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Strengthening disaster resilience in Indonesia: A framework for sustainable recovery through the pentahelix model

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ABSTRACT

Background: Disaster management has evolved into a multidimensional effort, particularly as global risks related to climate change, urbanization, and environmental degradation intensify. According to UNISDR and UNDRR, disasters result from the interplay of hazards, exposure, vulnerability, and capacity, disrupting communities and causing widespread human and environmental losses. In Indonesia, where various natural and anthropogenic hazards converge, sustainable disaster management is crucial to protecting development gains and community resilience. **Methods**: This study adopts a qualitative-descriptive approach by synthesizing conceptual frameworks from global and national disaster governance institutions such as UNISDR, BNPB, and related scholarly sources. The disaster management cycle—mitigation, preparedness, response, and recovery—is analyzed alongside the Indonesian Disaster Risk Index (IRBI) formulation to understand systemic risk factors and governance responses. **Findings:** Findings emphasize that effective disaster risk reduction requires a strong integration of sustainability principles across all stages of the disaster management cycle. These principles are best realized through the pentahelix collaboration model, involving five key stakeholders: government, community, private sector, academia, and media. This inclusive model promotes shared responsibility, adaptive capacity building, and the adoption of eco-friendly technologies to minimize environmental impact in disaster interventions. **Conclusion**: The successful implementation of sustainable disaster management strategies requires long-term commitment, policy alignment, and systemic coordination across sectors and scales—local, national, and international. While progress is being made, particularly through instruments such as the Indonesian Post-Disaster Needs Assessment/*Pengkajian Kebutuhan Pascabencana* (JITUPASNA), broader cooperation and innovation are essential to ensure that response and recovery efforts do not create new vulnerabilities or environmental risks. **Novelty/Originality of this article:** This study offers a novel perspective by emphasizing the systemic application of sustainability principles in disaster management beyond emergency response, embedding them into the core of disaster governance. Additionally, it highlights the significance of the pentahelix approach as a transformative model for building long-term resilience in disaster-prone contexts.

KEYWORDS: disaster management; sustainability; pentahelix collaboration.

1. Introduction

The United Nation Office for Disaster Risk Reduction (UNISDR, 2009) defines a disaster as a serious disruption of the functioning of a community or society of any scale due to a hazardous event interacting with conditions of exposure, vulnerability and capacity, causing one or more of the following: human, material, economic and environmental losses

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and impacts. Disasters occur when hazards seriously impact communities and households and destroy, either temporarily or over many years, the livelihood security of their members. Disasters result from a combination of hazard risk conditions, community vulnerability, and limited household or community capacity to mitigate the potential negative impacts of the hazard (Baas et al., 2008).

The Sendai Framework Terminology on Disaster Risk Reduction defines hazards as a process, phenomenon or human activity that can cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation. Hazards can be natural, anthropogenic/human-induced or a combination of both (e.g. environmental degradation and climate change (UNISDR, 2015). Disaster management is defined as organizing, planning and implementing measures to prepare for, respond to and recover from disasters (UNDRR, 2017). The term disaster management is often used interchangeably with emergency management, especially in the context of biological and technological hazards and for health emergencies.

Modern disaster management began to emerge in the mid-20th century when industrialized countries began to build civil defense systems. In his book entitled Introduction to International Disaster Management, (Coppola, 2011) describes modern disaster management into 4 phases, namely: (i) Disaster mitigation involves reducing or eliminating the likelihood/consequences of hazards; (ii) Disaster preparedness involves equipping people who may be affected by disasters with the ability to increase safety and reduce economic and other losses; (iii) Emergency response includes actions to reduce/eliminate the impact of disasters that have/are occurring, to prevent further impacts, financial and other losses; (iv) Disaster recovery includes efforts to return the lives of survivors to a normal situation, after a disaster event. This phase can last for months or years.

Hazards carry different risks for different individuals/community groups. The weight of risk is determined by the capacity and vulnerability situation of the community. UNISDR defines vulnerability as the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. While capacity is the combination of all the strengths, attributes and resources available within an organization, community or society to manage and reduce disaster risk and strengthen resilience. Furthermore, risk is defined as the combination of the probability of an event and its negative consequences. Risk can be reduced by increasing capacity and mitigating risk (UNISDR, 2009). The Indonesian Disaster Risk Index is calculated based on the following formula (PUSDATIN BNPB, 2021):

$$Risk = Danger \times \frac{Vulnerability}{Capacity} \quad \text{(Eq. 1)}$$

IRBI is a disaster analysis tool in the form of an index that shows the real history of disasters that have occurred and caused losses in the territory of Indonesia.

2. Methods

This study employs a qualitative descriptive approach through literature analysis and policy review to explore the framework of sustainable disaster management in Indonesia. Primary data sources include official documents from international agencies such as the United Nations Office for Disaster Risk Reduction (UNDRR), as well as national institutions like the Indonesian National Board for Disaster Management (BNPB). Key concepts such as disaster risk, vulnerability, capacity, and the disaster management cycle (mitigation, preparedness, response, recovery) were synthesized to provide a comprehensive understanding of Indonesia's disaster governance landscape. In particular, the study reviewed regulations including BNPB Head Regulation No. 11/2008 and disaster risk indicators like the Indonesian Disaster Risk Index (IRBI) to trace how disaster risk is quantified and managed at national and local levels.

The analysis further draws upon frameworks such as the Indonesian Post-Disaster Needs Assessment/Pengkajian Kebutuhan Pascabencana (JITUPASNA), which integrates damage and loss assessments (DALA) and human recovery needs (HRNA) into a structured tool for post-disaster recovery planning. A thematic analysis was conducted to extract key themes, especially the integration of sustainability principles and the pentahelix model (government, private sector, academia, community, and media) in disaster risk reduction and recovery efforts. By analyzing best practices and institutional frameworks, the study offers insights into how sustainable and inclusive models of disaster governance can enhance resilience and long-term recovery in disaster-prone countries like Indonesia.

3. Results and Discussion

3.1 Sustainable concepts in emergency response

In the last 2 decades (2000-2019), the Center for Research on the Epidemiology of Disasters (CRED) recorded 7,348 natural disasters worldwide, affecting 4.03 billion people and resulting in economic losses of USD 2.97 trillion. This figure has almost doubled, when compared to the previous 2 decades (1980-1999), namely 4,212 disaster events with losses of USD 1.63 trillion (UNDRR & CRED, 2020). The report also shows a significant increase in the incidence of climate-related disasters in the period 1980-1999 and 2000-2019. There was a significant increase in the compared time periods. Hurricane disaster events experienced the highest increase of 232.3% followed by flood disaster events which increased by 134.3%. The IPCC (Intergovernmental Panel on Climate Change) report in 2022 found strong evidence that climate change is contributing to humanitarian crises including increased numbers of displaced people, food insecurity and malnutrition (IPCC, 2022).

Indonesia is one of the countries that has various disaster threats. Indonesia's position on four major tectonic plates (Indo-Australian, Eurasian, Pacific and Philippine) makes it vulnerable to earthquakes and tsunamis. Plate tectonic activity causes the formation of a series of volcanoes along the islands of Sumatra, Java-Bali-Southeast Nusa Tenggara, northern Sulawesi-Maluku, and Papua. The series of volcanoes is part of the Asia-Pacific volcanoes, which is often called the Ring of Fire or the Pacific Circumpolar Series (PUSDATIN BNPB, 2023). Indonesia's position on the Equator and the shape of an archipelago also creates a high potential for various types of hydrometeorological disasters, namely: floods, flash floods, droughts, extreme weather (e.g., tornadoes), abrasion, extreme waves, land and forest fires (Taufan Maulana & Andriansyah, 2024). These risks are exacerbated by development activities that ignore environmental sustainability. BNPB's Indonesian Disaster Information Data (DIBI) states that 74.10% of disaster events that occurred during 2015-2021 were hydrometorological disasters and the rest (25.90%) were geological disasters. Geological disasters include earthquakes, tsunamis, volcanic eruptions and landslides (PUSDATIN BNPB, 2023).

Figure 1 shows the types and number of disasters in Indonesia from January 1 to October 15, 2024. During this period, there were 1,560 disasters in Indonesia, of which 98.7% (1,541) were hydrometeorological disasters. As of October 15, 2024, more than 4.7 million people were displaced and 373 people died. The 2019 Global Assessment Report (GAR) on Disaster Risk Reduction emphasizes sustainable development based on the principle of disaster risk reduction. Approaches to managing risk (current and future), require an understanding of the systemic and complex nature of risk. Due to its complex nature, risk management cannot be done in isolation. It requires a fundamental redesign of both financing and international development cooperation (UNDRR, 2019). The document lists seven global targets with guidance to reduce the impact of disasters, while addressing the underlying causes of disaster risk, and protecting development gains for current and future generations. The seven targets include: (i) Reduce the number of fatalities from disasters to less than 100,000 per decade, (ii) Reduce the number of people affected by disasters to less than 100,000 per decade.

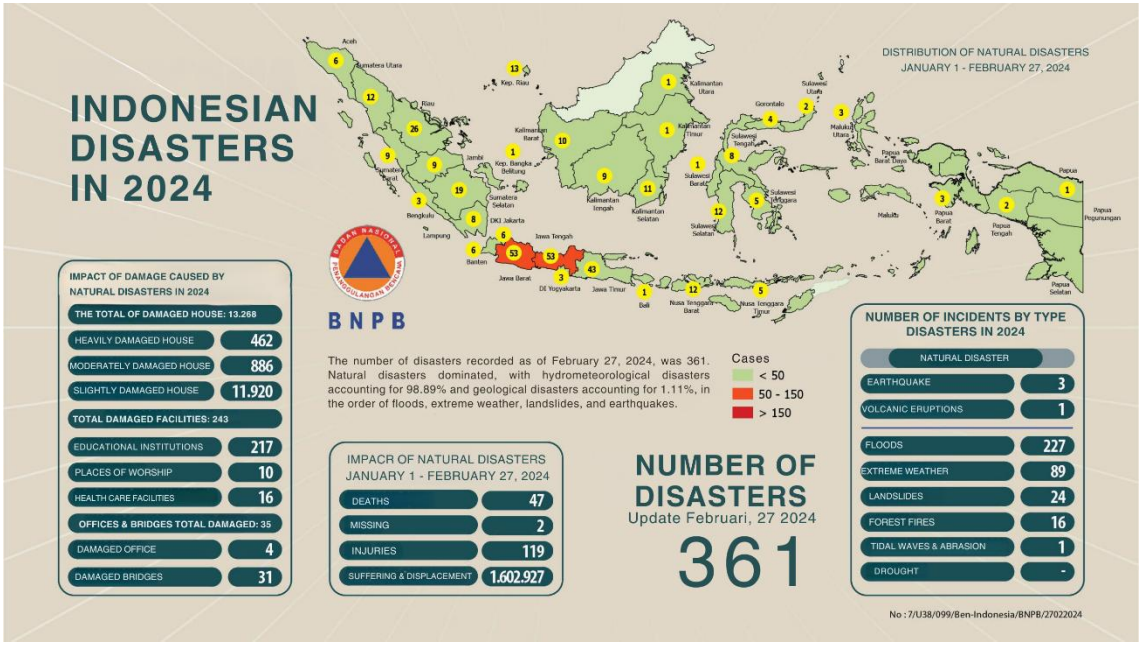

Fig. 1 Indonesia disaster infographic January 1 - October 15, 2024 (BNPB, 2024)

200,000 people per decade, (iii) Reduce economic losses from disasters to less than 100 billion USD per decade, (iv) Reduce losses to infrastructure and environmental assets to less than 100 billion USD per decade, (v) Increase the number of countries with national strategies for disaster risk reduction, (vi) Increase the number of countries with national strategies for disaster risk mitigation, (vii) Increase the number of countries with functioning disaster risk monitoring and evaluation systems (UNDRR, 2019). Sustainable development is defined as a development activity to meet current needs without compromising the ability to meet future needs. Sustainable development has 3 pillars, namely: social, environmental and economic, which must be considered harmonizing the interaction between these pillars (UNISDR, 2009).

The idea of sustainability is a form of long-term development that departs from the realization that planet Earth has limited resources. In its development, sustainable development is defined as an effort to fulfill the needs of human life but still within the carrying capacity of the ecosystem. Sustainable disaster management is an approach that ensures that emergency response not only addresses the immediate disaster event, but also strengthens the community's capacity to deal with future disasters. This includes ongoing planning, training and coordination to ensure that emergency response can be carried out effectively and efficiently (Rosyanti et al., 2024).

3.2 Challenges and opportunities

There are various challenges in managing sustainable disaster management in Indonesia among others. Sufficient investment for the construction of disaster-resistant infrastructure and the provision of early warning systems is often limited. According to a report by the International Federation of Red Cross and Red Crescent Societies (IFRC), the lack of domestic funding and financial assistance from governments severely hampers reconstruction and rehabilitation efforts (IFRC Disaster Law, 2022). Lack of public Awareness and Education: Communities need to be more aware and trained in dealing with disasters, including early signs of disasters and safe evacuation measures. A report from the International Organization for Migration (IOM) shows that public awareness of disaster risks is still low, especially in vulnerable areas (IOM, 2022). Inter-sector Coordination: Cooperation between different agencies and sectors is often hampered by a lack of effective

communication and coordination. A report from the Heinrich Böll Foundation states that the complexity and uncertainty of early warning systems is a major challenge in disaster risk management in Indonesia (Juwitasari, 2022).

Data and information management, the use and management of relevant data and information is often suboptimal, affecting the effectiveness of emergency response. A report from UNDRR in the 2019 GAR emphasized the importance of good data management to improve emergency response effectiveness (UNDRR, 2019). Regeneration and capacity Building: Ensuring that capacities and resources used in emergency response can be renewed and improved to deal with future disasters. A report from IOM shows that efforts to strengthen local capacity in disaster risk management are still urgently needed (IOM, 2022). Unsustainable program design, many emergency response programs are project-based and lack sustainability, making it difficult to maintain consistency in disaster mitigation efforts. A report from the IFRC highlights the importance of sustainable program design to ensure the sustainability of disaster mitigation efforts (IFRC Disaster Law, 2022). Cross-sector issues, the challenges of coping with disasters often involve multiple sectors working together, but there are often barriers to cross-sector cooperation. A report from IOM suggests that cross-sector cooperation is essential to address the complex challenges of disasters (IOM, 2022).

As a country with diverse potential disaster risks and a unique geographic and demographic context, the Indonesian government receives various supports for capacity building in disaster management. Some of them are USAID-HFI STEADY (Strengthening Disaster Management Capacity and Accompaniment of CSOs in Emergency Response, Coordination, and Advocacy) run by USAID and Humanitarian Forum Indonesia (HFI), which aims to increase the capacity of CSOs in disaster management.

Civil society in disaster response (U.S. Embassy Jakarta, 2023). In addition, the program strengthens interfaith collaboration for the construction of disaster-resistant houses of worship. Meanwhile, the World Bank-funded Indonesia Disaster Resilience Initiatives Project (IDRIP) with a loan of US$160 million helps Indonesia improve disaster resilience through a comprehensive approach (World Bank Indonesia, 2019). The Japan International Cooperation Agency (JICA) also frequently provides technical and financial assistance for training and development of disaster-resistant infrastructure. The Australian Department of Foreign Affairs and Trade (DFAT) supports preparedness training and local capacity building, while the European Union (EU) is involved in technology development and disaster management training. The United Nations Office for Project Services (UNOPS) is also supporting disaster- resistant infrastructure projects to strengthen national capacity. This support reflects global collaboration in helping Indonesia become more resilient to disaster threats.

Indonesia has a great opportunity to improve disaster coordination through utilizing the existence of civil society organizations (CSOs) that are active and established in discussions and advocacy related to disaster issues. CSOs in Indonesia, such as the Indonesian Red Cross (PMI), Humanitarian Forum Indonesia (HFI), and various other local organizations, have extensive networks at the community, national and international levels. Their existence provides a strong basis to support the government in harmonizing policies, improving communication across sectors, and ensuring inclusiveness in decision-making. The active role of CSOs in policy advocacy and disaster response programs allows for more effective synergy between the government, communities and the private sector. By empowering CSOs as strategic partners, Indonesia can accelerate local capacity building, improve the dissemination of disaster risk-related information, and facilitate the development of more sustainable community-based solutions. In addition, CSOs' expertise in managing resources and building community trust can be key in creating a disaster coordination system that is more adaptive and responsive to the needs on the ground.

The presence of civil society organizations (CSOs) can also be strengthened through the government's regulatory framework related to disaster coordination, including (Decree No. 308 of 2024 on Disaster Management Cluster, 2024). This cluster system divides responsibilities in various sectors such as logistics, health, evacuation and child protection,

involving the government, international organizations and CSOs. The clusters are designed to facilitate more organized cross-sector coordination during emergency response, ensuring that the needs of affected communities are met quickly and effectively. CSOs have a strategic role in supporting these clusters through resource mobilization and direct access to communities.

With this regulatory support, CSOs are not only complementary, but also strategic partners that contribute to the effectiveness of disaster response. This role allows CSOs to collaborate closely with the National Disaster Management Agency (BNPB) and the regional governments in supporting disaster policy implementation. This cluster-based collaboration clarifies the roles and responsibilities of each party, reduces overlapping efforts, and improves the overall efficiency of the disaster management system. The integration of CSOs into this regulatory framework creates stronger synergies, ensuring a more inclusive, coordinated and adaptive disaster

3.3 Case study

The urge to integrate sustainability principles has been widely voiced, including in humanitarian actions carried out by humanitarian agencies/actors. Since 2014, various studies have stated that the impact of humanitarian action both in the emergency response and recovery phases can have a negative effect on the environment, if not integrated with environmental principles/insights. In response, several agencies have started to take a greener approach, including the Red Cross Red Crescent Movement's (RCRC/ IFRC) Green Response Policy, Mercy Corps' commitment to reduce global emissions by 50% by 2030 and the Global Platform for Action on Sustainable Energy in Displacement Settings (GPA), which shows seriousness and progress in developing, testing, measuring and reporting how humanitarian action operations have led to more environmentally friendly practices (HAG et al., 2022).

The "Greening the System" initiative presented by the Humanitarian Advisory Group (HAG) aims to integrate environmental sustainability in humanitarian practice to support global climate change goals. The concept includes shifting the operational framework towards reducing carbon emissions, reducing waste, and adopting renewable energy solutions in humanitarian response. Key sectors to focus on for implementation include logistics, supply chain and infrastructure, emphasizing the use of environmentally friendly materials and climate-smart agricultural practices. The vision also emphasizes the importance of collaboration with local communities to ensure that the solutions implemented are appropriate to the regional context to be more effective (Humanitarian Horizons: Greening the System Framework for Greening Humanitarian Action in the Pacific, 2023).

The initiative has faced challenges to implementation, including motivational barriers and systemic challenges, such as the perception that sustainability efforts may come at the expense of life-saving activities, funding limitations, and a lack of expertise and tools for environmental action. Overcoming this requires behavior change across the humanitarian sector with clear guidance, flexible funding mechanisms, and capacity building initiatives to empower local and international disaster actors. Stakeholders need to prioritize more environmentally sustainable practices without compromising the core purpose of humanitarian assistance (HAG et al., 2022).

Indonesia has taken important steps to implement a greener humanitarian system. Some of the actions/strategies that have been carried out include: the development of disaster-resistant infrastructure, such as earthquake-resistant houses and flood safety systems, which help reduce the impact of disasters. In addition, Indonesia is also increasing the capacity of local communities through training programs that integrate the use of green technology and environmentally friendly practices. International cooperation with organizations such as USAID and

JICA also plays a role in introducing green technology in disaster management. The use of advanced technologies, such as satellites and sensors for early detection, has improved

the efficiency of disaster response. Finally, Indonesia strengthened disaster management coordination through the revision of the Head of BNPB Regulation Number 308 of 2024 on Disaster Management Clusters, which also integrates green practices in every stage of response.

3.4 Strategies and recommendations

Strategies to improve sustainability in disaster management must involve synergy between the government, communities, academia, media and the private sector. One important step is to increase the proportion of funding and allocation for preparedness activities in the National Disaster Management Agency (BNPB) fund. This approach allows for greater investment in training, provision of disaster-resistant infrastructure and strengthening the capacity of local communities before a disaster occurs. In addition, the use of evaluation results and lessons learned from various disaster responses is critical to designing emergency response strategies that are more structured, data-driven and responsive to real needs on the ground.

Cross-sector collaboration is also a key element to ensure sustainability. The government can work with the private sector to support technological innovations, such as the development of community-based early warning systems or environmentally friendly logistics solutions. Meanwhile, CSOs and communities can be involved in developing inclusive emergency response plans, ensuring that the voices of vulnerable groups are heard. Sustainability strategies also require policies that encourage environmentally friendly practices in emergency response, such as the use of renewable energy in refugee camps and waste reduction during response. With this holistic and collaborative approach, emergency response programs will not only be reactive, but also proactive in reducing the long-term impacts of disasters.

Strengthening the role of pentahelix in disaster management needs to be one of the government's priorities. The pentahelix approach involves synergy between government, academia, communities, the private sector and the media to create an inclusive and sustainable system. The government acts as a policy director and implementation supervisor, while academia provides scientific data and technological innovations to support evidence-based planning. Communities, as key actors, can be empowered through education and active participation in emergency response, while the private sector contributes through the provision of resources, technology and investment in innovative solutions. The media plays an important role in disseminating accurate information and raising public awareness. A structured collaboration between these five elements ensures that disaster management is more effective, responsive and sustainability-oriented.

4. Conclusions

Sustainable disaster management has become a priority in the formulation of disaster management strategies in Indonesia. To achieve this goal, collaboration between various parties is essential. This collaboration includes various parties, including: government, community, private sector, academia, and media through a pentahelic approach. By working together, we can strengthen community and national resilience to increasing disaster risks. This approach also integrates sustainability principles in every stage of emergency response, from mitigation to rehabilitation, with a focus on greener practices.

Sustainability in disaster management depends not only on government efforts, but also on support from all stakeholders, both regionally and globally. Greater cooperation between countries, international organizations and civil society is needed to advance more environmentally friendly and sustainable practices in disaster management. This includes adopting technologies and solutions that minimize environmental impacts, as well as ensuring that any measures taken are not only effective in saving lives, but also do not pose additional risks to the environment. This process will not happen in a short time because it requires systematic interventions and involves various sectors. It requires long-term

commitment and strong support from all parties to ensure that the principle of sustainability is applied thoroughly in disaster management. Only in this way, we can build better capacity and create a more resilient system to face future disaster challenges.

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Author Contribution
The author was responsible for the conceptualization, data collection, analysis, and manuscript writing. All aspects of the research, including the formulation of research questions, literature review, and interpretation of findings, were conducted independently. The author also reviewed and approved the final version of the manuscript.

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