UKR Journal of Arts, Humanities and Social Sciences (UKRJAHSS)
Homepage: https://ukrpublisher.com/ukrjahss/
Email: submit.ukrpublisher@gmail.com
Volume 2, Issue 7, 2026 **ISSN: 3107-359X (Online)**

Adapting Indonesia's National Disaster Mapping in the Era of Complex Disaster Risks

Joko Pramono

Faculty of Social & Political Science, University of Slamet Riyadi Surakarta, Indonesia.

***Corresponding Author**: Joko Pramono
DOI: *https://doi.org/10.5281/zenodo.21349940*

Article History
Original Research Article
Received: 17-05-2026
Accepted: 22-06-2026
Published: 14-07-2026

Citation: Pramono, J. (2026). Adapting Indonesia's national disaster mapping in the era of complex disaster risks. UKR Journal of Arts, Humanities and Social Sciences, 2(7), 70-80.

Abstract

Discussions of disaster scenarios and risks in this era tend to be complex, even as the nature of disasters themselves becomes increasingly complex. The concepts and mindset of most people remain limited to a "single hazard" perspective or in other words, they still view disasters as a cause-and-effect relationship. This cause-and-effect approach contrasts with the "multi-hazard" concept, which offers a more dynamic framework for mapping disasters. Indonesia, located in the Pacific Ring of Fire, is classified as having a high potential for disasters year after year; this is supported by data from the National Disaster Management Agency, which shows that disasters are predominantly hydrometeorological in nature. Therefore, the concept of multi-hazard has emerged as a well-established paradigm for understanding the relationships between disasters and all their triggering factors. This approach also distinguishes between different types of hazards and associated vulnerabilities, which can be identified as early as possible. However, a major challenge that significantly hinders disaster mitigation is the still-limited development of public awareness and understanding. Several theories supporting the multi-hazard approach conclude that disaster management requires reconstruction and mapping, particularly during the initial identification stage, governance, environmental interactions, and information dissemination. Research findings indicate that disaster mapping in Indonesia remains weak and tends to fall short of the multi-hazard concept. This is evidenced by the continued high number of fatalities and losses in every disaster.

***Keywords** – Disaster, Multi-Hazard, Image, Identification, Mitigation.*

INTRODUCTION

In today's world, disaster mapping has garnered significant attention from many parties as the nature and risks of disasters become increasingly clear. However, considerations in disaster prediction tend to remain partial, as they are still dominated by a "single-hazard" mindset. It cannot be denied that disaster risks are becoming increasingly complex amid the confusion of accounting for the interdependent interactions between different types of disasters. The complexity of life is inevitable, leading to many factors that trigger one another (cascading effects). The impacts of disasters are becoming increasingly difficult to predict and anticipate; in other words, the nature of a disaster can, at any moment, result in broader consequences.

There has been a significant increase in disasters over the past decade in terms of frequency, impact, and complexity. The main contributing factors are climate change and the dynamics of socio-ecological systems. Global data indicate that between 2000 and 2020, there were approximately 4,600 climate-related events, which affected the lives of more than 3.3 billion people worldwide (Donatti et al., 2024). Other contributing factors include extreme rainfall and landslides. It has become increasingly difficult to anticipate the vast majority of disasters early on, particularly in recent years (Gao et al., 2025). A Scopus bibliometric analysis indicates that disaster-related topics are currently attracting growing attention from researchers. There has been a rapid increase in research due to a focus on reactive approaches, particularly disaster mitigation and climate change adaptation. This trend is also linked to resilience (Hutagalung et al., 2025).

Indonesia, known as a country within the Pacific Ring of Fire, faces a very high risk of natural disasters. Indonesia's geographical location at the junction of three major tectonic plates contributes to its vulnerability, particularly to geologically-based disasters such as earthquakes, tsunamis, and volcanic eruptions. Other related disasters can stem from hydrometeorological causes, such as floods, landslides, and droughts. Natural factors are unpredictable, even for the government. However, it is important to adopt a perspective that recognizes other triggering factors that are equally significant in influencing natural conditions. These factors stem from human activities, including land use, population growth, and rapid urbanization. Until an ideal solution is found, these conditions create a gap of high vulnerability that threatens future sustainability.

Indonesia's National Disaster Management Agency has released startling data in recent years. The data reveals an increasing frequency of disasters, predominantly hydrometeorological in nature. The consistent occurrence of these disasters paints a clear picture, as they happen almost periodically (annually). Data from the National Disaster Management Agency indicates more than 3,000 cases of extreme disasters (CNBC, 2025). Floods and extreme weather are most often a threat to residents' survival. These events inevitably result in loss of life and significant economic losses. The public's right to public services is also disrupted because infrastructure is damaged, hindering the daily delivery of services.

A simplistic approach is no longer sufficient for understanding systemic disaster risks. Disaster risks are now recognized as "complex risks" due to the strong interconnections and interactions among various factors. High levels of uncertainty increasingly threaten to trigger a chain reaction. Other sectors can be further exacerbated by an initial trigger, which may involve a combination of factors such as a health crisis, infrastructure gridlock, a crisis in basic necessities, and psychological trauma.

Current disaster trends serve as a reminder to the global community that the reality of disasters and future risks can no longer be understood through simplistic thinking. A wide range of factors including environmental, social, and technological advancements interact, intertwine, and trigger disasters. Understanding the complexities of disasters in this era fundamentally requires a multi-hazard approach and a strong foundation in social-ecological reasoning.

The evolution of disaster management approaches has been the subject of various in-depth studies, all leading to the same conclusion: a hazard-oriented approach. The simplest way to understand "hazard-oriented" is to recognize that no disaster occurs in isolation without a triggering factor. Disasters are not isolated phenomena; they emerge dynamically due to the interaction among different types of hazards, exposure, and vulnerability (Jiang et al., 2022a). Ultimately, disaster mapping practices still require hazard identification (hazard-based mapping), whether by sector or by factor. The ability to capture multi-hazard interactions as disaster triggers has not yet been fully maximized by many groups. The rapid development of this concept is actually driven by the integration of several key factors, such as geology, physics, and hydrometeorology. The public's limited ability to gain a specific understanding of disaster vulnerability remains a distinct challenge to this day (Kariminejad et al., 2022a).

A preliminary conclusion that can be drawn is that current disaster trends are purely the result of shifts in human lifestyles. As the world becomes increasingly interconnected and interdependent, the frequency of disasters also increases alongside the daily lives of people worldwide. The primary challenge for the global community today is to focus more on enhancing resilience and developing strategies for future disaster risk management.

LITERATURE REVIEW

The appropriate research approach must begin with an understanding of and a primary focus on unraveling the problem. A hazard-oriented approach is an appropriate concept that can map the extent to which risks are identified. The United Nations Office for Disaster Risk Reduction provides one of the standard frameworks developed based on several disaster-linking factors (Jiang et al., 2022). These contributing factors simultaneously act as drivers of disasters that are complex, multi-hazard, uncertain, and involve vulnerabilities when linked across sectors (spillover effects).

Various types of disaster mapping have been developed within the context of disaster preparedness. Hazard mapping serves as the foundation for risk mapping, with all related activities centered on collecting vulnerability data. In previous studies, most scholars agreed that the challenges faced were not as complex as they are today (Kariminejad et al., 2022b). Simple implementations tended to serve as quick solutions to anticipate various limitations regarding potential disaster impacts. The concept of risk mapping establishes various logical dimensions to serve as foundational hypotheses prior to detailed data collection.

Essentially, the multi-hazard approach has become increasingly prevalent as disaster capacity has grown. This is particularly true when identifying vulnerable zones and areas characterized by simultaneous hazards. Such zones or areas are complex in nature because they involve the simultaneous interplay of processes, factors, and triggering actions rather than occurring one at a time. Several studies indicate that the multi-hazard approach offers a robust framework for detecting disaster risks (Heo et al., 2023). Disaster dynamics are never static, as each involves complex risks (Tempa & Yuden, 2023). Some of these studies also describe the phenomenon of cascading disasters unexpected, far-reaching events. The broader implications of cascading disasters are as follows:

1. Sequential events and widespread impacts: Simply put, a disaster does not affect only one sector but can significantly impact other sectors as well (for example, when an earthquake occurs, it damages the power grid, internet infrastructure, and clean water systems, and public facilities such as hospitals, schools, and administrative offices also feel the impact).
2. Chain reaction: Subsequent dangers can be more severe and further exacerbate the situation.
3. System interdependence: The nature of modern life often relies on technology for daily living and human interactions. For example, when a disaster paralyzes these sectors, human life can feel desolate, meaningless, and lacking in face-to-face interactions among people. This occurs because the ecosystem of human life has become accustomed to being interconnected virtually.
4. Systemic risk: The failure of a single sector such as the electricity grid will inevitably disrupt the daily activities of people who rely on electricity. When many jobs are disrupted, the pace of business and logistics is thrown into chaos, creating a multifactorial crisis.
5. Cross-border: Multifactorial crises do not occur only within small geographical areas but can spread across local, regional, national, and even continental borders. This is because, once again, it can be emphasized that people today have communication and operational patterns that are interconnected through technology

The explanations and interpretations of the literature above clearly demonstrate that the course of a disaster is inherently dynamic. Even predictions made by individuals or disaster-monitoring groups will never be 100% accurate. The nature of disasters stems from nature's reactions to various biotic, abiotic, or other organic influences.

Disaster studies in the modern era have undergone a shift in meaning. Originally, the entire world adopted a uniform, reactive approach when facing disasters. The modern era has given rise to more proactive approaches worldwide. The primary focus is no longer on how to respond to the onset of a disaster, but rather on how to survive in the face of potential disasters. Humans are inherently forced to coexist with the potential for disasters, so it is hoped that safer anticipation and preparation will emerge.

This shift in the modern disaster paradigm is key to anticipating sources of danger. Effective mitigation strategies are crucial for creating safer spatial planning and building mental resilience among community members. On the other hand, disaster identification can be used to determine several factors, such as predicting when a disaster will occur, its intensity, potential triggers, and the lethality of its impact should it occur. Science and knowledge are vital for supporting human survival.

The nature of natural disasters tends to be unpredictable and is often influenced by a series of complex interactions among various components of the Earth system such as the lithosphere, hydrosphere, atmosphere, and even the biosphere which are constantly interacting with one another. From the perspective of Earth sciences, these components can be likened to actors on a stage who orchestrate the occurrence of disasters.

The final theory that can be considered part of modern disaster management literature is Adaptive Governance or Adaptive Risk Management. Adaptive governance refers to the way a local government operates to recognize and implement disaster resilience management. The system is designed to be sustainable and flexible, and involves institutional collaboration by integrating local knowledge with scientific knowledge (Nikkanen et al., 2024). The objective of the adaptive governance theory is to bring together all relevant aspects to respond to the ever-changing dynamics of disaster risk (Danar et al., 2022). Several key dimensions linked to the concept of adaptive governance are: 1) governance as the structure and process of decision-making, 2) adaptation as the capacity to change and continuously learn from new scientific developments, and 3) the capabilities and mastery of the local area, which serve as valuable assets in geographical, ecological, and socio-cultural terms (Fitriadi et al., 2025).

Adaptive governance is a concept that encompasses several operational indicators, including multi-level coordination mechanisms, access to local and scientific knowledge, and meaningful community participation to continue adapting (learning) in the aftermath of a disaster (Chaffin et al., 2024). Community response and flexibility provide fundamental support before the government and relevant stakeholders can navigate all uncertainties related to disasters. The dynamics of disasters require a constant readiness to respond to uncertainty so that disaster risks can be mitigated (Linkov et al., 2018). Adaptive Governance essentially emphasizes a system that continuously learns about the current situation, implements comprehensive adaptations, and responds to all changes with preparedness.

Additionally, this concept emphasizes cross-sectoral collaboration and the integration of knowledge.

The Adaptive Governance approach underscores the importance of disaster mapping and the need for continuously updated information, especially in the digital era. Risks can be minimized when multi-stakeholder collaboration is established, making this approach strongly oriented toward preventive measures before threats arise. Databases can be utilized within disaster risk adaptation systems as awareness grows. This means that in this approach, the involvement of stakeholders such as the government, academia, the private sector, the public, and NGOs can create new elements to enhance effectiveness in addressing disaster threats, particularly the effectiveness of data exchange. Data validation is essential due to its critical nature, ensuring that future information distribution remains on track.

This study has a focus that is clearly distinct from previous research (although the relevance and subject matter are the same). Some previous studies generally focused on and mapped only single-hazard or multi-hazard scenarios, but did not do so comprehensively. In this study, the risks associated with complex disasters serve as the primary paradigm for long-term disaster analysis in Indonesia. Several aspects that can be integrated refer to various commonly identified vulnerabilities, as well as the extent to which existing disaster management practices have been implemented. The primary objective of this study is to contribute concepts, ideas, and preliminary frameworks. Conceptual contributions toward developing a disaster adaptation model and national disaster mapping in Indonesia are of great benefit in fostering a more responsive approach to anticipating risks and adapting to the ever-changing dynamics of the environment. The dynamics of disasters over the past few years have not been fully captured by previous research. Therefore, this study serves as an effort to reconstruct national disaster mapping based on early identification, governance, environmental interactions, and the continuous flow of information. This multi-hazard approach must be emphasized to understand the complexity of disasters, which cannot be addressed solely through a single perspective, as is the case with the single-hazard approach.

RESEARCH METHODS

This study employs a qualitative descriptive approach combined with a literature review to analyze the development of national disaster mapping in Indonesia within the context of complex disaster risks. This approach is used to understand the paradigm shift in disaster mapping, implementation challenges, and the need to adapt mapping systems in the era of multi-hazard and cascading disasters.

Research data were obtained from various scientific literature sources, including international and national journal articles, institutional reports, policy documents, and publications related to disaster risk reduction published between 2019 and 2025. The literature was selected based on its relevance to the themes of multi-hazard mapping, complex disaster risk, adaptive governance, and disaster risk reduction.

Data analysis was conducted qualitatively through a process of theme identification, conceptual interpretation, and argumentative synthesis to identify patterns in the development of disaster mapping and their implications for the national mapping system in Indonesia

RESULTS AND DISCUSSIONS

A. The Evolution of The Disaster Mapping Paradigm

There has been a significant paradigm shift, particularly in recent years. The initial orientation actually emerged with the introduction of the concept of single-hazard mapping, which tended to identify each disaster whether an earthquake, landslide, flood, or other event separately. The evolution of the disaster mapping paradigm is not intended to cause public anxiety. However, this paradigm seems to have evolved based on the causes and assumptions of many stakeholders worldwide. The tendency among the majority of the global community particularly thinkers and researchers focused on disaster studies has generated a new momentum to maintain hope while devising the best strategies to address disasters.

The multi-hazard mapping approach is becoming increasingly important, given that disaster risks worldwide no longer exist in isolation. Interactions and triggering factors that influence one another represent unlimited possibilities (Pourghasemi et al., 2020). The multi-hazard approach presents several forward-looking predictions that account for the interdependencies among various types of disasters. Clearly, this approach establishes reciprocal correlations between interconnected hazards. Therefore, it is important to understand the concept of multi-hazard mapping, which naturally encompasses the processes of data collection, processing, and presentation. Several studies explain that multi-hazard mapping techniques can be carried out through: 1) field surveys (terrestrial), aerial photography (photogrammetry), and secondary data surveys. During the data integration stage, the data will be adjusted according to the calculation methods and reference systems used in the analysis of specific map conditions. Finally, the data presentation stage commonly referred to as cartography produces processed results in the form of maps (Hidayatullah et al., 2023).

For now, multi-hazard mapping can be summarized as an approach using geodetic techniques. Its objective is clear:

to map various types of risks and disasters through a thorough identification process. Risks can occur in many regions and encompass numerous natural phenomena, such as floods, volcanic activity, landslides, earthquakes, and so on. Multi-hazard mapping is based on the key principle of establishing a standardized information system for both the public and authorities, such as the government. A crucial consideration is the expectation that this will lead to greater accuracy and effective mitigation measures. Some steps in multi-hazard mapping (Hidayatullah et al., 2023):

1. Geospatial Data Collection

   This stage is critical and crucial because the procedures involved are not arbitrary. The individuals involved in managing information and data are carefully selected professionals with in-depth expertise regarding the physical characteristics of a given area.

2. Risk Analysis

   The collected data serves as the basis for conducting risk analysis, with the goal of classifying vulnerable areas. The methodology employs mathematical modeling and statistical analysis to develop detailed assessments of the impacts and potential of each hazard.

3. Geospatial Modeling

   This technique involves data visualization, enabling the public to easily understand the distribution of potential disasters, including their potential, risks, and impacts should they occur.

4. Hazard Map Development

   Hazard maps represent the final stage, providing an overview of various risk levels and the potential spread of hazards within a region. These maps serve a further purpose by inspiring future government initiatives in spatial planning and strategic management efforts to address disasters at a higher level.

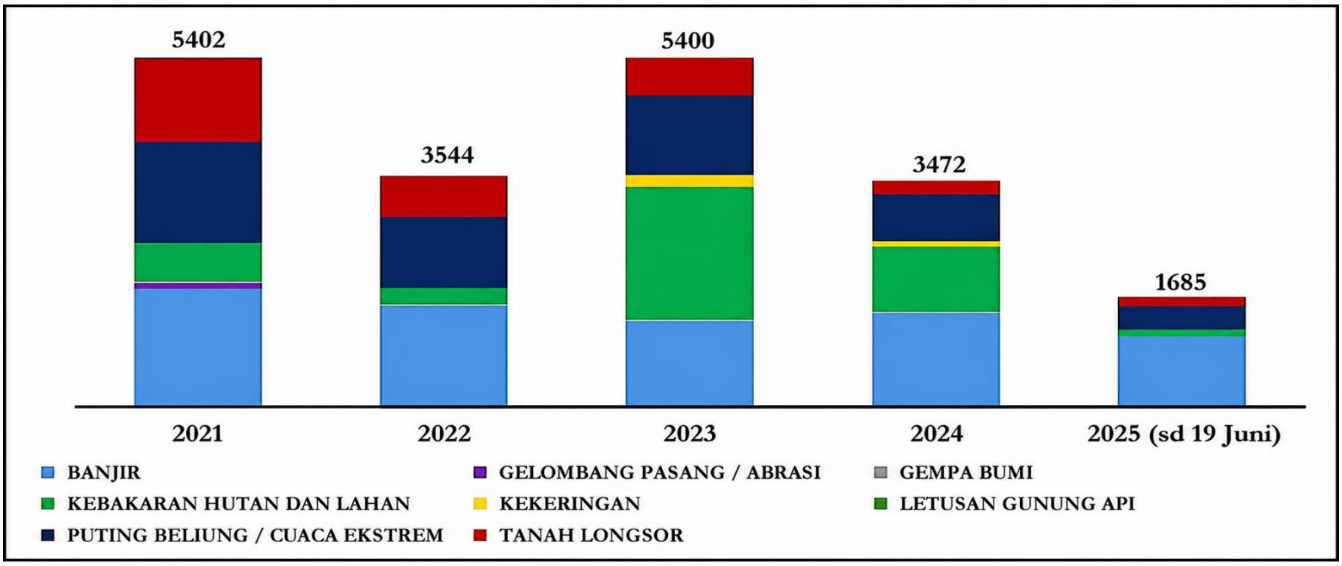
Mapping in the context of disasters is a fundamental step. Mapping is primarily about understanding regional conditions to support short-term analysis needs (rapid analysis). To address the unpredictable nature of natural disasters, a rapid assessment process in the form of real-time field mapping is required. It is even better when disaster maps include elements of impact and losses, making them easier for the public to understand. Additional support can come from well-developed post-disaster planning and programs (Khoiriah, 2022).

Mapping in various regions or disaster-prone areas will, in principle, facilitate pre-disaster monitoring and prediction. Rescue efforts can be maximized. All mapping efforts must also be supported by the distribution of information in the form of posters or leaflets, particularly regarding how to prevent disasters, recognize disasters, and provide initial disaster response. Public awareness will increase as information is disseminated in coordination with government agencies at the village, city, and provincial levels throughout Indonesia.

B. Disaster Trends in Indonesia Today

Throughout history, Indonesia has struggled to escape various major disaster threats such as earthquakes, volcanic eruptions, floods, landslides, and so on. Indirectly, these past events continue to affect nearly all aspects of people's socioeconomic lives. Over the past 15 years, the average annual losses incurred by the country due to natural disasters have reached 22 trillion rupiah. This fact reflects an alarming financial situation, especially given that Indonesia is located within the Ring of Fire, where the potential for disasters is ever-present.

Graphic 2.1 *Natural Disasters in Indonesia: 2021–June 2025*



Source: (CNBC, 2025)

New data shows that Indonesia is currently experiencing a trend toward new disaster patterns in the context of hydrometeorology. It is not just the natural disasters that frequently occur; rather, the most significant threats are re-emerging through hydrometeorological disasters. Among these hydrometeorological disasters are droughts, strong winds, and extreme weather. The potential for rainfall exists year-round in the equatorial region; moreover, rainfall patterns are so variable that they are difficult to predict (Greenlab, 2025). Heavy rainfall has its own cycle, after which a drought is very likely to follow a period of very little or no rainfall. These conditions present a dilemma and require special attention, as both can cause damage: flooding and drought.

Records from Indonesia's National Disaster Management Agency (BNPB) regarding the large number of people suffering and displaced date back to 2021. A total of 3,092 hydrometeorological disasters occurred, resulting in a total of 8,426,609 victims (BMKG, 2023). Globally, Indonesia is listed among the 33 countries with the highest disaster risk levels in the world. The Department of Civil and Environmental Engineering at Gadjah Mada University in Indonesia (2025) explains that while global climate change contributes to the rise in hydrometeorological disasters, high levels of human activity in land use and development pressures are also significant contributing factors. Land subsidence in urban areas has also contributed significantly to the increasing trend of flooding, thereby reducing Indonesia's resilience (Hendrawan et al., 2025).

Future disaster trends have been highlighted by some experts due to recent climate changes, particularly heavy rainfall in Indonesia. Vempi Satriya Adi Hendrawan, a hydroinformatics expert from Indonesia, stated that it is important to integrate multiple aspects when addressing disasters; if necessary, all development activities must be accompanied by infrastructure planning documents that account for hazards, exposure, and vulnerability. Disaster risks can very likely result in losses whether in the form of loss of life, injuries, or damage to property and valuables within a specific period.

Graphic 2.2 *Predictions of Indonesia's Lack of Preparedness in the Future*

Rank	Country	WorldRiskIndex	Exposure	Vulnerability	Susceptibility	Capacities	Capacities
1.	Philippines	46.56	39.99	54.20	50.10	58.54	54.30
2.	India	40.73	35.99	46.10	34.56	54.08	52.43
3.	Indonesia	39.80	39.89	39.71	24.80	51.27	49.24
4.	Colombia	39.26	31.54	48.86	47.85	50.87	47.91
5.	Mexico	38.96	50.08	30.31	44.39	12.53	50.07
6.	Myanmar	36.91	22.43	60.74	55.42	64.47	62.72
7.	Mozambique	34.39	18.10	65.33	65.91	63.33	66.79
8.	Russian Federation	31.22	28.35	34.38	26.49	39.99	38.36
9.	China	30.62	64.59	14.52	8.96	11.44	29.85
10.	Pakistan	26.82	13.11	54.85	40.52	63.30	64.34
11.	Bangladesh	26.71	16.57	43.07	27.09	59.29	49.73
12.	Papua New Guinea	26.51	18.84	37.29	57.52	13.36	67.46
13.	Vietnam	25.92	26.73	25.14	24.42	13.00	50.05
				....			
191.	San Marino	0.35	0.03	4.08	3.06	1.30	17.08
192.	Andorra	0.29	0.02	4.07	3.08	1.80	12.17
193.	Monaco	0.18	0.02	1.55	1.75	0.42	5.05

Quoted from: World Risk Report (2025)

The data above indicates that Indonesia's future preparedness is projected to fall within the "unprepared" zone due to the cumulative burden it faces when considering various types of disaster threats. Herliansyah's (2025) research reiterates that Indonesia cannot escape the influence of the three tectonic plates, which serve as natural triggers for natural disasters. It is even noted that all regions have varying levels of risk. Herliansyah's research aligns with the Multi-Hazard theory because it employs modern statistical methods that examine correlations among multiple indicators (not just a single indicator). The 12 indicators in question are used to measure the hidden interrelationships among the indicators of Hazard, Exposure, and Vulnerability. The results of his analysis reveal distinct characteristics in each region. However, the key findings and their significance lie in how the study's implications can inform the development of adaptation policies, including the following:

1. Mitigation strategies cannot be applied uniformly; therefore, recommendations must include critical phases that are continuously refined over time meaning ongoing studies are necessary to account for the uncertainty of when disasters will strike.
2. Java faces high risks, but its infrastructure quality and governance are better than in other regions, enabling it to mitigate those risks. In addition, the response from

many parties is also better because they are trained through experience, coordination, and positive interactions among relevant organizations, among other factors.

3. Other regions, such as the outlying parts of Indonesia namely Maluku and Papua face lower threats compared to other areas; however, their vulnerability to losses is very high because their infrastructure and accessibility are not as good as those in Java.

The above research presents several analyses that can inform the development of future disaster mapping adaptation concepts. An approach based on the interrelationships among indicators as adapted to various regional characteristics is a practical step toward refining the concept of national disaster mapping in Indonesia. Additional focus should be placed on community efforts, community preparedness, and community resilience in responding to disaster threats should they occur. The implications pertain to the dynamics of national government policy regarding all disaster trends. In other words, Indonesia requires a rapid and targeted response in the form of investment, emergency communications, or adequate logistics. All these aspects must be effectively implemented in disaster-prone areas, expanded, and disseminated. Therefore, natural disaster mapping for Indonesia's future requires precise action, as the associated risks and threats are already well understood through facts and up-to-date data.

There will be a series of significant hydrometeorological disasters throughout 2025 in Indonesia. The predominant disasters are floods and landslides. Several major islands in northern Indonesia experience extreme heavy rainfall. The impact is quite massive because, once again, these disasters do not occur in isolation but are interrelated. When extreme weather with high rainfall occurs, it gradually causes rivers to overflow and the land on the slopes and hills to erode (collapse). The subsequent chain of suffering results in loss of life as hundreds of thousands of homes are damaged, forcing survivors to evacuate. These hydrometeorological disasters in the form of floods create an ironic situation (Ayu, 2025). For example, floods trigger landslides, which in turn cut off road access, collapse bridges, paralyze public facilities, and create an electricity grid crisis for nearby residents.

The emergency conditions described above leave communities isolated. Given that modern society largely relies on electricity and internet access, it stands to reason that the development of disaster adaptation strategies is crucial. The discipline of preparing disaster adaptation materials requires a well-thought-out, up-to-date, and meticulous conceptual framework. Ideally, disaster risk trends in Indonesia should already be addressed at the national level, given the massive losses and trauma suffered by the majority of the population. Another natural trigger is the combination of meteorological, atmospheric, and environmental dynamics, including the formation of "Tropical Cyclone Senyar."

Deforestation and the degradation of river systems, which have been accumulating over the years in Indonesia, have created a resilience crisis in which the soil landscape has largely lost its ability to absorb water (Damiti et al., 2025). Problems arise from upstream to downstream, as the primary function of forested areas is to maintain ecosystem balance. Forest restoration to maintain ecosystem stability should ideally occur rapidly, even though human exploitation activities are extremely high (Pratama et al., 2026). Deforestation naturally disrupts the hydrological system in specific areas, causing a decline in the quality of forest resources (Rahman et al., 2024). This problem has serious implications for the adaptation cycle of disaster mapping in Indonesia because vital corridors and buffer zones are experiencing negative fragmentation. Ideally, connectivity between disaster-prone areas requires regular maintenance, accelerated ecosystem regeneration, and strict screening of all human activities before effective rehabilitation programs can be established.

C. Weaknesses in Mitigation, Directions for Disaster Adaptation, and the Need for Multi-Hazard Mapping

Weaknesses in the disaster mapping system's mitigation efforts can be interpreted as suboptimal disaster risk reduction measures. In Indonesia, the government's mitigation efforts have not been optimal in the pre-disaster phase, as evidenced by the high number of fatalities in every disaster. Although disasters are sometimes natural in nature, the situation is more complex in this era due to the occurrence of man-made disasters. Addressing these mitigation weaknesses ideally requires engagement and strategic planning, as it is not possible to completely avoid all disaster impacts. It is impossible to eliminate the threat of losses and prevent all loss of life whenever a disaster strikes. A key role for government agencies in Indonesia in addressing these mitigation weaknesses is to maximize effective pre-disaster and post-disaster response efforts. Furthermore, public preparedness for disasters remains relatively low.

Below are several international articles that the author has deliberately compiled to support the argument that Indonesia remains in a zone of mitigation weakness. Among them are findings that demonstrate how disaster mitigation weaknesses in Indonesia are not necessarily triggered solely by natural factors:

1. Mapping efforts have not been effectively linked to public understanding, as they are often still top-down

in nature. The public lacks an understanding of the risks, particularly in local areas where awareness is uneven. The community is not sufficiently involved or, in other words, is still viewed as a group that needs assistance. The mitigation system remains largely formal and fails to incorporate local community knowledge. While mapping information is now digital, its content is not easily understood by the general public, making it seem as though the information serves only to fulfill administrative requirements (Ledoh et al., 2026) .

2. Weak coordination among institutions persists, and policies remain sectoral particularly in terms of the fragmented management of disaster data. This reality stands in stark contrast to the increasingly complex dynamics of disaster risk in the modern era. A modern approach to disaster management requires the identification of numerous factors (Kusumasari et al., 2010).
3. Issues such as floods and environmental degradation must be understood as the result of many contributing factors. Among these is rapid urbanization, which leads to densely populated areas; when populations are dense, environmental quality declines a decline that can manifest as littering. Littering, in turn, leads to delays in waste management. Such conditions create a chain reaction that hinders the government's efforts to minimize disasters (Bamal et al., 2026).
4. Efforts to improve disaster management regulations actually began to gain momentum following the 2004 Aceh tsunami. However, the approach taken by the national government still appears to be reactive at the emergency response level. The situation would be more ideal if long-term programs were established, while also educating the public about urban development and uncontrolled land use (Kultsum et al., 2026).
5. Indonesia still lags significantly behind in terms of technology. Real-time monitoring has not yet reached the grassroots level; in other words, early warning and detection systems are not fully understood by the general public. Furthermore, climate change is constantly evolving, so an adaptive approach has not yet been established. The main challenge is to empower communities to develop their disaster response capabilities (Sunanda et al., 2025).

Several key aspects of disaster adaptation actually stem from a high level of awareness that is managed and balanced with the governance of human resources, materials, and economic considerations. Furthermore, mapping hazard levels, social and environmental vulnerabilities, infrastructure, and the fate of buffer zones and surrounding areas requires serious intervention from local to central government. The reality and the phenomenon of losses caused by natural disasters, which remain poorly addressed, indicate that, to this day, Indonesia remains at the "single-hazard" level of understanding. Public participation, involvement of local institutions, and government coordination to conduct disaster assessments as mitigation efforts have not yet received sufficient attention or conceptual updates.

Developments in disaster literature provide a strong understanding that climate change is always influenced by many factors. Human dependence on the environment and high levels of urbanization pose a greater risk of crises. Disaster mitigation serves as a complementary measure to both counterbalance and control disasters through the periodic mapping of affected areas. Mitigation cannot be limited to infrastructure development alone, as the nature of physical spatial planning requires strengthening the system as well. One of the main challenges of mitigation is the limited understanding of disaster characteristics and potential, which contributes to the formation of vulnerable groups.

Indonesia's existing system capabilities cannot be separated from disaster mitigation studies. Regardless, the current state of the system is believed to be a factor in integrating all forms of information, risks, and decision-making at the final level. Many identification efforts can be maximized according to specific priorities in each region. However, methods for utilizing static data across agencies and among policy makers often result in potential threats alone. In fact, the dynamics of disasters require specific mitigation, particularly regarding the interactions that trigger chain reactions of hazards. Mitigation efforts to date have been largely reactive, as there has been no clear concept for minimizing long-term risks (preventive measures).

Changes in Indonesia's physical and social environments are constantly evolving, further underscoring the need for a continuously updated mitigation agenda. The foundation of modern mitigation is part of disaster adaptation that can leverage extensive digital data integration. Drawing on diverse experiences across regions makes a high level of control entirely feasible. These activities can be carried out and directed on a full-time basis because Indonesia possesses all the necessary strategic tools particularly information, population distribution, and local experiences across regions in the context of disaster response.

From the perspective of adaptive governance, the effectiveness of disaster mitigation is not determined solely by the adequacy of a country's technology; rather, adaptive governance emphasizes the capacity of institutions to manage and distribute information down to the grassroots level (remote village communities). Such governance is essential to support responses to disasters should their course change at any time. The dynamics of disasters are not merely a matter of sudden onset; they have shifted to a level that defies human predictive reasoning.

CONCLUSION

Changes in the nature of disaster risks in Indonesia indicate that a disaster mapping approach focused on a single type of hazard is no longer sufficient to describe the increasingly complex dynamics of risk. The results of this study show that the national disaster mapping system still faces challenges in integrating information on hazards, exposure, vulnerability, capacity, and interactions between hazards that have the potential to cause cascading effects. On the other hand, developments in climate change, urbanization, and increased infrastructure exposure have accelerated changes in risk characteristics, meaning that the mapping system is no longer sufficient merely as a spatial representation of disaster-prone areas; rather, it needs to evolve into a risk information system capable of supporting adaptive mitigation and decision-making processes.

This study offers the perspective that the adaptation of national disaster mapping should be directed toward the development of a dynamic, integrated, and risk-governance-based system that accommodates a multi-hazard approach, socio-spatial vulnerabilities, and the principles of adaptive governance. The novelty of this study lies in its effort to reposition disaster mapping as an instrument of risk governance, rather than merely a cartographic product for identifying disaster-prone areas. Although conducted through a literature review approach, the results of this study are expected to serve as a conceptual foundation for the development of disaster mapping policies that are more responsive to changes in the nature of risks in Indonesia, as well as a reference for empirical research testing the implementation of this approach in various regional contexts.

REFERENCES

1. Ayu, W. (2025). *Bencana Hidrometeorologi Indonesia 2025: Tragedi yang Tertutup Drama Publik.* https://mapid.co.id/articles/bencana_hidrometeorologi_indonesia_2025_tragedi_yang_tertutup_drama_publik
2. Bamal, A., Uddin, M. G., Ahmadian, R., Miguez, M. G., & Olbert, A. I. (2026). Impact of floods on surface water quality: A systematic review and comprehensive assessment. *Journal of Hydrology*, *677*, 135916. https://doi.org/10.1016/j.jhydrol.2026.135916
3. BMKG. (2023). *Mengenal Bencana Hidrometeorologi dalam Era Digital – BMKG Knowledge Management System*. https://kms.bmkg.go.id/2023/02/mengenal-bencana-hidrometeorologi-dalam-era-digital/
4. Chaffin, B. C., Floyd, T. M., & Anzollitto, P. (2024). Environmental Governance Networks and Geography: A Research Agenda at the Confluence of Critical Concepts for Navigating Rapid Environmental Change. *Annals of the American Association of Geographers*, *114*(8), 1718–1730. https://doi.org/10.1080/24694452.2024.2343493
5. ck. (2025). *World Risk Report 2025*. WeltRisikoBericht. https://weltrisikobericht.de/worldriskreport/
6. CNBC. (2025). *RI Dikepung Bencana: Anggaran BNPB Dipangkas Hingga Terendah 15 Tahun*. CNBC Indonesia. https://www.cnbcindonesia.com/research/20250821065910-128-659935/ri-dikepung-bencana-anggaran-bnpb-dipangkas-hingga-terendah-15-tahun
7. Damiti, R. A., Pakaya, P., Prasetyo, M. H., Baderan, D. W. K., & Utina, R. (2025). Stabilitas ekosistem hutan indonesia dalam menghadapi deforestasi dan kerusakan lingkungan: Tinjauan literatur. *Botani: Publikasi Ilmu Tanaman Dan Agribisnis*, *2*(2), 176–188.
8. Danar, O. R., Ap, S., & Ap, M. (2022). *Teori governance*. Deepublish.
9. Departemen Teknik Sipil dan Lingkungan Universitas Gadjah Mada Indonesia. (2025). *Kerangka Ilmiah Bencana Hidrometeorologis, Tren Risiko ke Depan, serta Rekomendasi Kebijakan Berbasis Data dan Skenario (Sesi Speaker Webinar Nasional Early Warning, Early Action) – Departemen Teknik Sipil dan Lingkungan*. https://tsipil.ugm.ac.id/id/kerangka-ilmiah-bencana-hidrometeorologis-tren-risiko-ke-depan-serta-rekomendasi-kebijakan-berbasis-data-dan-skenario-sesi-speaker-webinar-nasional-early-warning-early-action/
10. Donatti, C. I., Nicholas, K., Fedele, G., Delforge, D., Speybroeck, N., Moraga, P., Blatter, J., Below, R., & Zvoleff, A. (2024). Global hotspots of climate-related disasters. *International Journal of Disaster Risk Reduction*, *108*, 104488. https://doi.org/10.1016/j.ijdrr.2024.104488
11. Fitriadi, Fadly, R., Rajagukguk, D. B., Prihandoko, R., & Amelia, N. W. (2025).

ADAPTIVE LOCAL GOVERNANCE DALAM PENGELOLAAN RISIKO BANJIR DI KAWASAN GAMBUT TUMBANG NUSA KALIMANTAN TENGAH. *Mimbar : Jurnal Penelitian Sosial Dan Politik*, *14*(2), 378–399. https://doi.org/10.32663/by4qq017

12. Gao, H., Xu, C., Wu, S., Li, T., & Huang, Y. (2025). Has the unpredictability of geological disasters been increased by global warming? *Npj Natural Hazards*, *2*(1), 55. https://doi.org/10.1038/s44304-025-00108-0

13. Greenlab. (2025). *Kenapa Indonesia Rentan Bencana Hidrometeorologi? Ini Penjelasan Lengkapnya—Greenlab*. https://greenlab.co.id/news/Kenapa-Indonesia-Rentan-Bencana-Hidrometeorologi-Ini-Penjelasan-Lengkapnya

14. Hendrawan, V. S. A., Rahardjo, A. P., Mawandha, H. G., Aldrian, E., Muhari, A., & Komori, D. (2025). Past and future climate–related hazards in Indonesia. *EGUsphere*, *2025*, 1–34.

15. Heo, S., Park, S., & Lee, D. K. (2023). Multi-hazard exposure mapping under climate crisis using random forest algorithm for the Kalimantan Islands, Indonesia. *Scientific Reports*, *13*(1), 13472. https://doi.org/10.1038/s41598-023-40106-8

16. Herliansyah, R. (2025). *Memahami Pola Risiko Bencana di Indonesia dengan Pendekatan Data Modern—LPPM ITK*. https://lppm.itk.ac.id/detail-hasil-penelitan/memahami-pola-risiko-bencana-di-indonesia-dengan-pendekatan-data-modern

17. Hidayatullah, J. R., Apriani, L., & Tisnasendjaja, A. R. (2023). *Peta Risiko Kota Cimahi: Strategi Pemanfaatan Sig Untuk Menilai Dan Mengurangi Kerawanan Multi-Hazard*. MEGA PRESS NUSANTARA. https://books.google.com/books?hl=id&lr=&id=MnIDEQAAQBAJ&oi=fnd&pg=PP1&dq=peta+risiko+kota+cimahi&ots=JFXWlf-CtP&sig=E5uuUSONkSJybTt3-QSi_wxN2Nk

18. Hutagalung, S. S., Yulianto, Y., & Rosalia, F. (2025). Global trends in social-ecological systems and disaster research: Bibliometric insights. *Jàmbá : Journal of Disaster Risk Studies*, *17*(1), 1874. https://doi.org/10.4102/jamba.v17i1.1874

19. Jiang, W., Wang, F., Zheng, X., Zheng, X., Qiao, X., Li, X., & Meng, Q. (2022a). Toward Interoperable Multi-hazard Modeling: A Disaster Management System for Disaster Model Service Chain. *International Journal of Disaster Risk Science*, *13*(6), 862–877. https://doi.org/10.1007/s13753-022-00450-1

20. Jiang, W., Wang, F., Zheng, X., Zheng, X., Qiao, X., Li, X., & Meng, Q. (2022b). Toward Interoperable Multi-hazard Modeling: A Disaster Management System for Disaster Model Service Chain. *International Journal of Disaster Risk Science*, *13*(6), 862–877. https://doi.org/10.1007/s13753-022-00450-1

21. Kariminejad, N., Pourghasemi, H. R., & Hosseinalizadeh, M. (2022a). Analytical techniques for mapping multi-hazard with geo-environmental modeling approaches and UAV images. *Scientific Reports*, *12*(1), 14946. https://doi.org/10.1038/s41598-022-18757-w

22. Kariminejad, N., Pourghasemi, H. R., & Hosseinalizadeh, M. (2022b). Analytical techniques for mapping multi-hazard with geo-environmental modeling approaches and UAV images. *Scientific Reports*, *12*(1), 14946. https://doi.org/10.1038/s41598-022-18757-w

23. Khoiriah, Z. (2022). *Siaga Bencana dalam Paradigma Perilaku Sosial*. GUEPEDIA.

24. Kultsum, R., Fauzia, A., Ali, C., Triatmadja, R., Rana, A. S. W., Tahalele, M., & Sutanto, M. H. (2026). Long-term disaster risk implications of post-tsunami housing reconstruction: An integrated socio-technical assessment of community perception, structural performance, and hazard exposure in Aceh, Indonesia. *Progress in Disaster Science*, 100596.

25. Kusumasari, B., Alam, Q., & Siddiqui, K. (2010). Resource capability for local government in managing disaster. *Disaster Prevention and Management*, *19*(4), 438–451. https://doi.org/10.1108/09653561011070367

26. Ledoh, L., Suroso, D. S. A., Sagala, S., & Suhirman, S. (2026). Integrating adaptive governance into disaster management planning in medium-sized cities: A case study of Kupang city, Indonesia. *Disaster Prevention and Management: An International Journal*, 1–14.

27. Linkov, I., Trump, B. D., Anklam, E., Berube, D., Boisseasu, P., Cummings, C., Ferson, S., Florin, M.-V., Goldstein, B., Hristozov, D., Jensen, K. A., Katalagarianakis, G., Kuzma, J., Lambert, J. H., Malloy, T., Malsch, I., Marcomini, A., Merad, M., Palma-Oliveira, J., … Vermeire, T. (2018). Comparative, collaborative, and integrative risk governance for emerging technologies. *Environment Systems and Decisions*, *38*(2), 170–176. https://doi.org/10.1007/s10669-018-9686-5

28. Nikkanen, M., Räsänen, A., & Juhola, S. (2024). Adaptive governance of disaster preparedness? The case of regional networks in Finland. *International Journal of Disaster Risk Reduction*, *108*, 104549. https://doi.org/10.1016/j.ijdrr.2024.104549

29. Pourghasemi, H. R., Kariminejad, N., Amiri, M., Edalat, M., Zarafshar, M., Blaschke, T., & Cerda, A. (2020). Assessing and mapping multi-hazard risk susceptibility using a machine learning technique. *Scientific Reports*, *10*(1), 3203. https://doi.org/10.1038/s41598-020-60191-3

30. Pratama, A. A., Maryudi, A., & Kleinschmit, D. (2026). Climate change in Indonesian forest governance: A frame analysis of the scientific discourse. *Forest Policy and Economics*, *186*, 103766. https://doi.org/10.1016/j.forpol.2026.103766

31. Rahman, R. A., White, B., & Ma, C. (2024). The effect of growth, deforestation, forest fires, and volcanoes on Indonesian regional air quality. *Journal of Cleaner Production*, *457*, 142311. https://doi.org/10.1016/j.jclepro.2024.142311

32. Sunanda, W., Setyonegoro, M. I. B., & Hadi, S. P. (2025). Advancing the carbon pricing framework in Indonesia: A systematic review of policies, challenges, and global lessons. *Results in Engineering*, 107155.

33. Tempa, K., & Yuden, K. (2023). Multi-hazard zoning for national scale population risk mapping: A pilot study in Bhutan Himalaya. *Geoenvironmental Disasters*, *10*(1), 7. https://doi.org/10.1186/s40677-023-00239-4