

Abstract

Indonesia's coastal regions are among the most disaster-prone areas in Southeast Asia, where repeated earthquakes and tsunamis test the resilience of local health systems. This study assessed post-disaster changes in governance, coordination and service capacity across 3 provinces of Aceh, West Sumatra and Central Sulawesi using secondary data from the Indonesian Ministry of Health, Health Crisis Management profiles. A pre-post evaluation framework was applied across 6 resilience dimensions of governance, coordination, human resources, infrastructure, logistics and financing. Results indicated substantial post-disaster improvements in governance and coordination, particularly in Aceh, but persistent weaknesses remain in logistics and health workforce readiness. The findings highlight the importance of continuous learning, sustained financing and inter-agency collaboration to strengthen local health system preparedness for future emergencies. These insights contribute practical lessons for disaster risk governance particularly in coastal and resource-constrained contexts.

Strengthening local health system resilience in coastal Indonesia: lessons from post-disaster governance and preparedness

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Introduction

Disasters are a persistent threat to coastal populations in Southeast Asia, particularly in Indonesia, one of the world's most hazard-prone archipelagos. The country's geographic position along the Pacific 'Ring of Fire' exposes it to frequent earthquakes, tsunamis and floods, which repeatedly disrupt health service delivery and exacerbate community vulnerability. Between 2006 and 2015, more than 130 major disasters affected over 10 million people across Indonesia resulting in significant mortality and damage to health infrastructure (Jang et al. 2021). The recurrence of such events highlights the critical role of the local health system as the first line of response in minimising disaster-related morbidity and mortality.

Disaster preparedness and mitigation are key components of environmental hazard management. The Sendai Framework for Disaster Risk Reduction 2015-2030 (UNDRR 2025) (Sendai Framework) emphasises the need for health systems to build resilience by integrating risk governance, early warning systems and community-based preparedness mechanisms. However, despite multiple reforms, local health systems in Indonesia, especially in coastal regions, remain fragile due to constrained logistics, weak inter-agency coordination and inadequate human resource capacity. These systemic weaknesses increase vulnerability to environmental hazards and reduce the effectiveness of post-disaster recovery and health protection (Bullock et al. 2013; Chan et al. 2019). The Sendai Framework emphasises the need to strengthen

disaster risk governance, invest in resilience and enhance preparedness across all sectors, including health systems (UNDRR 2015). Recent studies in Indonesia highlight the importance of local leadership and financing mechanisms in disaster governance, particularly in enhancing institutional and community resilience (Ruslanjari et al. 2024; Marlina et al. 2024). Several studies have also discussed coastal governance and community resilience in the Asia-Pacific region, such as case studies on managed relocation and community resilience (Elis and Bajracharya 2023; Wicaksono et al. 2024). However, specific studies on the resilience of health systems in Indonesia's coastal provinces are still limited.

Previous studies on disaster management in Indonesia have primarily focused on emergency response logistics or hospital-based preparedness (Fuady et al. 2011; Lopo et al. 2022) with limited evaluation of how lessons from past disaster events shape long-term governance and health-system resilience. There remains a lack of integrated analysis connecting institutional preparedness, mitigation measures and local health governance frameworks. This gap limits evidence-based policymaking for disaster-prone coastal regions where health infrastructure often faces recurrent risks.

Despite the increasing global emphasis on disaster risk reduction, local health systems in hazard-prone regions remain inadequately prepared to cope with large-scale disasters. In Indonesia's coastal areas, health institutions often operate within fragmented governance structures resulting in limited coordination and reactive crisis management. Previous research has concentrated on emergency response and hospital preparedness, providing little insight into how local health systems learn and adapt following disasters (Lopo et al. 2022; Fuady et al. 2011). Comparative evidence across provinces is scarce and the integration of health-system resilience within local disaster risk reduction frameworks remains underexplored.

The aim of this study was to address these gaps by applying a pre–post evaluation of local health-system preparedness and mitigation capacities grounded in the resilience framework adopted by the World Health Organization and adaptive governance theory to identify institutional learning processes that enhance disaster preparedness in Indonesia's coastal regions. By evaluating changes in governance, coordination, human resources, infrastructure and mitigation practices, this study identified institutional learning processes and persistent vulnerabilities within Indonesia's coastal health systems. The findings inform evidence-based policy strategies that strengthen disaster risk governance and enhance health-system resilience to environmental hazards.

Method

Study design and framework

This study applied a descriptive pre–post evaluation design to examine changes in disaster preparedness and mitigation capacities of local health systems in selected coastal provinces of Indonesia. The analysis followed a modified Theory of Change framework (Weiss 1997) linking the inputs (governance, resources and regulations) and processes (coordination and human resource capacity) to expected outcomes (improved resilience and mitigation readiness).

The indicators assessed are the existence of local government regulations on disaster management, the availability of technical regulations that support disaster management and supporting resources. The pre-disaster assessment was defined as the condition prior to the major disaster events (earthquakes and tsunamis) in each province. These events occurred in Aceh in 2004, West Sumatra in 2009 and Central Sulawesi in 2018. The post-disaster assessment refers to the condition following these major events.

For the purpose of analysis, we used the most recent assessment years available in the Health Crisis Center profiles published by the Ministry of Health of Indonesia.¹ The pre-disaster assessments for Aceh and West Sumatra correspond to the 2002 reporting cycle, while Central Sulawesi's pre-disaster assessment used the 2017 profile. The post-disaster assessments for Aceh and West Sumatra were taken from reporting years after 2017, whereas Central Sulawesi's post-disaster assessment used data from 2020.

It is acknowledged that other smaller-scale hazard events, such as seasonal flooding, may have occurred during the assessment periods chosen. However, no additional large-scale disasters of comparable severity occurred in the 3 provinces selected within this timeframe. Therefore, the pre–post comparison reflects the effects of a single major disaster event in each province without being confounded by subsequent disaster events.

Study area and data sources

The assessment was structured around 2 analytical dimensions:

1. preparedness: policies, regulations, early warning mechanisms, coordination and human resources
2. mitigation: logistics, hospital capacity, post-disaster rehabilitation and risk reduction programs.

Three coastal provinces were purposively selected based on their major disaster history and exposure to environmental hazards of Aceh (earthquake and tsunami

1. Health Crisis Center profiles, at Indonesia Health Profile | GHDx, <https://ghdx.healthdata.org/series/indonesia-health-profile>

in 2004), West Sumatra (earthquake 2009) and Central Sulawesi (earthquake, tsunami and liquefaction in 2018).

Secondary data were obtained from the Health Crisis Center of the Ministry of Health of the Republic of Indonesia, 2017 to 2002. Reports contained structured assessments of disaster preparedness, health infrastructure conditions and institutional arrangements at provincial and district levels. Supplementary peer-reviewed sources were used to triangulate contextual information on health response and governance reforms (Lee et al. 2005; Fuady et al. 2011; Lopo et al. 2022).

Public health emergencies, including the COVID-19 pandemic, were excluded because they are categorised separately and are not included in the preparedness and mitigation assessment system used in this dataset. Therefore, the scores analysed represent institutional preparedness for major geological disasters, not pandemic-related events.

Indicators and scoring

Each province's preparedness and mitigation performance was evaluated using 6 indicators extracted from the data of governance, coordination, human resources, infrastructure, logistics and financing. The results are shown in Table 1.

Data for each indicator were extracted from provincial Health Crisis Management profiles and verified through regional disaster management reports. Composite scores for preparedness and mitigation were calculated by averaging the 6 dimension scores, enabling comparison across provinces and time periods.

Analytical approach

Scores were synthesised into provincial preparedness and mitigation indices using simple additive scaling (average per dimension). Qualitative findings from the Ministry of Health of Republic of Indonesia reports were integrated to explain score variations. Interpretation focused on identifying patterns of institutional improvement, persistent weaknesses and cross-provincial lessons for resilient health-system governance in coastal contexts.

Results

Comparative preparedness and mitigation scores

The results of the comparative analysis across the 3 provinces are shown in Table 2.

Overall, all 3 provinces demonstrated measurable improvements in both preparedness and mitigation capacities following major disaster events. However, the degree of improvement varied, with Aceh showing the highest post-disaster resilience gains (Δ change (post - pre) = +2.5 preparedness; +2.2 mitigation) followed by West Sumatra and Central Sulawesi.

In Aceh, the 2004 tsunami triggered comprehensive institutional reforms, including the establishment of the Aceh Disaster Management Agency and the integration of health crisis units at the district level. These structural changes explain the significant improvement in both preparedness and mitigation scores. In West Sumatra, post-2009 reforms focused on strengthening hospital standards and forming rapid response teams, yet coordination across agencies remained fragmented, limiting the overall improvement. In Central Sulawesi, despite the creation of coordination mechanisms after the 2018 earthquake and tsunami, limited logistics and hospital capacity hinder operational readiness.

Institutional and governance improvements

Post-disaster reforms led to the creation of health crisis management units in all 3 provinces and the formalisation of standard operating procedures for coordination and rapid response. However, weaknesses remained in cross-sectoral integration, particularly between health offices, hospitals and local disaster management agencies. Provincial health offices often lacked the authority to mobilise resources across districts, which negatively affects the timeliness of response actions.

Resource and capacity challenges

Despite institutional progress, logistic and human resource gaps persist. There is uneven distribution of trained

Table 1: Dimensions and indicators of local health system resilience to disasters.

Dimension	Indicator*	Description
Governance	Existence of regional regulations on disaster management.	Legal framework and policy authority.
Coordination	Availability of SOPs and crisis management units.	Mechanisms for multiagency coordination.
Human resources	Availability of trained staff and rapid response teams.	Technical and non-technical capacity.
Infrastructure	Hospital readiness and functional health facilities.	Capacity for emergency medical response.
Logistics	Availability of medicines, supplies and equipment.	Material support for response operations.
Financing	Budget allocation for disaster risk reduction.	Dedicated financial support and continuity.

*Each indicator was rated on a 3-point ordinal scale where 1 = weak/non-existent, 2 = partial/developing and 3 = established/functional.

Table 2: Preparedness and mitigation scores (pre–post disaster evaluation).

Province	Preparedness (pre)	Preparedness (post)	Change (post - pre)	Mitigation (pre)	Mitigation (post)	Change (post - pre)	Improvements
Aceh	1.0	3.5	+2.5	1.2	3.4	+2.2	Establishment of regulations, standard operating procedures and HR capacity building programs.
West Sumatra	1.2	3.0	+1.8	1.5	3.1	+1.6	Hospital standards improved; rapid response teams formed.
Central Sulawesi	1.4	2.6	+1.2	1.3	2.5	+1.2	Coordination improved but logistics and hospital readiness remained low.

personnel and delayed mobilisation during emergencies, inadequate medical supplies and damaged infrastructure in remote coastal districts as well as inconsistent incentive mechanisms for emergency responders, particularly in Central Sulawesi. These findings align with regional assessments emphasising that resource fragility and governance fragmentation remain significant determinants of weak disaster health resilience in Indonesia's coastal zones.

Discussion

This study provided a comparative evaluation of local health system responses to major disasters in coastal Indonesia and revealed how crisis experiences stimulate institutional adaptation and policy reform. The pre–post evaluation demonstrates that, while all provinces selected for this study made measurable progress in preparedness and mitigation, disparities remain in governance effectiveness, coordination and resource allocation. These findings reinforce the understanding that disaster resilience in health systems depends on both structural capacity and adaptive governance.

Health system resilience and adaptive governance

The observed improvements, particularly in Aceh and West Sumatra, indicate that exposure to severe disasters can catalyse governance reforms and institutional learning. This finding aligns with Kruk et al. (2017) and Hanefeld et al. (2018) who emphasise that resilience arises not only from resources and infrastructure but also from the capacity of institutions to learn, reorganise and adapt following crises. Similar to experiences reported in post-earthquake Nepal and the Philippines, Indonesia's post-disaster recovery process shows how health governance structures evolve towards more formalised coordination and regulatory mechanisms (Nuzzo et al. 2019).

Adaptive governance in decentralised systems often faces fragmentation and unclear mandates that hinder rapid decision-making. In Central Sulawesi, for example, weak vertical coordination between provincial and district health offices constrained the mobilisation of medical personnel

and logistics during emergencies (Aldunce et al. 2015). This governance challenge is similar to 'coordination barriers', a common obstacle to effective disaster management in a multi-level governance context (Howes et al. 2020).

In line with previous studies on coastal community resilience, these findings indicate that governance reform and community engagement are crucial. However, previous studies focused on community adaptation (Fisher and Orchiston 2024), whereas this study highlights the central role of health facility resilience and institutional learning to maintain preparedness. Although previous research has highlighted community adaptation strategies (Elis and Bajracharya 2023), these findings show that improvements in regulatory frameworks and crisis units are indeed necessary, but they are not sufficient without simultaneous investment in logistics and hospital preparedness.

The findings underscore the importance of logistics capacity and the readiness of the healthcare workforce as part of local disaster response capabilities, particularly in terms of the availability of medical supplies and effective coordination among healthcare personnel (Carmody 2023).

Communication gaps during disasters are a major obstacle to coordinated health responses, especially in decentralised systems where information must move quickly between agencies and levels of government (King and Gurtner 2025). The challenges observed in Central Sulawesi reflect this broader pattern.

Integration with the Sendai Framework and the Global Disaster Risk Reduction agendas

These findings resonate with the priorities of the Sendai Framework particularly the call to 'Build Back Better' and enhance institutional readiness for future hazards. Integrating health systems within broader disaster risk governance contributes directly to Priority 4, Enhancing disaster preparedness for effective response, and Priority 2, Strengthening disaster risk governance. Resilient health systems are both a prerequisite and an outcome of effective disaster risk reduction implementation (Gnanapragasam et al. 2016; Oostlander et al. 2020).

In this study, provinces that institutionalised crisis management units and established clear standard

operating procedures after disasters demonstrated higher improvements in preparedness scores. Organisational learning and standardisation of response mechanisms are key determinants of institutional resilience (Sharifian et al. 2017). However, persistent shortfalls in financing and human resources suggest that Indonesia's health sector remains largely reactive, with limited investment in pre-disaster risk reduction.

Institutional learning and post-disaster adaptation

The results highlight that post-disaster recovery can serve as a critical window for institutional transformation (Djalante 2019). Aceh's extensive post-tsunami reconstruction, supported by national and international collaborations, produced lasting improvements in policy, coordination and capacity development. By contrast, Central Sulawesi's recent experience illustrates the ongoing challenge of transforming short-term humanitarian response into sustained governance reform.

The differences across provinces underline the importance of continuous monitoring, evaluation and learning loops within local health governance. Embedding evaluation mechanisms into post-disaster recovery processes allows institutions to capture lessons, revise policies, and strengthen resilience over time (Nuzzo et al. 2019).

These findings contribute to the growing discourse on the climate–disaster–health nexus. Climate change intensifies coastal hazards such as floods, storm surges and tsunamis, compounding the health effects of disasters (Ebi and Luchters 2021). Strengthening local health systems is central to building adaptive capacity in climate-sensitive regions. Resilient health systems must integrate climate adaptation, early warning systems and community-based surveillance to reduce mortality and morbidity (Robinson et al. 2024). From this perspective, Indonesia's coastal provinces represent frontline laboratories that link environmental hazard management with health system strengthening. Future strategies should align disaster risk governance, climate adaptation and health resilience policies into a unified framework; an approach increasingly recommended by global disaster risk reduction and planetary health agendas (Gnanapragasam et al. 2016; Ebi and Luchters 2021).

Policy and practical implications

Local governments should embed health crisis management units within formal administrative structures, ensuring that coordination persists beyond post-disaster recovery periods. Routine simulation exercises, emergency drills and pre-positioned logistic stockpiles should be mandated for high-risk provinces. Partnerships with academic institutions and NGOs can sustain continuous capacity development (Hanefeld et al. 2018).

Provincial governments should incorporate resilience indicators into regional development plans, linking health, environment and infrastructure policies. This would operationalise the concept of adaptive governance across sectors and scales (Aldunce et al. 2015). Ultimately, enhancing local health system resilience requires long-term governance commitment, consistent funding and institutionalised learning. Strengthening these pillars will allow coastal regions to better anticipate, absorb and adapt to the growing frequency of environmental hazards. Previous studies emphasise that regulatory improvements must be supported by specific financing mechanisms, as demonstrated by the Coastal and Estuarine Risk Management Program, which funds long-term mitigation and coastal infrastructure protection (Stone 2022). This is consistent with these findings that governance reforms alone are insufficient without parallel investments in health system logistics and facility preparedness.

Limitations

This study relied on secondary data from the Ministry of Health's Health Crisis Center profiles, in which preparedness and mitigation scores were completed by provincial and district officials. As these assessments are self-reported, they may be subject to assessor bias and may result in either over- or under-reporting of actual capacities. Additionally, variations in indicator interpretation and differences in training or familiarity with standard operating procedures across provinces may lead to inconsistencies in scoring. The assessment data recorded in official reports may therefore not fully reflect the quality or consistency of on-the-ground implementation. These limitations may introduce variability in measurement. However, the Health Crisis Center profiles remain the only standardised national dataset available for longitudinal comparison of local disaster preparedness.

In cases where a province experienced more than one disaster during the study period (e.g. an earthquake followed by flooding or an earthquake followed by a tsunami), the assessment did not distinguish the effect of each individual event. This is because the Health Crisis Center profiles report preparedness and mitigation scores at specific reporting intervals, which inherently capture cumulative institutional learning and changes resulting from multiple disaster exposures. As a result, the 'post' measurement reflects the combined effects of both major and minor disaster events rather than changes attributable to a single incident. While this approach is consistent with the structure of the available national data, it represents a limitation because the analysis cannot identify the specific contribution of each disaster event.

Conclusion

This study assessed the resilience of local health systems in 3 disaster-prone coastal provinces of Indonesia of Aceh, West Sumatra and Central Sulawesi by comparing preparedness and mitigation capacities before and after major natural disasters. The results show that disaster experiences triggered positive institutional changes, including stronger regulations, the establishment of crisis management units and improved coordination mechanisms. Nonetheless, significant gaps remain in logistics, trained personnel and inter-agency coordination. This highlights that policy reforms do not automatically translate into operational readiness. These findings reaffirm that resilience depends not only on infrastructure and resources but also on continuous institutional learning and adaptive governance.

From a policy perspective, strengthening local health-system resilience must become a sustained component of Indonesia's environmental hazard governance. Integrating health crisis management within the framework of disaster risk reduction consistent with the Sendai Framework and the Health System Resilience approach will help preparedness become institutionalised rather than reactive. Continued investment in training, financing and data-driven evaluation is essential to maintain progress beyond post-disaster recovery cycles. Future studies should extend this work through longitudinal and spatial analyses to capture how local health systems evolve and adapt under compounding climate and disaster pressures.

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