition, interviews with businesses that have experienced flooding were conducted, extracting key attributes and behaviours to accurately model business responses to flood events.	Agent-based modelling, combined with precise inundation predictions, provides insight into the vulnerability of businesses to flooding in urban areas, making it important to develop tailored flood preparedness strategies.
17	Analysis of urban households preparedness and municipal interventions to build flood resilience in Durban, South Africa: Implications for SDG 11	To evaluate and identify the factors that influence household preparedness levels, psychological impacts, the role of communication and flood insurance and assess the effectiveness of municipal interventions in building flood resilience in Durban, South Africa.	The survey approach related to data on flood-related experiences, levels of preparedness, access to flood insurance, and the psychological impacts felt by households in urban areas of Durban that are vulnerable to flooding. Statistical analyses were used to interpret the data and evaluate the effectiveness of municipal interventions in building flood resilience, including an evaluation of the flood warning communication system in use.	Municipal interventions face significant challenges in terms of flood warning communication and access to affordable flood insurance. The psychological impact of trauma requires mental health support. There is a need to improve flood warning communication systems to make them more effective and accessible to all levels of society.
18	A Comparative Assessment of Household Flood Disaster Preparedness in Flood-prone Rural and Urban Communities in Kaduna State, Nigeria	Identify factors that influence the level of flood disaster preparedness among households in rural and urban communities in Kaduna state, Nigeria and evaluate community awareness, available resources and the effectiveness of interventions by government agencies in preparing households for potential floods.	Surveys were conducted to assess household preparedness for flooding, while in-depth interviews were conducted with community leaders and SEMA officials to identify differences in perceptions regarding the effectiveness of disaster management interventions. Significant differences between household preparedness in the two regions were analyzed and factors affecting preparedness were identified.	Most households in rural and urban communities in Kaduna state are unprepared for floods, with lower preparedness due to lack of training and first aid equipment, as well as unavailability of early warning systems in rural areas.
19	Flood risk perception, disaster preparedness and response in flood-prone urban communities of Rivers State	Assess the vulnerability of socio-demographic factors such as flood risk perception, disaster preparedness, and response strategies of urban households in flood-prone areas of Rivers State, Nigeria, by examining their flood risk perception, disaster preparedness, and response strategies.	Cross-sectional survey design, collecting data from households in flood-prone urban communities in Rivers State using a structured questionnaire. Descriptive statistics and stepwise discriminant analysis were used to evaluate the relationship between socio-demographic variables (such as age, household size, flood risk awareness, and risk perception) and disaster preparedness. The analyses focused on differentiating between flood-prepared and unprepared households, based on their perceptions and adaptive capacity. The study also examined the impact of geographic location and previous flood experience on the level of preparedness.	Awareness of flood risk among urban households in Rivers State has not closed the disaster preparedness gap, especially among those living in low-lying floodplain areas. Socio-demographic factors, including age, household size, and risk perception, play an important role in determining the level of preparedness. Stronger community engagement and education on flood risks, as well as the importance of addressing structural vulnerabilities, such as inadequate drainage systems and unplanned urban development, are needed to improve overall flood resilience.

Table 4. Cont.

No	Title	Research Objectives	Research Methods	Research Conclusions
20	A non-immersive virtual reality serious game application for flood safety training	Develop and test the effectiveness of a non-immersive virtual reality-based serious game application, evaluate the impact of technology-based training on participants' knowledge, evacuation behaviour and response in simulated flood situations, and implement the use of technology as part of urban disaster mitigation strategies.	A quasi-experimental approach involved participants participating in a training session with an interactive story module simulating an urban flood scenario using a non-immersive virtual reality-based serious game application. An assessment of knowledge, risk perception and behavioural intention to evacuate was conducted by filling out questionnaires before and after the training. Statistical analyses were conducted to evaluate changes in these variables, and qualitative interviews were used to assess participants' experiences and potential improvements to the application.	The results of the training showed an increase in the participants' understanding of evacuation measures and mental preparedness in dealing with floods. The technology can be integrated into urban flood preparedness training programmes with further development of the training modules.
21	Predicting road flooding risk with crowdsourced reports and fine-grained traffic data	Developed a flood risk prediction model using crowdsourced data from user reports and traffic data to evaluate the effectiveness of combining topographic, hydrological and rainfall features in predicting road flooding during extreme storm events, as well as comparing random forest and AdaBoost, in detecting potentially flooded roads and understanding the role of different types of data in improving flood risk prediction.	Random forest and AdaBoost modelling, trained with topographic, hydrological, and temporal rainfall datasets, as well as crowdsourced flood report information via the Waze app and traffic speed data from INRIX from two storm events in Harris County. Analyses were conducted to assess each factor in predicting the probability of flooding on roads and to compare the performance of the two models in different storm cases. Model validation was done by measuring the AUC (Area Under the Curve) value to evaluate the prediction accuracy.	The combination of rainfall temporal factors with topography and hydrology can predict the flood risk of roads, especially under extreme storm conditions such as Hurricane Harvey. The random forest model is better than AdaBoost at predicting roads at risk of flooding, especially in slow-moving, heavy rainfall storms. The integration of crowdsourced data and traffic data can be an effective tool in disaster mitigation planning and community flood preparedness.
22	Navigating Flood Resilience: Challenges, Solutions, and Lessons Learnt from the Dominican Republic	Identify innovative strategies and technologies that can be applied to improve the preparedness and resilience of urban communities to flood risks, and to evaluate the effectiveness of disaster resilience frameworks applied in the local context.	Using a community resilience framework to assess physical, economic, environmental and social preparedness in the face of disasters, by analyzing data from multiple sources, including meteorological data, expert interviews and relevant international case studies. Integration of blockchain-based technology and swarm intelligence to develop technological solutions that can support disaster preparedness and management in Santo Domingo.	The application of innovative technologies and a comprehensive disaster resilience framework can significantly improve the flood preparedness and risk management in Santo Domingo. Pentahelix collaboration is essential in dealing with the challenges of urban flooding.
23	Flood risk assessment and quantification at the community and property level in the State of Iowa	Evaluating the level of vulnerability and identification of key factors affecting preparedness, application of data-driven technologies to strengthen early warning systems, and raising awareness of flood risks among urban communities by utilizing the integration of technology and community engagement.	Integration of survey data from communities with meteorological and hydrological data. Data analysis was conducted using statistical and geospatial modelling methods to assess the relationship between community preparedness and variables such as weather conditions, water flow patterns and land use change. The application of geographic information system (GIS) technology and hydrological modelling was used to predict flood risk and assess the effectiveness of early warning systems.	The integration of technology and community participation is critical for improving flood preparedness in urban areas. Communities with access to technology-based early warning systems show higher levels of preparedness than those without access.

Table 4. Cont.

No	Title	Research Objectives	Research Methods	Research Conclusions
24	Evaluation of geohazards in the Cape Girardeau area using LiDAR and GIS, Southeast Missouri, USA	Assess and map the Cape Girardeau region's vulnerability to various geological hazards, including landslides, sinkholes, and other seismic-related risks, using advanced LiDAR and GIS technologies.	Using high-resolution LiDAR and geospatial data to conduct a comprehensive analysis of the topography and geomorphology of the Cape Girardeau area. Using GIS-based spatial analysis, this research mapped the distribution of landslide susceptibility and identified important factors that contribute to geohazard risk, such as rainfall patterns, hydrological conditions, and underlying geology. Field observations and field surveys were conducted to validate the remote sensing data and document the physical characteristics of the identified geohazard sites. The study also used Generalized Weighted Linear Regression (GWLR) to rank and quantify the relative risks to people, property and infrastructure in the various zones.	The Cape Girardeau area is quite vulnerable to various geohazard threats, with landslide risk particularly prominent along the southeastern erosional cliffs of Crowley's Ridge. The analysis highlights the important role of rainfall and hydrology in triggering and worsening these geohazards, as well as the potential for sinkhole formation in karst-prone areas. The research emphasizes the need for targeted risk mitigation efforts, including improved infrastructure resilience and community preparedness, to address the identified vulnerabilities. The integration of geospatial technologies such as LiDAR and GIS into regional disaster risk management practices can effectively monitor and manage geohazard risks.
25	Addressing pluvial flash flooding through community-based collaborative research in Tijuana, Mexico	Integrate community-based research (residents, government and NGOs) with flood modelling to address Pluvial Flash Flood (PFF) risk and to improve flood risk management and planning in resource-constrained urban environments.	A collaborative approach, community-based research (CM), household surveys, focus groups, training sessions, and consultations with experts to gather data on local flood risks and community needs. Hydrological models, specifically FloodRISE-C and FloodRISE-G, were developed and refined based on feedback from end-users. Spatial analysis and scenario modelling were conducted to produce various flood hazard visualizations, including maps of flood depth, flood strength and erosion potential, tailored to community needs.	A collaborative, community-based approach to flood hazard modelling significantly increased the relevance and effectiveness of flood risk visualizations for end-users in Tijuana. Integrating local knowledge and addressing community-specific flood scenarios, the research produced a set of flood hazard visualizations that are scientifically robust and practically useful for flood risk planning and response.
26	Overcoming the Challenges of Water, Waste and Climate Change in Asian Cities	Evaluate variations in cities' performance and capacity in managing these risks and understand how cities can improve their performance through learning and knowledge exchange.	Using the City Blueprint Framework and the Global City Flood Risk Framework to assess the governance capacity and performance of Asian cities in addressing challenges related to water, waste, and climate change with indicator assessment data, stakeholder interviews, and literature review. Analyzes were conducted to identify factors influencing cities' performance in water management and climate change, and to explore potential improvements through cross-city collaboration.	Cities with greater social, environmental and financial pressures tend to have lower water management performance, while cities like Seoul and Singapore are excellent at water conservation and climate-resilient urban management. Adequate education and good governance are key enablers for improving city capacity and the need for a holistic and inclusive approach to urban water management to achieve sustainable and resilient outcomes.

Table 4. Cont.

No	Title	Research Objectives	Research Methods	Research Conclusions
27	Climatic and Hydrological Factors Affecting the Assessment of Flood Hazards and Resilience Using Modified UNDRR Indicators: Ayutthaya, Thailand	Assess flood risk based on land use, rainfall, and surface runoff using a modified indicator approach from UNDRR, evaluate community flood preparedness and assess resilience strategies adopted by local residents in the face of flood disasters.	Analytic Hierarchy Process (AHP) and Geographic Information System (GIS) approach to assess flood hazard and community resilience with survey data (on flood preparedness, access to basic services, and participation in community preparedness training) of 522 respondents in Ayutthaya. Meteorological and hydrological data were also used to identify key factors affecting flood risk. Spearman correlation analysis was used to link community preparedness with flood warning information, community hazard maps, and disaster relief payments.	Surface runoff is the most significant hydrological factor affecting flood risk in Ayutthaya, followed by land use and rainfall. The survey showed that half of the respondents did not receive flood-related information or disaster relief, and the majority had never been involved in community preparedness training. There is a need to increase community participation in flood preparedness training as well as better access to emergency services and disaster-related information.

A comparative analysis of the 27 included studies shows three levels of technology–community integration performance. Studies based on predictive modelling technologies (LSTM, ML, agent-based simulation: [37,56,68,73]) consistently reported high technical accuracy but low community co-production, with technology outputs provided to communities rather than developed with them. On the other hand, community-focused studies [38,58,64,71] achieved a higher level of engagement but they were based on self-reported perception data with limited methodological triangulation. Consistent ‘Yes’ across quality criteria Q3, Q5, Q7 and Q9 for these high-integration studies suggests methodological rigour and community engagement covary rather than trade off. Q3 reported standardized technology tools. The finding that only 11 of 27 articles (41%) reported standardized technology tools supports the conclusion that technology implementation in this domain is inconsistent and under-reported, and this is the gap that the proposed urban flood vulnerability index is intended to fill.

4. Discussion

Based on the data on research quality (Table 1) above, 24 articles had research questions relevant to urban flood risk and community preparedness (Q1). A total of 26 articles clearly explained the design and methodology (Q2). A total of 11 articles described standardized and valid technology-based tools (Q3). A total of 25 articles analyzed data with accurate interpretation of results (Q4). Representative sample sizes to show vulnerability and preparedness were found in 13 articles (Q5). A total of 26 studies made novel contributions with detailed descriptions of methodology, tools, results and interpretation (Q6). Seven articles explicitly described conflicts of interest and funding sources (Q7). A total of 21 articles explained the limitations of the study (Q8). A total of seven articles explained that the research results could be replicated or validated to avoid publication bias (Q9). There were 23 articles using valid and appropriate tools and methods for flood preparedness risks (Q10). Articles from Thailand (10 and 27), Italy (20), and USA (23 and 25) fulfilled all criteria for assessing article quality. Of the 27 articles, 11 described the use of standardized technology-based tools. This shows the potential for increased involvement of technology in the field of urban flood research and community preparedness integration. This is supported by the research results of Bakhtiari et al. (2024), which show that integrating the adoption and effectiveness of flood visualization technology into policies and regulations, providing funding and support, and promoting data accessibility and sharing ultimately leads to increased flood resilience [80].

The four major technology categories identified in this review, namely LSTM-based predictive modelling, GIS/LiDAR-based spatial analysis, crowdsourced data platforms, and blockchain-based information integrity systems, differ substantially in their data requirements, scalability, and community accessibility. LSTM models [56,73] are promising for flood prediction with high temporal resolution, but they require continuous high-quality hydrological time-series data, thus limiting their use in data-sparse urban settings common in the Global South. Crowdsourced platforms such as flood reporting integrated with Waze [73] could enable real-time community data contribution, but they are affected by spatial and demographic user biases in their reliability. Blockchain applications [74] provide verifiable data provenance for early warning systems, but remain at the prototyping stage and encounter major barriers in low-bandwidth, low-digital-literacy contexts. Importantly, none of the studies reviewed have deployed more than two of these technologies in an integrated pipeline and none have rigorously assessed end-user trust, interpretability or behavioural response, gaps that the proposed urban flood vulnerability index must be explicitly designed for. Recent developments in image-based flood depth recognition are an emerging frontier with significant potential for community-facing applications, outside the

technology categories covered in the reviewed corpus. Deep learning models with attention mechanisms such as the CBAM-improved ResNet50 models used in urban waterlogging disaster classification [81] can learn to directly extract flood depth estimates from visual inputs. This allows for damage assessment to be performed quickly and affordably without the need for specialized sensor infrastructure. No studies in the present corpus adopt this approach, but it should be incorporated into future urban flood vulnerability frameworks, particularly in dense urban environments where traditional hydrological sensor networks are insufficient or non-existent, with implications for long-term water security in flood-prone cities.

Technology is starting to be applied in flood mitigation efforts. The trend has started since 2022 to 2024. The integration of advanced technology with community-based preparedness metrics shows significant progress in assessing urban flood vulnerability. The gap in technology implementation and community involvement needs to be balanced with the development of a comprehensive urban flood vulnerability index so that it can provide a holistic approach. The study uses the development and utilization of LSTM multivariate artificial neural network technology for predictive hydrological modelling, crowdsourced data combined with traffic information for real-time updates and LiDAR and GIS for accurate topographic analysis. In addition, blockchain technology ensures the reliability of information used in flood predictions. The role of community preparedness in flood risk mitigation efforts can be assessed from perceptions, as well as community involvement in training and household social communities which are important for measuring the community's ability to respond to and recover from flood disasters. Disaster preparedness encompasses different levels of readiness, including community, institutional, household, and individual levels. In rural areas, most disaster preparedness initiatives focus on household readiness [82–88]. Most communities have not been provided with flood information nor have they participated in training sessions focused on flood preparedness [62]. The innovation and development of education and public engagement with non-immersive virtual reality interfaces and simulated flood hazard visualizations are needed so that flood risk information is accessible and understandable to all.

Real-time data integration through platforms such as RainBO increases the adaptability and relevance of urban flood vulnerability indices, allowing for risk updates and evolution based on current meteorological, hydrological and territorial data. Interventions of socio-economic and institutional factors, such as household economic resilience and the effectiveness of institutional responses, ensure that vulnerability assessments take into account the broader social context. The application of machine learning algorithms allows urban flood vulnerability indices to continuously evolve with refinements to assessments based on new data and community feedback.

A key finding of this review is that the technology–community engagement gap persists across almost all contexts studied, and this calls for a more nuanced understanding of what ‘community engagement’ actually means in flood risk governance. The reviewed literature identifies at least three different modes of engagement that are often conflated: (1) passive information reception (communities as recipients of flood warnings or risk maps); (2) participatory data co-production (communities as active contributors of local knowledge, crowdsourced observations or behavioural feedback); and (3) co-governance (communities as partners in decision-making on flood risk planning and resource allocation). Most studies reviewed operate at modality 1. Some studies that claim community ‘participation’ in their abstracts deliver modality 1 in their methodology [64]. This distinction has implications for the proposed urban flood vulnerability index, and if community engagement is operationalized only at modality 1, the index will quantify exposure to information, not actual preparedness capacity. Therefore, future index construction should

include indicators of engagement quality that distinguish between these modalities, based on participatory action research frameworks and adaptive co-management theory [89–92], ultimately strengthening community resilience and long-term water security in flood-prone urban areas.

The implications of this review are broader than technical flood management and are relevant to the governance architecture of smart city development. The evidence suggests three policy directions that are actionable. First, the authors suggest that municipal governments mandate standards for data interoperability for flood-related technologies, and the reviewed studies highlight a major fragmentation problem: LSTM models, GIS platforms and blockchain systems operate in separate institutional silos, preventing the type of integrated risk intelligence required for true urban resilience [59,74]. Second, national disaster management frameworks need to formally recognize community preparedness as a measurable, fundable outcome, rather than a co-benefit of infrastructure investment. Evidence indicates that communities with organized preparedness training and access to early warning systems have significantly higher flood resilience indicators [62]. Public funding mechanisms, however, often do not consider community capacity building as primary infrastructure. Third, the transition to smart city flood governance must be accompanied by equity safeguards; the reviewed literature consistently shows that technology-dependent early warning systems exclude low income, low literacy and informally housed populations [38], precisely those with the highest flood exposure. Thus, any comprehensive urban flood vulnerability index must have a governance readiness dimension to assess the existence of municipal capacity to operationalize the index equitably across socio-economic strata. Synthesizing these findings, this review then proposes a conceptual urban flood vulnerability index structured around four complementary dimensions: first, technological capacity, reflecting the availability and integration of predictive, spatial, and information integrity tools; second, the quality of community engagement, to distinguish passive information reception from participatory co-production and co-governance; third, socio-economic vulnerability, to capture the exposure of low-income, low-educated, and informally housed populations; and fourth, governance readiness, to assess the capacity of city governments to operationalize the index equitably, including safeguarding water security for the most vulnerable urban populations. The explicit integration of these four dimensions, rather than the isolated application of a single technology, constitutes the conceptual contribution of this review.

5. Future Research Directions

In this review, five priority directions are identified to advance the field of technology-integrated urban flood vulnerability assessment. First, validation studies are needed that combine multiple technologies. To the best of our knowledge, no previous study in the reviewed corpus has integrated LSTM predictive modelling, GIS-based vulnerability mapping and community engagement frameworks in a single validated pipeline. Future research should design longitudinal intervention studies to test the compound effect of technology–community integration on measurable preparedness outcomes. Second, the proposed index of urban flood vulnerability needs empirical operationalization and validation across contexts. The index development will be guided by the established methodology for composite indicators [93] with explicit weighting procedures, sensitivity analysis and pilot testing for at least three urban typologies: high-income data-rich cities, mid-income data-sparse cities and informal settlement zones. Third, Global South contexts are still very under-represented. Of the 27 studies reviewed, only four are from Sub-Saharan Africa and one from Southeast Asia. Given that urban flood exposure is disproportionately concentrated in low- and middle-income country cities [94], where adaptive capacity is lowest,

future research must proactively prioritize these geographies, resisting methodological approaches that assume data infrastructure comparable to the Global North. Fourth, the corpus analyzed has not discussed the role of gender, age and disability in technology access and flood preparedness. Future index architectures should embed social vulnerability dimensions, not tack them on as afterthoughts. Fifth, emerging deep learning approaches to flood depth classification from visual imagery (e.g., CBAM-ResNet50 applications) provide a low-cost, highly scalable frontier that should be systematically integrated into urban flood early warning systems, particularly in fast-urbanizing regions where sensor infrastructure lags population growth [95], and where water security remains critically at risk.

6. Conclusions

From 2022 to 2025, research on urban flood vulnerability has evolved towards the utilization of technology in flood mitigation efforts. The technologies used are multivariate LSTM artificial neural networks for predictive hydrological modelling, LiDAR and GIS for topographic analysis, and blockchain to ensure flood prediction data, as well as the use of non-immersive virtual reality interfaces and simulated flood hazard visualization directly involving the community so that flood risk information can be well-received. However, the gap between technology utilization and community involvement is very high, so there is a need to develop a comprehensive urban flood vulnerability index that can provide a holistic approach. The comprehensive approach parameterizes vulnerability and real-time updates, community engagement and infrastructure improvements, and planned preparedness, while also addressing water security as a critical dimension of urban resilience. Bridging the gap between technological advancement and community engagement, the urban flood vulnerability index provides the best standardized and adaptable method to assess urban flood vulnerability from various aspects.

Author Contributions: Conceptualization, A.S., M.F.Y., H.A., N.N. and R.N.A.; methodology, A.S. and M.F.Y.; software, M.F.Y. and N.N.; validation, A.S. and M.F.Y.; formal analysis, A.S. and M.F.Y.; investigation, A.S. and M.F.Y.; resources, M.F.Y. and N.N.; data curation, M.F.Y. and N.N.; writing—original draft preparation, A.S., M.F.Y., H.A., N.N. and R.N.A.; writing—review and editing, A.S., M.F.Y., H.A., N.N. and R.N.A.; visualization, A.S., M.F.Y. and N.N.; supervision, A.S. and H.A.; project administration, A.S.; funding acquisition, A.S. All authors have read and agreed to the published version of the manuscript.

Funding: This work is supported by the Research and Development (Risbang), Universitas Indonesia with research scheme the PUTI Q1 2024 and with contract numbers grant number [NKB-552/UN2.RST/HKP.05.00/2024].

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The dataset is available upon author request. The raw data supporting the conclusions of this article will be made available by the author upon request.

Acknowledgments: This research is part of the implementation of research with the theme Suburban Watershed, Water Security and Quality Index (2024). We thank the Research and Development (Risbang) Universitas Indonesia for support this research.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Amanowicz, Ł.; Ratajczak, K.; Dudkiewicz, E. Recent Advancements in Ventilation Systems Used to Decrease Energy Consumption in Buildings—Literature Review. *Energies* **2023**, *16*, 1853. [[CrossRef](#)]

2. Piotrowska, B.; Słyś, D. Comprehensive Analysis of the State of Technology in the Field of Waste Heat Recovery from Grey Water. *Energies* **2023**, *16*, 137. [\[CrossRef\]](#)
3. Szeląg, B.; Łagód, G.; Musz-Pomorska, A.; Widomski, M.K.; Stránský, D.; Sokáč, M.; Pokrývková, J.; Babko, R. Development of Rainfall-Runoff Models for Sustainable Stormwater Management in Urbanized Catchments. *Water* **2022**, *14*, 1997. [\[CrossRef\]](#)
4. Trošelj, J.; Nayak, S.; Hobohm, L.; Takemi, T. Real-time flash flood forecasting approach for development of early warning systems: Integrated hydrological and meteorological application. *Geomat. Nat. Hazards Risk* **2023**, *14*, 2269295. [\[CrossRef\]](#)
5. Spence, A.; Poortinga, W.; Pidgeon, N. The Psychological Distance of Climate Change. *Risk Anal.* **2012**, *32*, 957–972. [\[CrossRef\]](#) [\[PubMed\]](#)
6. Demski, C.; Capstick, S.; Pidgeon, N.; Sposato, R.G.; Spence, A. Experience of extreme weather affects climate change mitigation and adaptation responses. *Clim. Change* **2017**, *140*, 149–164. [\[CrossRef\]](#) [\[PubMed\]](#)
7. Sussams, L.W.; Sheate, W.R.; Eales, R.P. Green infrastructure as a climate change adaptation policy intervention: Muddying the waters or clearing a path to a more secure future? *J. Environ. Manag.* **2015**, *147*, 184–193. [\[CrossRef\]](#) [\[PubMed\]](#)
8. Šarapatka, B.; Bednář, M. Rainfall Erosivity Impact on Sustainable Management of Agricultural Land in Changing Climate Conditions. *Land* **2022**, *11*, 467. [\[CrossRef\]](#)
9. Stec, A.; Słyś, D. New Bioretention Drainage Channel as One of the Low-Impact Development Solutions: A Case Study from Poland. *Resources* **2023**, *12*, 82. [\[CrossRef\]](#)
10. Papadopoulos-Zachos, A.; Anagnostopoulou, C. The Link of Extreme Precipitation with the Clausius–Clapeyron Relation: The Case Study of Thessaloniki, Greece. *Environ. Sci. Proc.* **2023**, *26*, 7. [\[CrossRef\]](#)
11. Starzec, M.; Mullendore, G.L.; Kucera, P.A. Using radar reflectivity to evaluate the vertical structure of forecast convection. *J. Appl. Meteorol. Climatol.* **2018**, *57*, 2835–2849. [\[CrossRef\]](#)
12. Hörschemeyer, B.; Henrichs, M.; Dittmer, U.; Uhl, M. Parameterization for Modeling Blue–Green Infrastructures in Urban Settings Using SWMM-UrbanEVA. *Water* **2023**, *15*, 2840. [\[CrossRef\]](#)
13. Pan, C.; Wang, X.; Liu, L.; Wang, D.; Huang, H. Characteristics of heavy storms and the scaling relation with air temperature by event process-based analysis in South China. *Water* **2019**, *11*, 185. [\[CrossRef\]](#)
14. Houston, D.; Werrity, A.; Bassett, D.; Geddes, A.; Hoolachan, A.; McMillan, M. *Pluvial (Rain-Related) Flooding in Urban Areas: The Invisible Hazard*; Joseph Rowntree Foundation: London, UK, 2011; p. 96.
15. Banholzer, S.; Kossin, J.; Donner, S. The Impact of Climate Change on Natural Disasters. In *Reducing Disaster: Early Warning Systems for Climate Change*; Springer: Berlin/Heidelberg, Germany, 2014; pp. 21–49. [\[CrossRef\]](#)
16. Bernard, S.M.; Samet, J.M.; Grambsch, A.; Ebi, K.L.; Romieu, I. The potential impacts of climate variability and change on air pollution-related health effects in the United States. *Environ. Health Perspect.* **2001**, *109*, 199–209. [\[CrossRef\]](#)
17. Trenberth, K.E. Changes in precipitation with climate change. *Clim. Res.* **2011**, *47*, 123–138. [\[CrossRef\]](#)
18. Kumar, N. Fluvial Flood Risk in Contemporary Settlements: A Case of Vadodara City in the Vishwamitri Watershed. *Eng. Proc.* **2023**, *56*, 70. [\[CrossRef\]](#)
19. Piasecki, A.; Pilarska, A. Rainwater management in urban areas in Poland: Literature review. *Bull. Geogr. Phys. Geogr. Ser.* **2023**, *25*, 5–21. [\[CrossRef\]](#)
20. Piro, P.; Saleh, M.M.; Pirouz, B.; Turco, M.; Palermo, S.A. Smart and Innovative Systems for Urban Flooding Risk Management. In *2023 International Conference on Information and Communication Technologies for Disaster Management (ICT-DM)*; IEEE: New York, NY, USA, 2023; pp. 1–4. [\[CrossRef\]](#)
21. Quesada-Román, A.; Villalobos-Portilla, E.; Campos-Durán, D. Hydrometeorological disasters in urban areas of Costa Rica, Central America. *Environ. Hazards* **2020**, *20*, 264–278. [\[CrossRef\]](#)
22. Sharifi, A. Resilient urban forms: A macro-scale analysis. *Cities* **2018**, *85*, 1–14. [\[CrossRef\]](#)
23. Du, J.; Qian, L.; Rui, H.; Zuo, T.; Zheng, D.; Xu, Y.; Xu, C.Y. Assessing the effects of urbanization on annual runoff and flood events using an integrated hydrological modeling system for Qinhua River basin, China. *J. Hydrol.* **2012**, *464*, 127–139. [\[CrossRef\]](#)
24. Haghighatafshar, S.; Becker, P.; Moddemeyer, S.; Persson, A.; Sörensen, J.; Aspegren, H.; Jönsson, K. Paradigm shift in engineering of pluvial floods: From historical recurrence intervals to risk-based design for an uncertain future. *Sustain. Cities Soc.* **2020**, *61*, 102317. [\[CrossRef\]](#)
25. Palla, A.; Sansalone, J.J.; Gnecco, I.; Lanza, L.G. Storm water infiltration in a monitored green roof for hydrologic restoration. *Water Sci. Technol.* **2011**, *64*, 766–773. [\[CrossRef\]](#) [\[PubMed\]](#)
26. Zingraff-Hamed, A.; Bonnefond, M.; Bonthoux, S.; Legay, N.; Greulich, S.; Robert, A.; Rotgé, V.; Serrano, J.; Cao, Y.; Bala, R.; et al. Human–river encounter sites: Looking for harmony between humans and nature in cities. *Sustainability* **2021**, *13*, 2864. [\[CrossRef\]](#)
27. Mrozik, K.D. Problems of Local Flooding in Functional Urban Areas in Poland. *Water* **2022**, *14*, 2453. [\[CrossRef\]](#)
28. Zhao, X.; Li, H.; Cai, Q.; Pan, Y.; Qi, Y. Managing Extreme Rainfall and Flooding Events: A Case Study of the 20 July 2021 Zhengzhou Flood in China. *Climate* **2023**, *11*, 228. [\[CrossRef\]](#)
29. Cacciuttolo, C.; Garrido, F.; Painena, D.; Sotil, A. Evaluation of the Use of Permeable Interlocking Concrete Pavement in Chile: Urban Infrastructure Solution for Adaptation and Mitigation against Climate Change. *Water* **2023**, *15*, 4219. [\[CrossRef\]](#)

30. Strohbach, M.W.; Döring, A.O.; Möck, M.; Sedrez, M.; Mumm, O.; Schneider, A.K.; Weber, S.; Schröder, B. The 'hidden urbanization': Trends of impervious surface in low-density housing developments and resulting impacts on the water balance. *Front. Environ. Sci.* **2019**, *7*, 29. [\[CrossRef\]](#)
31. Joshua, I.D.; Salihu, A.C.; Mshelia, A.M.; Ubachukwu, N.N. Analysis of community-based pattern of water demand and supply. *J. Environ. Sci. Sustain. Dev.* **2023**, *6*, 228–248. [\[CrossRef\]](#)
32. Haaland, C.; van den Bosch, C.K. Challenges and strategies for urban green-space planning in cities undergoing densification: A review. *Urban For. Urban Green.* **2015**, *14*, 760–771. [\[CrossRef\]](#)
33. Hammond, M.J.; Chen, A.S.; Djordjević, S.; Butler, D.; Mark, O. Urban flood impact assessment: A state-of-the-art review. *Urban Water J.* **2015**, *12*, 14–29. [\[CrossRef\]](#)
34. Asteria, D.; Budidarmono; Herdiansyah, H.; Ni'mah, N.L. Gender sensitive education in watershed management to support environmentally friendly city. In *Proceedings of the IOP Conference Series Earth and Environmental Science*; IOP Publishing: Bristol, UK, 2018; p. 012146. [\[CrossRef\]](#)
35. Brilly, M.; Polic, M. Public perception of flood risks, flood forecasting and mitigation. *Nat. Hazards Earth Syst. Sci.* **2005**, *5*, 345–355. [\[CrossRef\]](#)
36. Oubennaceur, K.; Chokmani, K.; Lessard, F.; Gauthier, Y.; Baltazar, C.; Toussaint, J.P. Understanding Flood Risk Perception: A Case Study from Canada. *Sustainability* **2022**, *14*, 3087. [\[CrossRef\]](#)
37. Starzec, M.; Kordana-Obuch, S. Evaluating the Utility of Selected Machine Learning Models for Predicting Stormwater Levels in Small Streams. *Sustainability* **2024**, *16*, 783. [\[CrossRef\]](#)
38. Haikal, R.; Firdaus, T.; Nabila, S.H.; Chairunnisa, R.S. How social, behavioral, and policy factors impact water satisfaction and management in urban areas. *J. Environ. Sci. Sustain. Dev.* **2025**, *8*, 421–442. [\[CrossRef\]](#)
39. Šiljeg, S.; Milošević, R.; Mamut, M. Pluvial flood susceptibility in the local community of the City of Gospić (Croatia). *Sustainability* **2024**, *16*, 1701. [\[CrossRef\]](#)
40. Houston, D.; Ball, T.; Werritty, A.; Black, A.R. Social influences on flood preparedness and mitigation measures adopted by people living with flood risk. *Water* **2021**, *13*, 2972. [\[CrossRef\]](#)
41. Paton, D. Disaster preparedness: A social-cognitive perspective. *Disaster Prev. Manag. An. Int. J.* **2003**, *12*, 210–216. [\[CrossRef\]](#)
42. Guo, C.; Sim, T.; Su, G. Individual disaster preparedness in drought-and-flood-prone villages in northwest china: Impact of place, out-migration and community. *Int. J. Environ. Res. Public Health* **2021**, *18*, 1649. [\[CrossRef\]](#) [\[PubMed\]](#)
43. Shukla, S.B.; Prizomwala, S.P.; Ukey, V.; Bhatt, N.; Chamyal, L.S. Coastal geomorphology and tsunami hazard scenario along the Kachchh coast, Western India. *Indian J. Mar. Sci.* **2010**, *39*, 549–556.
44. Snyder, H. Literature review as a research methodology: An overview and guidelines. *J. Bus. Res.* **2019**, *104*, 333–339. [\[CrossRef\]](#)
45. Goyal, S.; Chauhan, S.; Mishra, P. Circular economy research: A bibliometric analysis (2000–2019) and future research insights. *J. Clean. Prod.* **2021**, *287*, 125011. [\[CrossRef\]](#)
46. Du, H.S.; Xu, J.; Li, Z.; Liu, Y.; Chu, S.K.W. Bibliometric mapping on sustainable development at the base-of-the-pyramid. *J. Clean. Prod.* **2021**, *281*, 125290. [\[CrossRef\]](#)
47. Gao, H.; Ding, X.H.; Wu, S. Exploring the domain of open innovation: Bibliometric and content analyses. *J. Clean. Prod.* **2020**, *275*, 122580. [\[CrossRef\]](#)
48. Ranjbari, M.; Saidani, M.; Esfandabadi, Z.S.; Peng, W.; Lam, S.S.; Aghbashlo, M.; Quatraro, F.; Tabatabaei, M. Two decades of research on waste management in the circular economy: Insights from bibliometric, text mining, and content analyses. *J. Clean. Prod.* **2021**, *314*, 128009. [\[CrossRef\]](#)
49. Feng, Y.; Zhu, Q.; Lai, K.H. Corporate social responsibility for supply chain management: A literature review and bibliometric analysis. *J. Clean. Prod.* **2017**, *158*, 296–307. [\[CrossRef\]](#)
50. Van Eck, N.J.; Waltman, L. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* **2010**, *84*, 523–538. [\[CrossRef\]](#) [\[PubMed\]](#)
51. Schardt, C.; Adams, M.B.; Owens, T.; Keitz, S.; Fontelo, P. Utilization of the PICO framework to improve searching PubMed for clinical questions. *BMC Med. Inform. Decis. Mak.* **2007**, *7*, 16. [\[CrossRef\]](#) [\[PubMed\]](#)
52. Booth, A.; Martyn-St James, M.; Clowes, M.; Sutton, A. *Systematic Approaches to a Successful Literature Review*; SAGE Publications Ltd.: London, UK, 2022. [\[CrossRef\]](#)
53. García-Feijoo, M.; Eizaguirre, A.; Rica-Aspiunza, A. Systematic review of sustainable-development-goal deployment in business schools. *Sustainability* **2020**, *12*, 440. [\[CrossRef\]](#)
54. Hong, Q.N.; Fàbregues, S.; Bartlett, G.; Boardman, F.; Cargo, M.; Dagenais, P.; Gagnon, M.P.; Griffiths, F.; Nicolau, B.; O'Cathain, A.; et al. The Mixed Methods Appraisal Tool (MMAT) version 2018 for information professionals and researchers. *Educ. Inf.* **2018**, *34*, 285–291. [\[CrossRef\]](#)
55. Twerefou, D.K.; Owusu, E.A.; Dovie, D.B.K. Correlates of flood preparedness in urban households: Evidence from the Greater Accra Metropolitan Area of Ghana. *Environ. Chall.* **2022**, *11*, 100706. [\[CrossRef\]](#)

56. Renteria-Mena, J.B.; Plaza, D.; Giraldo, E. Multivariate Hydrological Modeling Based on Long Short-Term Memory Networks for Water Level Forecasting[†]. *Information* **2024**, *15*, 358. [\[CrossRef\]](#)
57. Mugisho, G.M.; Swedi, D.P.; Enock, P.M.; Kalembu, M.I.; Lukeba, F.N.; Ngezirabona, S.V. Urban anthropization: Community vulnerability and resilience to flood hazards in eastern Democratic Republic of Congo. *Environ. Res. Commun.* **2024**, *6*, 025003. [\[CrossRef\]](#)
58. Rana, I.A.; Jamshed, A.; Younas, Z.I.; Bhatti, S.S. Characterizing flood risk perception in urban communities of Pakistan. *Int. J. Disaster Risk Reduct.* **2020**, *46*, 101624. [\[CrossRef\]](#)
59. Villani, G.; Nanni, S.; Tomei, F.; Pasetti, S.; Mangiaracina, R.; Agnetti, A.; Leoni, P.; Folegani, M.; Mazzini, G.; Botarelli, L.; et al. The rainbo platform for enhancing urban resilience to floods: An efficient tool for planning and emergency phases. *Climate* **2019**, *7*, 145. [\[CrossRef\]](#)
60. Salami, R.O.; von Meding, J.K.; Giggins, H. Vulnerability of human settlements to flood risk in the core area of Ibadan metropolis, Nigeria. *Jamba J. Disaster Risk Stud.* **2017**, *9*, 1–14. [\[CrossRef\]](#) [\[PubMed\]](#)
61. Guardiola-Albert, C.; Díez-Herrero, A.; Amerigo Cuervo-Arango, M.; Bodoque, J.M.; García, J.A.; Naranjo-Fernández, N.; Aroca-Jiménez, E. Analysing flash flood risk perception through a geostatistical approach in the village of Navaluenga, Central Spain. *J. Flood Risk Manag.* **2020**, *13*, e12590. [\[CrossRef\]](#)
62. Munpa, P.; Dubsok, A.; Phetrak, A.; Sirichokchatchawan, W.; Taneepanichskul, N.; Lohwacharin, J.; Kittipongvises, S.; Polprasert, C. Building a Resilient City through Sustainable Flood Risk Management: The Flood-Prone Area of Phra Nakhon Sri Ayutthaya, Thailand. *Sustainability* **2024**, *16*, 6450. [\[CrossRef\]](#)
63. Jafari, A.J.; Seyedin, H.; Baba, M.; Moslehi, S.; Sakahei, F.S.; Dowlati, M. Study of Households' Preparedness for Disasters and Emergencies in West Regions of Tehran Province, Iran. *Health Emerg. Disasters Q.* **2020**, *5*, 183–192. [\[CrossRef\]](#)
64. Suroso, H.; Fitri, L.E.; Hayati, Y.S. Relationship Between Community Attitudes and Flood Mitigation in the Welang Watershed in the Karangketug Urban Village, Pasuruan City. *Malays. J. Nurs.* **2020**, *12*, 106–111. [\[CrossRef\]](#)
65. Asare, G.; Tuffour, M. Urban flooding: Coping with Weiya Dam spillage by downstream communities in Ghana. *Jamba J. Disaster Risk Stud.* **2023**, *16*, 1476. [\[CrossRef\]](#) [\[PubMed\]](#)
66. Rana, I.A.; Bhatti, S.S.; Jamshed, A. Effectiveness of flood early warning system from the perspective of experts and three affected communities in urban areas of Pakistan. *Environ. Hazards* **2021**, *20*, 209–228. [\[CrossRef\]](#)
67. Forsyth, W.; Roberts, T.; Brewer, G. Conceptualising risk communication barriers to household flood preparedness. *Urban Gov.* **2023**, *3*, 116–129. [\[CrossRef\]](#)
68. Coates, G.; Hawe, G.I.; Wright, N.G.; Ahilan, S. Agent-based modelling and inundation prediction to enable the identification of businesses affected by flooding. *WIT Trans. Ecol. Environmen* **2014**, *184*, 13–22. [\[CrossRef\]](#)
69. Ebhuoma, E.E.; Nene, N.J.; Leonard, L. Analysis of urban households' preparedness and municipal interventions to build flood resilience in Durban, South Africa: Implications for SDG 11. *Environ. Sustain. Indic.* **2022**, *23*, 100454, 2024. [\[CrossRef\]](#)
70. Joshua, I.A.; Abubakar, A.A.; Ibrahim, M.S.; Nmadu, A.G.; Bashir, S.S.; Nwankwo, B. A Comparative Assessment of Household Flood Disaster Preparedness in Flood-prone Rural and Urban Communities in Kaduna State, Nigeria. *J. Community Med. Prim. Health Care* **2023**, *35*, 85–99. [\[CrossRef\]](#)
71. Elum, Z.A.; Olanrewaju, L. Flood Risk Perception, Disaster Preparedness and Response in Flood-Prone Communities. *Jamba J. Disaster Risk Stud.* **2022**, *14*, 1303. [\[CrossRef\]](#)
72. D'Amico, A.; Bernardini, G.; Lovreglio, R.; Quagliarini, E. A non-immersive virtual reality serious game application for flood safety training. *Int. J. Disaster Risk Reduct.* **2022**, *96*, 103940. [\[CrossRef\]](#)
73. Yuan, F.; Lee, C.C.; Mobley, W.; Farahmand, H.; Xu, Y.; Blessing, R.; Dong, S.; Mostafavi, A.; Brody, S.D. Predicting road flooding risk with crowdsourced reports and fine-grained traffic data. *Comput. Urban Sci.* **2023**, *3*, 15. [\[CrossRef\]](#)
74. Reynoso Vanderhorst, H.D.; Pathirage, C.; Proverbs, D. Navigating Flood Resilience: Challenges, Solutions, and Lessons Learnt from the Dominican Republic. *Water* **2024**, *16*, 382. [\[CrossRef\]](#)
75. Yildirim, E.; Just, C.; Demir, I. Flood risk assessment and quantification at the community and property level in the State of Iowa. *Int. J. Disaster Risk Reduct.* **2021**, *77*, 103106. [\[CrossRef\]](#)
76. Ilesanmi, O.B.; Rogers, J.D.; Oboh-Ikuenobe, F.E. Evaluation of geohazards in the Cape Girardeau area using LiDAR and GIS, Southeast Missouri, USA. *Environ. Earth Sci.* **2021**, *80*, 581. [\[CrossRef\]](#)
77. Goodrich, K.A.; Basolo, V.; Feldman, D.L.; Matthew, R.A.; Schubert, J.E.; Luke, A.; Eguiarte, A.; Boudreau, D.; Serrano, K.; Reyes, A.S.; et al. Addressing Pluvial Flash Flooding through Community-Based Collaborative Research in Tijuana, Mexico. *Water* **2020**, *12*, 1257. [\[CrossRef\]](#)
78. Rahmasary, A.N.; Robert, S.; Chang, I.S.; Jing, W.; Park, J.; Bluemling, B.; Koop, S.; van Leeuwen, K. Overcoming the Challenges of Water, Waste and Climate Change in Asian Cities. *Environ. Manag.* **2019**, *63*, 520–535. [\[CrossRef\]](#) [\[PubMed\]](#)
79. Munpa, P.; Kittipongvises, S.; Phetrak, A.; Sirichokchatchawan, W.; Taneepanichskul, N.; Lohwacharin, J.; Polprasert, C. Climatic and Hydrological Factors Affecting the Assessment of Flood Hazards and Resilience Using Modified UNDRR Indicators: Ayutthaya, Thailand. *Water* **2022**, *14*, 1603. [\[CrossRef\]](#)

80. Bakhtiari, V.; Piadeh, F.; Chen, A.S.; Behzadian, K. Stakeholder analysis in the application of cutting-edge digital visualisation technologies for urban flood risk management: A critical review. *Expert Syst. With Appl.* **2024**, *236*, 121426. [\[CrossRef\]](#)
81. Wu, L.; Liu, Y.; Zhang, J.; Zhang, B.; Wang, Z.; Tong, J.; Li, M.; Zhang, A. Identification of flood depth levels in urban waterlogging disaster caused by rainstorm using a CBAM-improved ResNet50. *Expert Syst. With Appl.* **2024**, *255*, 124382. [\[CrossRef\]](#)
82. Atreya, A.; Czajkowski, J.; Botzen, W.; Bustamante, G.; Campbell, K.; Collier, B.; Ianni, F.; Kunreuther, H.; Michel-Kerjan, E.; Montgomery, M. Adoption of flood preparedness actions: A household level study in rural communities in Tabasco, Mexico. *Int. J. Disaster Risk Reduct.* **2016**, *24*, 428–438. [\[CrossRef\]](#)
83. Chan, E.Y.Y.; Kim, J.H.; Lin, C.; Cheung, E.Y.L.; Lee, P.P.Y. Is previous disaster experience a good predictor for disaster preparedness in extreme poverty households in remote muslim minority based community in China? *J. Immigr. Minor. Health* **2014**, *16*, 466–472. [\[CrossRef\]](#) [\[PubMed\]](#)
84. Han, Z.; Lu, X.; Hörhager, E.I.; Yan, J. The effects of trust in government on earthquake survivors' risk perception and preparedness in China. *Nat. Hazards* **2017**, *86*, 437–452. [\[CrossRef\]](#)
85. Lim, G.H.; Lim, B.L.; Vasu, A. Survey of Factors Affecting Health Care Workers' Perception Towards Institutional and Individual Disaster Preparedness. *Prehospital Disaster Med.* **2013**, *28*, 353–358. [\[CrossRef\]](#) [\[PubMed\]](#)
86. Mabuku, M.P.; Senzanje, A.; Mudhara, M.; Jewitt, G.; Mulwafu, W. Rural households' flood preparedness and social determinants in Mwandia district of Zambia and Eastern Zambezi Region of Namibia. *Int. J. Disaster Risk Reduct.* **2018**, *28*, 284–297. [\[CrossRef\]](#)
87. Hanifa, S.; Mardiatno, D.; Ruslanjari, D. Assessment in the Potential of Sustainable Community Development. *J. Environ. Sci. Sustain. Dev.* **2024**, *7*, 444–459. [\[CrossRef\]](#)
88. Putri Saraswati, L.G. The Persistence of an Ecological Society: In-Depth Critical Analysis of the Community Movement in Geriana Kauh, Karangasem. *J. Environ. Sci. Sustain. Dev.* **2020**, *3*, 142–155. [\[CrossRef\]](#)
89. Prayuda, A.B.; Wijayanto, D. Social–ecological resilience of communities in facing the cumulative impacts of sand mining and climate change. *J. Crit. Ecol.* **2026**, *3*, 1–19. [\[CrossRef\]](#)
90. Armitage, D.R.; Plummer, R.; Berkes, F.; Arthur, R.I.; Charles, A.T.; Davidson-Hunt, I.J.; Diduck, A.P.; Doubleday, N.C.; Johnson, D.S.; Marschke, M.; et al. Adaptive co-management for social–ecological complexity. *Front. Ecol. Env.* **2009**, *7*, 95–102. [\[CrossRef\]](#)
91. Kurniawan, M.B.; Maulana, R.A.; Arifin, J.A.; Anthonius, F.; Kurniawan, M. Bridging awareness and action in flood risk reduction: Insights from a community-based evaluation. *ASEAN Nat. Disaster Mitig. Educ. J.* **2025**, *3*, 66–82. [\[CrossRef\]](#)
92. Reed, M.S. Stakeholder participation for environmental management: A literature review. *Biol. Conserv.* **2008**, *141*, 2417–2431. [\[CrossRef\]](#)
93. OECD; European Union; Joint Research Centre—European Commission. *Handbook on Constructing Composite Indicators: Methodology and User Guide*; OECD: Paris, France, 2008. [\[CrossRef\]](#)
94. Fariz, T.R.; Rizky, T.B.; Holeng, V.A.; Damayanti, M.; Heriyanti, A.P. Mapping Household Physical Vulnerability to Tidal Floods Through Indicator-Based Scoring Analysis. *Sustain. Reg. Sci. Dev.* **2025**, *2*, 111–128. [\[CrossRef\]](#)
95. Pamungkas, P.J.; Kristianto, A.; Prianto, M.D.; Rahman, R.Z.; Firmansyah, R.T. Revitalizing Flood-Prone Areas Through Socio-Environmental Strategies: A Qualitative Approach to Urban Flood Management. *Calam. J. Disaster Stud.* **2025**, *2*, 87–99. [\[CrossRef\]](#)

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.