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A Comprehensive Review of Bibliometric and Methodological Approaches in Flood Mitigation Studies: Current Trends and Future Directions

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Abstract

Climate change has become a pressing concern, with an alarming increase in flooding events posing significant risks to residential areas worldwide. As land and infrastructure development rapidly evolve, it is crucial to systematically analyze the bibliometric patterns and methodological trends in flood mitigation research, with a specific focus on residential building flood mitigation. This study presents a comprehensive comparative analysis of the bibliometric patterns and methodological trends in flood mitigation research over the past two decades, identifies prevailing gaps, and proposes future research directions to enhance the effectiveness of flood mitigation strategies. Using data from the Scopus database, 441 publications were objectively selected and subjected to metadata analysis. The study identifies top authors, contributing institutions, nations, and the distribution of contributions across different fields and methodologies. The findings emphasize the need for an integrated and interdisciplinary approach to flood reduction research, considering the complex interplay of social, ecological, and physical dimensions in flood risk management. The study reveals the predominance of Modeling and simulation approaches, geographic information systems (GIS) remote sensing approaches and Statistical and data-driven approaches as the most widely employed methodologies. Furthermore, it highlights the growing diversity of approaches, with increasing interest in machine learning algorithms and combined methods. Also, this study provides valuable recommendations for future research, emphasizing the importance of developing effective flood-mitigating strategies to enhance community resilience. It advocates for a multidisciplinary and integrated approach, leveraging geospatial technologies, machine learning algorithms, and collaborative methodologies to advance flood mitigation research and practice. Future research should consider exploring additional databases, including Web of Science, EBSCO, IEEE, and Google Scholar, to conduct a more comprehensive review of the available literature. There is need for future studies to conduct in-depth comparative analyses of flood mitigation methodologies, particularly in the context of residential buildings.

Keywords: Climate change, flood mitigation, research methodologies, systematic literature review, resilience

1. Introduction

Coastal flooding, exacerbated by the effects of climate change, presents an increasingly frequent and severe threat to vulnerable regions worldwide [1]. Hubert [2] suggests that by the end of the 21st century, the world is expected to experience an increase in global temperatures and a significant rise in sea levels. These changes are likely to exacerbate the occurrence and severity of flood events, with low-lying coastal regions being particularly vulnerable to the adverse effects of these phenomena [[3],[4]]. Compounding factors such as elevated water tables and diminished water-holding capacity further intensify the risks faced by these regions [5]. The consequential implications of climate-induced flooding extend beyond physical damage, encompassing environmental degradation, compromised critical infrastructure, and the vulnerability of coastal communities [[6],[7],[8],[7],[9],[10],[11]].

In order to address the growing threats posed by flooding, experts have proposed a comprehensive approach encompassing four fundamental principles: Accommodate, Protect, Retreat, and Avoid. This strategy has gained widespread recognition as a practical framework for managing flood risks and minimizing the potential damages associated with these events [[12],[13],[14],[15]]. This approach emphasizes the importance of adapting to changing environmental conditions, protecting vulnerable areas, relocating at-risk communities when necessary, and avoiding development in flood-prone regions. The implementation of these strategies relies on a combination of green and grey infrastructure solutions, such as living shorelines, wetlands preservation, dune reconstruction, stormwater management, and groundwater management [[16],[17],[18],[19]]. Coastal communities traditionally depend on rigid, hard defensive structures to protect against flood risks. However, in recent years, there has been a growing scepticism regarding these structures' economic viability and long-term efficacy in mitigating the impacts of flooding [[2],[20]]. The inability of hard defences to adapt to evolving environmental conditions and the high costs associated with their construction and maintenance has led to a shift in focus towards more sustainable and resilient solutions [[21],[22],[23]].

As highlighted by Hubert [2], an increasing body of literature that advocates for the effectiveness of green infrastructure solutions in flood mitigation. These solutions, including wetland restoration, green space development, and swale implementation, are designed to mitigate flooding impacts and promote sustainable water management. These natural features demonstrate effectiveness in trapping sediments,

reducing storm surge, enhancing flow resistance, and containing floodwaters [[24],[25],[26]]. The integration of green infrastructure into flood mitigation strategies, as guided by these design guidelines, not only provides environmental benefits but also offers cost-effective and adaptable solutions. According to Ballio et al. [27], design guidelines play a crucial role in ensuring that proposed flood mitigation solutions effectively address the specific challenges faced by small coastal towns in the context of climate change. While extensive literature exists on flood mitigation strategies for large cities, according to Diaconu et al., [13], there remains a notable gap in scientific methodologies and persistent concerns regarding flood risks in smaller coastal areas. This highlights the need for targeted research and the development of tailored approaches to address these communities' unique vulnerabilities and constraints.

Therefore, many scientific methodologies are employed to assess flood magnitude and its impact. These methods range from widely used hydraulic models for generating flood maps to bivariate statistics and machine learning models for estimating flood susceptibility [[24],[25],[26]]. Researchers also evaluate potential flood-induced damages by integrating flood maps with spatial data encompassing social and economic factors [28]. Geospatial data has been instrumental in facilitating real-time assessments of the economic impacts of floods. By leveraging these advancements, researchers and decision-makers can more accurately identify and map the areas and assets affected by flooding events, thereby improving the efficiency and effectiveness of response and recovery efforts. This article aims to systematically analyse the bibliometric patterns and methodological trends in flood mitigation research, with a specific focus on residential building flood mitigation. The research queries are:

1. Who are the key contributors (authors, institutions, and countries) to the field of residential flood mitigation research, and what are the most influential journals?
2. What are the dominant research methodologies employed in residential flood mitigation studies over the past two decades, and how have these approaches evolved?
3. What are the emerging trends and potential gaps in current research approaches to residential flood mitigation?

2. Research Methodology

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) procedures were employed to facilitate the analysis and screening of the collected studies. The utilisation of the PRISMA approach in this systematic review amplifies the calibre and dependability of the findings by introducing a uniform methodology for conducting, disclosing, and evaluating the chosen studies. The process of finding articles involves four key steps: identification, screening, eligibility, and inclusion, as

outlined by Mohamed Shaffril et al., [29]. Following these steps, the authors systematically discovered and synthesized relevant studies to conduct a comprehensive systematic literature review (SLR). This analysis focuses exclusively on scientific articles published by researchers using the Scopus database until December 2023. Scopus was selected for its high-quality publications and substantial influence on research advancement across multiple disciplines, researcher acknowledge that the exclusive use of this database represents a limitation of the study. Scopus, although extensive, does not encompass all available scientific publications. This choice may have led to the exclusion of relevant research published in other platforms or indexed in different databases. However, Scopus database has been identified as one of the largest citation databases of peer-reviewed literature, offering global research output across various fields [30]. To mitigate this limitation, researcher employed a rigorous systematic review process and analysed a large sample of 441 publications and Scopus indexes a wide range of influential journals in this field, as evidenced by the findings.

Specifically, articles containing the search keywords ("flood" OR "flooding" AND "methodology" AND "mitigation" AND “residential building”) in their TITLE-ABS-KEY were sought. Initially, 1,034 research works addressing various aspects of floods were identified. The screening process involved manual selection based on predetermined criteria by the authors or automatic approval/rejection using a database. Further details regarding the screening process are provided in Table 1.

Table 1: *Criteria of inclusion and exclusion*

Criterion	**Inclusion**	**Exclusion**
Timeline	2000 – 2023	Earlier than 2000
Document Type	Articles, Review article, Conference	Proceeding and Book, Editorial
Language	English	Non-English
Subject Area	Environmental Science Engineering Social Sciences Decision Sciences	Immunology and Microbiology, Chemical Engineering, Chemistry, and Medicine

Moshood et al., [31] highlight that the quality of a literature review hinges on the author's ability to conduct a thorough review process. This involves streamlining the systematic literature review (SLR) process and enhancing transparency in article selection. To refine the search, this study applied a "Refine Results" filter, limiting the publication years from 2000 to 2023 to only articles, review papers, conference papers and selecting articles written in English, resulting in 939 articles for further analysis. Subsequent examination revealed that 498 articles were irrelevant to the research focus, as they belonged to unrelated fields such as (Immunology, Microbiology, Chemical Engineering, Chemistry, and Medicine). After the

initial screening, 441 articles remained for further evaluation. The titles of these articles were carefully examined to ensure their relevance to the study's primary focus on flood research methodologies. Each article was individually reviewed to filter out topics not pertinent to the study's objectives. The selected articles were then classified into categories based on the central themes presented in their abstracts. In order to ensure consistency, the articles were cross-referenced with others addressing similar subjects. This process involved several iterations of abstract revisions to guarantee that the selected articles met the study's criteria. The analysis section of this paper presents the findings from the articles identified through the search criteria applied to the Scopus collection database, which was selected for its high-quality publications and substantial influence on research advancement across multiple disciplines.

The analysis incorporated a comprehensive range of academic sources, including peer-reviewed journal articles and conference papers, to ensure the inclusion of the most reputable and impactful literature. While English was the predominant language among researchers, a few papers were also found in Italian and Russian. However, non-English language articles were excluded from the study to maintain alignment with the proposed objective criteria and ensure a focused approach. Employing a systematic literature review process, the selected publications underwent rigorous screening, filtering, and evaluation to determine their suitability for inclusion in the analysis. An iterative selection strategy was employed to ensure thoroughness and methodological rigour, as depicted in Figure 1, guiding the comprehensive identification and assessment of relevant literature.

Figure 1: *Overview of Paper Identification, Selection, and Inclusion Process*

3. Findings

3.1 Metadata Analysis and Observations

The following section presents a comprehensive metadata analysis and its valuable insights. The analysis is based on a total of 441 publications, which were carefully examined to extract key information and trends. Understanding the methodology employed in this analysis is crucial to interpret the findings accurately. In cases where a manuscript has multiple authors, each author is counted individually during the metadata analysis. This approach ensures that every contributor receives proper recognition for their work. For example, if a paper is co-authored by Wu X., Zhang Z., Xiong S., Zhang W., Tang J., Li Z., An B., and Li R., each of these authors would receive one publication credit. In addition, the country-based analysis is derived from countries of the authors. This approach provides insight into the geographical

distribution of research output based on where the researchers are located or affiliated. This method acknowledges the collaborative nature of research and the individual contributions of each author.

Similarly, the respective nations and institutes of the authors also receive one publication credit each. This allows for a comprehensive analysis of the geographic distribution of research and the identification of leading institutions in the field of flood mitigation. The analysis provides a holistic view of the research landscape by assigning credit to both authors and their affiliated institutions. It is important to note that the specific statistical findings presented in this study are summarized rather than presented as an exhaustive list. This approach enhances the readability and clarity of the analysis, making it more accessible to a wider audience. The study highlights the key trends and insights that emerged from the metadata analysis by focusing on the most significant and relevant findings.

The study presents a curated selection of the most meaningful and impactful findings. This approach facilitates a deeper understanding of the research landscape and the identification of potential areas for further investigation. Furthermore, summarising findings enables the researchers to draw meaningful conclusions and provide actionable recommendations based on the metadata analysis. By distilling the key insights from the data, the study can offer valuable guidance to researchers, policymakers, and other stakeholders involved in flood mitigation efforts. The metadata analysis presented in this section offers a robust and insightful examination of the 441 publications related to flood mitigation. By carefully considering the contributions of individual authors, their affiliated institutions, and the geographic distribution of research, the study provides a nuanced understanding of the field's current state.

3.1.1 Publications by Year

The time analysis conducted in this study serves two primary purposes. The first objective is to examine the temporal trend and distribution of research on various methodologies employed in flood mitigation studies. By analysing the publication dates of the selected papers, researchers can gain insights into the evolution of research approaches and the shifts in focus over time. This analysis helps identify periods of increased research activity and highlights the emergence of new methodologies or the decline of others. The second objective of the time analysis is to identify the key factors influencing the observed temporal trend. By examining the broader context in which the research was conducted, researchers can pinpoint specific events, advancements, or societal changes that have shaped the direction and intensity of

flood mitigation research. These factors may include major flood events, technological breakthroughs, policy changes, or increased public awareness of flood risks.

In order to accomplish these objectives, the researchers systematically organized and examined a total of 441 papers sourced from the Scopus database. The papers were stored in an Excel file and arranged chronologically based on their publication dates. This chronological arrangement allows for a clear visualization of the temporal distribution of research methodologies over the past twenty-three years. Figure 2 presents a graphical representation of the number of papers related to various research methodologies in flood mitigation published yearly from 2000 to 2023. This visual representation enables researchers to identify patterns, trends, and significant changes in research output over time. By analysing the graph, researchers can observe periods of increased research activity and any notable gaps or plateaus in publication numbers.

The time analysis provides valuable insights into the development and progression of flood mitigation research. It helps identify the years or periods that have witnessed a surge in research activity, indicating a heightened interest or need for advancements in this field. For example, an increase in publications following a significant flood event may suggest a renewed focus on flood mitigation strategies in response to the devastating impacts of the event. Furthermore, the time analysis can reveal shifts in the dominant research methodologies employed over time. As new technologies, data sources, or analytical techniques become available, researchers may adopt novel approaches to study flood mitigation. By examining the temporal distribution of different methodologies, researchers can identify the emergence of innovative methods and the decline of older ones, providing insights into the evolution of research practices in this field.

Identifying key factors influencing the temporal trend is important in understanding the broader context of flood mitigation research. These factors may include technological advancements, such as the availability of high-resolution satellite imagery or improved computational capabilities, which have enabled researchers to conduct more sophisticated analyses. Policy changes, such as introducing new flood management regulations or allocating research funding, can also significantly impact the direction and intensity of flood mitigation research. Researchers can comprehensively understand the temporal dynamics of flood mitigation research by conducting a time analysis of the selected papers. This analysis provides a foundation for identifying trends, patterns, and influential factors that have shaped the field over the past twenty-three years. The insights gained from this analysis can inform future research directions, highlight areas requiring further investigation, and guide policy decisions related to flood mitigation strategies. The selected papers, published between 2000 and 2023, demonstrate a notable increase in the number of publications after 2001 (Figure 2).

Figure 2: *Number of Publications Per Year*

This trend highlights the growing importance and interest in research methodologies related to flood mitigation. Researchers have made significant contributions to this field in the last decade, with an average of 51 papers published in 2023. This is a substantial increase compared to the year 2000, which saw the lowest number of publications, with only three papers. The rise in publications can be attributed to floods' critical adverse effects and environmental shock. Floods have become a primary concern for researchers as they strive to develop effective mitigation strategies and minimize the devastating consequences of these events. The increasing frequency and severity of floods and the growing population and infrastructure development in flood-prone areas have further emphasized the need for robust research in this field.

3.1.2 Subject Area

Examining the distribution of articles in the Scopus database reveals a multidisciplinary approach to flood mitigation research. Environmental Science emerges as the most prominent field, with 152 papers out of the total 441 papers. This highlights the vital link between flood mitigation and environmental studies as researchers seek to understand the complex interactions between floods and ecosystems.

Earth and Planetary Sciences follow closely, with 96 papers indicating the importance of understanding the geological and hydrological processes contributing to flood events. Engineering also plays a crucial role, with 95 papers focusing on designing and implementing flood mitigation infrastructure and strategies. The inclusion of Social Sciences, with 63 papers, underscores the societal dimensions of flood mitigation, such as community resilience, risk perception, and public policy. With 35 papers, Decision Sciences emphasizes the importance of data-driven approaches and decision support systems in flood mitigation. These fields offer unique perspectives and insights, from the financial aspects of flood risk management to the role of materials science in developing resilient infrastructure and the cultural and historical dimensions of flooding.

The multidisciplinary nature of flood mitigation research highlights the complexity of the problem and the need for a holistic approach. By integrating knowledge and expertise from various fields, researchers can develop comprehensive strategies that address the multiple facets of flood mitigation, from understanding the physical processes to considering the social, economic, and environmental implications. As the threat of floods continues to grow in the face of climate change and rapid urbanization, it is evident

that flood mitigation will remain a priority for researchers in the coming years. The increasing number of publications and the diverse range of disciplines involved demonstrate the scientific community's commitment to tackling this critical issue and developing innovative solutions to protect communities and ecosystems from the devastating impacts of floods. Figure 3 presents a comprehensive breakdown of the subject areas covered in the analysis of flood mitigation research.

Figure 3: *Subject Area*

3.1.3 Publications by Institutions

Figure 4 illustrates the interconnections among researchers contributing to flood mitigation research. It highlights the collaborative nature of this field, and the networks formed by authors from various institutions. The Università degli Studi di Napoli Federico II emerges as a leading contributor with 10 publications, demonstrating strong commitment to flood mitigation research. The University of Tehran also contributed 10 papers, detailing the global nature of research in this field. Following closely, the Chinese Academy of Sciences made significant contributions with 9 publications, highlighting the importance of national research organizations in driving progress and innovation. These institutions' high publication outputs reflect their expertise and prominence in flood mitigation research. Their contributions attract top talent, encourage collaboration, and facilitate knowledge exchange, benefiting the broader academic community and society. This analysis shows the importance of supporting research institutions to advance knowledge in critical areas like flood mitigation, which can inform policies and improve community resilience.

Figure 4: *Top Fifteen Institutions by Publications*

3.1.4 Prominent Researchers

The authors have made a dedicated effort to identify the most influential and productive researchers in the field of flood mitigation methodologies and their impact on flood mitigation research. Figure 5 presents the relevant information, and the total number of publications attributed to the top fifteen most productive academics. These scholars have been ranked based on their overall career output regarding

the number of published papers, highlighting their significant contributions to the field. As depicted in Figure 5, Karamouz, M. emerges as the most prolific author, contributing seven papers to the analysed body of work. This achievement demonstrates Karamouz, M.'s extensive expertise and dedication to advancing the understanding of flood mitigation methodologies. Their research has likely provided valuable insights and innovative approaches to the field, making them a leading figure in this study area. Following closely behind, De Paola, F., and Friedland, C.J., are listed as the second, third, and fourth most productive authors, respectively. Each of these researchers has contributed to 6 different articles, showcasing their substantial involvement and commitment to flood mitigation research. Their consistent output and diverse range of publications indicate their broad knowledge and ability to explore various aspects of flood mitigation methodologies.

De Risi, R., Mostafiz, R.B., and Rohli, R.V., are highly ranked, each having published four articles. These researchers' contributions further demonstrate the depth and breadth of methodologies applied in flood mitigation studies. Their research has likely provided significant findings and perspectives that have helped to shape the current understanding of this subject. The rankings of these top ten scholars, according to Scopus, offer a comprehensive overview of their significant contributions. Their collective body of work represents a substantial portion of the research analysed in this study, highlighting their influence and impact on the field.

It is worth noting that the ranking of these researchers is based on the number of publications they have contributed to the specific dataset analysed in this study. While this provides a valuable indication of their productivity and influence within this particular context, it is essential to acknowledge that there may be other highly influential researchers in the field whose work was not captured in this analysis. Nevertheless, identifying these top fifteen scholars serves to recognize their dedication, expertise, and significant contributions to advancing flood mitigation methodologies. Their research has undoubtedly played a crucial role in expanding the knowledge base, developing new approaches, and driving innovation in this critical field. By highlighting their achievements, this study aims to inspire further research and collaboration, building upon the foundation laid by these influential academics.

Figure 5: *Top Fifteen Authors*

3.1.5 Publications by Countries

The primary objective of this analysis was to highlight geographic areas that demonstrate a strong interest in flood mitigation methodologies. In order to achieve this, each of the 441 papers stored in the Excel file was categorized based on the countries mentioned in their abstracts, and each country was then assigned to its respective continent. This approach allowed for a focused analysis of flood mitigation methodologies within the subset of papers.

Figure 6 illustrates the global distribution of flood mitigation research methodologies. The world map presented in the first graphic indicates the number of papers published by each country on flood mitigation methodologies. The United States emerges as the leading contributor, with a total of 99 articles published on this topic. Italy closely follows with 59 publications, while China ranks third, publishing 46 articles. The United Kingdom secures the fourth position, contributing 44 articles to the literature. Australia and India rank sixth and seventh, with 28 papers, respectively. The findings clearly demonstrate that publications from the United States, Europe, and Asia dominate the literature. This observation can be attributed to several factors, including the increased awareness and knowledge of sustainable development practices in these regions.

The United States' leading position in flood mitigation research can be linked to its extensive resources, advanced technological capabilities, and the presence of numerous research institutions focusing on this field. The country's vulnerability to various types of flooding, such as coastal, riverine, and urban flooding, has also driven the need for effective mitigation strategies. European countries, particularly Italy and the United Kingdom, have contributed substantially to flood mitigation research. These nations have proactively addressed flood risks, driven by the rising incidence and severity of flooding events in contemporary years.

China's ranking as the third-largest contributor can be attributed to its rapid economic growth, urbanization, and associated increase in flood risks. The country has invested heavily in flood control infrastructure and has recognized the importance of developing effective mitigation strategies to protect its population and assets. Australia, Indian and Germany's significant contributions to highlight the global nature of this issue and the need for collaborative efforts to address it. Australia's unique climate and geography, characterized by extreme weather events and extensive coastlines, have necessitated the development of robust flood mitigation measures. Conversely, Germany has been at the forefront of sustainable development and actively promoted flood mitigation and climate change adaptation research. The geographic analysis provides valuable insights into the global distribution of flood mitigation research and the regions that have been most active in this field. It explained the need for continued research and collaboration across countries and continents to develop effective and sustainable solutions to the growing challenge of flooding in a changing climate.

Figure 6: *Top Fifteen Countries*

3.1.6 Publications by Journals

Natural Hazards emerged as the leading publication outlet, with 45 out of the total 441 articles reviewed, which shows its significant contribution to the field of flood mitigation research. The International Journal of Disaster Resilience in the Built Environment followed closely, publishing 27 articles on this topic. Additionally, the Journal of Hydrology and Journal of Science of the Total Environment each contributed 19 articles, highlighting their roles in disseminating flood mitigation research. Figure 7 presents the publication by journals.

Also, the International Journal of Climate Change Strategies and Management and the International Journal of Disaster Risk Reduction published 14 articles underscoring the importance of addressing flood mitigation in climate change adaptation and disaster risk reduction strategies. These journals have played a pivotal role in advancing knowledge and fostering interdisciplinary discussions on the complex challenges posed by flooding events. The diversity of journals represented in this review reflects the multidisciplinary nature of flood mitigation research, encompassing disciplines such as hydrology, environmental science, civil engineering, urban planning, and disaster management. This wide range of publication outlets demonstrates the breadth and depth of research efforts dedicated to understanding, assessing, and mitigating the impacts of floods on communities and ecosystems worldwide.

Figure 7: *Publications by Journals*

3.1.7 Word Cloud

Word clouds and ATLAS.ti 9 software are valuable tools for visualizing and analyzing textual content. Word clouds provide a quick overview of frequently occurring words in a text, representing word significance through font size. They offer an intuitive way to grasp main topics or themes [32]. ATLAS.ti 9 software addresses the limitations of basic word clouds by enabling systematic merging and display of words from multiple documents. This extended word cloud visualization allows researchers to compare terms and word frequencies across multiple documents, identify common words and those unique to specific subsets, and gain a comprehensive overview of similarities and differences in word usage [33].

Figure 8 and Table 2 illustrate a word cloud generated using ATLAS.ti 9 for flood mitigation research. The concentric arrangement in Figure 8 shows individual document word clouds in the outer circle and combined word clouds in the inner circles. Words in the innermost circle appear in all analyzed documents, indicating their overall relevance. This visual representation provides an immediate impression of key terms and their relative importance in the field of flood mitigation research.

Figure 8: *Word Cloud Information on Flood Mitigation*

Table 2 complements the word cloud by presenting a quantitative breakdown of the most frequent keywords based on the Scopus data. The table lists the top ten terms along with their occurrence counts. "Flood Risk" appears most frequently with 158 occurrences, followed by "Climate Change" with 150 and "Flooding Mitigation" with 129. This quantitative data supports the visual representation in Figure 8, offering a more precise understanding of term frequencies. Together, the word cloud and table provide readers with both a visual and numerical insight into the key concepts and their prevalence in flood mitigation research literature.

Table 2: *Word Cloud*

Keyword	**No.**
Flood Risk	158
Climate Change	150
Flooding Mitigation	129
Flood Hazard	120
Risk Assessment	89
Risk Mitigation	88
Mitigation Measures	60
Risk Management	59
Mitigation Strategies	58
Flood Events	57

3.*2* *Research Methods and Advances in Flood Research*

A thorough examination of the selected papers revealed a remarkable diversity in the methods used for flood mitigation research (see Figure 9). The methodologies were identified and classified into seven unique categories with thirty-one subcategories, showing researchers' broad spectrum of approaches in this

field. These categories ranged from modelling and simulation techniques to GIS and remote sensing, field data collection and monitoring, statistical and data-driven methods, multi-criteria decision analysis, qualitative and participatory approaches, and review-based methodologies.

This diversity highlights the complexity of flood mitigation research and the need for a multifaceted approach to address the multidimensional challenges of flooding events. Each methodology contributes unique insights and perspectives, enabling researchers to explore different aspects of flood dynamics, risk assessment, and mitigation strategies. The integration of these various approaches fosters a holistic understanding of flood risks, encompassing physical, social, economic, and environmental dimensions. The identification and classification of these methodological categories provide a comprehensive overview of the research landscape and underscore the importance of interdisciplinary collaboration and the synthesis of knowledge from diverse fields. By combining and leveraging the strengths of different methodologies, researchers can develop more effective and sustainable solutions for mitigating the impacts of floods on communities, infrastructure, and the environment.

Figure 9: *Research Methods in Flood Mitigation Research*

3.2.1 Modelling and Simulation

Among the various methodologies employed in flood mitigation research, Modelling and Simulation (see Figure 9) emerged as the most widely adopted approach, with 148 out of the 441 reviewed articles (33.6%) utilizing these techniques [[27],[34],[35],[36],[37],[38],[39],[40],[12]].. This highlights the significance and prevalence of these methods in flood mitigation research.

Modelling and Simulation techniques allow researchers to create virtual representations of real-world systems, enabling them to study the behaviour and dynamics of floods under various scenarios and conditions. These methods provide a powerful tool for understanding and predicting the complex phenomena associated with flooding, ultimately aiding in developing effective mitigation strategies. Within Modelling and Simulation, several subcategories emerged, each addressing specific aspects of flood mitigation research [[27],[35],[38],[39]]. Hydrologic/hydraulic modelling, with 35 articles (7.9%), focused on simulating the movement and behaviour of water in natural and artificial systems. Rainfall-runoff

modelling, represented by 25 articles (5.7%), aimed to understand the relationship between precipitation and surface water flow, which is crucial for flood forecasting and risk assessment.

Flood inundation modelling, with 23 articles (5.2%), focused on the extent and depth of floodwaters, enabling the identification of vulnerable areas and the development of evacuation plans. The flood risk assessment modelling covered in 21 articles (4.8%) considered various factors such as hydrology, topography, and infrastructure to assess how floods could impact communities and infrastructure. Additionally, 15 articles (3.4%) focused on debris flow/landslide modelling, examining the intricate interactions between water, soil, and debris that can worsen flood hazards. Coastal flooding/storm surge modelling, described in 16 articles (3.6%), investigated the impacts of hurricanes and storm surges on coastal areas, offering valuable insights for these communities. Also, 13 articles (2.9%) focused on multi-hazard modelling, recognizing the interconnected nature of various hazards and their compounding effects on flood risk. Del-Rosal-Salido et al. [34], applied flood modeling techniques to assess the effects of sea-level rise on compound flooding. Bertsch [41] developed an indicator-based approach to assess industrial assets at risk of flooding. They applied the methodology to identify and prioritize industrial assets in Germany potentially vulnerable to flooding, demonstrating the approach's usefulness for risk assessment and management. Zhou et al. [42] quantified the hydrological responses to climate change in a small watershed in Southern China. They found that despite little change in total annual precipitation from 1950 to 2009, soil moisture decreased significantly, and the watershed is moving towards a drought-like condition due to the intensification of rainfall storms and the increasing number of annual no-rain days. This holistic approach allows for a more comprehensive understanding and mitigation of flood-related disasters.

Figure 10: *Modelling and Simulation Techniques*

3.2.2 GIS and Remote Sensing Approaches

The second most frequently employed methodology was GIS and Remote Sensing shown in Figure 11, with 76 articles (17.2%) employing these techniques [[43],[44],[45],[46],[47],[48],[49],[50],[51]]. GIS and Remote Sensing play an important role in flood mitigation research by providing spatial data, enabling the mapping and analysis of flood-prone areas, and facilitating the integration of various datasets for a

comprehensive understanding of flood risks. Several subcategories emerged within the GIS and Remote Sensing approaches, each contributing to different aspects of flood mitigation research. GIS-based analysis and mapping, represented by 29 articles (6.6%), focused on utilizing Geographic Information Systems (GIS) to analyze and visualize spatial data, create flood hazard maps, and identify high-risk areas.

In 26 articles (5.9%), remote sensing data analysis used satellite imagery, aerial photography, and other remote sensing technologies to monitor and assess flood events and extract valuable data for flood modelling and forecasting. Additionally, 11 articles (2.5%) focused on integrating GIS and remote sensing techniques to achieve a more comprehensive understanding of flood dynamics. This integrated approach allows for the fusion of spatial data from various sources, enabling advanced analysis and decision-making in flood mitigation efforts. Ten articles (2.3%) used spatial multi-criteria analysis methods, often employed in GIS-based decision-making processes. The use of GIS and remote sensing techniques, enables researchers to effectively map and analyse flood-prone areas, monitor flood events in real-time, and develop early warning systems, ultimately contributing to more effective flood mitigation strategies and disaster preparedness. Sahana & Sajjad [52] assessed the vulnerability to storm surge flooding using remote sensing and GIS techniques in the Sundarban Biosphere Reserve, India. They found that nearly half of the villages are high to very highly vulnerable, with the southern parts and areas adjacent to the coast being the most vulnerable. Hao et al. [46] developed an innovative approach combining Synthetic Aperture Radar (SAR) imagery with advanced machine learning algorithms to conduct comprehensive basin-wide flood depth analysis and exposure mapping.

The development of GIS techniques further facilitated the spatialization of these methodologies, paving the way for combined methods. Initially, statistical analysis was primarily used for estimating flood frequency, while remote sensing techniques marked the beginning of more advanced methodologies. Subsequently, methods based on GIS techniques, modelling and simulation, and more recently, machine learning algorithms, have gained prominence. The advancements in data processing techniques, coupled with the ability to handle large volumes of data and a wide range of parameters, have enabled the development of highly precise methodological approaches for mitigating the impacts of floods.

Figure 11: *GIS and Remote Sensing Approaches*

3.2.3 Field Data Collection and Monitoring Approaches

Field data collection and monitoring approaches played a vital role in flood mitigation research, with 65 articles (14.7%) employing these methodologies (see Figure 12). These approaches provide invaluable insights into real-world flood events and enable a deeper understanding of the underlying processes and dynamics involved [[53],[54],[55],[56],[57]]. Figure 12 shows the key themes within this category. One of the critical methods within this category was field surveys and observations, which were utilized in 21 articles (4.8%). Researchers conducted on-site investigations, gathering first-hand data on flood characteristics, impacts, and associated factors. These field studies allowed for the collection of empirical evidence, validation of models, and the identification of unique local challenges. Another critical approach was monitoring and sensor networks, featured in 13 articles (2.9%). These techniques involved the deployment of various sensors and monitoring equipment to continuously collect data on water levels, precipitation, soil moisture, and other relevant parameters. Real-time monitoring enables early warning systems, rapid response, and the refinement of predictive models. Historical data analysis, employed in 11 articles (2.5%), involved examining past flood events and their associated impacts. Through the analysis of historical data, scholars can discern recurring patterns, trends, and potential risk factors, thus enriching the comprehension of flood dynamics and improving risk assessment processes. The case studies, represented by ten articles (2.3%), provided in-depth examinations of specific flood events or locations. These studies allowed researchers to analyse the unique characteristics, challenges, and lessons learned from real-world scenarios, facilitating the development of tailored mitigation strategies.

Furthermore, 10 articles (2.3%) addressed climate change scenarios, acknowledging the potential impacts of global warming on flood patterns and intensities. Researchers incorporated climate change projections into their research to anticipate future challenges and developed proactive mitigation measures to address the evolving risks associated with climate-related flooding. Field data collection and monitoring approaches offer invaluable insights into the complexities of flood events, enabling researchers to bridge the gap between theoretical models and real-world observations. Obahoundje et al. [58] investigated the influence of stratospheric aerosol geoengineering on temperature and precipitation extremes in Africa using climate change scenarios. They found that geoengineering could reduce regional warming but with a significant decrease in rainfall in the tropics, potentially exacerbating drought risks in some regions. Beltaos [59] studied the role of waves in ice-jam flooding in the Peace-Athabasca Delta, Canada. The study found that significant ice jams can form in the middle section of the river and generate steep waves that can amplify hydrodynamic forces and cause ice cover dislodgment, leading to flooding in the delta. These methodologies contribute to a more comprehensive understanding of flood dynamics, risk assessment, and the development of effective mitigation strategies tailored to specific regions and scenarios.

Figure 12: *Field Data Collection and Monitoring Approaches*

3.2.4 Statistical and Data-Driven Approaches

Statistical and data-driven approaches played a pivotal role in flood mitigation research, with 52 articles (11.8%) employing these methodologies. These techniques leverage the power of data analysis, statistical modelling, and advanced computational methods to gain insights and make informed decisions in the context of flood risk management [[60],[61],[62],[63],[64],[65],[66],[67]]. Figure 13 presents four themes that emerged from this category. One of the prominent methods within this category was probabilistic and statistical analysis, which was employed in 22 articles (5.0%). These approaches involve applying statistical techniques to quantify flood events' likelihood and potential impacts. Researchers can develop probabilistic models to estimate flood frequencies, magnitudes, and associated risks by analyzing historical data, meteorological records, and various environmental factors. Probabilistic and statistical analyses are particularly valuable for flood risk assessment and mapping. This enable the identification of areas with high flood probabilities, facilitating the prioritization of mitigation efforts and informing decision-making processes related to land-use planning, infrastructure development, and emergency preparedness [[62],[63]].

Another approach within this category was machine learning and data mining, featured in 20 articles (4.5%). These techniques leverage advanced algorithms and computational methods to uncover patterns, relationships, and insights from large and complex datasets related to flood events. Machine learning models can be trained on historical data, remote sensing imagery, and other relevant information to learn and recognize patterns associated with flood occurrences, magnitudes, and impacts [62]. These models can then be applied to new data to predict future flood events, assess potential risks, and support decision-making processes.

On the other hand, data mining techniques enable the extraction of valuable information from diverse and heterogeneous data sources, such as sensor networks, social media data, and crowdsourced observations [63]. These methodologies facilitate an enhanced comprehension of flood dynamics, the identification of contributing factors, and the refinement of predictive model precision by revealing clandestine patterns and associations [65]. Stochastic modelling includes five articles (1.1% of the total) that deal with developing and applying stochastic models, which incorporate random or probabilistic processes, to model natural hazards or disaster-related phenomena. Extreme value analysis also includes

five articles (1.1% of the total) that focus on the statistical analysis of extreme values or rare events, which is particularly relevant in the context of natural hazards and disaster risk assessment, where extreme events can have significant impacts.

Integrating statistical and data-driven approaches with other methodologies, such as hydrologic modelling, GIS, and remote sensing, can lead to powerful synergies. For example, Adnan et al. [68] stated that machine learning models can be combined with hydrologic models to improve flood forecasting accuracy. Data mining techniques can be applied to remote sensing data to identify flood-prone areas more effectively. These statistical and data-driven approaches contribute to a better understanding of flood risks and support the development of early warning systems, disaster response planning, and the optimization of mitigation strategies [[62],[65]]. Frigerio Porta et al. [69] proposed a stochastic methodology for assessing flood hazards in urban areas, considering multiple sources of uncertainty. The method was applied to a case study in Sondrio, Italy. IHAM-based analysis enables probabilistic flood hazard mapping and provides decision-makers with information for devising and implementing flood risk mitigation strategies. By leveraging the power of data and advanced computational techniques, researchers can make more informed decisions and develop more effective solutions for addressing the complex challenges posed by flood events. Hong et al., [70] proposed a machine learning-based methodology for flood susceptibility mapping in the Poyang County, China. The support vector machine (SVM) model outperformed other models, and the results can help local governments better allocate resources and implement flood risk mitigation measures.

Figure 13: *Statistical and Data-Driven Approaches*

3.2.5 Multi-Criteria Decision Analysis Approaches

Multi-criteria decision analysis approaches were employed in 37 articles (8.4%) with five emerging themes as shown in Figure 14. These methodologies provide a structured framework for evaluating and comparing various alternatives or strategies based on multiple criteria, taking into account the diverse factors and trade-offs involved in flood risk management [[71],[36],[72],[37],[73],[74],[15],[75]]. The most prominent method within this category was multi-criteria evaluation, used in 11 articles (2.5%). Multi-criteria evaluation techniques allow researchers and decision-makers to assess and rank different flood mitigation options by considering multiple criteria simultaneously. These criteria may include economic costs, environmental impacts, social implications, technical feasibility, and risk reduction potential

[[37],[74]]. Multi-criteria evaluation methods Assign weights and scores to each criterion. Providing a systematic approach to integrating various stakeholder perspectives, prioritizing objectives, and identifying the most suitable mitigation strategies for a given context. These methods promote transparency and facilitate informed decision-making, ensuring that all relevant factors are considered in a comprehensive manner.

Another critical approach in this category was cost-benefit analysis, which was featured in 12 articles (2.7%). Cost-benefit analysis is a widely used economic evaluation technique that compares the monetized costs and benefits associated with different flood mitigation alternatives. This approach enables decision-makers to assess the economic viability and potential return on investment of proposed mitigation measures, such as infrastructure projects, early warning systems, or land-use policies [[36],[15]]. By quantifying and comparing the expected costs, including construction, maintenance, and potential damage costs, with the anticipated benefits, such as property protection, reduced economic losses, and improved safety, the cost-benefit analysis provides valuable insights for prioritizing and selecting the most cost-effective mitigation strategies. The optimization category comprises five articles (1.1% of the total) that discuss optimization methods commonly used to seek the best solutions or decision alternatives in natural hazards and disaster risk management. Early warning systems cover four articles (0.9%) that underscore the significance of early warning systems for natural hazards, which are important for timely preparedness and response efforts. Spatial decision support includes five articles (1.1% of the total) that consider spatial decision support systems. These systems integrate spatial data and analysis tools to aid decision-making processes related to natural hazards and disaster risk management.

Multi-criteria decision analysis approaches offer a robust framework for addressing the complexities inherent in flood mitigation research and decision-making processes [75]. Rose et al. [76] conducted a benefit-cost analysis of FEMA hazard mitigation grants for earthquake, flood, and wind hazards. The results indicate that the overall benefit-cost ratio for FEMA mitigation grants is about 4:1, with the ratio varying from 1.5 for earthquake mitigation to 5.1 for flood mitigation. By combining multiple evaluation criteria and integrating diverse perspectives, these methodologies facilitate a comprehensive understanding of the trade-offs involved and support the identification of optimal solutions tailored to specific contexts and stakeholder priorities. Ultimately, these approaches contribute to more informed and sustainable flood risk management practices.

Figure 14: *Multi-Criteria Decision Analysis Approaches*

3.2.6 Qualitative and Participatory Approaches

Qualitative and participatory approaches also emerged as a category as presented in Figure 15, with 35 articles (7.9%) employing these methodologies. These approaches recognize the importance of stakeholder engagement, interdisciplinary collaboration, and the integration of diverse perspectives in addressing the complex challenges of flood risk management. Stakeholder engagement and participatory methods were central to 10 articles (2.3%) [[77],[78],[79],[80]]. These methodologies involve actively engaging with various stakeholders, such as local communities, government agencies, non-governmental organizations, and industry representatives, throughout the research process. By fostering dialogue and incorporating stakeholder input, these approaches ensure flood mitigation strategies are grounded in local knowledge, cultural contexts, and community priorities.

Participatory methods can take various forms, including focus group discussions, community workshops, and collaborative mapping exercises. These activities gather valuable insights from stakeholders and promote a sense of ownership and buy-in, increasing the likelihood of successful implementation and long-term sustainability of flood mitigation measures. Furthermore, stakeholder engagement can help identify potential conflicts, concerns, or barriers that may arise while implementing mitigation strategies. Participatory approaches can facilitate more effective and equitable decision-making processes by addressing these issues proactively and fostering trust and transparency.

Another critical aspect of the qualitative and participatory approaches was multi-domain integration, which was featured in 10 articles (2.3%). Flood mitigation research often requires a holistic understanding of various domains, including hydrology, meteorology, urban planning, social sciences, and environmental management. Multi-domain integration promotes interdisciplinary collaboration and the synthesis of knowledge from diverse fields. Land use change scenarios include 9 articles (2.0% of the total) that explore land use change scenarios and their implications for natural hazards and disaster risk management. These scenarios may involve changes in land cover, urbanization patterns, or other factors that influence hazard exposure and vulnerability. The subcategory "Interviews" includes 6 articles, accounting for 1.4% of the total 441 articles. These articles employ interviews as a qualitative research method to collect data and gain insights regarding natural hazards and disaster risk management. Interviews allow researchers to gather in-depth information from individuals or groups who have experienced or been impacted by natural hazards. Through interviews, researchers can explore personal perspectives, local knowledge, and lived experiences, which can provide valuable context and a nuanced understanding of the complex issues surrounding natural hazards and disaster risk management. Bringing together experts from different disciplines, multi-domain integration approaches facilitate the exchange of ideas, methodologies, and perspectives. This cross-pollination of knowledge can lead to innovative solutions that address the multifaceted nature of flood risks. For example, integrating hydrological data with urban planning

considerations can inform the development of resilient infrastructure and land-use policies that mitigate flood impacts in urban areas.

Moreover, multi-domain integration can help bridge the gap between scientific research and practical implementation. By involving stakeholders from different domains, such as policymakers, urban planners, and emergency management professionals, these approaches ensure that research outputs are tailored to real-world needs and can be effectively translated into actionable strategies. Qualitative and participatory approaches contribute to a more comprehensive understanding of flood risks and foster community empowerment, stakeholder buy-in, and the co-creation of sustainable solutions. Mikoš [57] examined public perception and stakeholder involvement in the crisis management of a debris flow event in Slovenia. The study highlighted the importance of involving local stakeholders in the decision-making process and the need for improved communication and coordination among different actors involved in disaster management. By embracing diverse perspectives and promoting interdisciplinary collaboration, these methodologies address the social, cultural, and institutional dimensions of flood mitigation, complementing and enriching the technical and scientific aspects of the research.

Figure 15: *Qualitative and Participatory Approaches*

3.2.7 Review-Based Approaches

Review-based approaches played a pivotal role in flood mitigation research, with 28 articles (6.3%) employing these methodologies. The themes are illustrated in Figure 16. These approaches involve synthesizing and critically analysing existing literature and research findings, comprehensively understanding the current state of knowledge and identifying gaps, trends, and future research directions [[68],[54]]. Systematic literature reviews were the most prominent method within this category, utilized in 16 articles (3.6%). Meta-analysis subcategory includes 16 articles (3.6% of the total) that focus on conducting meta-analyses. Meta-analysis is a statistical technique combining multiple studies' results to provide a quantitative summary or synthesis of the overall findings. These reviews typically involve comprehensive database searches, predefined inclusion and exclusion criteria application, and a critical appraisal of the selected studies.

Meta-analysis and analysis of the existing body of literature allow researchers to comprehensively understand the current knowledge landscape, methodologies employed, and research findings related to flood mitigation. These reviews can reveal emerging trends, highlight areas of consensus or disagreement,

and identify potential gaps or limitations in the current research. Meta-analysis also plays a crucial role in informing future research directions and priorities. By synthesizing the available evidence, these reviews can pinpoint areas that require further investigation, suggest methodological improvements, or highlight the need for interdisciplinary collaborations to address complex flood-related challenges.

In addition, 12 articles (2.7%) employed literature reviews as part of their methodological approach. While less structured than systematic reviews, these literature reviews provide valuable insights by critically analysing and synthesizing relevant studies within a particular domain or research area. Literature reviews can help researchers contextualize their work within the broader field of flood mitigation research, identify theoretical frameworks or conceptual models that can guide their investigations, and uncover potential research opportunities or areas that have been overlooked or underexplored. Furthermore, review-based approaches can facilitate knowledge transfer and dissemination within the research community. By consolidating and summarizing existing knowledge, these reviews can serve as valuable resources for researchers, policymakers, and practitioners, enabling them to stay up-to-date with the latest developments and findings in flood mitigation. Das et al. [54] review the current status and suggest advancements in ice-jam flood hazard and risk assessment. The authors highlight the need for a comprehensive and effective methodology for assessing ice-jam flood hazards and risks, as existing methods are often unavailable or less developed compared to open-water flood hazard and risk assessment. Wang et al., [81] identify the key factors affecting carbon and water cycles in South Asia. Although not explicitly focused on flood mitigation, understanding the factors influencing water cycles can provide valuable insights for the region's flood risk assessment and management. Rus et al., [82] present a new literature review on the resilience assessment of complex urban systems to natural disasters. The authors discuss the importance of considering both the physical components (e.g., buildings, infrastructure) and social components (e.g., community) of urban systems in resilience assessment and the dynamic interactions between them.

Review-based approaches contribute to the advancement of flood mitigation research by synthesizing and critically evaluating existing knowledge, identifying research gaps and emerging trends, informing future research directions, and facilitating knowledge dissemination and collaboration within the scientific community. These methodologies play a crucial role in building a strong foundation for future investigations and ensuring that research efforts address pressing challenges and advance the understanding of flood-related phenomena.

Figure 16: *Review-Based Approaches*

In this review, the methodical identification and classification of seven unique categories with thirty-one subcategories offer a comprehensive overview of the research landscape in flood mitigation. By shedding light on the diverse approaches employed by researchers, it becomes clear that a multifaceted and holistic approach is important for effectively understanding, assessing, and mitigating flood risks. Each of these methodologies contributes unique insights and perspectives to the field of flood mitigation research. For example, modelling and simulation techniques enable researchers to create virtual representations of real-world systems, allowing them to study the behavior and dynamics of floods under various scenarios and conditions. GIS and remote sensing approaches provide spatial data and mapping capabilities, facilitating the analysis of flood-prone areas and the integration of diverse datasets for a comprehensive risk assessment. Field data collection and monitoring methods offer invaluable insights into real-world flood events, bridging the gap between theoretical models and on-the-ground observations. Statistical and data-driven approaches leverage the power of data analysis, statistical modelling, and advanced computational techniques to uncover patterns and relationships and make informed decisions for flood risk management.

Multi-criteria decision analysis approaches provide a structured framework for evaluating and comparing various mitigation strategies based on multiple criteria, considering economic, environmental, social, and technical factors. Qualitative and participatory methodologies recognize the importance of stakeholder engagement, interdisciplinary collaboration, and the integration of diverse perspectives, fostering community empowerment and the co-creation of sustainable solutions. Review-based approaches, such as systematic literature reviews and traditional literature reviews, play a crucial role in synthesizing and critically analyzing existing knowledge, identifying research gaps, and informing future research directions. These methodologies facilitate knowledge dissemination and collaboration within the scientific community.

The diversity of methodologies identified in this review underscores the importance of a multifaceted approach to addressing the complex challenges posed by flooding events. By combining and integrating various methods, researchers can develop a more holistic understanding of flood risks, encompassing physical, social, economic, and environmental dimensions. Interdisciplinary collaboration and integrating different methodological approaches can lead to synergistic effects, enabling innovative solutions and more comprehensive strategies for flood mitigation. This holistic approach is essential for

addressing the multifaceted nature of flood risks and developing effective and sustainable mitigation measures that consider the intricate interplay between natural, built, and human systems.

4. Conclusions

This systematic review aims to systematically analyze the bibliometric patterns and methodological trends in flood mitigation research, with a specific focus on residential building flood mitigation to provide insights and ideas for future research. This comprehensive systematic literature review provides an in-depth analysis of the bibliometric and methodological approaches employed in flood mitigation studies between 2000 and 2023. The study emphasizes the importance and urgency of addressing flood risks, which have been exacerbated by the compounding effects of climate change and rapid urbanization. Flooding events have become increasingly frequent and severe, posing significant threats to communities, infrastructure, and ecosystems worldwide.

Through a rigorous systematic review process, the study presents a comparative analysis of research methodologies employed in flood mitigation studies. Existing studies were critically evaluated to identify the strengths, limitations, and potential synergies of various methodological approaches. Leveraging data from the extensive Scopus database, a total of 441 publications were objectively selected and subjected to comprehensive bibliometric and metadata analysis. This comprehensive analysis identified key contributors to flood mitigation research, including prominent authors, institutions, and nations, while also examining the distribution of contributions across various fields and methodological domains. A meticulous review of the selected papers unveiled a remarkable diversity in research methodologies, which were categorized into seven distinct classes with thirty-one subcategories, reflecting the multifaceted approaches employed by researchers in this field.

The study revealed that modelling and simulation techniques, geographic information systems (GIS), remote sensing technologies, and statistical and data-driven methods have emerged as the dominant methodological approaches in flood mitigation research. These advanced tools have proven instrumental in enhancing the understanding and prediction of complex hydrological processes, simulating water flow dynamics during flood events with increased accuracy, and assessing flood hazards more precisely and comprehensively. The integration of geospatial technologies has significantly improved the efficiency and precision of flood modelling and forecasting efforts. This technological synergy has enabled researchers to develop more robust and reliable flood mitigation strategies, potentially leading to more effective disaster preparedness and response measures.

Moreover, the study highlights a growing diversification of methodological approaches, with an increasing interest in leveraging machine learning algorithms and combined methods. While statistical analysis has traditionally been employed, particularly in estimating flood frequency, the advent of geographic information systems (GIS) techniques has facilitated the spatialization of these methodologies, leading to the development of hybrid algorithms and enhanced precision in mitigating flood effects. The findings of this comprehensive review highlight the critical need for an integrated and interdisciplinary approach to flood reduction research. Flooding events are intrinsically linked to complex interactions between social, ecological, and physical dimensions, necessitating a holistic understanding of flood risk management. Addressing the multifaceted challenges posed by floods requires a collaborative effort that transcends disciplinary boundaries and incorporates diverse methodological perspectives.

The study identifies the United States, Italy, China, and the United Kingdom as leaders in flood mitigation research, reflecting heightened awareness and prioritization of sustainable development practices in these nations. However, limitations persist, including challenges in data acquisition, transmission, processing, and interpretation, as well as disparities in analysis methodologies. The Università degli Studi di Napoli Federico II, the University of Tehran, and the Chinese Academy of Sciences emerge as prominent contributors to flood mitigation research, demonstrating their institutional expertise and commitment in this field. Karamouz, M. stands out as the most prolific author, showcasing their extensive expertise and dedication to advancing flood mitigation methodologies. Other significant contributors include De Paola, F., Friedland, C.J., De Risi, R., Mostafiz, R.B., and Rohli, R.V.

The study's comprehensive analysis provides valuable recommendations for future research endeavors, emphasizing the importance of developing effective flood-mitigating strategies to enhance the resilience of residential communities, infrastructure, and ecosystems. It advocates for a multidisciplinary and integrated approach that synergistically combines geospatial technologies, machine learning algorithms, and combined methodologies, thereby advancing flood mitigation research and practice. This integrated approach will enable researchers and practitioners to leverage the strengths of various methodologies, leading to more accurate flood risk assessments, improved early warning systems, and more effective mitigation strategies.

Furthermore, the study underscores the significance of increased collaboration and knowledge sharing among researchers, practitioners, and policymakers at local, national, and international levels. Fostering an environment conducive to translating research findings into practical applications is crucial for developing and implementing effective flood mitigation strategies. Engaging stakeholders, including local communities, government agencies, non-governmental organizations, and industry partners, is vital to ensuring the effectiveness and long-term sustainability of flood mitigation efforts.

This study contributes significantly to advancing the understanding of bibliometric trends and methodological approaches in flood mitigation studies. It emphasizes the profound importance of continued research and innovation in this field, recognizing the urgency of addressing the growing threat of flooding in the face of climate change and rapid urbanization. Adopting a holistic and interdisciplinary approach, researchers and practitioners can develop more effective flood mitigation strategies to make communities more resilient. This approach necessitates the integration of diverse methodologies, including geospatial technologies, machine learning algorithms, and collaborative methods, to comprehensively address the multifaceted challenges posed by flooding events.

The study's recommendations serve as a valuable roadmap for future research endeavors, guiding the development of targeted strategies and guidelines tailored to the unique vulnerabilities of different regions and communities. Additionally, the exploration of cutting-edge techniques, such as real-time flood economic loss estimation using geospatial data, holds the potential to revolutionize risk management and response efforts, enabling more informed decision-making and resource allocation. Ultimately, this comprehensive systematic literature review emphasizes the critical importance of collaborative efforts, knowledge sharing, and stakeholder engagement in the pursuit of effective flood mitigation solutions. By fostering a collaborative environment and leveraging the strengths of diverse disciplines, perspectives, and methodologies, this can collectively enhance the capacity to mitigate the devastating impacts of flooding and build more resilient communities, infrastructure, and ecosystems.

5. Implications and Future Research

The findings of this study offer valuable recommendations for future research endeavors, emphasizing the paramount importance of developing effective flood-mitigation strategies to boost the resilience of communities. It advocates for a multidisciplinary and integrated approach that synergistically combines geospatial technologies, machine learning algorithms, and collaborative methodologies, thereby advancing flood mitigation research and practice. The study recognizes the increased exposure of coastal areas to the impacts of climate change. To address this challenge, the study calls for the development of targeted design guidelines and recommendations. These guidelines and recommendations should be tailored to specifically address climate change-induced flooding in coastal regions. Additionally, it highlights the potential of leveraging real-time flood economic loss estimation using geospatial data, which can significantly enhance the efficiency and effectiveness of flood risk management and response efforts. Moreover, the study underscores the critical need for increased collaboration and knowledge-sharing among researchers, practitioners, and policymakers. This collaborative approach is essential for facilitating the seamless translation of research findings into practical applications that can effectively mitigate flood risks and enhance community resilience. Emphasizing the importance of stakeholder engagement, the study

highlights the necessity of involving local communities in the development and implementation of flood mitigation strategies. Integrating local knowledge and perspectives, these strategies can better address context-specific challenges and ensure long-term effectiveness and sustainability.

The identified trend towards integrating geospatial technologies and machine learning algorithms suggests a need for increased investment in these advanced tools and the training of personnel to effectively utilize them. Policymakers should consider updating regulatory frameworks to accommodate and encourage the use of these innovative approaches in flood risk assessment and management. This study findings emphasize the critical importance of developing targeted design guidelines for climate change-induced flooding in coastal regions. This calls for a reevaluation of current building codes and land-use planning strategies in vulnerable coastal areas, potentially leading to more resilient infrastructure design and stricter zoning regulations. The potential of real-time flood economic loss estimation using geospatial data highlights an opportunity for governments and insurance companies to develop more responsive and accurate risk assessment models. This could lead to more efficient resource allocation during flood events and more equitable insurance pricing in flood-prone areas. Furthermore, the study underscores the need for increased collaboration among researchers, practitioners, and policymakers. This suggests the establishment of interdisciplinary working groups or regular forums to facilitate knowledge exchange and ensure research findings are effectively translated into policy and practice. Also, the emphasis on stakeholder engagement and integration of local knowledge calls for a more participatory approach to flood mitigation planning. Local governments should consider establishing community-based flood management committees and incorporating traditional ecological knowledge into their strategies.

This systematic literature review makes a significant contribution to advancing the understanding of research methodologies in flood mitigation. It emphasizes the profound importance of continued research and innovation in this field, recognizing the urgency of addressing the growing threat of flooding in the face of climate change and rapid urbanization. By adopting a holistic and interdisciplinary approach, researchers and practitioners can develop more effective flood mitigation strategies that enhance the resilience of residential communities. This approach necessitates the integration of diverse methodologies, including geospatial technologies, machine learning algorithms, and collaborative methods, to comprehensively address the multifaceted challenges posed by flooding events.

The study's recommendations lay the foundation for future research endeavors, guiding the development of targeted strategies and guidelines tailored to the unique exposure of coastal regions. Additionally, the exploration of real-time flood economic loss estimation techniques using geospatial data holds the potential to revolutionize risk management and response efforts, enabling more informed decision-making and resource allocation. Ultimately, this systematic literature review serves as a clarion

call for increased collaboration, knowledge sharing, and stakeholder engagement in the pursuit of effective flood mitigation solutions. However, it is important to acknowledge the limitations of this study, such as the potential omission of relevant research published in databases other than SCOPUS. In order to address this issue, future research should consider exploring additional databases, including Web of Science, EBSCO, IEEE, and Google Scholar, to conduct a more comprehensive review of the available literature. There is need for future studies to conduct in-depth comparative analyses of flood mitigation methodologies, particularly in the context of residential buildings. The mixed method approach and combination of methods are also proposed for future study. In addition, this systematic approach aims to provide a comprehensive overview of flood mitigation research methodologies, researcher acknowledge the potential for publication bias in the studies analysed. In order to mitigate these potential biases, the study included a wide range of publication types, analysed publications over an extended period (2000-2023), and considered publications from various disciplines [83]. However, this study recognize that these measures may not completely eliminate publication bias. This study specifically concentrates on residential building flooding mitigation. Future research could benefit from including grey literature on urban flood management, rural flood prevention techniques, conducting sensitivity analyses, and employing statistical methods to detect and quantify potential publication bias. Acknowledging these limitations, the study aims to provide a more transparent interpretation of the findings.

Ethics Statement

Not applicable because this work does not involve the use of animal or human subjects.

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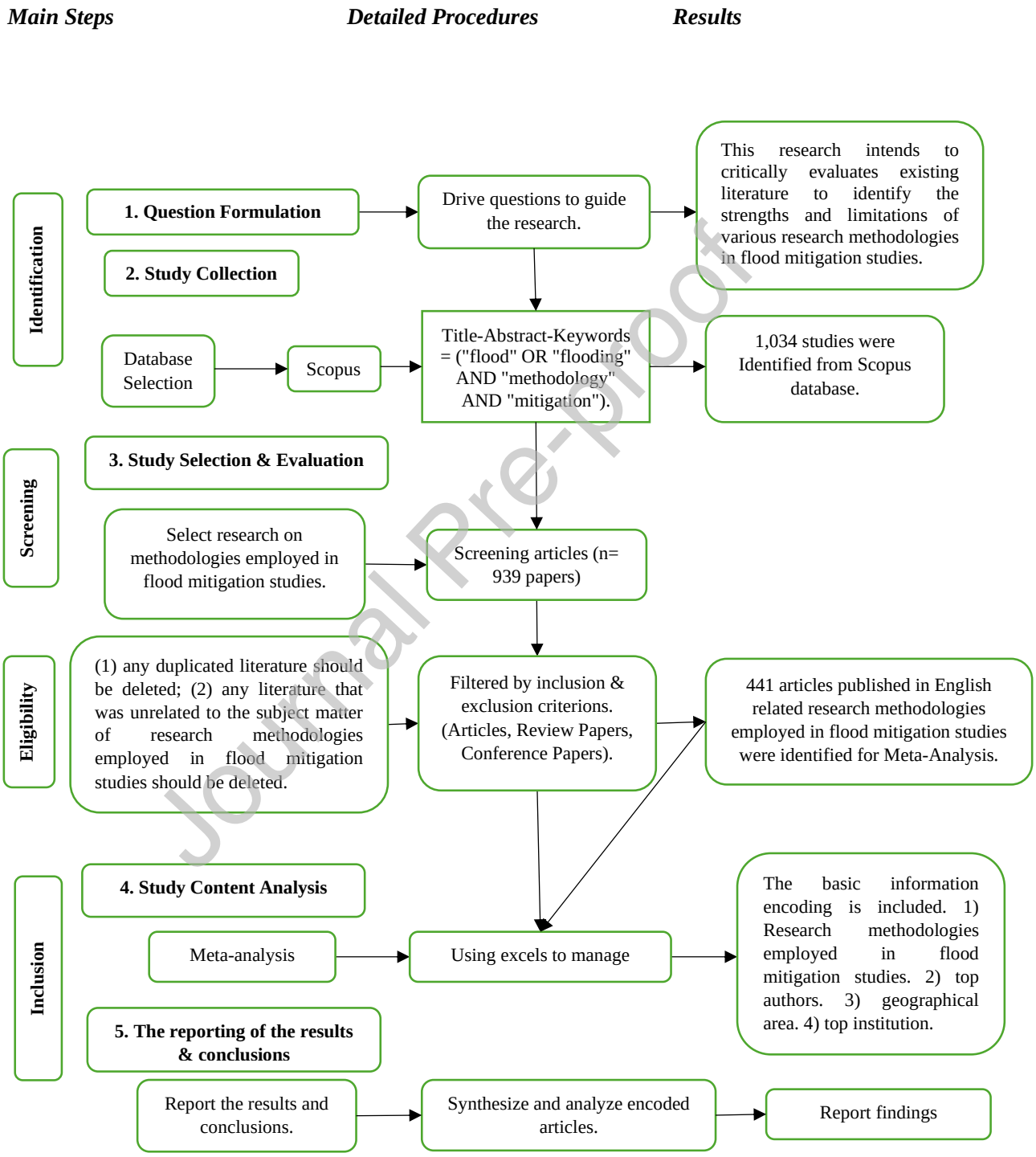

Figure 1: *Overview of Paper Identification, Selection, and Inclusion Process*

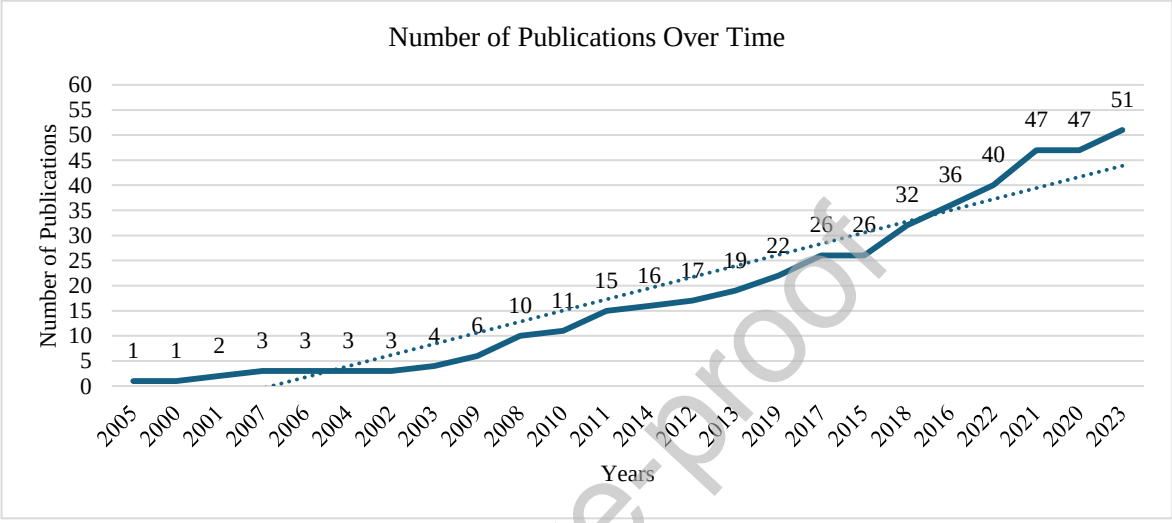

Figure 2: *Number of Publications Per Year*

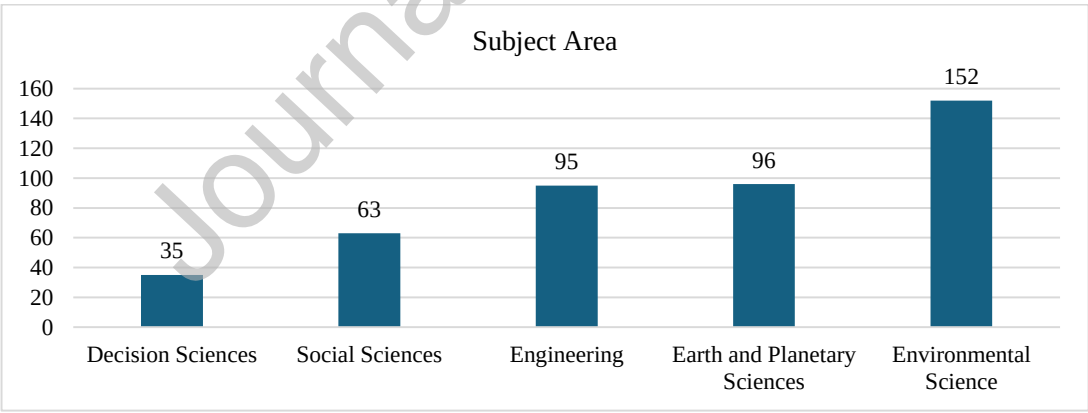

Figure 3: *Subject Area*

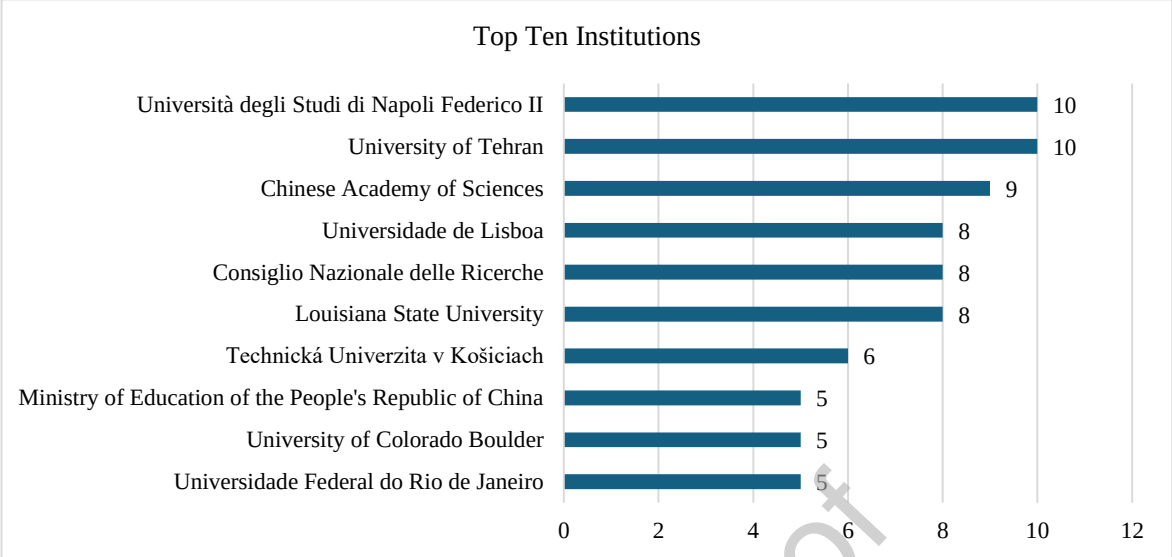

Figure 4: *Top Fifteen Institutions by Publications*

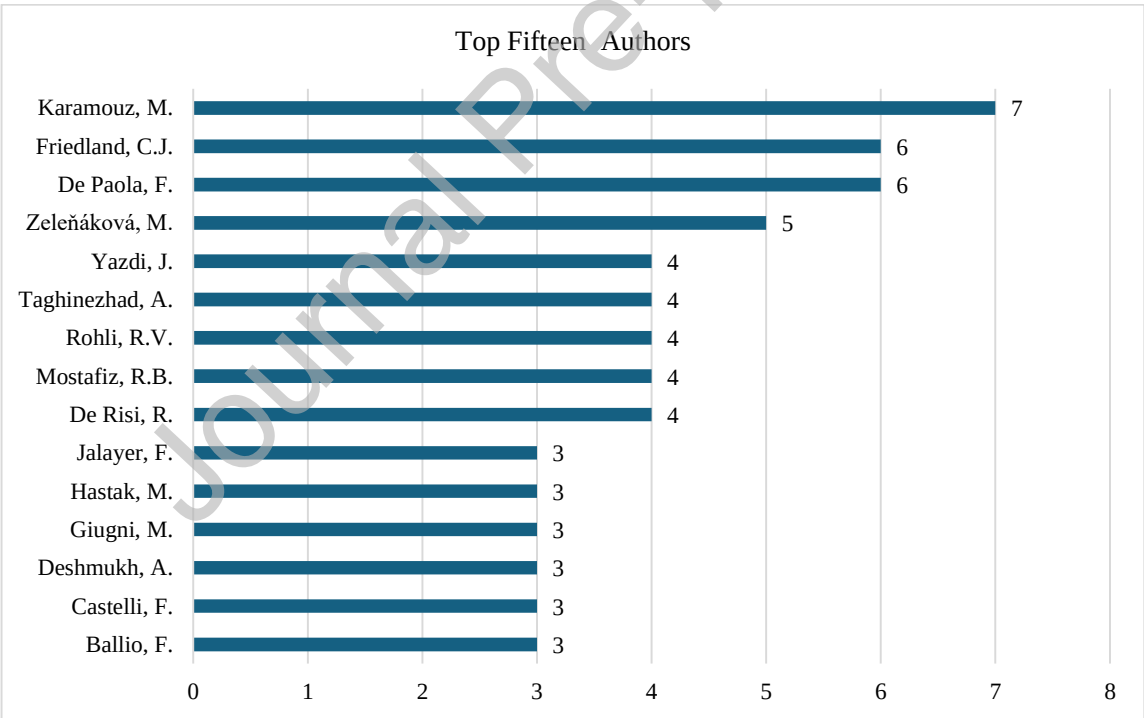

Figure 5: *Top Fifteen Authors*

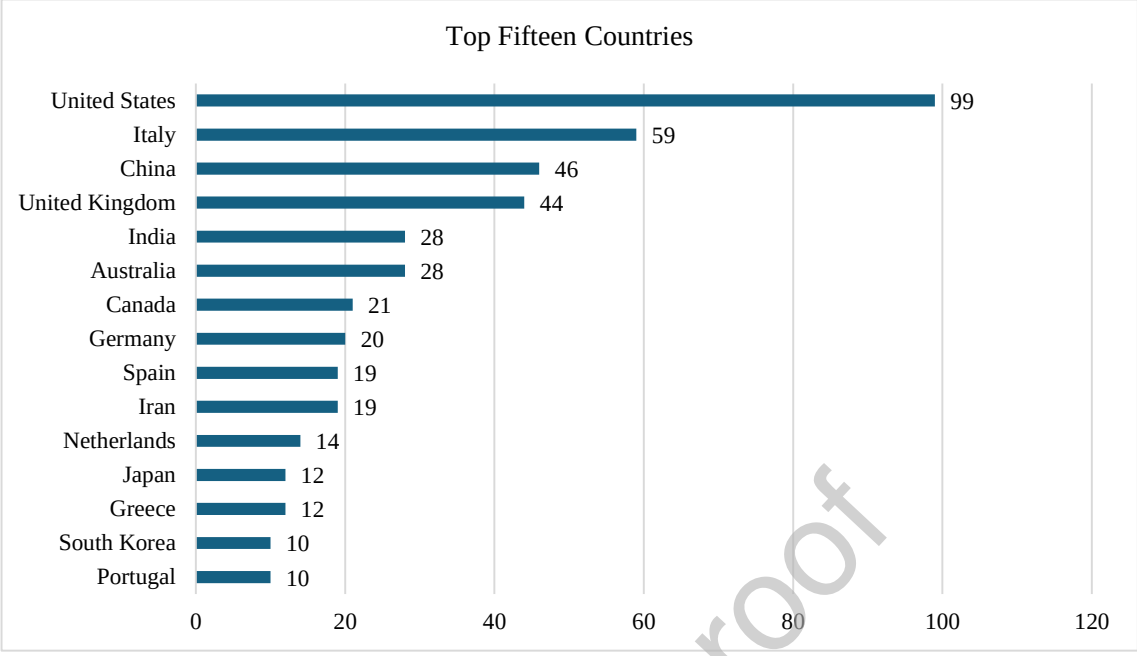

Figure 6: *Top Fifteen Countries*

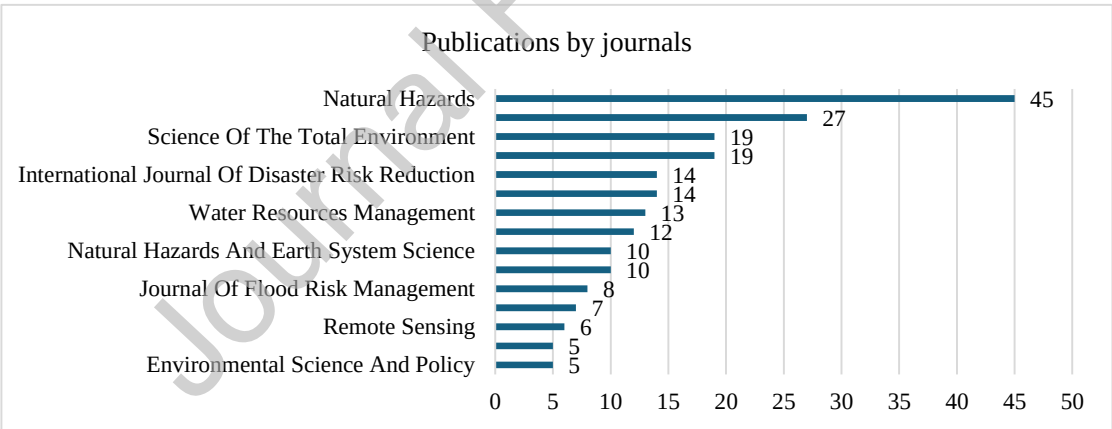

Figure 7: *Publications by Journals*

Figure 8: *Word Cloud Information on Flood Mitigation*

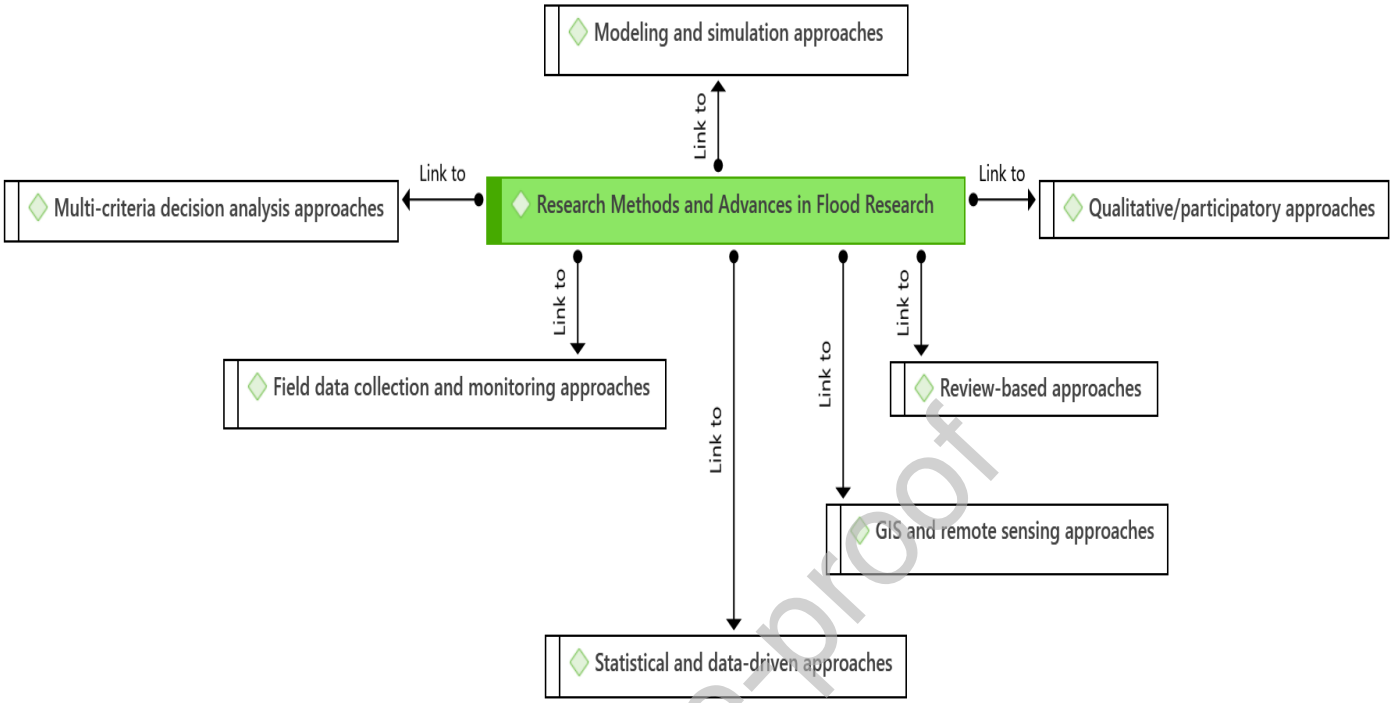

Figure 9: *Research Methods in Flood Mitigation Research*

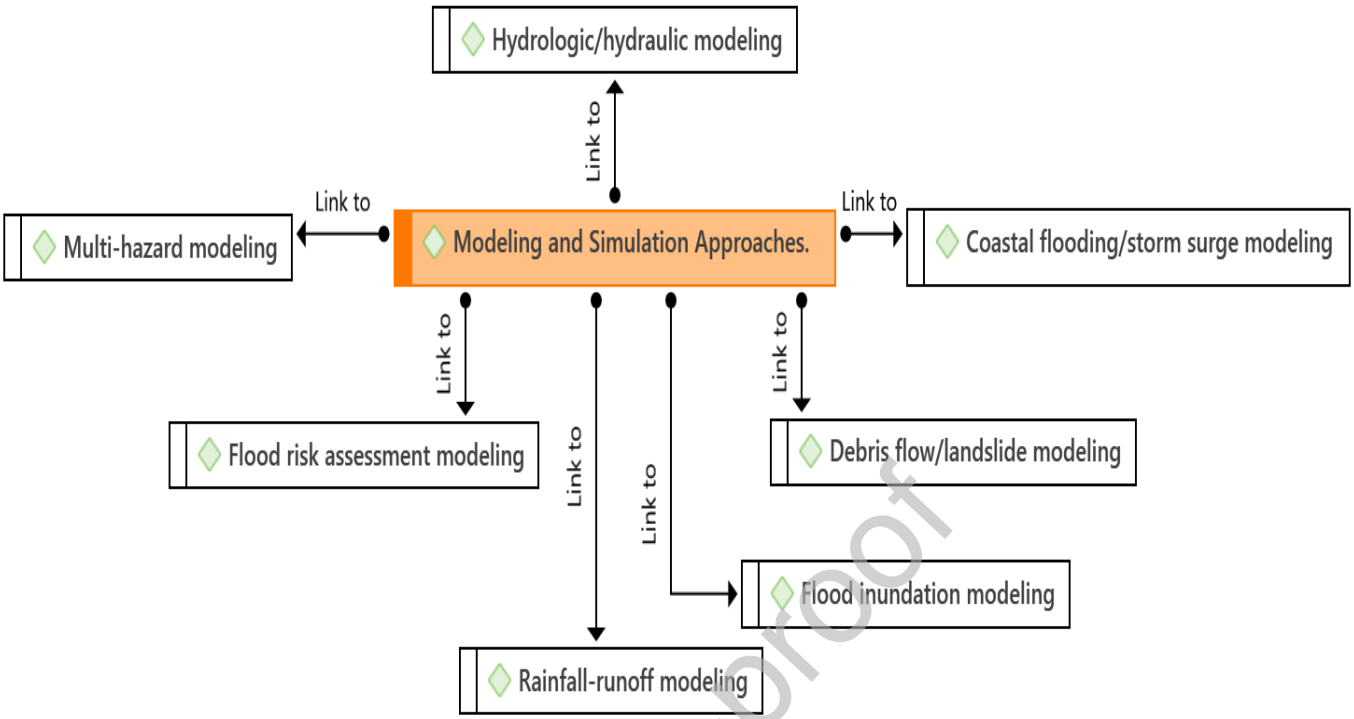

Figure 10: *Modelling and Simulation Techniques*

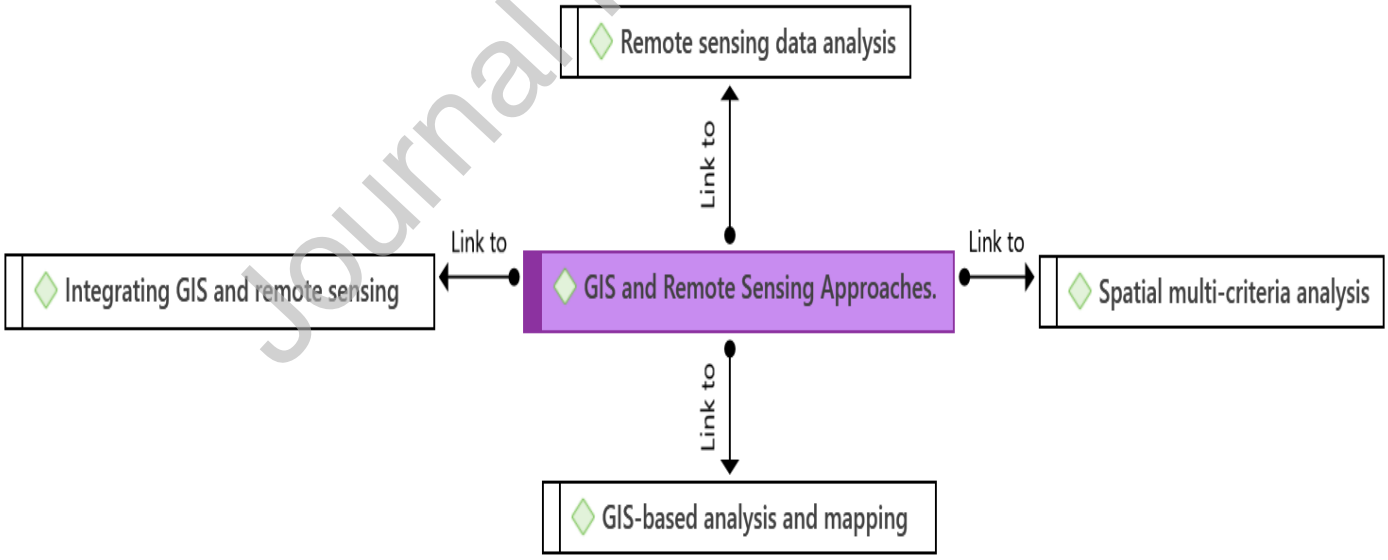

Figure 11: *GIS and Remote Sensing Approaches*

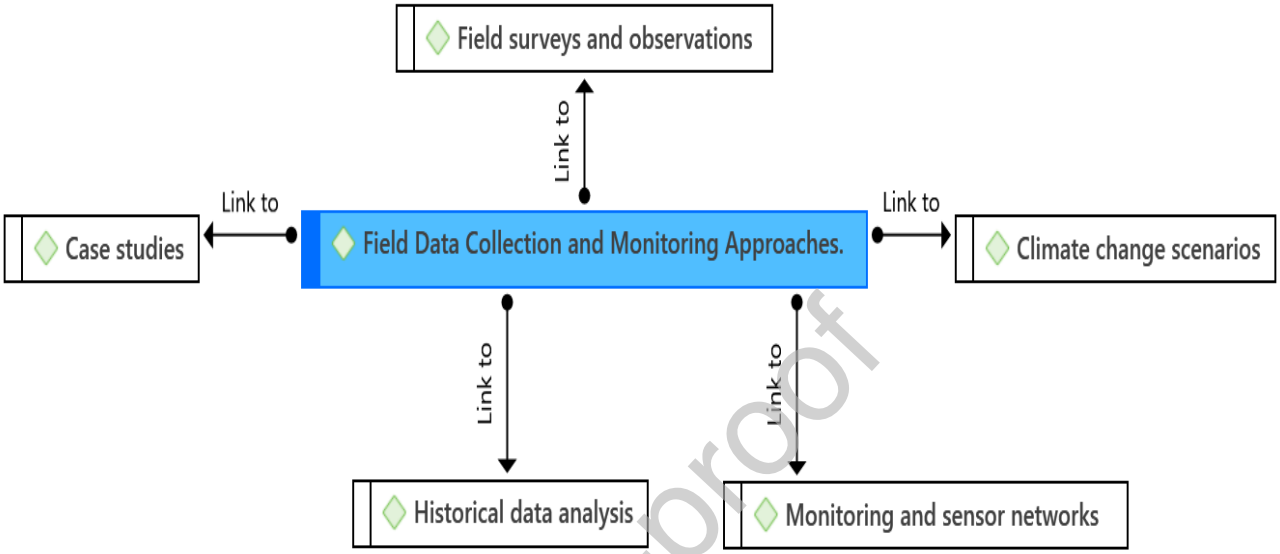

Figure 12: *Field Data Collection and Monitoring Approaches*

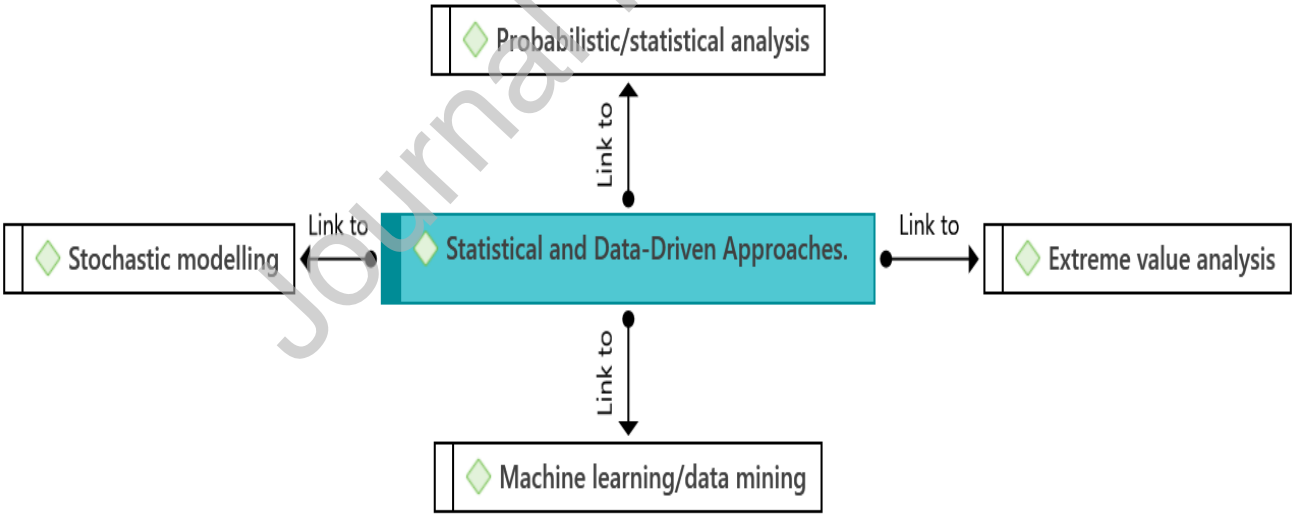

Figure 13: *Statistical and Data-Driven Approaches*

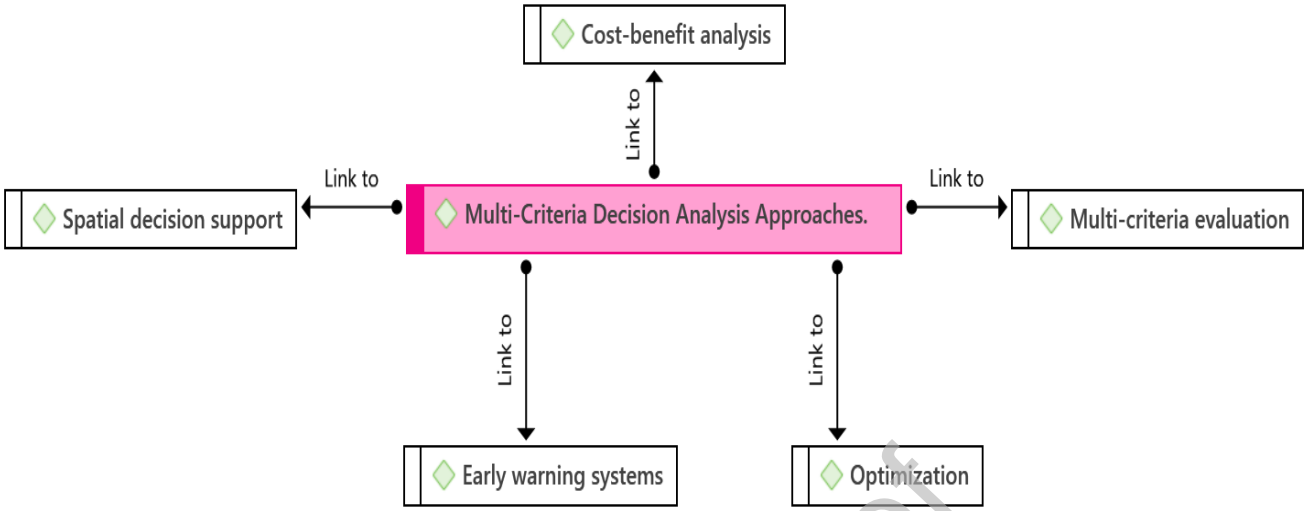

Figure 14: *Multi-Criteria Decision Analysis Approaches*

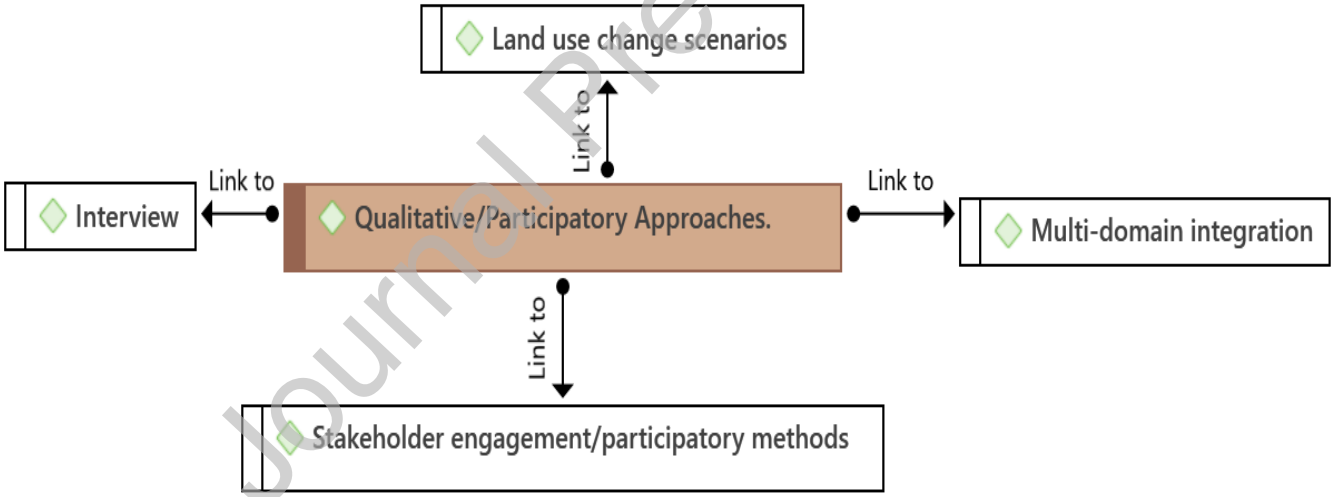

Figure 15: *Qualitative and Participatory Approaches*

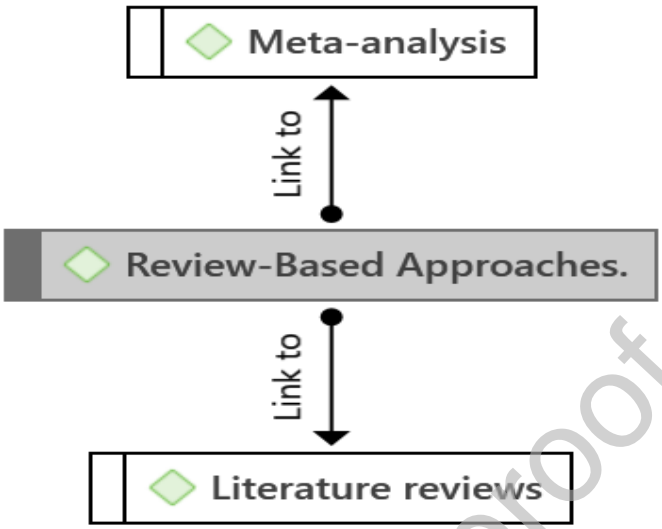

Figure 16: *Review-Based Approaches*

Declaration of Interest Statement

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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