Article

Knowledge Mapping and Trend Analysis of Disaster Mitigation Research in the Sulawesi Islands of Indonesia: A Bibliometric Study Using VOSviewer

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Abstract: Indonesia, as an archipelagic country located on the Pacific Ring of Fire, faces a high risk of natural disasters, including earthquakes, tsunamis and volcanic eruptions. Sulawesi Island, which frequently experiences disasters, is the focus of this research to analyze trends and map knowledge related to disaster mitigation. The aim of this research is to highlight the effectiveness of existing mitigation strategies and identify areas that require further attention. The method used is bibliometric analysis with VOSviewer software, using Publish or Perish 8, of key terms in scientific literature. Data includes articles published between 2019 and 2024, with strict inclusion criteria to ensure relevance to disaster mitigation in Sulawesi. Research findings show that the four main types of disasters are floods, landslides, volcanic eruptions and tsunamis. disaster mitigation in Sulawesi. In addition, there is a lack of knowledge and implementation of sustainable mitigation strategies, as well as the need for active involvement of local communities in mitigation programs. The implications of this research emphasize the importance of evaluating existing disaster mitigation programs and more effective development policies, which can increase community preparedness and resilience to disasters. It is hoped that this research can make a significant contribution to efforts to reduce disaster risk in the region, as well as encourage collaboration between government, institutions and society in improving disaster mitigation.

Keywords: Bibliometric; disaster mitigation; mapping; natural disasters; Sulawesi

Introduction

Indonesia has a vast archipelago stretching from west to east with diverse surface contours. The country consists of mountains ranging from Papua to Sumatra. Additionally, Indonesia is known for being located on the Pacific Ring of Fire, with more active volcanoes than inactive ones (Jalinur & Rahmi, 2022). These volcanoes stretch across the seas from northern Kalimantan to southern Java. The presence of volcanoes has a significant impact on Indonesian society (Shultz et al., 2016).

Indonesia's position on the Pacific Ring of Fire, combined with its mountainous archipelago, makes it one of the most disaster-prone regions, particularly vulnerable to earthquakes, volcanic eruptions, floods, and landslides (Santos et al., 2020). Additionally, high rainfall results in floods and landslides, particularly during the rainy season. Landslides caused by heavy rainfall and steep topography are another frequent natural

landslides (Santos et al., 2020). Additionally, high rainfall results in floods and landslides, particularly during the rainy season. Landslides caused by heavy rainfall and steep topography are another frequent natural disaster in the Indonesian archipelago. Floods often damage infrastructure, disrupt economic activities, and threaten community safety (Royani & Idhani, 2018). Deforestation and uncontrolled land use exacerbate these problems, as the soil cannot absorb rainwater, increasing the risk of floods and landslides (Cariolet et al., 2019). These disasters are further compounded by a lack of infrastructure, early warning systems, and disaster management knowledge (Akter & Wamba, 2017). Therefore, addressing natural disasters requires a holistic and integrated approach, including improving early warning systems, educating communities about disaster mitigation, and enhancing environmental management to reduce future disaster risks and consequences (Sangkala & Gerdtz, 2018). The new paradigm for disaster management emphasizes stakeholders being proactive and embarking on activities that can prevent or reduce disaster risk (Ganiyu et al., 2017)

Addressing the phenomenon of natural disasters requires alternatives to enhance community awareness of disaster mitigation (Dai et al., 2020). In-depth and comprehensive research can offer valuable information on the best ways to reduce the risks and effects of disasters (Barnes et al., 2019). Knowledge mapping in the field of disaster mitigation is crucial to support the research process (Jiang et al., 2019). This mapping focuses on scientific articles available on Google Scholar, one of the largest and most comprehensive research portals (Ritchie & Jiang, 2021). According to Royani and Idhani 2018 scientific articles are vital tools for communicating and sharing information, essential for the advancement of science (Royani & Idhani, 2018). Disaster mitigation research is becoming increasingly interdisciplinary, drawing from fields such as environmental science, engineering, social sciences, and public policy. This convergence of disciplines is essential for developing comprehensive approaches that address the multifaceted nature of disasters and their impacts on communities (Ganiyu et al., 2017).

Knowledge mapping aims to identify trends, research focuses, and influential authors and institutions in the field of disaster mitigation (Sharma et al., 2019). This mapping can help guide future research and provide a robust foundation for data-driven policy considerations (Izumi et al., 2019; Mendonca et al., 2019). This research focuses on the Sulawesi Islands because they frequently experience disasters (H. Liu et al., 2020). Risk assessment, community preparedness, and the use of local wisdom are some aspects of disaster mitigation discussed in this mapping (Astuti et al., 2021). Knowledge mapping shows the relationships between key concepts and emerging research trends through VOSviewer analysis (Kankanamge et al., 2019; Mohd Bakri et al., 2024). This enables the identification of areas requiring additional attention and the development of more efficient mitigation methods (Sangkala & Gerdtz, 2018). The analysis also identifies frequently cited authors and institutions, providing insights into the existing network of researchers and collaborations in this field (Kankanamge et al., 2019).

This study aims to provide a knowledge map of disaster mitigation in the Sulawesi Islands, Indonesia. Using a bibliometric method based on VOSviewer software. The bibliometric analysis method is one approach that is increasingly recognized as effective in describing the development of science and research trends in various fields (Aziz, 2022; Opabola et al., 2023). In the context of disaster mitigation, this method allows researchers to identify patterns, the most discussed topics, and the relationships between researchers and institutions involved. By systematically analyzing existing literature, bibliometrics are able to show the direction of research development while revealing potential gaps that have not been widely explored. Limited collaboration between the government, institutions, and the community in disaster mitigation efforts can hinder the effectiveness of mitigation measures(Zhang et al., 2019). The use of bibliometrics in disaster mitigation studies in Sulawesi has high relevance because this region is vulnerable to various natural disasters, such as earthquakes and tsunamis. However, the existing scientific literature on disaster mitigation in Indonesia, especially in Sulawesi. This research is expected to fill this gap by providing a clearer picture of the development of disaster mitigation research in this region. Research trends in disaster mitigation with a focus on the Sulawesi Islands are still needed to improve community preparedness for disasters and minimize their impacts.

Methodology

The qualitative research method is used in this study, encompassing literature review and thematic analysis. In qualitative research, data analysis is referred to as thematic analysis, according to Braun & Clarke, (2019) The purpose of this analysis is to identify patterns or themes that emerge from the data collected by the researchers, ultimately producing data organized into groups based on relevant themes or patterns. As described by Fereday & Muir-Cochrane (2006) :

> *"Thematic analysis is a highly effective method when research aims to delve into qualitative data in detail to uncover the interrelated patterns within a phenomenon and to explain the extent to which the phenomenon occurs from the researchers' perspective."*

The sample for this study was selected using the Publish or Perish 8 program, which can be accessed through its official website at https://harzing.com/resources/publish-or-perish.Langkah First, internationally recognized databases, such as Scopus and Web of Science, were used to ensure broad coverage. Next, relevant keywords such as "Disaster Mitigation," "Sulawesi," and "Risk Reduction" were applied to identify articles related to disaster mitigation in the Sulawesi Islands. Inclusion criteria included articles that explicitly addressed disaster mitigation in the Sulawesi region, published in journals published in the 2019-2024 period. Irrelevant articles, such as those focusing on disasters without a mitigation context, were excluded. After that, the relevance of the articles was assessed based on focus, number of citations, and topicality. Selected articles were then analyzed using the VOSviewer tool to identify knowledge maps, research trends, and collaborations between researchers. The researcher determined the research period from 2019 to 2024. This period was chosen to limit the diversity of previous research. The research included both recent and past research, but the researcher filtered the results by only including research articles, as the focus of this research was articles. Research articles are considered particularly important as they contain new elements and evolve as science advances. The program then collected and checked academic citations from Google Scholar. The sampling process is illustrated in Figure 1 below.
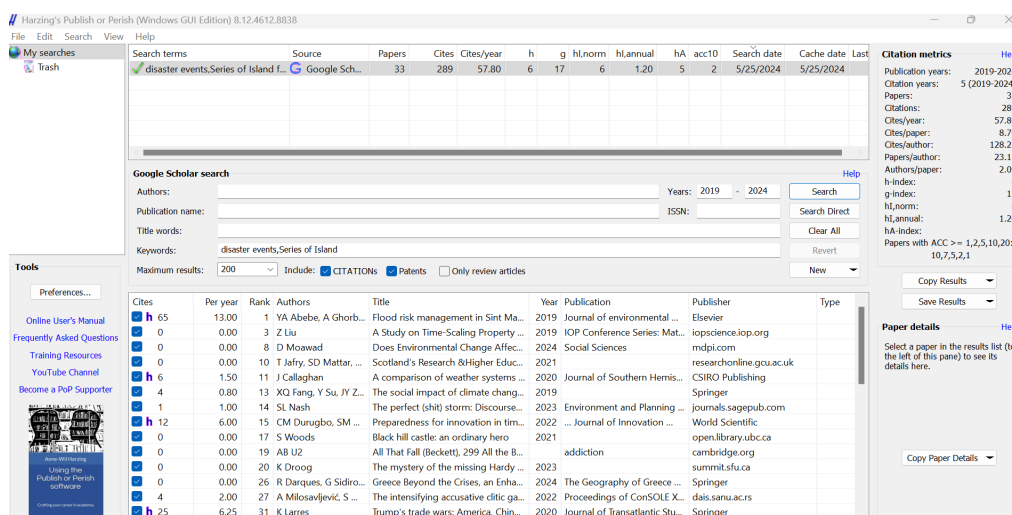

Figure 1. Selection of research sample
Source: Results of Search Using Publish or Perish

After obtaining the relevant research sample, the next step is to analyze the topic of disaster mitigation in the Sulawesi Islands using VOSviewer software. This program enables the creation and visualization of co-occurrence networks of key terms in the scientific literature. The first step is to import the relevant bibliographic data, including journals, researchers, or personal publications related to the topic, into VOSviewer and select mapping based on text data. VOSviewer then identifies and maps the key terms that frequently co-occur in the literature. This network shows the relationships between various terms, providing insights into key topics and research trends in disaster mitigation in the Sulawesi Islands. The visualization of

this network helps identify clusters of closely related terms, indicating the main research focuses and gaps in the existing literature, thus providing a foundation for further research. This approach results in a comprehensive visual map that supports the development of more effective mitigation policies and strategies, as illustrated in Figure 2.
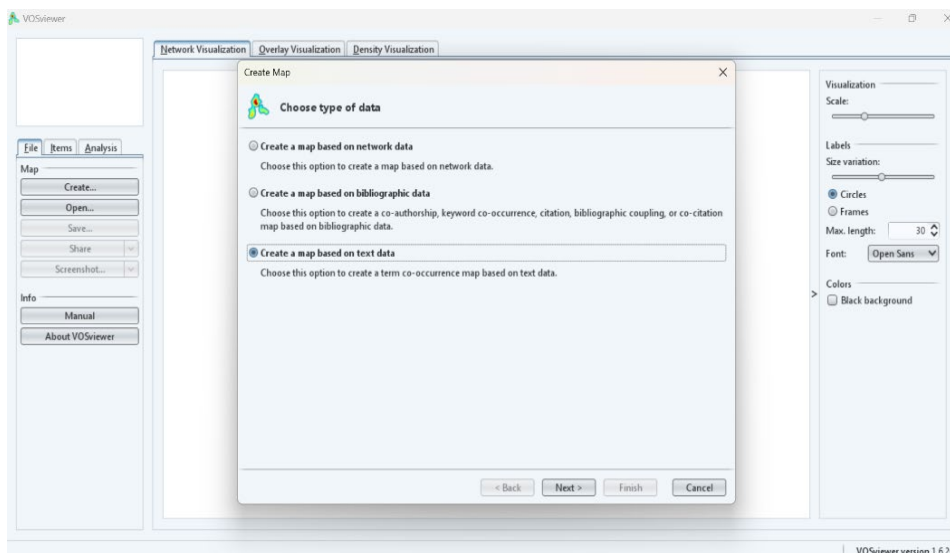

Figure 2. Determination of map from Vosviewer analysis
Source: Research Results Initiating VOSviewer

Subsequently, the titles and abstracts from the research bibliographies are chosen for data analysis. This method is selected because it offers a broader and more in-depth knowledge mapping. As illustrated in Figure 3.
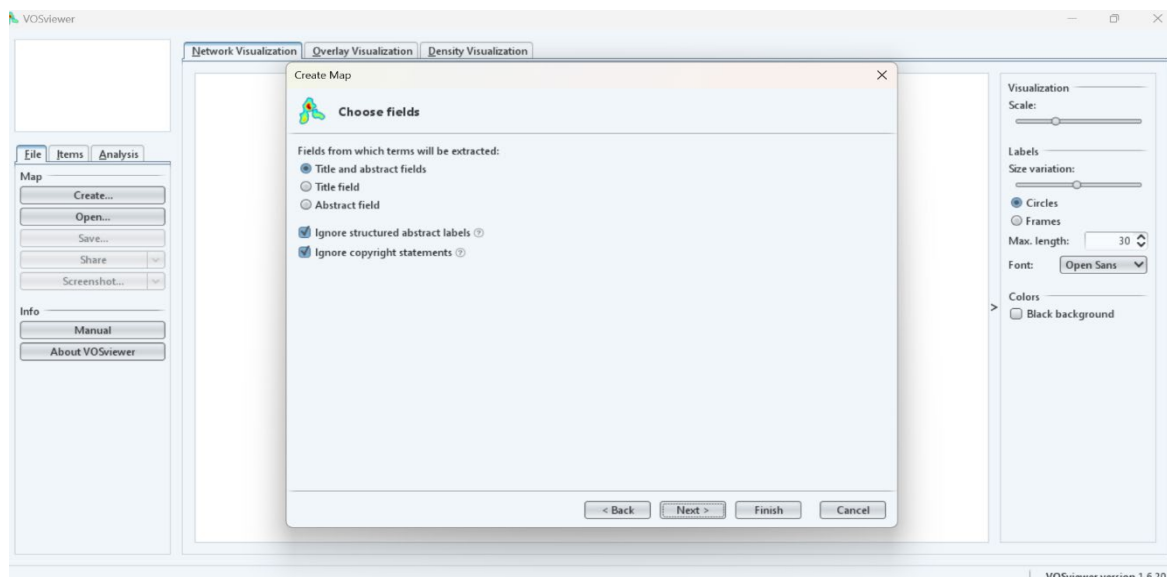

Figure 3. Process for determining filter types
Source: Research Results Initiating VOSviewer

After collecting the bibliographic data and completing the selection process for mapping based on titles and abstracts, the next step is to filter the terms. The relevant terms are then filtered to provide a mapped overview of disaster mitigation information in the Sulawesi Islands, Indonesia. The results will align with the research needs. The term filtering process is illustrated in Figure 4.

Figure 4. Process of filtering terms
Source: Research Results Initiating VOSviewer

Findings

Mapping the field of disaster mitigation research in the Indonesian Islands involves analyzing articles uploaded to scientific journals and available on Google Scholar (Albris et al., 2020). From 2016 to 2023, there were 4,841 natural and non-natural disasters in the Sulawesi Islands, Indonesia, with the largest being the COVID-19 virus outbreak, which significantly altered societal life (Cui et al., 2021). To understand the dynamic changes caused by these disasters in Indonesia, this scientific article focuses on societal phenomena that can transform scientific fields. Using Publish or Perish, 3,934 scientific articles were identified. These data were then imported into VOSviewer, resulting in 73 branches.

The mapping reveals three main branches stemming from a central node labeled "disaster sequence." The studies on disasters and disaster mitigation concepts form the upper left branch, while research on disaster-affected islands, data, and disaster policies are discussed in the lower left branch. Figure 5 illustrates the knowledge mapping of "Disaster Mitigation," divided into three interconnected main branches. The right branch shows relationships, with red spreading to the left branch. The mapping results indicate that disaster mitigation efforts serve as the central focus for both the left and right branches.

Analysis using VOSviewer shows a significant relationship between disaster management and community resilience in facing disasters. Disaster management includes four main stages: preparedness, mitigation, response, and recovery. These fourth stages are interrelated in building effective community resilience. Preparedness ensures communities are prepared to face emergency situations through planning, training, and simulation, which can reduce casualties and damage. Mitigation focuses on efforts to reduce risks before a disaster through prevention strategies such as strengthening buildings and preserving the environment. The response includes rapid and coordinated post-disaster action, supported by collaboration between stakeholders. Recovery includes infrastructure restoration and economic and social recovery, helping society return to normal stronger. Collaboration between governments, organizations and local communities plays an important role in all stages of disaster management. Disaster education also strengthens community preparedness. Overall, integrated disaster management can significantly increase community resilience.
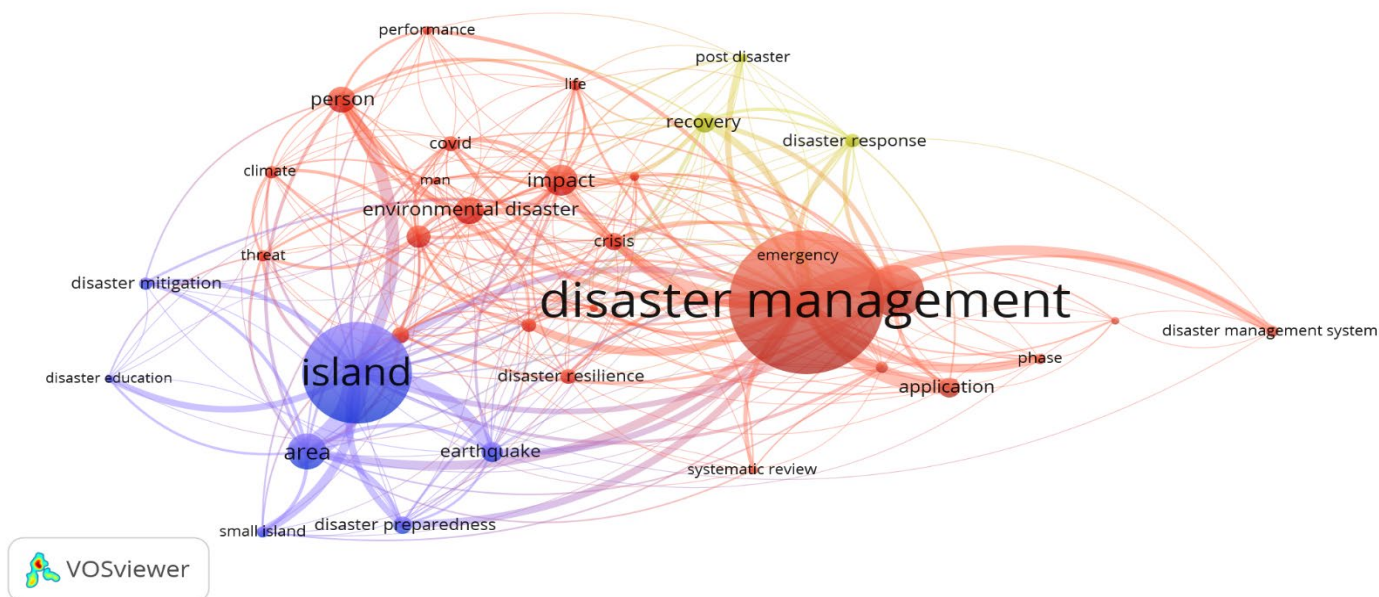
Figure 5. Results of data processing with VOSviewer
Source:VOSviewer Data Analysis

The mapping results reveal the relationship between the disaster sequences (the central node) and the various practical actions undertaken by communities. Studies (Fahriyani & Harmaningsih, 2019) indicate that the government has made significant efforts to leverage advanced technology to monitor disaster sequences (Nalau & Verrall, 2021). Consequently, these studies highlight the connection between disaster mitigation efforts and the various types of disasters occurring on the islands, as illustrated by the VOSviewer visualization in Figure 6 below:
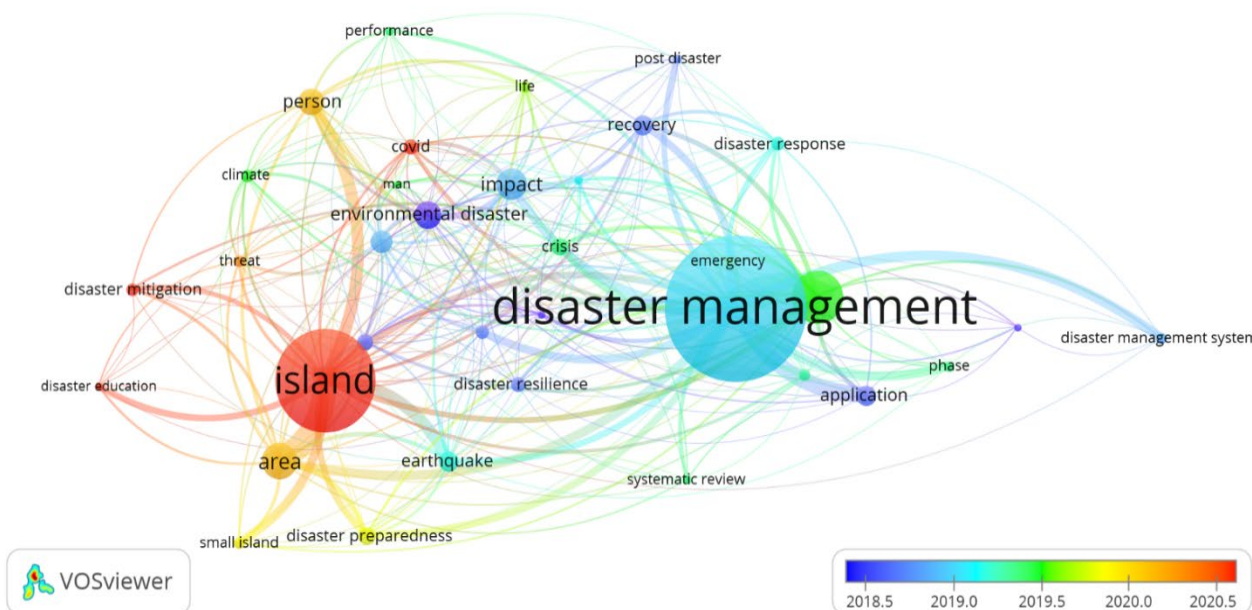
Figure 6. Results of data processing - keyword analysis and publication time information
Source: VOSviewer Data Analysis

From Figure 6, it can be observed that research related to disaster sequences frequently appeared from January 2020 to May 2020. In contrast, research on disasters in the Indonesian Islands was more common from 2016 to 2023. Additionally, disaster research specifically appears in 2024. The results show that the threat of island disasters is very high. Given the potential for disasters such as floods, landslides, and earthquakes that can cause material losses, casualties, and have an impact on the survival and welfare of the community (Trias & Cook, 2021). Therefore, disaster mitigation is imperative through strategic measures, such as careful planning, development of disaster-resistant infrastructure and implementation of early warning systems Retnani Latifah (2021),. However, the effectiveness of these mitigation measures is highly dependent on adequate disaster education, which aims to increase public awareness of the risks and actions that need to be taken. By building capacity through education, it is hoped that island communities can become more resilient to disaster threats and reduce their vulnerability.

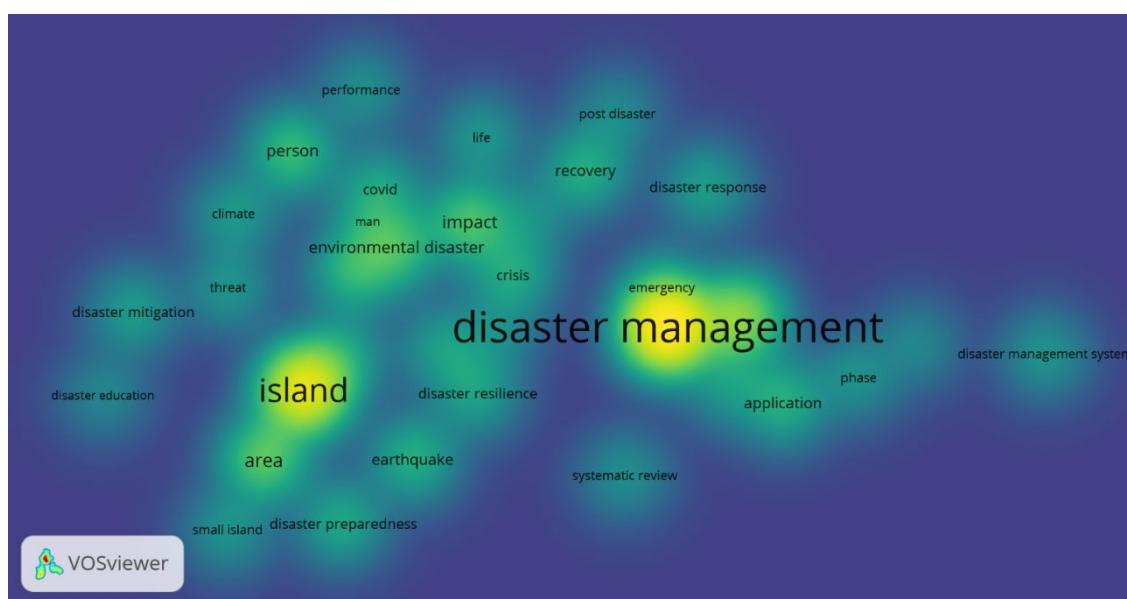
Figure 7. Results of data visualization
Source: VOSviewer Data Analysis

Figure 7 illustrates the relationship between disasters and island regions. According to James M. Shultz, his research findings indicate that small island states are highly vulnerable to natural disasters such as climate change impacts and sea-level rise (Le Cozannet et al., 2020). One notable example is Cyclone Pam, which struck Vanuatu in 2015 (Sublime & Kalinicheva, 2019), causing extensive damage to crops, emergency food supplies, and infrastructure (Li et al., 2021). Additionally, Vanuatu had limited mental health services before the disaster, highlighting significant gaps in mental health care and psychological complications post-disaster (Yong et al., 2022). Post-disaster periods tend to exacerbate psychological disorders such as anxiety, substance abuse, and complex grief (Jafari et al., 2019). Unfortunately, formal emergency responses often neglect psychosocial support and mental health responses after disasters, as observed in Vanuatu following Cyclone Pam (Demiroz & Haase, 2020). Disasters not only cause destruction but also provide populations with opportunities to unite and rebuild a fairer healthcare system(Sovacool et al., 2018). Consequently, this research emphasizes the importance of enhancing the disaster risk management capabilities of small island developing states, addressing mental health post-disaster, and promoting disaster resilience.

The results of the analysis show that the study does not address floods and landslides, which are often overlooked in the literature compared to earthquakes or volcanic eruptions . While both of these disasters have significant impacts, especially in areas prone to heavy rainfall, greater attention is often given to the more dramatic disasters (Chmutina & Von Meding, 2019). This creates a gap in disaster mitigation efforts, where policies prioritize disasters that are often in the news. As a result, resources for flood and landslide prevention are neglected, increasing community vulnerability (Trias & Cook, 2021). Therefore, it is important to increase

literacy and awareness regarding mitigation of these two disasters so that a more balanced policy can be implemented.

The findings of this study can be implemented to improve disaster mitigation in communities through several concrete steps. First, local governments can launch educational programs that include training in schools and community centers on evacuation techniques and the use of first aid kits. In addition, the development of mobile applications that provide real-time information on potential disasters can improve community preparedness. Investment in disaster-resistant infrastructure, such as buildings and drainage systems that meet mitigation standards, is also important to reduce the risk of loss. The establishment of disaster mitigation volunteer groups at the village level can be done to train communities to respond to emergencies.

Discussion

Results of disaster research in the Sulawesi islands, analyzed using VOSviewer, indicate approaches to managing disasters in the Sulawesi Islands region. Floods, landslides, volcanic eruptions, and tsunamis were the primary subjects of study in the Indonesian archipelago, based on a bibliometric analysis of 33 research articles. Mapping the literature's keywords, terms such as "disaster risk," "disaster mitigation," "preparedness," "hazard assessment," and "local wisdom" frequently appeared interconnected, demonstrating that researchers' primary focus was on strategies to reduce disaster impacts. (Ismiati et al., 2020).

Using VOSviewer as a bibliometric visualization tool, a study conducted on research articles concerning disasters in archipelagos, specifically in the Sulawesi Islands of Indonesia, yielded significant findings that provide explanations for disaster mitigation in the region (Usman et al., 2022). The primary results indicate that four major types of natural disasters floods, landslides, volcanic eruptions, and tsunamis are the focus of disaster research in the Sulawesi Islands. This is evidenced by keyword analysis, which shows that these terms frequently appear and are interrelated in various articles. This concentration highlights the frequency and impact of these disasters.

Co-citation analysis identified authors and institutions, such as (Wekke 2019), as playing a significant role in shaping disaster mitigation issues in Sulawesi (Bukvic et al., 2020). The literature review highlights their influence and the relevance of their research on disaster mitigation (Kucharczyk & Hugenholtz, 2021). Following major disasters, such as the earthquake and tsunami in Palu in 2018, temporal mapping reveals an increase in disaster mitigation research. The academic community actively responds to significant events by conducting research to enhance knowledge and find ways to mitigate them(J. Liu et al., 2022). This academic response fosters the creation of new knowledge and strategies to address similar disasters in the future.

The research findings underscore the importance of community preparedness and the utilization of local wisdom in disaster mitigation planning (Zwęgliński, 2020). Local wisdom often encompasses time-tested knowledge on the best ways to handle extreme natural conditions, making it a crucial resource in disaster response (Sendjaja et al., 2020). Integrating local wisdom into mitigation strategies is both a logical and practical approach (Rana, 2020). The analysis results can assist policymakers in developing better, evidence-based disaster mitigation policies. The study demonstrates that approaches incorporating risk assessment, preparedness, and the use of local knowledge are essential for effective disaster mitigation policies (Manan et al., 2023).

A comprehensive method can create policies that are more responsive and aligned with local needs (Shi et al., 2020). With numerous institutions participating in disaster mitigation research, collaboration at both national and international levels facilitates the exchange of knowledge and best practices in addressing disaster challenges (Sweileh, 2019). Such cooperation aims to accelerate the development of innovative and efficient solutions to reduce disaster risks in the Sulawesi Islands and other regions.Overall, findings from the research utilizing VOSviewer provide a broad overview of the focus and trends in disaster mitigation research in the Sulawesi Islands. This study emphasizes that various methods, such as risk assessment, community preparedness, and the integration of local wisdom, are necessary in efforts to reduce the impact of natural disasters. It is hoped that these findings will serve as a foundation for better disaster mitigation policies and practices in the future.Using VOSviewer as a bibliometric visualization tool, research conducted on scholarly

articles about natural disasters in the Sulawesi Islands, Indonesia, yielded significant findings that provide insights into disaster mitigation strategies in the region. The main results indicate that the four major types of natural disasters floods, landslides, volcanic eruptions, and tsunamis are the primary focus of research on natural disasters in the Sulawesi Islands. This is evidenced by keyword analysis, which shows that these terms frequently appear and are interrelated in various articles. This concentration underscores the frequency and impact of these disasters in the area.

This research explains that the implementation of comprehensive disaster management at various levels, including government, local communities and non-governmental organizations, has a significant impact on community resilience. Findings show that each stage in disaster management-preparedness, mitigation, response and recovery-directly contributes to strengthening communities' ability to cope with disasters. Preparedness involves the active participation of communities in emergency response planning and disaster simulations, which aim to prepare them for emergency situations. It includes training involving various community groups and raising awareness of disaster risks, which in turn improves their ability to respond quickly and appropriately when disasters occur.

The mitigation phase emphasizes the importance of preventive measures, such as infrastructure strengthening and environmental preservation. Mitigation aims to reduce disaster risk through structural and non-structural approaches. These strategies include the construction of earthquake- or flood-resistant infrastructure, as well as environmental preservation to prevent further damage. With proper mitigation, communities will be better prepared for disasters, and their impacts can be minimized. A rapid and coordinated response is essential to minimize disaster losses and casualties. An effective response requires good collaboration between various stakeholders, such as the government, non-governmental organizations and communities.

The establishment of an integrated disaster command center is crucial in ensuring the allocation of resources and assistance goes well, so that the distribution of aid can be done quickly and on target.In the recovery phase, a holistic approach is needed to restore the condition of the community, both socially and economically. Recovery not only includes physical reconstruction, but also involves psychosocial support as well as economic rehabilitation to strengthen long-term resilience. Effective collaboration between stakeholders is also a key element in ensuring community capacity building through continuous education and training programs. Thorough implementation of these strategies will increase community resilience to future disasters.

Disaster mitigation practices in Sulawesi have shown varying results, influenced by community preparedness, government support, and the use of technology. For example, a community initiative in Sigi Regency, Central Sulawesi, which conducted evacuation training and built earthquake-resistant houses after the 2018 earthquake and tsunami, succeeded in increasing the culture of preparedness. However, in Palu, despite efforts to raise awareness of disaster risks, challenges such as suboptimal spatial planning policies and slow infrastructure recovery still hampered mitigation (Sangkala & Gerdtz, 2018). Limited access to information and technology in remote areas, as well as reliance on traditional practices, also reduced the effectiveness of early warning systems.The success of disaster mitigation practices depends on the integration of local knowledge, government policies, and technology (Ismiati et al., 2020). Some areas have successfully demonstrated that collaboration between parties can improve preparedness, while others show the need for improvements in technology planning and distribution (Usman et al., 2022). Government agencies and NGOs can use local knowledge mapping to design more effective preparedness and early warning systems, combining traditional knowledge with modern technology. This collaborative approach is essential to building an inclusive early warning system, utilizing natural signs that are familiar to the community.

Community-based education and training programs that integrate technology, such as early warning applications and natural signs, can increase community participation in disaster mitigation. Local knowledge maps can help in allocating resources and designing policies that are appropriate to the specific conditions of each region, reducing the gap in preparedness between urban and rural areas. The National Disaster Management Agency (BNPB) can use this mapping data to design realistic disaster scenarios in simulation exercises, involving local communities (Bouyerbou et al., 2019). Thus, knowledge mapping has the potential

to produce a more adaptive and responsive preparedness system to the specific needs of each community in Indonesia.

Conclusion
Bibliometric study of disaster mitigation research articles in Sulawesi Islands, Indonesia, using VOSviewer provides insights into the focus and research trends in addressing natural disasters in the region. Key findings indicate that floods, landslides, volcanic eruptions, and tsunamis are major research focuses, with terms such as "disaster risk," "disaster mitigation," "preparedness," "hazard assessment," and "local wisdom" frequently appearing and interconnected. This demonstrates researchers' high attention to strategies for reducing disaster impacts in the Sulawesi Islands. Through collaboration among national and international institutions, knowledge exchange and best practice sharing in disaster response can be enhanced, accelerating the development of innovative and efficient solutions to reduce disaster risks in the region.

Shortcomings in practical implementation analysis of research findings related to disaster mitigation efforts in the field highlight the need for greater attention to social and cultural aspects in disaster mitigation strategies by actively involving local community participation. Therefore, further research is recommended to focus on evaluating the effectiveness of current disaster mitigation programs through community-based surveys and assessing the sustainability of mitigation strategies in Sulawesi's unique socio-geographic context. The evaluation should involve field surveys and interviews with stakeholders and expand the scope to include sustainability aspects of disaster mitigation programs. Additionally, it is crucial to identify best-fit models that align with the geographic and social contexts of Sulawesi Islands. Subsequent research is expected to make a more significant contribution to enhancing disaster preparedness and mitigation in the region.

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

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